MODELLING CHANGES IN THE MERCHANTABILITY OF INDIVIDUAL TREES IN TROPICAL RAINFOREST

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Summary

The deterioration of merchantable trees over time is often assumed to be negligible in growth models and yield calculations. Although the annual probability of becoming unmerchantable is small, the cumulative probability over a cutting cycle is significant, and should be included in yield studies.

Logistic regression analyses of permanent sample plot data revealed that changing merchantability can be modelled using species, stand basal area, tree size and time since last logging. The equation developed for the rainforests of north Queensland indicates that up to ten percent of trees may become unmerchantable during a forty year cutting cycle.

Résumé

Il est souvent supposé, dans les modèles de croissance et les calculs de la possibilité, que la détérioration des arbres marchands au cours du temps est négligeable. Quoique la probabilité annuelle qu'un arbre cesse d'être marchand soit faible, la probabilité cumulative au cours d'une rotation est significative et l'on devrait l'incorporer dans les études de la possibilité.

Des analyses par régression logistique de données relatives à des placettes d'échantillonnage permanentes ont montré que l'on peut créer un modèle des changements de la qualité marchande en utilisant l'essence, la surface terrière du peuplement, la grandeur de l'arbre et le temps écoulé depuis la dernière rotation. L'équation développée pour les forêts denses humides du nord de la Queensland indique que jusqu'à dix pour cent des arbres peuvent cesser d'être marchands au cours d'une rotation de quarante ans.

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Resumen

Con frecuencia, en modelos de crecimiento y cálculos de producción, se asume que el deterioro de árboles comerciales a través del tiempo es insignificante. No obstante de que la probabilidad anual de perder su valor comercial es pequeña, la probabilidad acumulativa sobre un ciclo de corte es importante, y debe ser incluida en estudios de producción. Los análisis logísticos de regresión de datos de parcelas permanentes revelaron que los cambios de valor comercial pueden modelarse utilizando especies, área basal del rodal, tamaño del árbol y tiempo desde la última explotación forestal. La ecuación desarrollada para los bosques tropicales del norte de Queensland indica que más de un diez por ciento de los árboles pueden perder su valor comercial durante un ciclo de corte de cuarenta años.

Introduction

A substantial proportion of trees in tropical rainforests may contain sufficient defects to render the tree unmerchantable. In these forests, the merchantability of each tree is usually assessed during inventory, and may be determined by the log length and straightness, the presence of scars, fungi and other external defects, and by the anticipated amount of internal defect. Such merchantability assessment guards against overestimates of standing volume.

Yield studies generally ignore the changing merchantability of trees. Although it is valid to assume that merchantability does not change in the short term, this assumption may lead to an overestimate of the long term yields. To ensure unbiassed estimates of the sustained yield, the changing merchantability status of stems should be modelled.

Data

The tropical rainforests of north-east Queensland were managed for conservation and timber production for more than eighty years (JUST, 1991) until their World Heritage nomination in 1988. Management of these forests was supported by a comprehensive research programme (QUEENSLAND DEPARTMENT OF FORESTRY, 1983) which provided a database of 250 permanent sample plots with a measurement history of up to forty years. These plots sample virgin, logged and silviculturally treated forests (VANCLAY, 1990).

Permanent sample plots range in size from 0.04 to 0.5 hectares, and have been frequently re-measured. All trees exceeding 10 cm dbh (diameter over bark at breast height (1.3 m) or above buttressing) were measured for diameter and subjectively assessed as merchantable or unmerchantable. To improve the consistency of assessments, assessors had access to previous assessments while in the field.

Pairs of remeasurements were selected from the database to try to attain an interval between remeasurements of approximately five years, which did not span any logging or silvicultural activity. A data file was created for input to the statistical package GLIM (PAYNE, 1986), and contained 44 000 individual tree records of species, dbh and change in merchantability, and stand variables such as site quality, stand basal area, time since last logging and soil type.

Preliminary analyses of the data revealed that change in merchantability was found to be uni-directional; useful stems became useless, but useless stems never became useful. Thus change in merchantability was coded as 1 for useful trees which remained useful, and 0 for useful trees which became useless at the next re-measurement. Of the data, 89 trees were observed to change to useless.

Method

Modelling change in merchantability is analogous to modelling mortality. The probability that a tree survives as a merchantable stem may be modelled using logistic regression, adjusted to account for the varying periods of observation. The transformation implied is

$$y = Log\left[\frac{p^{1/t}}{1 - p^{1/t}}\right]$$

where t is the number of years between remeasurements and p is the proportion of trees surviving as merchantable stems. However, GLIM (PAYNE, 1986) enables logistic regression to be performed without explicitly transforming the data, and this enables individual tree observations to be used (VANCLAY, 1989).

As few instances of stems becoming non-commercial were recorded in the data, it was not possible to derive prediction equations for each individual species, and the individual species were combined according to the species groups defined in the treemarking guidelines (PRESTON and VANCLAY, 1988; VANCLAY, 1989). Statistical analyses revealed that many of these nine groups were not significantly different, so they were further combined into two groups:

– Treemarking groups A, B and forest hardwoods, and
– Treemarking groups C, D and optional species.

The former group comprises the more durable and valuable species, while the latter comprises less durable species.

