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PREFACE

This paper has been prepared in the interests of community discussion of recent proposals for World Heritage Listing of the wet tropics of north Queensland. It presents the results of studies carried out in 1985, which provided the basis for sawmill allocations for the period 1 October 1986 to 30 September 1991. Consequently, the paper does not discuss in detail the subsequent reduction of the allowable cut for Zone 2 (Innisfail-Tully) from 14 000 to 12 320 cubic metres per year, in response to damage from Cyclone Winifred. Details of this reduction are reported in Preston (1987).

ABSTRACT

Calculation of timber yields from north Queensland rainforests indicate that the long term average yield is in the vicinity of 63 000 cubic metres per year, and that an allowable cut of 60 000 cubic metres per year should apply for the period 1986–1991. These calculations apply to the 158 000 hectares of Crown land managed for timber production between Townsville and the Daintree River.

Estimates were prepared using cutting cycle analysis, and incorporated a number of innovations made possible by advances in computing technology. These included simulating the growth of individual plots rather than of stratum averages, and the use of a dynamic growth model which accomodated stand density, composition and site quality.

INTRODUCTION

The tropical rainforests of north Queensland are one of Australia's most valuable natural resources. They are highly valued for their conservation significance and ecological diversity, and sustain a harvest of valuable cabinet, veneer and structural timbers.

The study area includes all coastal and hinterland tropical rainforest between Townsville and the Daintree River. This region is divided into five allocation zones (Figure 1) which form the basis for regulation of timber supplies. This study appraises the allowable cut of rainforest timber from the state forests, timber reserves, and other Crown lands in each allocation zone for the period 1 October 1986 to 30 September 1991. Yields will be reviewed prior to 1991 in accordance with Departmental policy to review the allowable cut in all native forests every five years.

OVERVIEW OF YIELD REGULATION

The process of yield regulation comprises three major stages. The long term average yield[22] is first calculated to give a sound perspective of the future resource position. This provides the basis for determination of the allowable cut, which is set for a five year period for each allocation zone. Within each zone, allocations of timber are offered to sawmilling firms entitled to crown supplies, so that they sum to the allowable cut.

Calculation of the long term average yield entails several basic operations:

- the area of forest capable of producing timber is determined. Forest subject to special management (e.g. scientific areas[16], buffer strips[4] along creeks) and inaccessible or unproductive forest is excluded.
- a detailed inventory of the existing forest is prepared by measuring temporary plots and recording the species, size and merchantability of each tree within the plot.

22,16,4 See glossary for description of terms identified by superscript numbers.

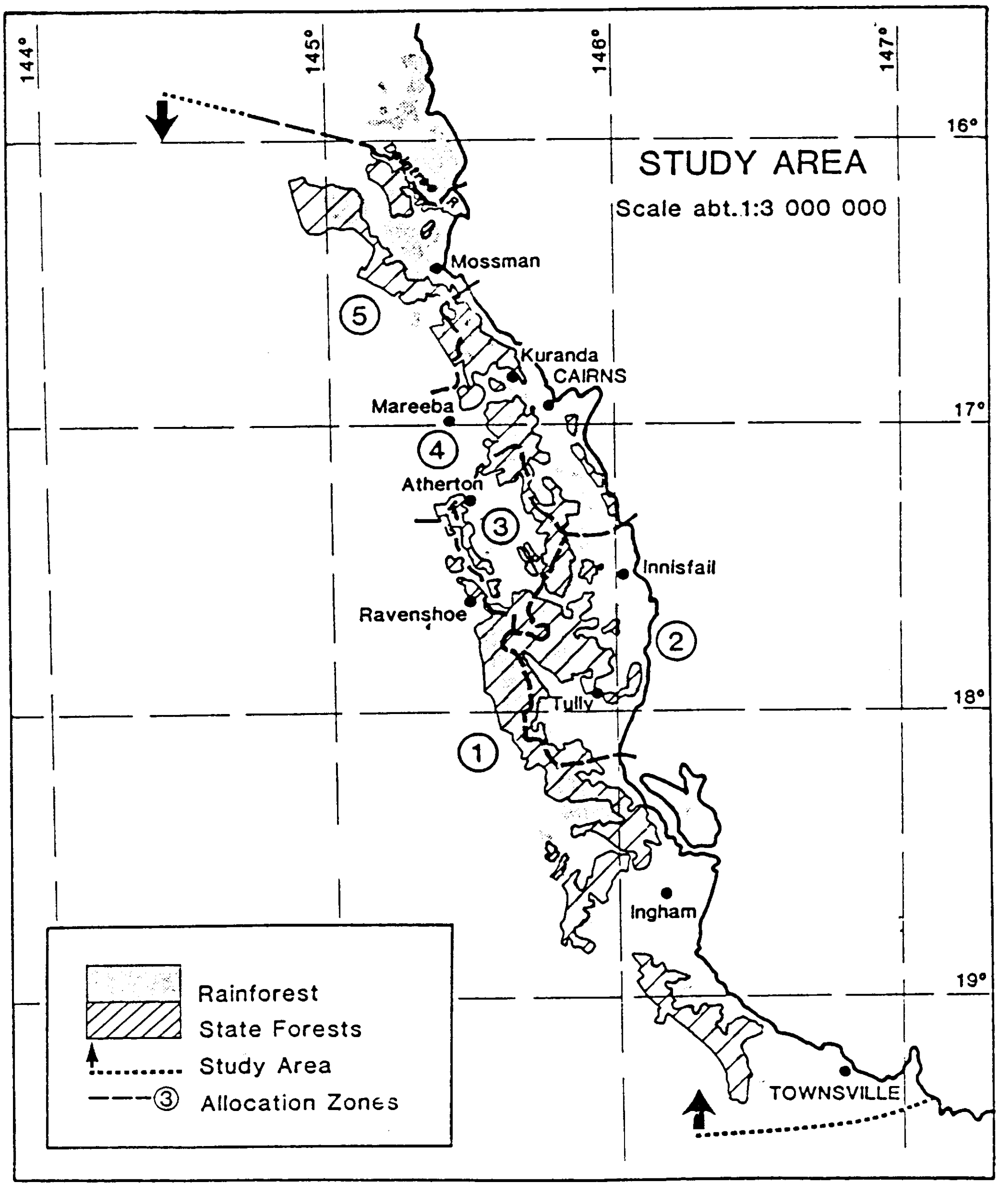


Figure 1. Location of the study area

- the future condition (number, size and merchantability of trees) of each inventory plot is predicted by simulating the growth (diameter increment, mortality and recruitment[15]) of the forest over time.
- at selected intervals, a timber harvest is simulated to indicate which stems would be removed in logging, and to predict mortality to the residual stand[18] arising from felling and snigging damage.
- the anticipated harvest volume is then calculated using volume equations[21].
- the growth and harvesting of each inventory plot is simulated through several cutting cycles[7] to ensure the continuity of future timber harvests.

This procedure provides an estimate of the timber yield which can be sustained under the specified management regime and assumed economic conditions. Timber harvesting can be sustained at any level not exceeding this yield.

CALCULATION OF TIMBER YIELDS

Area Estimates

Area estimates are an essential ingredient of the resource forecast, and due account must be taken of unproductive land such as rock outcrops, stream buffers, and other areas which cannot be logged. To facilitate the preparation of area estimates, a computerized area information system was commenced in 1978, and was used in the present calculation. It was based on the New South Wales FORINS System (Hoschke and Squire 1978), and records management information at each 1000 metre Australian Map Grid (AMG) intersection within the study region. Although this provides relatively "coarse" information (in that the best estimate attainable is to the nearest 100 hectares), it is an efficient mechanism for dealing with large amounts of data over extensive areas of forest. This system was used to calculate the area utilized for timber production within the study area (Table 1), and within each allocation zone (Table 2).

Data were drawn primarily from timber management maps and included tenure, allocation zone, management intention and logging history. These maps were prepared by field staff during the period 1978 to 1980 using historical timber sales records dating back to the mid 1950's, and have been regularly updated. Where no records were available, estimates of accessibility and productivity were prepared from interpretation of 1 : 25 000 scale aerial photographs.

