**UNIVERSITI PUTRA MALAYSIA**

# GROWTH AND DEVELOPMENT OF A MALAYSIAN DIPTEROCARP FOREST AFTER HARVEST

**THAKUR BABU KARKEE**

# GROWTH AND DEVELOPMENT OF A MALAYSIAN DIPTEROCARP FOREST AFTER HARVEST

By

THAKUR BABU KARKEE

Thesis Submitted in Fulfillment of the Requirements
for the Degree of Master of Science in the Faculty of Forestry
Universiti Pertanian Malaysia

August, 1993

## DEDICATION

This work is dedicated to my parents who always inspired me for pursuing higher education.

## ACKNOWLEDGEMENT

I wish to express my gratitude to the Institute of Forestry Central Campus at Pokhara, Nepal for providing the opportunity to study and to the USAID for financial support.

I am grateful to my supervisory committee: present chairman Associate Professor Dr. Lim Meng Tsai, former chairman Associate Professor Dr. Yusuf Hadi and Dr. Nor Aini Ab. Shukor for their generous guidance and inspiration throughout the study. Profound appreciation is extended to Dr. Steven Korsgaard of the FAO in the Forestry Department Headquarters, Peninsular Malaysia for his help in programming. My sincere appreciation goes to Dr. Wan Razali Mohd. of the Forest Research Institute, Malaysia for his constructive suggestions. I would like to thank Mr. Yong Teng Koon of the Forestry Department Headquarters, who provided me data and literature on the Lebir Forest Reserve in Kelantan, Peninsular Malaysia. I am grateful to my colleagues, Mr. Bimal K. Poudyal and Mr. Suresh K. Shrestha for their assistance.

Love and patience from my parents, my wife, Sanju Karki and my son, Ankur Karki have encouraged me to accomplish this task. I would like to express my deepest appreciation and thanks to them.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF ABBREVIATIONS

### Stand Parameters

BMAI = Mean Annual Basal Area Increment
DMAI = Mean Annual Diameter Increment
MAM = Mean Annual Mortality
SMAI = Mean Annual Stems Increment

### Harvesting Intensities (HIs)

HHI = High Harvesting Intensity
LHI = Low Harvesting Intensity
MHI = Medium Harvesting Intensity

### Species Groups (SG)

DM = Dipterocarps Meranti
DNM = Dipterocarp Non-meranti
HHW = Heavy Hard Wood (Non-dipterocarps)
LHW = Light Hard Wood (Non-dipterocarps)
MHW = Medium Hard Wood (Non-dipterocarps)
NM = Non-marketable
PM = Potentially Marketable
PS = Pioneer Species

### Others

AIFM = Asean Institute of Forest Management
ANOVA = Analysis of Variance
asl = Above Sea Level
dbh = Diameter at Breast Height
CV = Coeffficient of Variation
DMRT = Duncan's Multiple Range Test
FT = Forest Types
HIs = Harvesting Intensities
LFR = Lebir Forest Reserve
MISC = Miscellaneous
PSPs = Permanent Sample Plots
RMSE = Root Mean Square Error
SMS = Selective Management System

Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Master of Science.

**GROWTH AND DEVELOPMENT OF A MALAYSIAN DIPTEROCARP FOREST AFTER HARVEST**

*By*

**THAKUR BABU KARKEE**

August, 1993

Chairman : Associate Professor Lim Meng Tsai, Ph. D.
Faculty : Forestry

The success of the Selective Management System (SMS) in managing the hill dipterocarp forests of Peninsular Malaysia depends, among others, on the types of trees in the residual stand and the ability of these trees to grow and form the next crop. Specific information on growth and development of the residual stand is urgently required to evaluate the management system and its suitability in different forest types.

In this study, data are analysed from logged over stands in the Lebir Forest Reserve, Peninsular Malaysia, which has been subjected to three harvesting intensities (HIs). The data consists of nine measurements covering a 14-year (1978-1991) period collected from nine permanent sample plots of size 200X200 m design under the systematic line sampling method. The plots were harvested first in 1977.

Stocking, basal area and dbh growth of most species groups and HIs trees over 5 cm and over 15 cm dbh after harvest were significantly different ($p < 0.01$) between the hill and lowland forests. The 5-15 cm dbh trees constituted more than 70% of the total stocking and 20% of total basal area. The stocking by dbh classes followed an inverse J-shape curve. The residual stand was dominated by non-dipterocarps. The potentially marketable (PM) and non-marketable species together accounted for more than 60% of total stocking and 58% of total basal area in the both forests.

