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VERIFICATION AND VALIDATION OF SAMPLING INTENSITIES IN THE PRE-FELLING INVENTORY OF A TROPICAL FOREST IN PENINSULAR MALAYSIA

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By

WAN MOHD SHUKRI BIN WAN AHMAD

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Forestry, Universiti Putra Malaysia.

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THIS M.SC THESIS IS SPECIALLY DEDICATED TO.............

NORAINI BINTI MOHD ZAHID..........mama

WAN MUHAMMAD AQIF SHAHIRAN...........aqif

WAN NUR ARINA SYUHADA..........erin

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LIST OF ABBREVIATIONS

FRIM	-	Forest Research Institute Malaysia
FDPM	-	Forestry Department of Peninsular Malaysia
PFE	-	Permanent Forest Estates
MUS	-	Malayan Uniform System
SMS	-	Selective Management System
Pre-F	-	Pre-felling
dbh	-	Diameter at breast height
DM	-	Dipterocarp, Meranti
DNM	-	Dipterocarp, Non-Meranti
ALL DIPT	-	All Dipterocarps
ND. LHW	-	Non-Dipterocarp, Light Hardwoods
ND. MHW	-	Non-Dipterocarp, Medium Hardwoods
ND. HHW	-	Non-Dipterocarp, Heavy Hardwoods
MISC	-	Miscellaneous
ALL NON-DIPT	-	All Non-Dipterocarps
PFR	-	Pasoh Forest Reserve

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

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December, 1997

Chairman: Associate Professor Kamis Awang, Ph. D.

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This study was carried out on a randomly chosen 40 ha (800 m x 500 m) forest area within the 50 ha Demography Project of the Forest Research Institute Malaysia (FRIM) in Pasoh Forest Reserve, Negri Sembilan. A total of 30 ha out of 40 ha study area were used as a Calibration data set and the 10 ha remaining area as a Validation data set. The percent sample or intensity of sampling was determined at various confidence and error levels, viz., from 80% to 95% confidence with ±5% to ±20% error in estimating tree density, basal area and volume. Results obtained from both calibration and validation data sets were used to assess the notion that the statistical reliability of the SMS's Pre-felling inventory (by Forestry Department Peninsular Malaysia) is at 95% confidence and ±20% error levels.

Results showed different intensities of sampling regarding classification into diameter, plot size and species groups to the three parameters measured at different confidence and error levels. At 1% sampling intensity to inventorise density of trees 5 cm - <15 cm dbh in 10 m x 10 m plot, the confidence and error levels of respectively 95% and ±15% or 90% and ±10% would be better reliability levels. The 95% and ±15% levels were also true for estimating basal area and volume. At 5% sampling intensity of trees 15 cm - <30 cm dbh (20 m x 25 m plot), its reliability was at 90% confidence and ±10% error limits for either tree density, basal area or volume estimation. However, at 10% sampling intensity of trees ≥30 cm dbh (20 m x 50 m plot), the 95% confidence and ±20% error held true in estimating tree volume. Classification into species groups showed that higher sampling intensity was needed to sample volume of Dipterocarps species compared to tree density, basal area and other species groups at any confidence and error levels. Results also showed that plot 10 m x 10 m yielded lower sampling intensity for trees <30cm dbh and plot 20 m x 25 m for trees ≥30 cm dbh at any confidence and error levels. The implications of attaching confidence and error levels to the sampling intensity are also discussed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