The gross productive area[1] (or mapped area) of rainforest was determined by multiplying the number of sample points in each allocation zone believed to be available, accessible and productive, by 100 hectares per point.

The productive area[1] was calculated from the gross productive area by applying a correction factor to adjust for inaccessible or unproductive rainforest misclassified as accessible and productive on management maps. This factor was determined from inventory by calculating the proportion of plots located on contiguous areas of inaccessible rainforest, and was found to be 0.839 for areas logged before 1970, and 0.960 for areas logged since 1970. The difference reflects the improved accuracy of information arising from more intensive management in recent years. A check was also made to determine if any land outside the gross productive area had been misclassified (i.e. actually productive). About 98 percent was classified correctly, and about two percent was marginal. Misinterpretation of inaccessible and unproductive land was therefore assumed to be negligible, and no attempt was made to establish inventory plots in these areas.

Table 1. Rainforest tenure — Townsville to Daintree River.

Tenure and management	Area (ha) Sub-total	Sub-total	Total	Percent
Areas where logging is excluded				
1. Special management areas	54 000			9
2. Inaccessible and unproductive forest and buffer strips	227 000			39
		281 000		48
Productive area		158 000		27
State forests, timber reserves and other crown lands			439 000	75
National park			105 000	18
Freehold			42 000	7
Total			586 000	100

Table 2. Area of rainforest by allocation zone.

Allocation zone	Productive area (ha)
1. Ingham – Ravenshoe	52 500
2. Innisfail – Tully	31 900
3. Tablelands	27 600
4. Cairns – Kuranda	24 300
5. Windsor – Lewis	21 700
Total: all zones	158 000

The nett productive area[1] (or effective area) was used as the basis for yield calculations, and was determined by adjusting the productive area for small areas of rock, road and stream buffers. A netting factor of 0.956 was estimated from inventory data by calculating the proportion of stems on each plot which were assessed as inaccessible or unavailable.

At any given time the loggable area[1] of rainforest is less than the nett productive area. This occurs because areas currently considered uneconomic to log may be logged at a later date. To take account of this in yield calculations, any inventory plot (and its associated nett productive area) that would not produce a minimum yield of five cubic metres per hectare at the midpoint of a cutting cycle was excluded from logging in that cycle, but would remain eligible to be logged in subsequent cycles. This procedure reflects current resource and operating conditions, and generally ensures a viable yield of 12 cubic metres per hectare of gross productive area. An estimate of the loggable area may therefore be obtained by multiplying the nett productive area by the proportion of inventory plots yielding more than five cubic metres per hectare at the time of (simulated) logging. During simulation, about 10 percent of the nett productive area was only logged every alternate cutting cycle.

In the Department's 1981 allowable cut calculation, the loggable area was used as the basis for calculations, and was defined as the area able to be logged in each of the next three cutting cycles. This was calculated as 0.91 of the nett productive area, and derived from the observation that 17 out of 181 inventory plots then available were considered unproductive or loggable only within 100 years.

Inventory

Inventory data collected during the period 1978 to 1985 were used in the current calculation. Temporary plots were established at predetermined 1000 metre AMG intersections, selected from the area information system using stratified random sampling with logging history as the primary stratum. As most logging of accessible and productive virgin[19] rainforest will be completed in the near future, all inventory plots in virgin stands were excluded from these calculations. Three different types of plot were used over this period (Table 3).

Table 3. Plot types and sampling intensity.

Year	Plot type	Plots per allocation zone†					Total
		1	2	3	4	5	plots
1978-81	Point sample	34	15	98	19	5	171
1983	Point sample	44	0	0	0	0	44
1984	Fixed area	21	15	8	26	14	84
1985	Fixed/point	10	4	2	4	0	20
Totals		109	34	108	49	19	319

† plots in virgin stands excluded.

During the period 1978 to 1983, clusters of ten point samples[14] were employed, in which an optical wedge[13] with a basal area factor[3] (BAF) of 10 square metres per hectare was used, and all stems exceeding three centimetres diameter (at breast height or above buttress, over bark) were measured. During 1984, fixed area plots were favoured. All stems exceeding 30 cm diameter were sampled on a half hectare plot, and stems exceeding 20 cm diameter were sampled on a 0.125 ha sub-sample. During 1985, a small number of plots were established using a new approach. These plots sampled all stems exceeding 40 cm diameter over one hectare, and used four point samples (BAF 2.3 sq m/ha) to sample stems 3 to 40 cm diameter.

The species, diameter, merchantability and visual thinning[20] was recorded for each tree on all plots.

There is no compelling statistical advantage in the use of any of these plot types in preference to the others for description of the current stand or to provide forecasts. For quantifying the existing stand, there is some advantage in having a large heterogeneous plot to minimize between-plot variation. Conversely, for simulation studies, a small homogeneous plot is more appropriate. In practice, cost factors and the preference of field staff are of greater consequence.

Growth Model

An integral part of yield forecasting is growth prediction. Growth models for plantations and for monospecific forests have become sophisticated and highly accurate. Rainforests comprise hundreds of species, posing a much more difficult challenge. Notwithstanding this, a dynamic growth model for rainforests has been developed and was used in the present study. The model is described by Vanclay (1987) and the data upon which it is based is summarized in Queensland Department of Forestry (1983).

The growth model has functions for diameter increment, tree mortality, and recruitment of new trees into the stand. Each of these functions takes into account the site quality, the soil parent material, the stand composition and density, and the size of the individual trees. Site quality, expressed as good or poor, is determined objectively by assessing soil parent material, presence of indicator species[11] , estimated residual volume after visual thinning, and average log length (Vanclay, in press). The model recognises several soil parent materials: acid volcanic, basic volcanic, coarse granite, Tully granite, sedimentary-metamorphic and alluvial-colluvial. In general, coarse-grained granite-derived soils support the most productive forests.

It is impractical to develop individual functions for each of the several hundred tree species represented in north Queensland rainforests. Accordingly, commercial[5] species were grouped into four growth groups[17] according to their growth habit:

- large fast growing;
- large slow growing;
- (comparatively) small fast growing; and
- small slow growing.

Practical necessity required the use of a single group for all non-commercial species. This grouping has ecological significance, with gap opportunists contained in the large fast group, pioneer species in the small fast group, and shade tolerant species in the slow groups.

The model does not retain the species identity of each tree, but employs species groups formed from trees having membership of the same growth and harvesting groups[17], and using the same volume equation. The identity of the inventory data (as distinct from predicted recruitment) is also retained. This enables the flagging of yield forecasts which include predicted recruitment.

The growth functions employed in the model were fitted to the data using linear regression to ensure that estimates are unbiased. Because diameter increment data were sparse for large trees, the functions were constrained to be asymptotic to subjectively determined maximum diameters (Figure 2).

Because the 1984 data sampled only stems exceeding 20 cm diameter, recruitment was predicted at 20 cm diameter. However, where stems smaller than 20 cm were measured, these data were utilized, and the recruitment function was activated only when observed small stems exceeded 20 cm diameter. Stems smaller than 10 cm diameter were ignored, as with point samples (especially with BAF 10 sq m/ha), these represent very large numbers of stems per hectare, and may convey an unrealistic impression of stand composition.

Harvesting Model

Prior to logging, trees thought capable of producing a merchantable[12] log are marked for removal in accordance with Departmental guidelines (Appendix 1). When felled, some stems reveal defects not evident when the tree was standing. Depending on the amount of this defect, the log may be classified as compulsory[6] or optional. Only compulsory timber is debited to the sawmill allocation.

Essential components of the harvesting model are the logging rule, which indicates stems to be removed; an allowance to predict the compulsory proportion of the logged stems, and a damage function, which predicts mortality arising from felling and snigging damage to the residual stand.

