ISSN 1341-562X

JOURNAL OF FOREST PLANNING

Vol. 4 No. 1

April, 1998

Japan Society of Forest Planning

JOURNAL OF FOREST PLANNING

Submisson of Manuscripts

Manuscripts should be submitted to following Editorial Office.

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Forest Management Division,
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1 Matsunosato, Kukizaki-machi, Inashiki-gun, Ibaraki 305-8687, Japan
Phone: +81-298-73-3211 ext. 636
Fax : +81-298-73-3799

Subscription Information

Journal of Forest Planning is published halfyearly. The subscription price for 1996 is ¥5,000 and the single issue price is ¥2,500. Subscription orders can be sent to following office.

Tohoshoten,
106 NKB Azeria Building, 7-7 Shinogawa-cho,
Shinjyuku-ku, Tokyo 162-0814, Japan
Phone: +81-3-3269-2131
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Journal of Forest Planning is published by Japan Society of Forest Planning, Faculty of Agriculture, Kyoto Prefectural University, 1 Hangi-cho Shimogamo, Sakyo-ku, Kyoto 606-8522, Japan

JOURNAL OF

FOREST PLANNING

Vol.4, No.1 April, 1998

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Article

TROPIS: Tree Growth and Permanent Plot Information System

Jerome K. Vanclay*

ABSTRACT

TROPIS, the Tree Growth and Permanent Plot Information System, contains five elements: (1) a network of people willing to share permanent plot data and tree growth information, serviced by newsletters and information sources hosted at http://www.cgnet.org/cifor/research/tropis.html (or available from CIFOR), (2) an index of people and institutions holding permanent plot data, (3) a database management system to assist more efficient data management, (4) a system to facilitate site-matching by identifying comparable sites and allowing foreign data to be used when no local growth information exists, and (5) an inference system to allow growth estimates to be made in the absence of empirical data. The index or metadatabase contains references to 12,000 plots with 3,000 species provided by 100 contributors, and is growing at about 1,000 plots per month. Searches of the database are welcomed, and may be directed to the author.

Keyword : tree growth, permanent sample plot, metadata

INTRODUCTION

TROPIS is the acronym for the Tree Growth and Permanent Plot Information System sponsored by CIFOR, the Center for International Forestry Research, to promote more effective use of existing data and knowledge about tree growth. Several recent reviews report a paucity of long-term studies in terrestrial ecology (e.g., STRAYER *et al.*, 1986; TILMAN, 1989); this presumably relates more to the availability of data from long term permanent plots, rather than the existence of such studies. TROPIS attempts to redress this situation by drawing attention to existing studies. TROPIS is concerned primarily with information about permanent plots and tree growth in both planted and natural forests throughout the world. It has five components:

1. a network of people willing to share permanent plot data and tree growth information;
2. an index (metadatabase) of people and institutions with permanent plots;
3. a database management system to promote more efficient handling of data;
4. site-matching software to facilitate use of supplementary data from comparable sites; and
5. an inference system to allow growth estimates to be made in the absence of empirical data.

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THE NETWORK

TROPIS is about people, and about information. So unless they request otherwise, all contributors and clients of TROPIS are placed on the mailing list of *TROPIS-Update*, a twice-a-year information sheet informing of recent developments and progress. At present, *TROPIS-Update* goes to about 200 people by email, and to a further 200 by regular mail. Others are also welcome to subscribe, and may do so by sending an email to listserv@cgnet.com with the message "subscribe tropis" or by contacting the author. Back issues of *TROPIS-Update* are archived at http://www.cgiar.org/cifor/research/tropis.html.

TROPIS also provides information via the internet, at http://www.cgiar.org/cifor/research/tropis.html. In addition to the latest information on TROPIS, this site offers advice on how to contribute and how to search TROPIS,

and offers hypertext links to other sources of long-term permanent plot data. Although these other sources may serve different objectives and have different scales, they are consistent with the TROPIS objective to make better use of existing data. If you are aware of monitoring efforts not documented in the TROPIS internet pages, please bring them to the attention of the author.

THE INDEX

The core of TROPIS is the index (or metadatabase) of people and their plots, maintained in a relational database. The database is designed to fulfill two primary needs:

1. to provide for efficient cross-checking, error-checking and updating,
2. to facilitate searches for plots matching a wide range of specified criteria, including, but not limited to location, forest type, taxa, plot area, measurement history, etc.