Results

The major influences on merchantability were species group, stand basal area, tree size and time since last logging (Table 1). Soils derived from coarse granites had a significantly higher incidence of trees becoming unmerchantable. Site quality had no detectable effect.

TABLE 1. Analysis of Deviance

Source	d.f.	Deviance (Chi-squared)	Probability
Fitted Model	6	240	<0.0001
Species group	1	81	<0.0001
Stand basal area	1	56	<0.0001
Tree size (group 1)	1	39	<0.0001
Time since logging (group 2)	1	29	<0.0001
Coarse granite soils	1	19	<0.0001
Species-basal area interaction	1	16	<0.0002
Other variables examined			
Site quality	1	2.0	0.15
Time since logging (group 1)	1	1.4	0.2
Tree size (group 2)	1	1.3	0.2
Other soils	4	3.1	0.5
Species-granite interaction	1	0.2	0.6

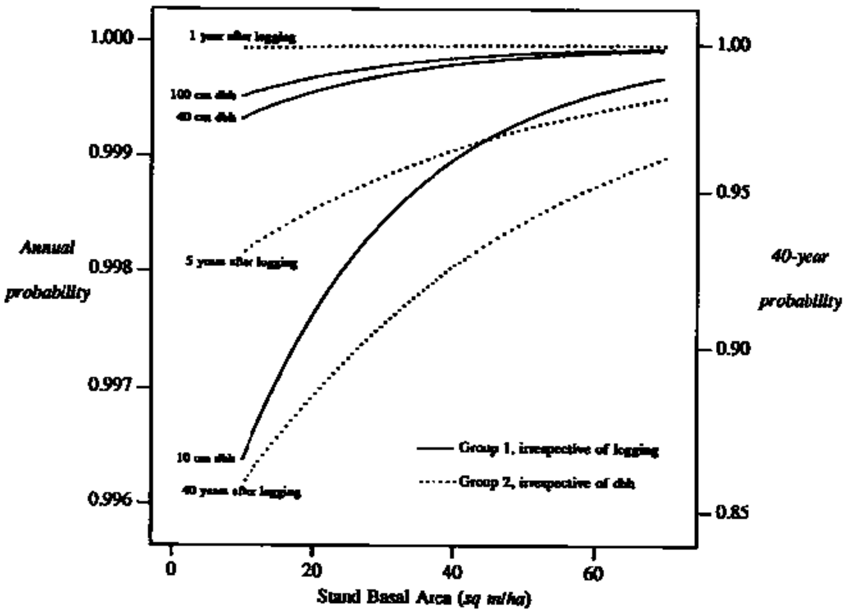
The resulting prediction equations are:

$$p_1 = \left(1 + e^{-(7.450 + 0.04195BA - 22.49/DBH - 0.4213CG)}\right)^{-1}$$

$$p_2 = \left(1 + e^{-(5.240 + 0.02238BA - 4.186/TSL - 0.4213CG)}\right)^{-1}$$

where p_i is the annual probability that a merchantable tree of species group i survives as merchantable (ie. does not become unmerchantable), BA is stand basal area (m^2/ha) exceeding 10 cm dbh, TSL is time since last logging (*years*), DBH is dbh (*cm*), and CG takes the value one for soils derived from coarse grained granites and zero otherwise. The n year probability of remaining merchantable may be computed as p^n, and the probability of becoming unmerchantable as $1-p^n$. The relationship for non-granite soils is illustrated in Figure 1.

FIGURE 1. Proportion of Stems remaining Merchantable



Discussion

The strong influence of time since last logging on species group 2 is not unexpected, as treemarking guidelines (PRESTON and VANCLAY, 1988) require trees with visible defect to be harvested, while healthy and vigorous trees are retained. The monotonic nature of the response (ie. $1/TSL$) was unexpected, as logging inevitably causes some damage which may be expected to give rise to increased defect in the future. A number of other transformations of time since logging were examined, but none provided a better fit than the reciprocal. For virgin stands, the reciprocal of time since logging was assigned the value zero. This was appropriate, as they were found to have significantly more deterioration than stands which have not been logged for forty to fifty years.

Changing merchantability exhibited a significant correlation with soils derived from course grained granites, increasing the probability of deterioration by fifty per cent (eg. survival of 0.998 for non-granite soils corresponds to 0.997 for granite soils). However, soils derived from Tully (fine grained) granites did not exhibit this effect (Table 1). It is likely that this correlation is not solely due to the soil type, but also due in part to exposure (viz. granite forms many of the ridges and hills which are exposed to wind and storm damage).

These equations imply that up to ten percent of trees initially assessed as merchantable may deteriorate and become unmerchantable during a forty year logging cycle (Figure 1). This may have a significant effect on yield estimates.

Conclusion

This study has illustrated that deterioration of merchantable stems during the logging cycle is significant and should be simulated in growth models and yield studies. Changing merchantability can readily be estimated using logistic regression.

Factors significant in predicting deterioration in the rainforests of north Queensland included species, stand basal area, tree size and time since last logging. A prediction equation for these forests suggests that the annual proportion of stems becoming unmerchantable is generally less than one half of one percent, but that the cumulative proportion over a forty year cutting cycle may be as high as ten percent.

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