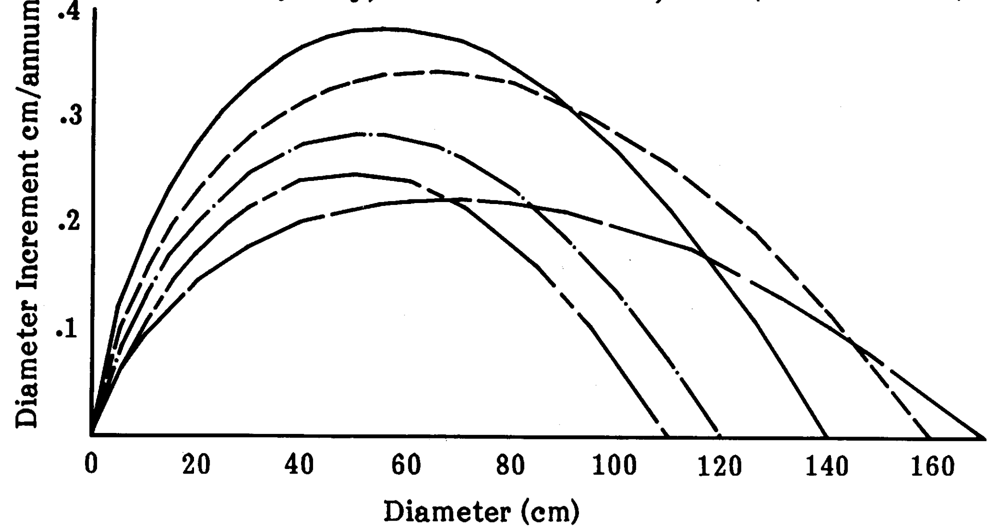
To simulate harvesting, species were placed into nine harvesting groups [17], based on the treemarking groups defined in Appendix 1 and on merchantability (Table 4). Two diameters may determine whether a tree is selected for harvesting. Trees smaller than the cutting diameter[9] may be removed only if they exceed 40 cm diameter and can be expected to die prior to the next logging. Stems above the cutting diameter and up to the retention diameter[9] will generally be removed unless they have exceptional form or vigour, or are required as a seed tree. Stems exceeding the retention diameter must be marked for logging.

Table 4 also shows that the current (1986) treemarking rules are intermediate to logging rules A and B, but most closely resemble rule A. The logging rule describes these treemarking guidelines as a series of simple linear relationships which predict the percentage of stems harvested (Figure 3). Two different logging rules were evaluated. Logging Rule A reflects removals under the 1985 treemarking guidelines; Logging Rule B incorporates a reduced retention interval[9].

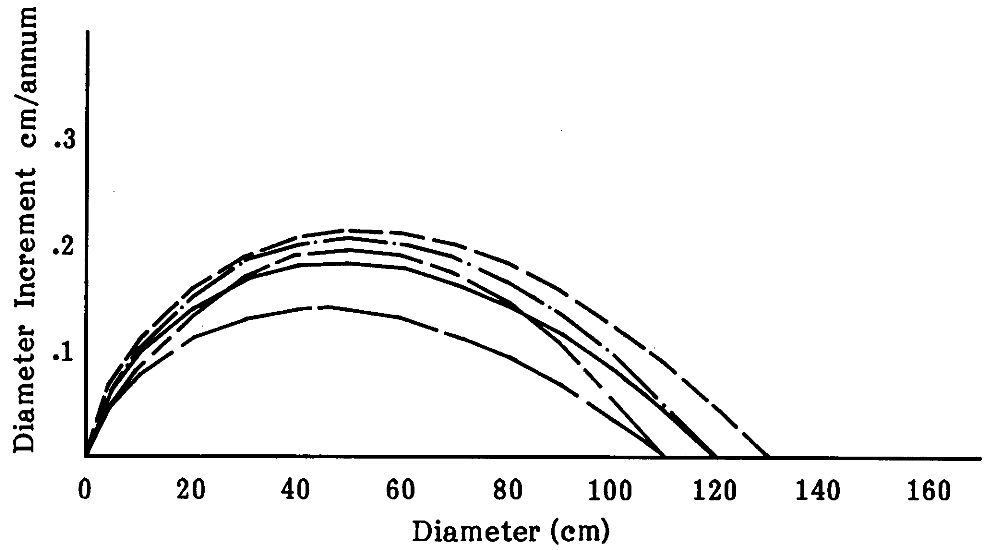
The logging rules were prepared from visual thinning assessments on the 1985 inventory plots. These data were used in preference to other alternatives, as the 1985 inventory plots were large (1 ha) and were expressly established by experienced field staff in stands logged before 1970.

Best Sites, Low Basal Area

(Good Site Quality, Coarse Granite Soil, 20 m^2/ha Basal Area)

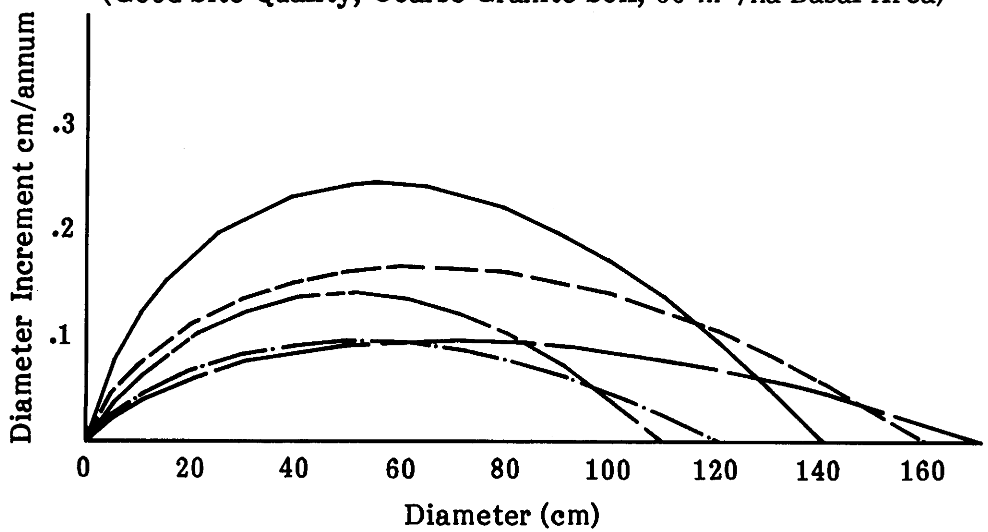


Worst Sites, Low Basal Area
(Poor Site Quality, Tully Granite Soil, 20 m^2/ha Basal Area)



Best Sites, High Basal Area

(Good Site Quality, Coarse Granite Soil, 60 m^2/ha Basal Area)



Worst Sites, High Basal Area
(Poor Site Quality, Tully Granite Soil, 60 m^2/ha Basal Area)

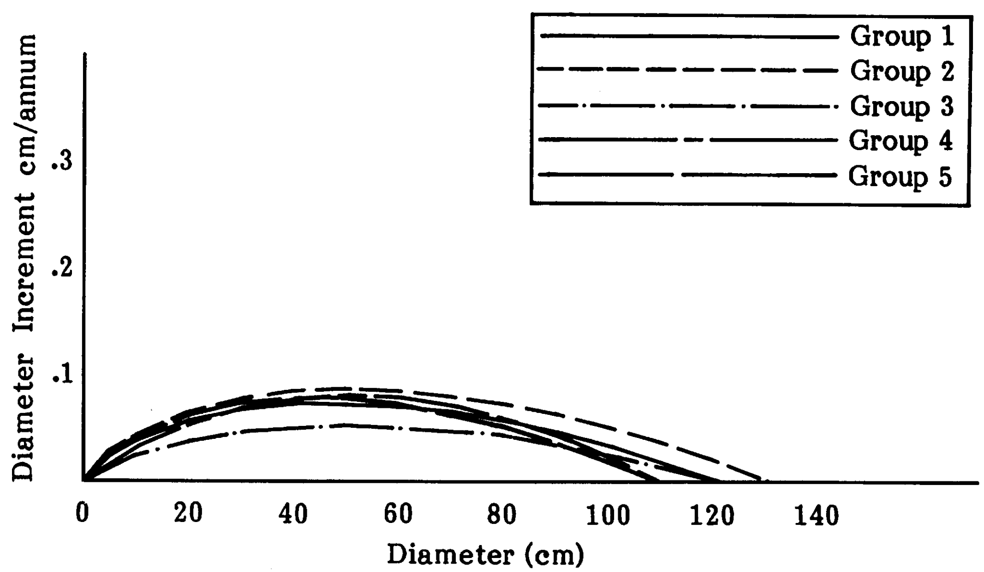


Figure 2. (p. 8, opposite). Diameter Increment Functions.