The database structure is outlined in Figure 1, and in the data entry form in the appendix. The database is essentially hierarchical: the key element of the database is the informant. Each informant may contribute information on many plot series, each of which has consistent objectives. In turn, each series may comprise many plots, each of which may have a different location, a different size, etc. And each plot may contain many species. A series may be a thinning or spacing experiment, some species or provenance trials, a continuous forest inventory system, or any other aggregation of plots convenient to the informant. Plots need not be current, and discontinued or abandoned plots may be included provided that the location is known and the plot data remain accessible. In addition to details of the informant, we try to record details of additional contact people associated with plots, to maintain continuity when people transfer, retire or otherwise cease their involvement with the plots. Thus the relational structure revealed in Fig. 1 may appear complex, but ensures data integrity.

TROPIS currently contains references to over 12,000 plots with over 3,000 species in all parts of the world. When first proposed, the original emphasis of TROPIS was on tropical plantations, but workers dealing with natural forests have been particularly enthusiastic in their support for this initiative, contributing over 60% of all entries and diversifying the content of the index. Tables 1 and 2 give an indication of the present scope of TROPIS.

At present, searches are possible only via mail, fax or email requests to the TROPIS-coordinator at CIFOR, but it is anticipated that self-service on-line searching will be made available soon (assisted searches will continue to be available for those without Internet access). Clients may search for plots with specified taxa, locations (latitude/longitude or place name), silvicultural treatment, or other specified criteria and combinations. Some requests previously fulfilled include searches for

- plots with particular species and/or locations (regions, latitudes, elevations, etc.);
- plots planted with two species and a range of spacing and thinning treatments; and
- plots in logged natural forest with several remeasures spanning at least 40 years.

The main outcome of such searches is a list of people to contact, with details of the nature and amount of relevant data held. A catalogue of past searches is also maintained, so that clients with similar requests can be advised of their common interests.

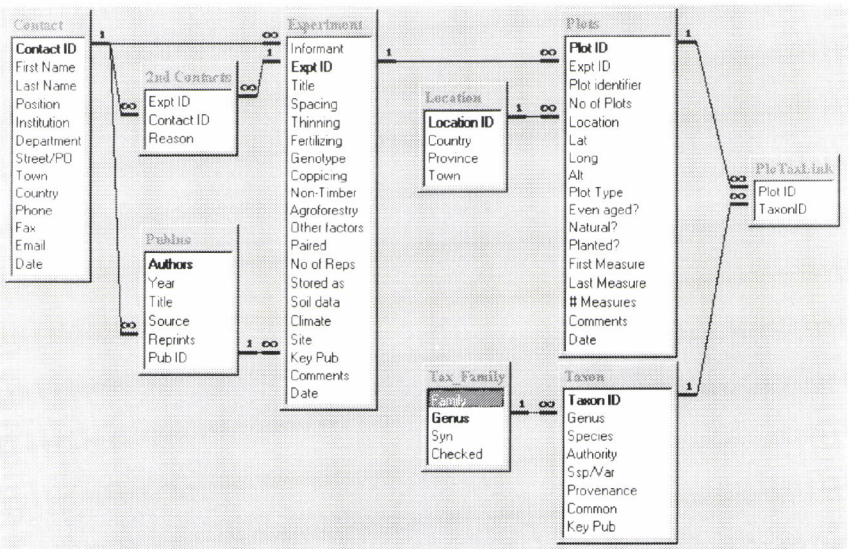

Fig. 1 Simplified representation of the TROPIS metadatabase.

Table 1 Top ten species represented in the TROPIS index.

No. of Plots	Species
964	*Pinus caribaea var hondurensis*
953	*Acacia mangium*
798	*Eucalyptus camaldulensis*
709	*Corymbia citriodora*
596	*Pinus caribaea*
350	*Eucalyptus acmenoides*
341	*Gmelina arborea*
297	*Eucalyptus crebra*
268	*Acacia auriculiformis*
253	*Cassia siamea*

Table 2 Top ten countries in the TROPIS index.