The final stocking and basal area was found to be associated with residual stocking and basal area. The mean annual increment of stocking and basal area (SMAI and BMAI) were highest in the low harvesting intensity plots (LHI) of the hill forest and the high harvesting intensity (HHI) plots of the lowland forest, while the mean annual dbh increment and mortality (DMAI and MAM) of both forest were highest in the HHI plots. The SMAI and BMAI of PM species was highest in the hill forest while that of pioneer species (PS) was highest in the lowland forest.

The DMAI of dipterocarp meranti (DM) and PS were significantly ($p < 0.05$) higher than other species groups in both forests. The MAM was not significantly different between the hill and lowland forests. For trees over 15 cm dbh, the MAM of dipterocarps species was significantly ($p < 0.05$) higher than other species groups. The hill forest was found to be rich in stocking and basal area while the SMAI, BMAI, DMAI and MAM were higher in the lowland forest.

The dbh growth and mortality equations were constructed for trees over 15 cm dbh. Years after harvest and the density measures (derivatives of stocking and basal area) were found to be the best independent variables to explain dbh growth and mortality. The predicted values from all the projection equations are not significantly different from the actual values for the measurement periods. Moreover, residual plotting showed no evidence of lack of fit for most of the equations. The dbh growth equations predict decreasing DMAI over time except for non-dipterocarp medium hard wood (MHW) of the hill forest. Mortality equation for most species predicts that MAM stabilises to below 3% after 15 years while the mortality for dipterocarps is exponential in nature. The validity of the equations need to be verified for future use.

The implication of the results on SMS is discussed. The results suggested that intermediate silvicultural treatments may require to control decreasing DMAI and high mortality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia untuk memenuhi syarat ijazah Master Sains.

**TUMBESARAN DAN PEMBANGUNAN HUTAN DIPTEROKARP DI MALAYSIA SELAPAS TEBANGAN**

*Oleh*

**Thakur Babu Karkee**

August, 1993

Pengerusi : Professor Madya Lim Meng Tsai, Ph. D.
Fakulti : Perhutanan

Kejayaan sistem pengurusan terpilih (SMS) dalam pengurusan hutan bukit dipterokarp di Semenanjung Malaysia bergantung, antara lain, kepada jenis pokok di dalam dirian tinggal dan keupayaan mereka tumbuh dan membentuk dirian yang berikutnya. Maklumat khusus mangenai tumbesaran dan pembangunan dirian tinggal amat diperlukan bagi menilai sistem pengurusan tersebut dan kesesuaiannya bagi pelbagai jenis hutan yang berlainan.

Kajian ini menganalisiskan data dari kawasan bekas pembalakan di Hutan Simpan Lebir di Kelantan, Malaysia, yang telah dituai manggunakan tiga intensiti tebangan (HIs). Data tersebut terdiri dari sembilan pengukuran tahunan yang meliputi jangkamasa 14 tahun (1978-1991) dikumpul dari sembilan petak sampel kekal berukuran 200X200 m dibentukkan mengikut kaedah bancian lurus sistematik.

Stocking, keluasan pangkal dan pertambahan diameter bagi pokok yang melebihi 5 cm dan 15 cm diameter paras dada (dbh) mempunyai perbezaan

bererti ($p<0.01$) di antara hutan bukit dan hutan pamah. Pokok-pokok 5-15 cm dbh menyumbangkan 70 peratus daripada jumlah bilangan pokok dan 20 peratus daripada jumlah keluasan pangkal. Taburan bilangan pokok mengikut kelas dbh berbentuk lengkung-J terbalik. Spesis yang berpotensi untuk diniaga (PM) dan yang tak boleh diniaga bersama-sama membentuk lebih dari 60 peratus daripada jumlah bilangan pokok dan 58 peratus daripada jumlah keluasan pangkal dalam kedua-dua jenis hutan.

Purata tambahan tahunan bagi bilangan pokok dan keluasan pangkal (SMAI dan BMAI) adalah paling tinggi di petak intensiti tebangan rendah (LHI) di hutan bukit dan petak intensiti tebangan tinggi (HHI) di hutan pamah, sementara purata tambahan tahunan bagi diameter dan purata tahun kematian (DMAI dan MAM) bagi kedua-dua jenis hutan adalah paling tinggi dalam petak HHI. SMAI dan BMAI bagi spesis PM adalah paling tinggi di hutan bukit sementara bagi spesies perintis (PS) adalah paling tinggi di hutan pamah.