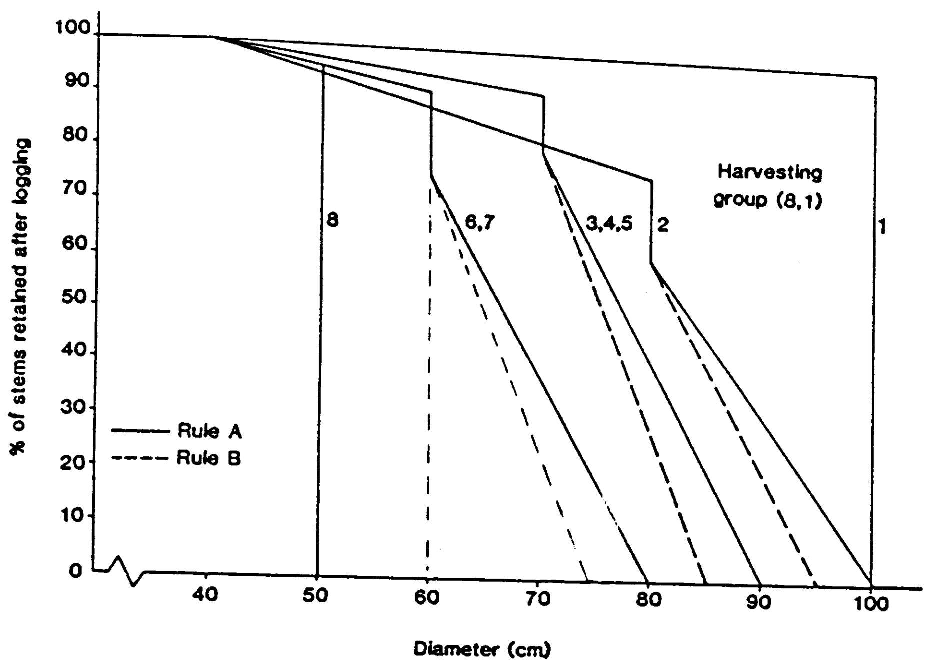


Figure 3. Logging Rule

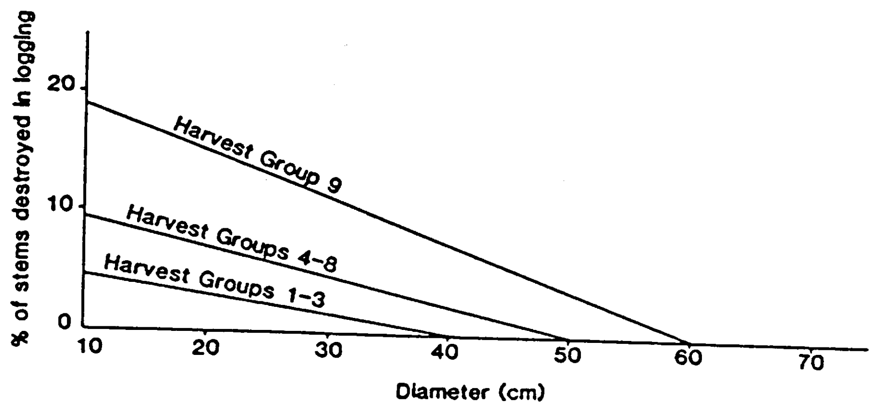


Figure 4. Damage Function

Table 4. Harvest groups.

Harvest group	Treemarking group	Cutting diameter	Retention interval: Logging rule A	Logging rule B	1986 treemarking guidelines
1	Qld walnut	100	0	0	0
2	A	80	20	15	20
3	A	70	20	15	20
4	B	70	20	15	20
5	B	70	20	15	20
6	C	60	20	15	20
7	D1	60	20	0	0
8	D2	50	0	0	0
9	Non-commercial	–	–	–	–

Logging damage functions were expressed as a series of simple linear relationships fitted by eye (Figure 4). Data were derived from nine rainforest sites (three recut and six virgin) sampled before and after logging, using clusters of 60 point samples (BAF 10 sq m/ha) on a 30 metre grid.

It was determined from Departmental logging records that non-compulsory stems comprised three percent of harvest group 1 to 3 stems, and seven percent of group 4 to 8 stems.

Volume Equations

Reliable rainforest volume equations are available in the form of two-way equations which predict log volume from tree diameter and log length (Vanclay *et al* 1987). However, since forecasting future log lengths is unnecessarily complex and inaccurate, one-way equations predicting log volume from diameter are required. One-way equations were developed, using data from the 1978–81 inventory. Inventory data included estimates of log lengths and centre diameters (the diameter over bark, half way along the log), and measurements of diameter at breast height or above buttress, over bark. Although it is desirable to use measured data for the development of volume equations, such data were available from only a few geographic locations, which were believed to be unrepresentative of the resource as a whole. Thus the use of the geographically diverse inventory data was considered preferable.

Log volumes for the inventory data were calculated using Huber's formula[10] from the estimated log length, and the estimated centre diameter reduced by a standard (0.956) bark thickness correction factor. Experience suggests that inventory staff can reliably estimate the log length on a standing tree, but that estimates of stem diameters higher up the bole are less accurate. Thus a scaling factor was developed to ensure that the one-way equation produced estimates consistent with the more reliable two-way equation. The resulting volume equations are presented in Figure 5.

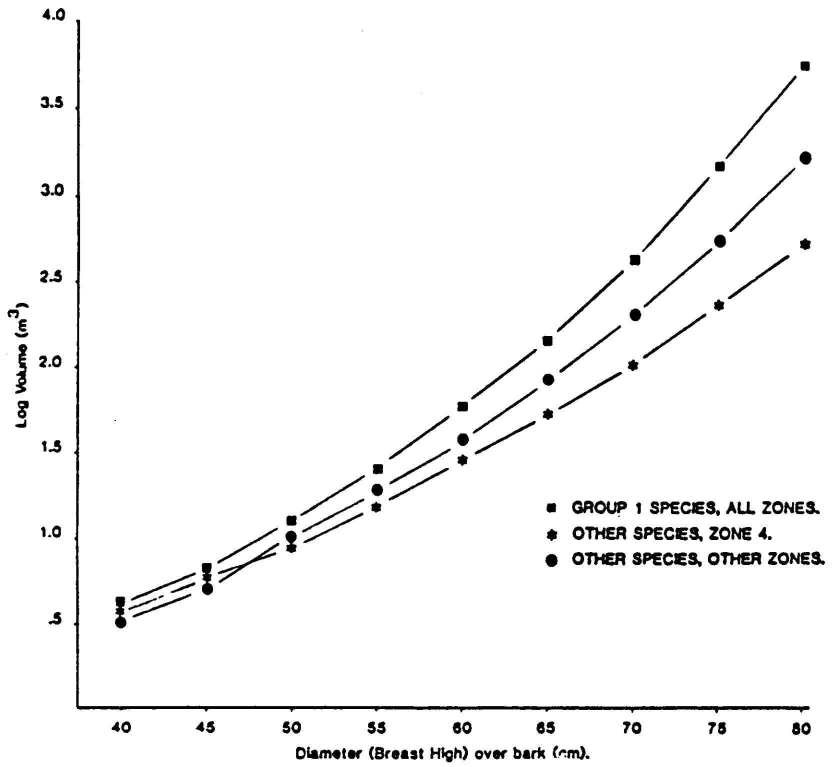


Figure 5. Volume equations

Yield Calculations

Existing resource. Table 5 presents a description of the current standing loggable volume. This volume would be removed under a tree-marked sale, and is not the total merchantable volume. It is evident that the current loggable volume of about 2 million cubic metres would be sufficient to maintain the present rate of logging for many years, even if it is assumed that there is no growth.