MENGUJI DAN MENGESAHKAN INTENSITI PERSAMPELAN INVENTORI SEBELUM TEBANGAN HUTAN TROPIKA DI SEMENANJUNG MALAYSIA

Oleh

WAN MOHD SHUKRI BIN WAN AHMAD

Disember, 1997

Pengerusi: Profesor Madya Kamis Awang, Ph. D.
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Kajian ini telah dijalankan di kawasan seluas 40 ha (800 m x 500 m) yang dipilih secara rawak yang terletak di dalam kawasan Projek Demografi 50 ha oleh Institut Penyelidikan Perhutanan Malaysia (FRIM) di Hutan Simpanan Pasoh, Negeri Sembilan. Seluas 30 ha dari 40 ha dari kawasan tersebut digunakan sebagai kawasan set Data Kalibrasi dan 10 ha sebagai kawasan set Data Kesahihan. Intensiti persampelan ditentukan pada pelbagai tahap keyakinan dan tahap ralat iaitu dari 80% hingga 95% keyakinan dengan ±5% hingga ±20% ralat dalam menganggarkan persempalan bilangan pokok, luas pangkal dan isipadu. Keputusan yang diperolehi dari ke dua-dua set Data Kalibrasi dan set Data Kesahihan digunakan bagi menentukan bahawa inventory sebelum tebangan yang diamalkan oleh Jabatan Perhutanan Semenanjung Malaysia ialah pada tahap keyakinan 95% dan ralat ±20%.

Keputusan menunjukkan intensiti persampelan yang berbeza berdasarkan kepada pengkelasan diameter, kumpulan spesis dan saiz plot terhadap ketiga-tiga parameter yang diukur pada tahap keyakinan dan ralat yang berbeza. Tahap keyakinan 95% dan ralat 15% atau 90% dan 10% didapati lebih menghampiri pada intensiti persampelan 1% yang digunakan bagi penyampelan bilangan pokok 5 sm - <15 sm diameter paras dada (dpd) dalam plot 10 m x 10 m. Tahap keyakinan

95% dan ralat 15% juga didapati boleh digunakan bagi penyampelan luas pangkal dan isipadu. Penyampelan pokok bersaiz 15 sm - <30 sm dpd. dalam plot 20 m x 25 m bagi menganggarkan bilangan, luas pangkal dan isipadu adalah lebih teliti sekiranya dilakukan pada tahap keyakinan 90% dan ralat ±10%. Walau bagaimanapun, intensiti persampelan 10% adalah benar bagi menyampel pokok ≥30 sm dpd. pada plot 20 m x 50 m. Pengkelasan kepada kumpulan spesis menunjukkan bahawa penyempelan isipadu spesis Dipterokap memerlukan intensiti yang lebih tinggi berbanding bilangan pokok, luas pangkal dan lain-lain kumpulan spesis pada semua tahap keyakinan dan ralat, saiz plot serta kelas diameter. Keputusan juga menunjukkan saiz plot 10 m x 10 m adalah memerlukan intensiti penyempelan yang lebih rendah bagi pokok <30 sm dpd dan saiz plot 20 m x 25 m bagi pokok ≥30 sm dpd pada semua tahap keyakinan dan ralat yang digunakan. Implikasi hubungan tahap keyakinan dan ralat dengan intensiti persampelan turut dibincangkan.

CHAPTER 1

INTRODUCTION

The tropical rainforest is probably one of the most complex ecosystems in the world. It is a dynamic system possessing a very high order of organisations in which physiological, morphological and ecological features in individual plant and animal members are strongly linked to form a variable continuum in time. The fauna and flora are numerous and diverse. The richness of its flora and fauna makes it an important factor, for example in the conversion of carbon dioxide to oxygen. The information on the fauna and flora is still much to be discovered, especially in terms of their values to man and their contributions to the working of the ecosystem.

The flora of tropical rainforest is estimated to comprise 25,000 species of flowering plants (van Steenis, 1971, quoted by Whitmore, 1975) which is about 10% of the world flora. In Peninsular Malaysia alone there are over 1,600 species of trees which grow to 90 cm girth and larger (Whitmore, 1975) but of which only about 650 species are currently considered to be of economic value (Peh and Wong, 1980).

Various attempts have been made to summarize the composition of the world's tropical forest; some are locally based and others are very complex in description. One very useful description of tropical forest type given by Slee (1983) based on Schimper (1903). The forest is subdivided into three major categories (i) wet evergreen, (ii) moist deciduous and (iii) dry deciduous. He had also given some special categories, such as mangrove, bamboo and coniferous.

Forest inventory and monitoring is a key issue when managing valuable renewable forest resources. No sensible forest policy is possible if the quantity and quality and the changes and trends of forests are not known.