Country	No. of Plots
Indonesia	2,937
Australia	1,666
Fiji	833
Brazil	830
Kenya	762
Uganda	634
Malaysia	518
Thailand	434
Bangladesh	336
Honduras	296

DATABASE MANAGEMENT

Several sources, including some contributors to TROPIS, indicate that many researchers have some difficulty in compiling field data into an efficient database. Informal surveys of contributors who store data as paper or word-processor files revealed difficulties with basic technical aspects of database design, often rather similar in nature. TROPIS attempts to eliminate some of this unnecessary duplication by providing a standard database system free to any contributor who requests it. Such standard database systems have been proposed before, often with limited success, but one such system, MIRA (UGALDE, 1988, 1989), has been used extensively in Latin America for several years, and appears to meet the basic requirements of many TROPIS participants. Thus CIFOR has sponsored the development of a new version of MIRA, based on a standard platform (MicroSoft-Foxpro) and made multilingual (English, Spanish, and French, plus the ability to customize to a fourth language). The prototype is now being tested, and will be available shortly.

COMPARABLE SITES

Researchers studying tree growth are often handicapped by the paucity of data, or by the absence of independent data to corroborate their findings. Tree ring analyses are not always possible, so growth data often must be obtained from direct measurement. Reliable growth estimates require permanent plots that have been remeasured regularly over long periods, and these are not always available. However, there are many plots worldwide, and some of these may be used if an objective basis such as homoclime analysis can be used to select comparable growing conditions. Such analyses are commonly undertaken to assist species and provenance selection (e.g., BOOTH, 1990a, b, 1991), but the issue of identifying comparable plots is analogous. Thus TROPIS will include software to enable such comparisons to be completed efficiently. This work is still in progress, but will be accessible by mail, fax, email and on-line when completed.

OBJECTIVE INFERENCES

Homoclime analyses are useful when data are available from comparable sites elsewhere, but this is not always the case. In some cases, despite judicious searches, no comparable data can be located, and yet it may still necessary to make some forecast about the suitability of a species on a given site. Despite this difficult situation, it may still be possible to provide a reasonable estimate, by making expert inferences from existing knowledge about the site and about the species under consideration. The PLANTGRO system (HACKETT, 1991; HACKETT and VANCLAY, 1997) has been used with some success for agricultural crops, and is being enhanced so that inferences about tree growth can be made in the absence of empirical data. A preliminary version of PLANTGRO for trees is currently being tested, and will soon be available.

PLANTGRO can only make growth predictions on the basis of information contained in specific files, and the construction of these files requires some specialist knowledge and empircal testing. Files for several important tree species are available at http://www.cgiar.org/cifor/research/tropis.html, but users may need to construct additional files for new species. Thus an expert system, INFER, was developed to help users compile plant-files suitable suitable for use with PLANTGRO. INFER presently exists as a paper-based expert system, but is being implemented as a Windows-based package and should soon be available on-line as well as a stand-alone package.

HOW TO PARTICIPATE

The objective of TROPIS is to help people learn more about trees and forests, and to help them manage these resources better. Anyone may contribute information on their permanent plots to the TROPIS system, provided that they agree in principle to share their data with others,

subject of course, to a mutually satisfactory agreement between the data owner and the intending user. Conversely, anyone may use any of the five components of the system, provided that they respect the rights of contributors.

Subscriptions to *TROPIS-Update* may be emailed directly to the listserver, or directed to the author, and anyone with internet access may browse the TROPIS internet pages. Information about permanent plots is welcomed from anyone with the appropriate authority, and may be submitted to the author using the form in Fig. 2 the appendix, or using the form found in the TROPIS internet pages. At present, searches of the index must be directed via the author, but on-line searching should become available soon. The other components, MIRA and PLANTGRO, will soon be available for general use. Their availability will be announced in *TROPIS-Update*.

ACKNOWLEDGEMENTS

I am indebted to the participants of the December 1995 workshop (Robert de Kock, Vitoon Luangviriyasaeng, Peter Muraya, Luis Ugalde, Tim Vercoe and Howard Wright) for their help in refining TROPIS concept into its the present form, and to the 100-odd contributors who have provided entries for the TROPIS index. TROPIS is supported by Japanese Official Development Assistance (ODA). MIRA was developed at CATIE under the direction of Luis Ugalde. PLANTGRO and INFER were developed by Clive Hackett of Plantsoft Services.

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(Received 8 September 1997)
(Accepted 23 October 1997)

TROPIS: An index to permanent plots in the tropics.

Please complete this form for all plots you know about: Copy as necessary. If you need more space, add an extra page.

If you would prefer to create an ASCII or dbase file directly, please contact Jerry Vanclay for more details.