Table 5 also illustrates how the loggable area may vary with the logging rule applied. A comparison of the loggable areas given in Table 5 with the productive areas given in Table 2 reveals that at present, only two thirds of the productive area could be logged.

Cutting cycle analysis. Cutting cycle analysis[8] (McGrath and Carron 1966) has been widely used for calculation of the allowable cut for irregular Australian native forests, and was used in this study. Cutting cycle analysis requires a nett productive area estimate, inventory data, growth and harvesting models and volume equations. It also requires a nominal cutting cycle to be specified. For north Queensland rainforests, a cutting cycle of 40 years was adopted for all zones.

Table 5. Volumes presently available.

Allocation zone	Estimated loggable area (ha)	Estimated average yield (cu m/ha)	Estimated loggable volume (cu m)	Average stem volume (cu m)
Logging rule A				
1	38 700	15	599 400	2.50
2†	24 400	18	433 600	2.23
3	23 200	19	440 500	2.43
4	13 300	17	226 200	2.06
5	14 800	18	266 500	2.01
Total	114 400	17	1 926 200	2.25
Logging rule B				
1	38 700	17	668 000	2.48
2†	25 300	20	498 700	2.18
3	23 200	22	502 000	2.38
4	15 300	18	273 300	1.97
5	15 700	19	298 400	1.97
Total	118 200	19	2 240 400	2.20

† estimates for Zone 2 prior to Cyclone Winifred.

Traditionally, cutting cycle analysis involves stratifying each allocation zone, computing the average stand table and area within each stratum, and conducting the analysis on this aggregated data. As the actual time of harvest of any area cannot be determined, logging is simulated at the mid-point of each cycle. Thus for a 40 year cycle, logging would be simulated at 20, 60 and 100 years for the first, second and third cutting cycles respectively.

Computer software developed for the current study allowed simulation of the growth of each individual plot rather than the stratum average stand. The yield from each plot was weighted by the corresponding nett productive area, stratified by soil parent material and logging history (pre-1970, post-1970). Cutting cycle analysis was performed separately for each allocation zone using only inventory data from plots located in that zone.

Growth predictions. Table 6 provides a summary of the estimated average basal area[2] of trees exceeding 20 cm diameter on all plots in logged rainforest within each zone. Average values for logging rules A and B are presented, since differences in simulated pre-logging basal areas for successive cycles were non-significant and were less than one square metre per hectare. There is a steady increase in basal area from about 32 sq m/ha before simulation, to 44 sq m/ha after 100 years. This increase is not inconsistent with field observations, as inventory plots commonly record stand basal areas in excess of 50 sq m/ha. The increase is attributed to the replacement of a few large commercial stems with a larger number of vigorously-growing smaller stems, which do not reach a merchantable size within the time span encompassed by the simulations in the present study.

Table 6. Basal area of rainforest.

	Basal area (sq m/ha) †			
		Simulated pre-logging BA		
Allocation zone	**Initial BA logged stands**	**Year 20**	**Year 60**	**Year 100**
1	33	37	40	42
2	28	32	38	41
3	35	39	41	42
4	30	35	41	45
5	32	38	44	48
Average	32	36	41	44

† of stems 20+ cm diameter

Calculation of timber yields. The results of simulating three 40-year cutting cycles for each allocation zone, using both logging rules, are reported in Table 7. Although logging rule B consistently provides a higher yield in the first cutting cycle, it cannot be sustained on a 40-year cycle. Under rule A, the annual cut reaches stability in all zones except in Zone 3, where either a longer cycle or a modified logging rule is indicated.

Setting the allowable cut. The overall average yield determined by cutting cycle analysis using logging rule A and a 40-year cycle is 63 100 cu m/year. However, there is some evidence in Table 7 that the prognosis for the medium term is for slightly lower yields, and about 59 000 cu m/year would appear sustainable in the long term.

Allowable cuts based on these calculations are reported in Table 8. The annual cut in Zone 5 has been maintained at 5000 cubic metres, well below its long term sustainable level, because of the recent management history of the Windsor Tableland (Queensland Department of Forestry, 1981). The converse situation applies in Zone 3 which can sustain a much higher cut in the first cutting cycle. The allowable cut from Zone 3 was therefore set at 12 000 cubic metres per year.

Table 7. Results of cutting cycle analysis.

		Logging rule A			Logging rule B		
Alloc. zone	Year	Average yield (cu m/ha)	Loggable area (ha)	Annual cut (cu m/year)	Average yield (cu m/ha)	Loggable area (ha)	Annual cut (cu m/year)
1	20	20	42 500	21 700	23	43 800	24 800
	60	17	44 600	18 500	17	45 300	19 300
	100	16	46 900	19 100	17	43 600	18 400
2	20	22	27 400	15 200	25	28 000	17 300
	60	19	26 900	13 000	19	26 500	12 800
	100	19	27 800	12 900	18	27 200	12 000
3	20	24	24 100	14 600	28	24 300	16 800
	60	16	24 000	9 700	17	23 600	10 200
	100	14	22 800	8 100	13	20 400	6 800
4	20	19	19 400	9 200	22	19 900	10 700
	60	17	21 400	9 000	18	21 400	9 400
	100	18	22 000	9 600	17	21 900	9 500
5	20	24	16 600	9 900	27	16 600	11 100
	60	19	20 000	9 300	20	19 500	9 600
	100	18	21 000	9 300	18	20 100	8 900
All	20	22	130 000	70 600	25	132 600	80 700
	60	18	126 900	59 500	18	136 300	61 300
	100	17	140 500	59 000	17	133 200	55 600

Table 8. Timber yields derived from rule A.

Allocation zone	Short term yield (cu m/year)	Long-term average yield (cu m/year)	Adopted allowable cut (1986-91) (cu m/year)
1	21 700	19 800	20 000
2†	15 200	13 700	14 000
3	14 600	10 800	12 000
4	9 200	9 300	9 000
5	9 900	9 500	5 000
Total	70 600	63 100	60 000

† yields in Zone 2 prior to Cyclone Winifred.

DISCUSSION

This study encompasses several major improvements in methodology since the last review. These include:

- simulating the growth of each individual inventory plot, rather than the stratum average stand.
- identifying more species groups within the growth model, thus enabling more precise prediction of growth and harvesting.
- accounting for site quality, soil parent material, and stand density and composition within the growth model.
- determining the loggable area during each cutting cycle, rather than assuming the future status of the stand at the commencement of projection.

This study has ensured, as far as is possible within financial and time constraints, that yield estimates are precise and free of bias.

The precision of yield calculations may be influenced by the nature of data used for development of the growth and harvesting models and volume equations. Covariates such as site productivity and soil parent material should extend the applicability of the growth model, and a local volume equation was used for Zone 4. However, a single harvesting model was used throughout these calculations.

One important factor which may tend to inflate current calculations is the tendency for yields per hectare and loggable volumes to decline, suggesting that either the logging rule should be more conservative, or the cycle length should be increased. Either would lead to reduced yields.

Two factors may tend to underestimate the true yield. All inventory data which sampled virgin forest was excluded from yield estimates presented in this report. As these plots generally carry a higher standing volume, their inclusion would tend to increase yields. The growth model constrains increments of large stems to ensure realistic maximum tree sizes. This ensures robust long term forecasts, but may contribute to underestimating the increments of large trees.

It would appear that yields during the time frame of this study will be assured. However, the changing nature of the timber resource will need to be addressed by the sawmilling industry.

Opportunities for improvements in the current study and other yield studies in native forests have been highlighted by a Task Force (Vanclay *et al* 1987), and will be addressed before the next scheduled review of the allowable cut in 1991. An on-going inventory programme has been instituted, and additional inventory will be conducted where necessary. Alternative techniques such as yield scheduling (Vanclay *et al* 1987) may enable greater reliability and operational utility of yield calculations.