DMAI bagi meranti dipterokarp (DM) dan PS lebih tinggi daripada kumpulan spesis lain dalam kedua-dua jenis hutan. MAM tidak berbeza antara kedua-dua jenis hutan. Begi pokok yang melebihi 15 cm dbh, MAM spesis dipterokarp adalah lebih tinggi dari kumpulan spesis lain. Hutan bukit didapati kaya dengan bilangan pokok dan keluasan pangkal tetapi SMAI, BMAI, DMAI dan MAM adalah lebih tinggi di dalam hutan pamah.

Persamaan-persamaan pertumbuhan diameter dan kematian telah dibina untuk pokok melebihi 15 cm dbh. Tahun selepas tuai dan ukuran kepadatan adalah pemboleh ubah yang sesuai untuk menjangkakan pertumbuhan dan kematian. Nilai dijangkakan dari semua unjuran persamaan tidak mempunyai perbezaan yang bererti ($p < 0.05$) dari nilai sebenar bagi jangkamasa pengukuran tersebut. Persamaan-persamaan pertambahan dbh meramalkan pengurangan DMAI keculi bagi kayu keras sederhana bukan dipterokarp di hutan bukit. Persamaan kematian bagi kebanyakan species menunjukkan bahawa kadar kematian menghala kepada kurang daripada 3% selepas 15 tahun. Persamaan kematian untuk dipterokarp bercorak eksponential. Semua persamaan ini haruslah dikaji dan disahkan semula sebelum digunakan untuk hutan lain.

Implikasi keputusan kajian ini terhadap SMS dibincangkan. Keputusan menunjukkan bahawa rawatan silvikultur perlu dijalankan untuk mengawal dan mengelakkan daripada kejatuhan DMAI dan kematian yang tinggi.

# CHAPTER I

# INTRODUCTION

## Problem Statement

The quality of forest management planning relies upon the availability of forest information which facilitates projection of growth and timber yields of stands (Rayner and Turner, 1990). So, knowledge of forest growth and development is fundamental to strategically plan the use of forest resources. Forest growth and development study comprises the quantification of the biological process of tree growth in response to various factors and silvicultural treatments. A carefully devised suitable quantitative model should be capable of testing silvicultural treatments and be useful as a basis for recommending those which could optimise the given forest resources over time.

Growth and yield models of tropical forests have been used in four principal areas: estimation of allowable cut, industrial and economic planning, silvicultural and forest management research, and strategic planning of the forest sector (Alder, 1983). In timber management, they have been employed for timber harvest scheduling decisions such as when, where, and how much to cut, and other management decisions such as economic rotation and cutting cycle, and rationalisation of optimal business decisions related to processing and marketing of wood products (Mendoza and Gumpal, 1987).

In Peninsular Malaysia, the importance of forest growth information has been discussed by Thang and Yong (1989). The ultimate use of such information is to develop growth models for sound forest management. Very few studies have been conducted on the quantification of stand attributes in Malaysia. The reasons are due to related problems in data acquisition and analysis resulting from the complex forest structure and site specificity of growth factors (Borhan, 1985), and insufficient computer facilities and expertise to handle the data (Thang and Yong, 1989).

The Selective Management System (SMS) was introduced in 1977 to manage the hill dipterocarp forests of Malaysia. It emphasises the dependency on intermediate sized trees to form the next crop. It assumes that there will be adequate intermediate sized trees left after an economic harvest and the residual stand will have adequate regeneration and growth. The system further assumes an annual diameter at breast height (dbh) growth of 0.80 cm, annual mortality of 0.9% and annual ingrowth of 0.6% for all marketable species over 30 cm dbh and that these will remain constant over time, so that the next cutting could be conducted again in as short as 25-30 years (Thang, 1987; and Appanah and Weinland, 1990).

However, opposing views have emerged on the sustainability of the SMS for managing the dipterocarp forests. Some of the questions yet to be answered are: Will there be sufficient middle size trees? Will the system provide adequate seedling regeneration to form the crop in subsequent cycles? Will the assumed growth and mortality rate remain the same over time or some intermediate silvicultural treatment be required to adjust it? Also, are the assumed values for dbh growth, mortality and ingrowth resonable for the current forest? As such, the assumptions mentioned above need to be verified.

More information about the stand condition is required to answer those questions and to improve the forest management system, because the main current problem is the limited knowledge on mixed dipterocarp forests. Some of the previous studies (Tang, 1977; Wan Razali, 1986; and Yong, 1990) reported that the proportion of dipterocarps in the hill forest was almost double than that of the lowland forest, and that lowland forests were more variable than the hill forest in terms of stocking. The mean annual mortality (MAM) rate for both hill and lowland forest was approximately 2% for all surviving trees over 10 cm dbh.