About yourself

Your name: _____ Position: _____

Institute: _____

Street or PO Box: _____

Town: _____ Country: _____

Phone: _____ Fax: _____ E-mail: _____

Other people associated with these plots:

_____

Are they the: owner / initiator / collaborator / DB manager / user ? (circle one)

About the Experiment or Plot Series

Experiment Identifier: _____

Title: _____

Tick if it examines: Spacing ☐ Thinning / logging / treatment ☐ Fertilizing ☐ Genotype ☐

Non-timber products ☐ Agroforestry ☐ Coppice ☐ Other (State) _____

Are there paired treatment - control plots? Yes / No How many replications ? ☐

How are data stored ? Paper / ASCII file / Spreadsheet / Database

Details recorded: **Soil**: None/Some/Detailed; **Climate**: None/Some/Detailed; **Site**: None/Some/Detailed

Key Reference (Full citation: author, date, title, source): _____

_____

Comments: _____

_____

Plot Details (N.B. Each experiment/series may have many plot records)

Identifier for this record: ☐ Number of plots: ☐

Location: Country: _____ Province: _____ Nearest Town: _____

Latitude: ____° ____' ____"N/S Longitude: ____° ____' ____"E/W Elevation: _____(m ASL)

Plot Area: _____(ha) Minimum DBH: _____(cm) Stem maps or X-Y coords? Y / N

Tick if all tree species are measured ☐ If all stems above min DBH are measured ☐

List of Plot Identifiers : _____

Tick if plot is even-aged ☐ is natural forest ☐

Year planted ☐ First measured ☐ Last measured ☐

Number of measures : _____

List main species present on plot:

_____

Comments: _____

Please return to Jerry Vanclay, CIFOR, P.O. Box 6596 JKPWB, Jakarta 10065, Indonesia

Fax: +62-251-622100, Tel. +62-251-622622, E-mail: j.vanclay@cgnet.com

Fig. 2 The form used to contribute an entry to the TROPIS index

Article

The Unknown Factor to Forestry Investment in New Zealand

Nicola Spence*

ABSTRACT

The protection regime instituted under the New Zealand Crown Forest Assets Act 1989 was established with two objectives in mind. First, to ensure Maori grievances relating to Crown forest land were adequately redressed; and second, to enable the forestry industry to develop by guaranteeing security of tenure. The second objective has clearly been achieved. The focus of this research is maybe be on a problem uniquely found in New Zealand but without an understanding of this situation by Pacific Rim forest investors, problems are bound to unnecessarily emerge.

Keyword : Crown Forest Assets, forestry licence, Waitangi Tribunal

INTRODUCTION

Japan is the world's second largest economy after the USA, accounting for nearly one fifth of world GNP and more than two thirds of East Asian GDP. Japan is the world's largest exporter of cash, eclipsing even OPEC in its heyday. Japanese FDI into New Zealand has remained relatively stable since 1992. A prerequisite for growth is, however, investment. Pacific Rim investment, and in particular Japanese investment, is important. Japan is New Zealand's second largest trading partner. Our economies are complementary - we have a surplus of the same resources Japan is required to import. The significance of this relationship makes it important for Japanese and New Zealander investors unlike to understand the dynamics of each other's societies especially in regards to indigenous rights. The greatest threat to foreign investment in New Zealand has come from Maori activists who claim that they will burn down forests and destroy hydro dams if foreign investment continued without consultation with the various Maori leaders.

Since there are few indigenous rights in Japan, how can Japanese investors ever start to fully understand what is politically happening in New Zealand when most New Zealanders find themselves confused at the complexity of issues involved around the protection of indigenous rights in relation to Crown forest land? It is this land which many foreign forest investors want to buy. It is perhaps because the author is a New Zealander who has lived in Japan for 12 years that this question aroused her interest as a result of her dissertation research into legislation related to investment into forested land in both Japan and New Zealand. Yet this interest involves more pure curiosity: there are two competing norms here constraining strategies for regulating human activities that affect "common property resources." These sets of norms are: state sovereignty versus state responsibility and freedom of use versus equitable use. The issues are complex. They are not solely concerned with foreign direct investment.

Maori land grievances, for example, go back to the first days of European settlement in New Zealand. All attempts to resolve them over the last 150 years have failed dismally and the loss of land to the first white immigrants remains one of Maoridom's most outstanding injustices. To resolve these injustices, the protection regime instituted under the Crown Forest Assets Act 1989 was, for example, established first, to ensure Maori grievances relating to Crown forest land were adequately redressed; and second, to enable the forestry industry to develop by guaranteeing security of tenure. The second objective has clearly been achieved. The forestry industry is booming and the own

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ership of forest assets has not changed hands.