CONCLUSIONS

This study indicates that the allowable cut for the 1987–1991 period should not exceed 60 000 cubic metres per year. Allowable cuts in Zones 3 and 5 will be readjusted as necessary in future reviews of allocations.

Yields per hectare in recut forests will be close to the margins of current economic viability. Important future influences will be the market price of sawn and veneer timber, and the efficiency of harvesting operations.

REFERENCES

Hoschke, F.G. and Squire, R.H. (1978). Review of FORINS (Forest Resource Inventory System). Interim report 1976. N.S.W. Forestry Commission Technical Paper No. 38: 60 pages.

McGrath, K.P. and Carron, L.I. (1966). Prescribed yield from previously unmanaged indigenous forests. Proc. 6th World Forestry Congress, Madrid. 3: 2371–2376.

Preston, R.A. (1987). Use of LANDSAT 5 MSS imagery to map cyclone damage to rainforests in north Queensland. *In* Bruce, D. (Ed.). Fourth Australasian Conference on Remote Sensing, pp. 250–260. Adelaide, 1987. 2 vols.

Queensland Department of Forestry. (1981). Timber production from north Queensland's rainforests. Position paper. vii + 25pp + 3 maps.

Queensland Department of Forestry (1983). Rainforest research in north Queensland. Position paper. vii + 52 pp.

Vanclay, J.K. (1987). A stand growth model for yield regulation in north Queensland rainforests. IUFRO Forest Growth Modelling and Prediction Conference 1987, 8pp. Minneapolis, Minnesota, U.S.A.

Vanclay, J.K. A growth model for north Queensland rainforests. *Forest Ecology and Management.* (in press).

Vanclay, J.K., Henry, N.B., McCormack, B.L. and Preston, R.A. (1987). Report of the native forest resources task force. Unpublished, Queensland Department of Forestry: 103 pp.

GLOSSARY

1. Area

Gross productive area. The area marked on maps as available for harvesting and capable of producing timber.

Productive area. The gross productive area minus a correction factor for country misclassified as inaccessible or unproductive.

Nett productive area. Productive area minus unmappable fragments.

Loggable area. Nett productive area minus low yielding areas uneconomic to log.

2. Basal area

The sum of the sectional areas of tree stems at 1.3 metres above ground, expressed in square metres per hectare. In the case of rainforest tree stems, sectional areas measured above buttress may be included in calculations of basal area.

3. Basal area factor

The intensity of point sampling. For example, with BAF 10 sq m/ha, each stem sampled would represent 10 sq m/ha.

4. Buffer strip

A strip of forest left undisturbed adjacent to perennial streams to inhibit sedimentation.

5. Commercial

Refers to tree species which produce timber useful for cabinet, veneer or structural purposes.

6. Compulsory

Compulsory species. When marked by a Forest Officer, a tree of a compulsory species must be cut by the log purchaser to test whether it can yield a compulsory log. Trees of other (or non-compulsory) species may be treemarked by a forest officer, but cutting is then at the purchaser's option. A list of compulsory species is contained in the treemarking guidelines for north Queensland rainforests.

Compulsory log. A log which, according to Departmental specifications, is large enough and sufficiently free of defect to be processed by a sawmill. A log not meeting the Departmental specification is classed as optional, and may be removed from the forest at the purchaser's choice.

7. Cutting cycle

The planned or assumed period between any two consecutive loggings in any one stand.

8. Cutting cycle analysis

A technique for yield forecasting in irregular native forests.

9. Harvesting diameter

Cutting diameter. The diameter at which a tree is normally harvested, as specified in treemarking guidelines.

Retention diameter. The diameter at which all merchantable trees (other than seed trees) must be logged.

Retention interval. The difference between the retention and cutting diameters.

10. Huber's formula

A method used to assess the solid volume of round timber of a stem or log by multiplying the cross sectional area (at the mid-length) by the length.

11. Indicator species

A species, the prescence of which is indicative of the productive capacity of a particular site (with respect to soil nutrient status, drainage, precipitation or other factors).

12. Merchantable

Refers to commercial species over 40 cm diameter, which when felled, would produce a compulsory log.

13. Optical wedge

A hand held instrument incorporating fixed angle, used during point sample inventory.

14. Point sample

A sampling technique characterized by a point at which trees are sampled with probability proportional to size. Small trees are sampled over a small area, and large trees are sampled over a large circular area centered on that point.

15. Recruitment

The process which describes the growth of trees into a specified diameter class.

16. Scientific area

Areas of native forest within State Forest selected and managed to preserve significant ecosystems and to provide for their scientific investigation.

17. Species group

Growth group. Four groups based on the rate of growth (fast or slow) and maximum size (large or small); a fifth group of non-commercial species.

Harvesting group. Eight groups related to treemarking (cutting diameter, retention interval), and a ninth group of unmerchantable stems.

18. Stand

A community of trees possessing sufficient uniformity as regards composition and spatial arrangement to be distinguishable from adjacent communities, so forming a management entity.

19. Virgin

Rainforest that has not been logged.

20. Visual thinning

An ocular estimate of whether a tree would be marked for removal at the time of plot measurement under the current treemarking guidelines.

21. Volume equation

A mathematical function which provides an estimate of the average log volume in cubic metres, given one or more external dimensions such as stem diameter or height.

22. Yield

Refers to timber that is removed or is able to be removed from the forest.

APPENDIX 1

TREEMARKING GUIDELINES FOR

NORTH QUEENSLAND RAINFORESTS

9.02.01 **Subject**

Treemarking for Mill Logs in North Queensland Rainforests.

9.02.02 **General**

These guidelines replace all previous instructions on this topic.

9.02.03 **Objectives**

The Department of Forestry applies multiple use management principles to achieve its overall State Forest management objective which is the sustainable production of forest products within a balanced conservation programme. In the area of wood production the management objective is to ensure that as far as possible the State's net requirements for wood products can be met from its combined Crown and private resource.

The periodic harvesting of wood from State Forests and Timber Reserves is an essential component of the overall management strategy and treemarking is recognised as the regulatory mechanism which constrains the harvesting process within the requirements of defined management objectives.

The objectives of treemarking are:

1. To harvest from the accumulated capital growth component of the forest while retaining a forest structure which is consistent with the objective of sustained yield management.

2. To comply with defined environmental guidelines.

3. To encourage regeneration in accordance with the principles of sustained yield management.

4. To manage species composition to improve growth and wood quality.

These objectives are enlarged upon below:

9.02.04 **To harvest from the accumulated capital growth component of the forest while retaining a forest structure which is consistent with the objective of sustained yield management.**

If the maximum sustainable yield of forest products is to be achieved, it is necessary to ensure that those trees which are needed to produce the future harvests from the area are retained. The retention of additional merchantable stems is not desirable unless they are necessary for the fulfillment of the objectives in sections 9.02.05 to 9.02.07.

9.02.05 **To comply with defined environmental guidelines.**

1. Thoughtful treemarking can help to minimise the environmental impact of logging operations. It is important that any environmental guidelines which apply to the area being treemarked as well as any general departmental guidelines e.g. Guidelines for the Selective Logging of Rainforest Areas in North Queensland State Forests and Timber Reserves, be considered carefully before treemarking commences.

2. While conservation of genetic types, provenances or species is normally a function of the Scientific Area (S.A.) system, in some cases this is impractical. In these cases, the sale proposal will provide guidelines to achieve the desired objective.

3. As a general rule, it is desirable to have at least 50% canopy cover over the net productive area of the sale (excluding roads and ramps) once logging is complete. Where necessary the guidelines in sections 9.02.10 to 9.02.15 should be modified to achieve this objective.

9.02.06 **To encourage regeneration in accordance with the principles of sustained yield management.**

The promotion of regeneration is an essential consideration when undertaking treemarking. The guidelines recognise this by ensuring an adequate seed source is retained.