The mean annual dbh increment (DMAI) was found to be higher for larger dbh trees for all species groups with a mean of 0.25 cm for surviving trees over 5 cm dbh. The DMAI of dipterocarps was found to be higher than the non-dipterocarps for all dbh classes. All species showed decreasing dbh growth with increasing total basal area. However, the mean annual basal area for most of the species groups found increasing. These results need to be further verified.

## Objectives

The overall objective of the study is to analyse the growth and development of a tropical dipterocarp forests after harvest, in the Lebir Forest Reserve (LFR) in Kelantan, Malaysia. Specifically, the study aims to:

i) determine the mean stocking and basal area of stand after harvest by species group, dbh class and harvesting intensity (HI);

ii) determine the mean dbh increment and mortality of trees after harvest by species group, dbh class and HI; and

iii) develop relationships of dbh increment and mortality after harvest with stand parameters.

## CHAPTER II

## LITERATURE REVIEW

This chapter is a review of the various models used in growth and yield studies followed by discussions on selected models for uneven-aged forests. Following this general review, growth and yield studies in Malaysia are reviewed.

### Growth and Yield Models

Growth and yield studies involve the analyses of the development of stand attributes such as stocking, basal area, volume, dbh increment and mortality over time. One approach of such studies is to analyse the growth performance of stand attributes of different forest types according to species groups and dbh classes. Such a study would enable us to evaluate how well maintained the stocking is and whether any silvicultural treatment will be required. It would also assist in determining the appropriate cutting limits of a particular species and evaluate the effects of previous treatments. The ultimate use of such basic stand information is to develop growth and yield models. A wide variety of growth and yield equations have been used in modelling, and new approaches are developed every year. Ideally, the growth and yield models should include, as inputs, the variables that account significantly for growth of the forest stand. The output should include variables which have economic bearing on the management decisions (Chang, 1989). Nautiyal and Belli (1989) proposed to include even the variables representing water, nutrient and solar radiation for site factor in the models. However, the accurate measurement of such variables is still questionable.

Based on the terminology of Clutter *et al.* (1983) to describe variable density stand model and the convention of Munro (1974) to classify individual tree models, Davis and Johnson (1986) have classified growth and yield models into three basic groups: whole stand models, size class models, and individual tree models. These models have been used mainly in temperate forests for even aged, uneven aged and mixed species stands.

**Whole Stand Models**

Whole stand models use parameters such as stocking, basal area and standing volume to predict the growth and, consequently, the yield of the forest at some future time. These models can forecast the stand characteristics of interest almost equally and cheaply compared to other models, and have been much used in mixed uneven-aged forests (Buongiorno and Michie, 1980; and Vanclay, 1989). Different models use different independent variables. A common feature of whole stand models is that they use stand density as the independent variable and predict the stand growth directly. Other models, however, take a two-stage approach: estimating the future stand density first and then using that value to predict the future stand growth. Diameter distribution models are also considered as whole stand models.

Whole stand models can be classified into density free models and variable density models. Density free models rely on either 'normal' or 'average' density concepts (Avery and Burkhart, 1983). The normality concept allows for the determination of potential growth of fully stocked natural stands on different sites. A normal yield table shows the estimate of the maximum yield of the natural stands at each age as well as basal area, average stand diameter, number of trees per unit area and site index. The average density concept is used to formulate empirical yield tables.

Variable density models consider density as a dynamic part of the stand projection system and use density as an independent variable. This type of model has been used for many natural and planted species and stand conditions. Some of the early examples of yield tables based on such models include those of MacKinney *et al.* (1937) for mixed loblolly pine stands, and Duerr and Gevorkiantz (1938) for uneven-aged hemlock and yellow birch stands. MacKinney *et al.* (1937) used age, stand density and composition index (ratio of basal area of pine to the total stand basal), while Duerr and Gevorkiantz (1938) used age, site class, density and a merchantability class to predict future yield of the stands.

Yield tables were later replaced by functional forms. Functional models have been considered as alternatives to overcome limitations imposed by the normality concept in density free model. With the advancement of computer technology and increasing use of regression techniques, many researchers have used growth and yield equations rather than tables to present yield estimates.

In tropical forests, Borhan (1985), Mendoza and Setyarso (1986), and Mendoza and Gumpal (1987) used such equations for the dipterocarp forests of Malaysia, the Philippines and Indonesia, respectively. Borhan (1985) employed the static yield modelling approach using multiple regression for analysing the dipterocarp forest stand in Labis Forest Reserve, Malaysia. He found that the time after harvest was not a significant variable in predicting the standing basal area and volume; however, he used data for only four years