The focus of this research is, however, on the first objective: the effective settlement of Maori grievances[1]. The settlement process established under the Crown Forest Assets Act 1989 was politically pragmatic for the New Zealand Government as well as being a comprehensive piece of legislation which provides the mechanism to assist Maori achieve the earliest possible resolution of the ownership of Crown forest licensed lands either by their return to Maori or by their release to the Crown unencumbered by claims. The Waitangi Tribunal established, under the Crown Forest Assets Act 1989, has the power to make binding recommendations on the Crown to return land that was taken from Maori in breach of the Treaty of Waitangi 1840[2]. In addition the Tribunal has the potential to award large sums of compensation to Maori claimants for all land wrongfully acquired from the Maori through the aggressive advance of an imperial and colonial power[3]. The Crown Forest Assets Act 1989 is a milestone in both the legal recognition of Maori rights under the Treaty of Waitangi as well as a positive step towards the settlement of Maori forestry claims.

The Crown Forest Rental Trust, which administers this process, has been charged with the responsibility of expediting the settlement of the ownership of all Crown forest licensed lands in order to transfer the capital funds of the Trust to the confirmed beneficiaries. Whether the Crown Forest Rental Trust is, however, effective is up for interpretation and has not been without criticism. As a result of this criticism, the Trust constantly reassesses its obligation to maximize the efficiency and effectiveness of claim preparation, presentation and negotiation to Maori claimants.

Although the Trust is providing greater assistance to claimants, ten out of all the 56 Trust claims, as of December 1997, are expected to be either to proceed to hearings with the Waitangi Tribunal[4] or in direct negotiations with the Crown. The length of time these claims are taking to be resolved is the main grievance within the Maori community.

Reporting of Waitangi Tribunal forestry claims is also becoming increasingly urgent with the growing fear of the government's discussion to settle all land claims before the Waitangi Tribunal by 31 December 2004. The threat of the Crown[5] putting a limit on the amount of money available for the settlement of Maori Treaty claims is currently under debate. The estimated sum of money involved will be approximately $NZ1 billion. Present claims under negotiation are estimated to be worth approximately $NZ 16.6 million for a single tribe. Reducing the sum to $NZ 1 billion will not be sufficient to redress the grievances. Compensation capable of being awarded under the Crown Forest Assets Act 1989 may exceed the rumoured $NZ1 billion mark.

Other grievances which have lead to claims that the system is ineffective include pressures[6] on the Waitangi Tribunal itself which have meant that claims related to Crown forest land are not being dealt with as expeditiously as Crown Forest Rental Trust desires. It is of importance to the Trust to assist claimants to get every claim before the Tribunal, the only body with authority to confirm ownership of Crown forest land. If the Crown is truly committed to settling Crown forestry land grievances they should use the money earnt from forestry rental proceeds to enable the Tribunal to hear forestry claims with greater efficiency.

Although the focus of this research is the effective settlement of Maori grievances, from the foreign forestry investors' perspective, this focus should informative as much of the information included in this research is not available in Japan even from the New Zealand Embassy in Tokyo. As expected growth in the New Zealand forest industry is estimated to increase ten-fold within the next few years, this research should also be invaluable in that it alerts future foreign investors to a unknown 'risk' investing in Crown forest land operations in New Zealand.

The purpose of this research is therefore to examine the effectiveness of the system established under the Crown Forest Assets Act 1989 in protecting Maori claims to forestry land and in providing adequate compensation for grievances. Next it analyses the protection mechanisms established under the Crown Forest Assets Act 1989. These include Crown Forestry Licences, the Crown Forest Rental Trust and the recommendatory powers of the Waitangi Tribunal. Although the main focus of this research is on the working of the Crown Forest Rental Trust, it is equally important to consider the ratifications of any decisions made by the Waitangi Tribunal on Crown land which is currently leased by foreign forestry investors. To this end, this paper also considers the scope for compensation under the Crown Forest Assets Act 1989 and the future for joint ventures to Crown forest land.