Forest inventories have been conducted since the end of the middle ages when concerns about the wood supply for firewood grew more seriously. In earlier times, all stems in the forest were counted and some cases even numbered to provide a complete inventory for planning production. Later, this way changed to a system where "representative" sections of the forest were selected and these sections measured completely. The total was then calculated by a blow up factor. This method has been used by the early foresters, often with good success, provided the selected area was truly representative of the forest condition (Dieter, 1993).

Silviculture research in tropical rainforests over the last twenty years has attempted to develop and synthesize knowledge on the establishment and management of plantation for timber production. It has also focused on the dynamics of natural forests, with and without human interventions.

Tropical rainforests have provided commercial timber and fuelwood over two centuries, and have been managed under several silvicultural systems for the last five decades. These systems tried to increase the amount and quality of timber produced by manipulating stand density and composition. These systems often relied on rules concerning pre-felling (Pre-F) and post-felling (Post-F) inventories, and timber stand improvement. The choice of the management regime may depend on the types of forest, the timber market and the forest policy of a country or forest owner.

Forestry in Malaysia

Malaysia's natural forests continue to play a major role in the economy, contributing much to the development of forestry-based industries, of primary as well as downstream manufacturing activities.

The natural forest resources of Peninsular Malaysia were maintained at a level of about 6.0 million ha or 45% of the total land area in 1995 (Kementerian Perusahaan Utama, 1996). They included 4.7 million ha of Permanent Forest Estates (PFE), 0.7 million ha of Stateland Forest Estates and about 0.6 million ha of Wildlife Reserve. The Permanent Forest Estates constituted about 78% of the total forest resources, while Stateland Forests constituted 12%. Wildlife reserves made up 10% of the total forest areas. The main types found are Inland forests (5.54 million ha or 93%), Peat Swamp forests (0.29 million ha or 5%) and the Mangroves forests (0.11 million ha or 2%). The Peat Swamp forests are mainly located in Selangor, Pahang, Terengganu and Johor while the Mangrove forests are found mainly in the coastal areas of Perak, Johor, Selangor and Kedah.

Malaysia has a land mass of 32.90 million ha., of which almost 58.1% (19.12 million ha) is covered with natural forests. Tree cover is further complemented by another 14.6% of plantations, mainly of oil palm, rubber and cocoa. This figure makes Malaysia one of the most forested countries in the world with 72.7% of its land mass covered with trees.

Malaysia's forestry policy requires adequate establishment of Permanent Forest Estate (PFE) in order to ensure a continuous supply of forest resources. The PFE covers about 42.6% (14.01 million ha.) of Malaysia's total land area. In addition, 2.12 million ha. outside of the PFE are also designated as national parks and wildlife sanctuaries. Thus the total area of natural forest under management amounts to about 16 million ha (Kementerian Perusahaan Utama, 1996).

The forestry sector in Malaysia has always played an important role in the national economy. In 1995 it contributed about RM11 billion in export earnings to the country. This constituted 7% of the total export earnings. It also provided direct employment for about 243,007 persons (Kementerian Perusahaan Utama, 1996). To manage this valuable forest, various silviculture systems have been developed in Malaysia. The historical development of natural forest silviculture led to the Malayan Uniform Systems (MUS) (Wyatt-Smith, 1963). MUS has been the basic silvicultural system used since the 1950's. It was developed for lowland dipterocarp forests rich in Meranti (*Shorea* spp.) and Keruing (*Dipterocarpus* spp.). However, MUS has not been effective in the hill forest due to the comparatively more difficult terrain, uneven stocking, lack of natural regeneration on the forest floor before logging because of irregular seeding from potential mother trees (Thang, 1986). Since the bulk of the permanent forest estate now consists of hill forests, the system has now been changed to the Selective Management Systems (SMS), a polycyclic logging system in which a 25-30 year cutting cycle is anticipated.

The MUS consists of removing the mature crop in one single felling of all trees down to 45cm dbh for all species and releasing the selected natural regenerations of varying ages, which are mainly the light-demanding medium and light hardwood species. This system has been successfully applied to the lowland dipterocarp forest, but has been found to be unsuccessful in the hill dipterocarp forest (Wyatt-Smith, 1963).