9.02.07 **To manage species composition to improve growth and wood quality.**

1. It is recognised that some species are preferable to others in terms of their growth and wood quality characteristics. The treemarking guidelines recognise this in two ways:

   - Species have been grouped (see section 9.02.15). Group A species should be retained in preference to Groups B, C or D. However, there is no preference for retention between these latter groups e.g. Group B species are not preferred to Group C on the basis of Group alone.

   - The cutting diameter limit for each species i.e. the diameter above which a tree will not normally be retained, has been set according to the pattern of its growth potential.

2. As logging damage to retained stems will adversely affect the productivity of the stand, it is important that it be minimised. To assist in achieving this, the treemarker should:

   - Indicate the direction(s) of fall for any stem which is to be cut. By doing this, growing stock damage as a result of falling operations should be minimised.

   - Clearly indicate stems required for retention which are especially valuable or vulnerable to logging damage (section 9.02.09 describes how this should be done). Examples of the former include seed trees; of the latter, trees near the edge of a proposed snig track.

9.02.08 **Variations in Treemarking Guidelines**

A requirement in achieving the objectives is a common sense interpretation of the various guidelines referred to below. The principles and philosophies behind the guidelines must be observed at all times.

In some cases it will be necessary to vary the guidelines in order to achieve the objectives outlined in sections 9.02.03 to 9.02.07. (In particular, note section 9.02.05.) Wherever possible, these variations (and the reasons for them) should be covered in the sale proposal. Changes during the currency of a sale should be documented and approved by the Sub-District Forester.

9.02.09 **Treemarking Technique**

1. The technique used for the physical process of treemarking may vary from time to time depending upon the cost and practicality of available procedures. Paintmarking is generally favoured but axe blaze marking has also been used effectively. As a general principle the technique should:

   - include adequate safeguards against malpractice;

   - clearly transmit the intention of the treemarker to the cutter; and

   - be cost effective.

The technique to be used should be approved by the Sub-District Forester.

2. If a cutter indicates that he cannot fall the tree in the direction indicated, that it is too dangerous to fall, or that it is a dud i.e. a tree which is useless for sawmilling purposes, the treemarker should carefully consider the cutter's reason(s). If he thinks they are reasonable, then corrective action should be taken.

3. It is often difficult to decide whether a tree contains a border-line mill log or is a dud. Relevant considerations are:

   - If the treemarker considers that a tree has a reasonable chance of making a log then it should be marked for felling, provided the damage done to the residual stand by felling a marginal stem does not outweigh the potential volume return.

   - There is no departmental policy on the percentage of duds which are acceptable on any sale area. Each tree should be treated on its merits.

   - The quality of trees which have been cut in the general area should be taken intc consideration.

4. Where the treemarker wishes to draw the attention of the logging contractors to a specific retained stem, this can be achieved by painting a continuous ring around the tree.

5. All areas should be treemarked to a face.

9.02.10 Cutting Diameters

Unless a tree is required for retention under the provisions of sections 9.02.11 or 9.02.12 then it is to be marked for removal if its diameter exceeds the cutting diameter nominated for the species in section 9.02.15.

9.02.11 Seed Trees

1. Seed trees are required at an average spacing of 40 x 40 m.

2. The minimum acceptable DBH/ABOB is 40 cm and the maximum is 20 cm above the normal cutting diameter (see section 9.02.15). Preference should be given to trees between 40 cm DBH/ABOB and the normal cutting diameter.

3. Where possible seed trees should have reasonably long boles (greater than 6 m) with well developed, healthy crowns.

4. Preference should be given to retention of trees in order of their species desirability (see section 9.02.15). There is no preference between Groups B, C or D.

5. Seed trees are not required where the post-logging stand will have either:

   - 75 well spaced stems per hectare of Group A species which are 3 m plus in height or

   - 170 well spaced stems per hectare of any commercial species which are 3 m plus in height.

9.02.12 Outstanding Trees

It is desirable to retain healthy, growing trees of some species which have outstanding vigour and form, even if they exceed the nominated cutting diameter, because of their potential to enhance future yields.

However, the total number of trees retained under this section and section 9.02.11 (seed trees) which exceed the cutting diameter limit, should not exceed 7 stems per hectare. Only trees of Groups A, B or C species may be retained under the provisions of this section.

Where a choice exists, Group A species are preferred for retention.

Normal cutting diameters and maximum retention sizes are as follows:

Species Group	Normal Cutting Diameter (cm)	Maximum Retention Diameter (cm)
Queensland Walnut	100	100
Other A	(80	100
Group	(70	90
B	70	90
C	60	80
D-1	60	60
D-2	50	50
	(70	90
Forest Hardwoods	(60	80

9.02.13 Removals below cutting diameter.

Trees may be marked for removal below the normal cutting diameter for that species only if they are defective or severely damaged and they will produce a log of at least minimum standard.

9.02.14 Species protected from non-salvage logging.

The following species, while compulsory, are only to be removed on a salvage basis.

Trade Name Australian Standard 2543-1983	Botanical Name
Queensland Kauri Pine	Agathis microstachya
Satin Silky Oak	Macadamia sp.

9.02.15 **Compulsory Species List and Cutting Diameter Limits**

Group A species are in order of desirability, for retention.

Group B, C and D are alphabetical listings only. There is no preference for retention between Groups B, C and D species.

Limit dbhob (cms)	Trade Name Australian Standard 2543-1983	Botanical Name	Comment
GROUP A			
80	Queensland maple	Flindersia brayleyana	
80	Red Cedar	Toona australis	
80	Maple Silkwood	Flindersia pimenteliana	
80	Queensland Kauri Pine	Agathis robusta Agathis atropurpurea	syn. A. palmerstonii
80	Northern Silky Oak	Cardwellia sublimis	
70	Silver Silkwood	Flindersia acuminata	
70	Silver Ash	Flindersia schottiana Flindersia bourjotiana	syn. F. pubescens No tree showing undulating or roping patterns on the bole surface is to be marked for removal.
100	Queensland Walnut	Endiandra palmerstonii	
70	Hickory Ash	Flindersia iffliana	
GROUP B			
70	Black Pine	Prumnopitys amara	syn. Podocarpus amara
70	Briar Silky Oak	Musgravea heterophylla	
70	Johnstone River Hardwood	Backhousia bancroftii	
70	Red Silkwood	Palaquium galactoxylum	
70	Red Siris	Albizia toona	
70	Red Tulip Oak	Argyrondendron peralatum	
70	Satin Oak	Oreocallis wickhamii	
70	White Beech	Gmelina fasciculiflora	
70	White Cheesewood	Alstonia scholaris	
GROUP C			
60	Barringtonia	Barringtonia calyptrata	
60	Black Bean	Castanospermum australe	
60	Blush Silky Oak	Opisthiolepis heterophylla	
60	Bolly Silkwood	Cryptocarya oblata	
60	Boonjie Blush Walnut	Beilschmiedia sp. excluding **B. obtusifolia (blush walnut)**	
60	Brown Quandong	Elaeocarpus coorangooloo Elaeocarpus ruminatus	
60	Brown Walnut	Endiandra acuminata	Syn. E. subtriplinervis
60	Brush Mahogany	Geissois biagiana	
60	Crater Silky Oak	Musgravea stenostachya	Compulsory at minimum stumpage
60	Cream Mahogany	Chisocheton longistipitatus	
60	Damson	Terminalia sericocarpa	
60	Evodia	Euodia elleryana	
60	Fishtail Silky Oak	Neorites kevediana	
60	Grey Carabeen	Sloanea macbrydei	
60	Grey Satinash	Eugenia gustavioides	
60	Kuranda Satinash	Eugenia kuranda	
60	Magnolia	Galbulimima belgraveana	
60	Miva Mahogany	Dysoxylum muelleri	
60	Northern Evodia	Euodia vitiflora	
60	Pepperwood	Cinnamomum laubatii	
60	Pink Myrtle	Metrosideros queenslandica	