THE STATE-OWNED ENTERPRISES ACT 1986

After the wars of the 1860s conflicts between Maori and the forces of colonization moved from the battlefield to the courts. Law served as an equally lethal weapon of armoury of the colonial state of New Zealand. The Maori appealed to the colonial judiciary to enforce the Treaty of Waitangi for over a century, and with equal consistency, the courts rejected their pleas[7]. First, they declared the Treaty of Waitangi was a nullity, deeming Maori to be insufficiently civilized to enter into a binding international treaty. This was later refined by declining jurisdiction to enforce the Treaty unless it was incorporated by the Crown into the relevant New Zealand domestic law. The settler government, in the name of the Crown, could decide

whether or not to be bound by its own Treaty obligations. Those precedents remained 'received' until 1980.

Then the climate changed. The Fourth Labour Government responded to the crisis facing the New Zealand economy with a radical programme to reorganize economic and political power. The second crisis New Zealand faced, and which had been gathering momentum over the past decade, was Maori land grievances, suppression of their culture, and the dishonouring of the Treaty of Waitangi since it was signed in Waitangi with the British on 6 February 1840. Recognition of Maori rights is a new phenomenon in New Zealand but since the radical transfer of power over the last 11 years has raised three vital questions for the legal system: How far would the courts intervene in the process of transition? Once transition had occurred, how far would the courts extend their powers of those agencies outside the formal boundaries of the state, if those agencies were exercising quasi-state power? Finally, how creatively would the courts interpret existing common law doctrine and legislation, or even depart from them, to protect from the excesses of the market-place those individuals and collectives who lacked economic, social or political power? With the process of transition, there was little evidence of substantial judicial intervention in the restructuring process. The advent of the State-Owned Enterprises Act 1986 [8], however, brought to the head the issue of the protection of the Maori land claims and the settlement of the grievances under the Treaty of Waitangi within the realm of the Courts. Section 9 of the Act states that nothing of this Act shall permit the Crown to act in a manner inconsistent with the 'principles of the Treaty of Waitangi'. The essence of the 'principles' lay in the reciprocal obligations of good faith and reasonableness by the parties to the Treaty. That required the Crown to make informed decisions about the political impact of its policies on the rights of the Maori under the Treaty including consultation when Ministers considered they needed more information. Treaty obligations carried into municipal law -making are directly enforceable by the courts[9]. Existing case law precedent was decidedly hostile to the Treaty. Customary aboriginal title had been extinguished over most of the land. Statutory references to the Treaty and to Maori rights were rare. Those which did exist, as with fisheries, had often been rendered impotent by narrow judicial interpretation.

Government, however in the end, retains the final say. The State-Owned Enterprises Act 1986 provides protection for Maori claims for State-Owned Enterprise land lodged with the Waitangi Tribunal at the same time that the Act came into force. The proposed transfer of land by the Crown under the State-Owned Enterprises Act without any mechanism for protecting land claims lodged subsequently to that date initiated litigation between the New Zealand Maori Council and the Crown in 1987[10]. In approving the terms the Court of Appeal added purely the New Zealand Maori Council wanted to ensure that all Maori land claims would be protected regardless of the time when they were lodged with the Waitangi Tribunal. The Waitangi Tribunal (State Enterprises) Act 1988 later guaranteed this.

In July 1988 the Minister of Finance announced the Government's intention to sell the state's commercial forestry assets aimed at substantially reducing the level of public debt. Included in the strategy was the sale of government owned assets and business. The commercial forests were among the assets the Government decided to sell. A Forestry Working Group was established with the objective of deciding the form in which the Crown's forestry assets would be sold. In October 1988, it recommended sale in the form of transferable cutting rights, with the estate split into a number of sale parcels. It also recommended that protection mechanisms outlined in the Treaty of Waitangi (State Enterprises) Act 1975 for Maori claims could be disadvantageous to the Crown because they might jeopardize sales revenue, and the loss of potential for development of downstream, due to the nature of the forestry industry. The Crown should retain ownership of the afforested land and should directly sell forestry commercial rights instead of transferring the forest land to the Forestry Corporation[11] which would act as the Crown's sales agent, undertaking the management of both the forests and the sales process. The Crown would therefore be able to circumvent the provisions of the Treaty of Waitangi (State Enterprises) Act 1975 thus in effect separating the land from the trees. The land would be therefore safeguarded until any Maori claim thereon was resolved while at the same time allowing for the rental of trees on that very land. These recommendations were accepted by Government.

At a national meeting, held in Rotorua on 20 January 1989 to discuss the proposed sale of forestry rights and the protection of Maori claims to Crown forestry land, the Minister of State-Owned Enterprises reconfirmed the Government's decision to sell the Crown's commercial forestry was irreversible[12]. The discussion focussed therefore on the issue of how to best protect Maori land claims while selling forestry rights to provide security of tenure to purchasers.