Consequently, the Selective Management System (SMS) was introduced in 1978 to allow for more flexible timber harvesting regimes which are consistent with the need to safeguard the environment and at the same time to take advantage of the demand of the timber market. More importantly, it discourages the poison-girdling of the presently uncommercial species which will not only conserve the wood but also the genetic resources available in the forests for the future.

The SMS requires the selection of management (harvesting) regimes based on inventory data which will be equitable to both loggers and forest owner as well as ensuring ecological balance and environmental quality. In practice, under the SMS the next cut is expected in 30 years after the first logging with an expected net economic outturn of 30-40 m^3 per ha enriched with dipterocarp species.

Current Pre-F forest inventory practice uses different plot sizes resulting in different inventory intensities. For example, the main inventory plot of 20 m x 50 m has an inventory intensity of 10% and 20 m x 25 m uses inventory intensity of 5%. Table 1 explains briefly on the inventory plots of the current Pre-F inventory.

Table 1: Inventory Plot Information

Plot	Size (m)	Area		Inventory intensity (%)	Tree size class
		m^2	Ha		
First	50 x 20	1000	0.1000	10.00	≥45 cm diameter 30 cm to <45 cm diameter
Second	25 x 20	500	0.0500	5.00	15 cm to <30 cm diameter
Third	10 x 10	100	0.0100	1.00	5 cm to <15 cm diameter
Fourth	5 x 5	25	0.0025	0.25	1.5 m height to <5 cm diameter
Fifth	2 x 2	4	0.0004	0.04	15 cm height to <1.5 m height

These different intensities of inventorying the forest have been applied since SMS was introduced. Little research has been done to verify the accuracy of the sampling intensities used and whether such intensity was used to inventory the volume, basal area or density of trees in a given stand.

Concerns about the accuracy of current practices of the Pre-F inventory intensities led to the initiation of this project to be proposed.

Statement of Problems/Justification

The need for quantitative tree data has made it necessary to give serious consideration to methods of forest sampling. It is important to recognise the need for adequate sampling and what constitutes an adequate sample.

In every country, there are different conditions for forestry practice and different requirements for the information system. Therefore, an optimum inventory design/technique will always be a unique one.

The problem of quality and quantity assessment of the growing stock, especially in the course of tropical forest inventories, has been tackled by several authors during the past years (Wyatt-Smith, 1966; Wong, 1976; Ashton, 1976). However, these research projects cannot yet be considered as final and the approaches proposed are not yet sufficiently tested in practice. Therefore, a survey of the present situation of this important sector of inventory needs to be done.

Forest planning for exploitation of tropical forests for sustained yield management is not feasible without accurate inventory result. Since methods of data collection have made extraordinary progress during the last two decades, an efficient synopsis of the techniques of forest inventory is urgently needed.

Zöhrer and Forster (1987) stated that in forest inventory, highly qualified experts are necessary to develop an optimum inventory methodology and adequate techniques for the given purpose. Otherwise, the obtained information is unreliable, misleading and therefore, useless. A successful forest resource inventory yields the advantages of the strategic planning of forestry can be based on sound information. Hopefully, with this kind of research, many skill persons on forest inventory can be trained.

In Peninsular Malaysia forest sampling to determine the stocking available before commercial felling (Pre-F inventory) usually varies between 1 to 10% intensity for the three plot sizes, viz, 10 m x 10 m, 20 m x 25 m, 20 m x 50 m. The confidence and error level used are 95% and 20% respectively (Wan Razali, 1995). However, little research has been done to verify the accuracy of these current Pre-F inventory practices.

Verification of the current sampling intensities is important to reorganise the forest inventory practices aiming at introducing sustainable management of the forest resources. It is the basis for the work of field officers, managers and research officers alike. Without accurate measurements, efficient designs for inventories, data processing based on sound statistical procedures and without the knowledge of the trees' growth, sustainable management with high outturn can never be put into practice.