Limit dbhob (cms)	Trade Name Australian Standard 2543-1983	Botanical Name	Comment
60	Red Eungella Satinash	Eugenia sp.	N.B. Do not mark stems above 100 cm DBH/ABOB. Restrict marking to trees actively growing i.e. wide sapwood band.
60	Red Penda	Xanthostemon whitei	No tree in excess of 180 cm DBH/ABOB is to be marked for removal unless requested by the purchaser
60	Rose Alder	Caldcluvia australiensis	syn. Ackama australiensis
60	Rose Butternut	Blepharocarya involucrigera	
60	Rose Mahogany	Dysoxylum fraseranum	
60	Rose Silky Oak	Placospermum coriaceum Darlingia ferruginea	
60	Sassafras	Doryphora aromatica Daphnandra dielsii	
60	Satin Sycamore	Ceratopetalum succirubrum	
60	Scented Maple	Flindersia laevicarpa	
60	Silver Quandong	Elaeocarpus grandis	
60	Spur Mahogany	Dysoxylum pettigrewianum	
60	Stony Backhousia	Backhousia hughesii	
60	White Carabeen	Sloanea langii	
60	White Eungella Satinash	Eugenia spp. aff. smithii	
60	Yellow Bean	Ormosia ormondii	Syn. Podopetalum ormondii
60	Yellow Satinash	Eugenia sp.	
60	Yellow Siris	Albizia xanthoxylon	
60	Yellow Walnut	Beilschmiedia bancroftii	No tree showing undulating or roping pattern on the bole surface of this species is to be marked for removal.

GROUP D-1

Limit dbhob (cms)	Trade Name Australian Standard 2543-1983	Botanical Name	Comment
60	Blush Alder	Sloanea australis	No tree showing undulating or roping pattern on the bole surface of this species is to be marked for removal.
60	Brown Tulip Oak	Argyrodendron trifoliolatum	
60	Buff Silky Oak	Sphalmium racemosum	syn. Orites racemosa
60	Canary Beech	Polyalthia michaelii	
60	Cassowary Satinash	Acmena graveolens	
60	Cheesewood	Nauclea orientalis	
60	Cherry Satinash	Eugenia luehmannii	
60	Endospermum	Endospermum peltatum	
60	Hard Leichhardt	Neonauclea sp.	
60	Kwila	Instia bijuga	
60	Lillipilli Satinash	Acmena smithii	syn. Eungenia smithii
60	Mararie	Pseudoweinmannia lachnocarpa	
60	Paperbark Satinash	Eugenia sp.	
60	Pink Mahogany	Dysoxylum oppositifolium	
60	Plum Satinash	Eugenia cryptophlebia	
60	Rose Maple	Cryptocarya rigida	
60	Rose Walnut	Endiandra cowleyana	
60	Rough-barked Satinash	Eugenia trachyphloia	
60	Salmon Bean	Archidendron vaillantii	

Limit dbhob (cms)	Trade Name Australian Standard 2543-1983	Botanical Name	Comment
60	Scentless Rosewood	Synoum muelleri	
60	Tulip Plum	Pleiogynium timorense	
60	White Birch	Schizomeria whitei	
60	White Siris	Ailanthus triphysa	
60	Yellow Boxwood	Planchonella obovoidea	
	Planchonella pohlmaniana		
60	Yellow Penda	Tristania pachysperma	

GROUP D-2

Limit dbhob (cms)	Trade Name	Botanical Name	Comment
50	Almondbark	Prunus turnerana	
50	Blackwood	Acacia melanoxylon	
50	Bollywood	Litsea bindoniana	
		Litsea glutinosa	
		Litsea leefeana	
		Litsea reticulata	
		Litsea sp.	
50	Brown Pine	Podocarpus elatus	
50	Brown Salwood	Acacia aulacocarpa Acacia mangium	N.B. In pure stands, treemark to 60 cm DBHOB to avoid excessive damage to retained trees.
50	Brown Silky Oak	Darlingia darlingiana	
50	Brush Cypress Pine	Callitris macleayana	
50	Creek Satinash	Eugenia australis	
50	Hard Milkwood	Alstonia muellerana	
50	Hard Quandong	Elaeocarpus sericopetalus	
50	Lightwood	Acacia implexa	
50	Northern Quandong	Elaeocarpus foveolatus	
50	Nutmeg	Myristica insipida	syn. M. muelleri
50	Pink Ash	Alphitonia petriei	
50	Pink Satinash	Syzygium dictyophlebium	
50	Tropical Quandong	Elaeocarpus largiflorens	
50	White Cedar	Melia azedarach var. australasica	
50	White Hazelwood	Symplocos cochinchinensis var. stawellii	
50	Yellow Evodia	Euodia bonwickii	

ALTERATIONS TO STANDARD TRADE NAMES

Former Name	New Name
Northern Hard Quandong	See Hard Quandong
Northern Rose Walnut	See Rose Walnut
Northern Sassafras	See Sassafras or Grey Sassafras
Northern Scentless Rosewood	See Scentless Rosewood
Northern Silver Ash	See Silver Ash
Queensland Silver Ash	See Silver Ash
Northern Yellow Boxwood	See Yellow Boxwood

Computer codes for old trade names remain in the system, and are accepted without alteration.

COMPULSORY HARDWOOD SPECIES

The listed forest hardwood species can occur in association with rainforest species and adjacent to rainforest margins. When encountered, removal shall be compulsory and debited against allocation. (Such occurrences have been included in inventory assessments and are regarded as part of the rainforest resource for allocation purposes.)

70	Broad-leaved Tea-tree	Melaleuca leucadendron
70	Cadaga	Eucalyptus torrelliana
70	Forest Red Gum	Eucalyptus tereticornis
70	Grey Ironbark	Eucalyptus drepanophylla
70	Rose Gum	Eucalyptus grandis
70	*Red Mahogany	Eucalyptus pellita
70		Eucalyptus resinfera
70	Turpentine	Syncarpia glomulifera
60	White Stringybark	Eucalyptus phaeotricha

*Compulsory Species but at minimum stumpage.

9.02.17 **Non Compulsory Species List.**

Trade Name Australian Standard 2543-1983	Botanical Name
Bignonia	Deplanchea tetraphylla
Black Silky Oak	Stenocarpus reticulatus
Blush Satinash	Eugenia hemilampra
Blush Touriga	Calophyllum australianum
Blush Walnut	Beilschmiedia obtusifolia
Blushwood	Hylandia dockrillii (formerly Euphorbiaceae)
Brown Cudgerie	Canarium australasicum
Brown Penda	Xanthostemon chrysanthus
Bumpy Satinash	Eugenia cormiflora
Buttonwood	Glochidion ferdinandi etc.
Calendonian Oak	Carnarvonia araliifolia
Candlenut	Aleurites moluccana
Coach Walnut (formerly included under Brown Walnut)	Endiandra dichrophylla (anomalous) Endiandra glauca Endiandra rubescens syn. E. montana Endiandra tooram
Eumundi Quandong	Elaeocarpus eumundi
Grey Boxwood	Drypetes australasica
Grey Sassafras	Dryadodaphne novoguineensis
Hairy Walnut	Endiandra pubens
Hard Alder	Pullea stutzeri
Hickory Boxwood	Planchonella euphlebia
Incensewood	Pseudocarapa nitidula
Ivory Mahogany	Dysoxylum gaudichaudianum syn. D. decandrum
Kapok-tree	Bombax ceiba
Macintyre's Boxwood	Xanthophyllum octandrum
Pink Sycamore	Ceratopetalum virchowii
Plum Boxwood	Chrysophyllum chartaceum syn. Niemeyera chartacea
Red Ash	Alphitonia whitei
Redheart	Dissiliaria baloghioides
Scaly Ash	Ganophyllum falcatum
Scrub Turpentine	Canarium australianum Canarium muelleri
Silky Celtis	Celtis paniculata
Silver Sycamore	Cryptocarya glaucescens
Spotted Silky oak	Buckinghamia celsissima
Whelan's Silky Oak	Macadamia whelanii