HONOURING AND INTERPRETING THE TREATY OF WAITANGI

In the Court of Appeal[13] the Crown argued that the New Zealand Maori Council's application did not come within the scope of the leave reserved by the Court in 1987 decision which was concern with the transfer of land by the Crown under the State-Owned Enterprises Act 1986. Section 27 of that Act prevented the transfer of land from a State enterprise to any person except the Crown where

a claim in respect of that land had been submitted to the Waitangi Tribunal before 16 December 1986. The New Zealand Maori Council argued that the transfer of land by the Crown was inconsistent with Section 9 of the State-Owned Enterprises Act 1986 because there was no protection for the Maori land claims lodged after 16 December 1986. In New Zealand Maori Council v Attorney-General [1987], the Court expressed the view that the Treaty of Waitangi was a solemn compact in which for its part 'the Crown sought legitimacy from the indigenous people for its acquisition of sovereignty and in return it gave certain guarantees. That basis of compact requires each party to act reasonably and in good faith towards the other'. In the context of Government action under 'the Treaty of Waitangi', Judge Richardson found that 'the concept of honour of the Crown also has continuing expression.....in the international law doctrine of good faith'[14]. The Court therefore directed as part of its decision that the Crown and Maori device a scheme of safeguards to ensure transfers under the State-Owned Enterprises Act 1986 would not prejudice Maori claims. The scheme had to be submitted to the Court for approval.

As a result the Crown proposed[15] and the New Zealand Maori Council agreed to a system of safeguards by which if land transferred to a State enterprise is recommended by the Tribunal to be returned to Maori ownership the Crown is bound if necessary to re-acquire the land from any third party who may have acquired it by on-sale in the meantime and to return it to Maori ownership paying compensation to the third party [16].

This system was embodied in the Treaty of Waitangi (State Enterprises) Act 1988. The Court of Appeal approved the scheme of safeguards and stated the this was a precaution[17] The Court of Appeal held that the application under the leave reserved was satisfied because the matter is linked sufficiently closely with the judgement to make it unjust to refuse to hear the application[18]. The New Zealand Forestry Corporation as a state-owned enterprise clearly came within the State-Owned Enterprises Act 1986 and the 1987 judgement. The Court's decision meant that there was no procedural bar to the New Zealand Maori Council's application regarding the sale of forest assets.

All parties agreed that they would use their best endeavours to enable the Waitangi Tribunal to identify and process all claims relating to forestry lands and to make recommendations within the shortest reasonable period[19]. The Agreement provided that where the Waitangi Tribunal recommended that the forest land be returned to Maori ownership the Crown would transfer the land to the successful claimant. Compensation was to be awarded to successful claimants along with the return of the land[20].

Clause 11 of the Agreement allowed for the establishment of a Crown Forest Rental Trust. The annual rental payments received by the Crown were to be put into the trust and the interest was to be made available to assist Maori in the preparation, presentation and negotiation of claims before the Waitangi Tribunal which were involved with, or could involve, forest lands covered by the Agreement[21].

The latter part of the Agreement provides for funds already incurred by Maori in reaching and fulfilling this Agreement. The Agreement was signed on 20 July 1989. As a result of the Crown-Maori Agreement the Court of Appeal 1990 ordered by consent that the earlier application pursuant to leave reserved be dismissed[22]. The provisions of the Agreement were to form the basis of the Crown Forest Assets Act which was enacted in 1989.

In the late 1980s the forestry industry became important to New Zealand's economy. The Crown wanted to ensure New Zealand's forestry industry developed and proposed to sell off the Crown's commercial forest assets not only with the aim of enabling this to happen but also in reducing the government debt. The Maori wanted reassurance that this process would not jeopardise Maori claims to large areas of Crown forestry land. The compromise reached is embodied in the Crown Forest Assets Act 1989. The onus is therefore on the Crown not to transfer assets until it is plain that the claim is not well founded or satisfactory safeguards are provided.