Objectives

The objectives of this study are:

1) to verify or validate the accuracy of the Pre-F sampling intensities as currently practised by the Forestry Department of Peninsular Malaysia and others that use the same method;
2) to determine whether such inventory intensity was used to inventory the volume, basal area or density of trees in a given stand; and
3) to determine the accuracy of statistical reliability, i.e. confidence and error levels associated with the Pre-F inventory of the Forestry Department of Peninsular Malaysia.

CHAPTER 2

LITERATURE REVIEW

Forest Inventory/Sampling Definition

Forest inventory is the enumeration of pertinent data such as volume, increment, mortality, etc., for the assessment of productivity of a forest at particular point in time (Jeffers, 1985). Repeated continuous inventory implies the regular enumeration of the productivity in such a way as to provide a continuous check on the changes taking place in that characteristic of the forest.

Husch et al. (1982) defined forest inventory as the procedure for obtaining information on the quantity and quality of the forest resource and many of the characteristics of the land area on which the trees are growing. Most forest inventories have been, and will continue to be, timber estimates. An inventory is an information-gathering process that provides one of the bases for rational decisions. The decisions may be required for the purchase or sale of timber or for preparation of timber-harvesting plan in forest management.

Forest Mensuration and Inventory technical working group of ASEAN Institute of Forest Management in its report defined forest inventory as a survey of forest area to determine such data as area condition, timber, size, volume, and species, rates of change for specific purposes such as planning, purchase, evaluation management, or harvesting. While Pre-F inventory was defined as an inventory carried out to assess royalty payments to be collected and to determine the economic viability of a possible extraction (AIFM, 1987).

Sukhatme (1970) stated that a sampling method is a scientific and rational procedure of selecting units from the population and providing a sample that is expected to be representative of the whole population. In other word, by utilizing the sampling method it is possible to estimate the population total, average or proportion while at the same time reducing the size of the survey operation. Much time and labour have been saved by the application of the theory of sampling to tackle problems which require collecting and recording a large number of observations.

The concept of inventory may, of course, be extended to the characteristics, for example the health of the forest, or residues of pesticides, herbicides and pollutants. It may also be extended to assessments of damage due to various pests, for example insect pests and deer, recreation, windblow, or erosion. However, to be effective, the result of the inventory needs to be related to the appropriate forcing function or functions, and such relationship can only be inferred from an understanding of the dynamics of change. It is also important to be able to measure the state of the forest at any one point in time. Such measurement requires particular types of sampling design (Ware and Cunia, 1962).

In Malaya, the concept of sample plot was first established in 1901 by the late Mr. A.M. Burn-Murdock, the first Conservator of Forest (Setten, 1954). In 1915, the whole subject of sample plot was recognised at the First Malayan Forest Conference presided over by Mr. G.E.S. Cubitts, the second Conservator of Forest.

Forest Sampling Studies

Forestry, in its most basic form, involves the utilisation of wood and therefore of trees from forests in a most sustainable way. Ecologically, harvesting or logging is a retrogressive step of succession and the degree of reversion is affected by the intensity of logging. It is obvious, therefore, that by controlling logging through proper management and planning, the effects of logging can be reduced and any set-back minimised so that natural succession can occur to reforest the area again.

Forest management planning is dependent upon the dynamics of the forest. It involves the integration of all forestry disciplines and requires an understanding of all characteristics of the forest resource. The most important characteristics of the forest resource is that it is renewable and that it changes overtime, making sampling in inventory of forest resources vital to the forestry activities.

People have been making estimates on the extent of forest resources since they first started staying at one place and staking out territorial claims to the land. Information sought was if the lands could supply the needed game, fuel, and building material (Lund, 1993).

In 1946, the first electronic digital computer was developed. By 1950, automated data processing (ADP) gained popularity in the field of inventory. Users found the computer enables them to process information faster and with less error. It also permitted foresters to carry out previously complicated and cumbersome calculations. This capability led to the development and use of more statistically-complex, but efficient sample designs (Lund, 1993).

The application of sampling in forestry problem is not new. Many studies have been successfully conducted based on sampling theory and technique such as