CROWN FOREST ASSETS ACT 1989

The result was the enactment of the Crown Forest Assets Act 1989. This piece of legislation enables the Crown to sell its exotic forest assets by establishing the State's right to sell the standing trees outright and established the Crown Forestry Licence, a property right to the use and management of the land on which those trees stand. This gives effect to the agreement made between the then government and Maori interests relating to the Treaty of Waitangi where Maori are guaranteed "full exclusive and undisturbed possession of their Lands and Estates Forests Fisheries and other properties.....so long as it is their wish" while the Crown "the exclusive right of Preemption over such lands as the proprietors thereof may be disposed to alienate". There are on-going claims over the legality of the way in which some of the land was acquired from the Maori. Indeed of all the lands formerly administered by the New Zealand Forestry Corporation all of that in the South Island and 76 percent of that in the North Island is presently under claim (CLARKE *et al.* 1990).

CROWN FORESTRY LICENCES

The Crown Forest Assets Act 1989, s.14 empowers the responsible Ministers, or persons to whom the Ministers have delegated authority to grant a Crown Forestry Li

cense in respect of any Crown forest land to any person to whom Crown forestry assets on, or that relate to, that land, have been transferred. In other words, the purchaser of a Crown Forestry Licence buys outright the assets on the land and at the same time is granted a tradable right, to use the land for a period up to 70 years.

The statutory basis for this grant as I have stated is found in the Crown Forest Assets Act 1989. In consideration for this grant the Licensee (forestry company) must pay both a lump sum for the existing forest and improvements which is currently set at 7 percent of the unimproved value of the land and an ongoing annual licence fee based on the land value as that term is defined in the Licence. That is, land will be revalued every three years and consumer price indexation is to be used to adjust the rent to account for inflation in between revaluations.

The length of the licence is dependent upon the district where the forest is situated. The Third Schedule lists the districts where the initial term applies. If the forest is situated within one of these districts, the licence includes an initial fixed period and then continues on an annual basis by way of automatic extension.

The Crown Forest Assets Act 1989 provides for notice to be given to the licensee where the Waitangi Tribunal has made a recommendation that land be returned to Maori ownership. The Act specifies a termination of 35 years. Where there is an initial fixed term in the forestry licence the notice shall terminate after 35 years subsequent to the initial expiration.

The licensee's rights during the termination period are limited to the act of protecting, managing, harvesting, and processing the tree crops standing on that land at the commencement of that period. During the termination period where forest assets are no longer required by the licensee, notice is given to the licensor. The licensor shall then take possession of that land and the land will no longer be subject to the Crown Forest Licence.

The Crown Forest Assets Act 1989 states also that the forestry licence should include a provision whereby if the Waitangi Tribunal recommends that the land not be liable for return to Maori ownership the licence shall be deemed to have been granted for an initial fixed term of 35 years. Protective covenants and easements are also included in the forestry licences and the licences may be registered under the New Zealand Land Transfer Act 1952.

The Forestry Licence is an extensive document. Sections 14-17 include provisions relating to Waitangi Tribunal recommendations. Where a recommendation is made the Crown must notify the licensee. As discussed above in such cases the licence will be deemed to have been granted for an initial term of 35 years. The Crown is entitled to terminate the licence by giving a 35-year termination period notice. Where the termination notice is given during the initial fixed term the 35-year period shall begin at the end of the initial fixed term.

Where the Waitangi Tribunal recommends the land be transferred to Maori the transfer is subject to the relevant forestry licence. The proprietors (Maori owners) become the licensor. During the termination period the licence recognizes the right of the Maori proprietors to enter and use the land as well as the licensee to control entry for safety and protection of trees, building, plant and equipment and related items.

Land that is no longer required by the licensee during the termination period is to be surrendered to the proprietors. The licensee has the right to remove structures or buildings that are capable of removal. Section 16.9 provides for arbitration should a dispute arise between the licensee and the proprietors.

Where the Waitangi Tribunal recommends that part of the land be returned to Maori ownership, the Crown shall give the licensee a terminating notice specifying the area of land to be returned to Maori ownership. The termination period is the same as for recommendations for all the land to be returned. The Crown shall consult with prospective proprietors and the licensee about covenants, easements, etc. to ensure the mutual enjoyment of the adjoining land.

The forestry licences are an attempt to ensure that forestry investors are guaranteed security of tenure while Maori claims are safeguarded. The forestry licence is a compromise between the two. Since the Waitangi Tribunal has not yet made any recommendations regarding Crown forest land, we do not know how smoothly the return of Maori land will proceed. It is hoped that the compromise established in the forestry licences will be implemented to ensure the continued growth of the forestry industry and the settlement of Maori grievances.

CROWN FOREST RENTAL TRUST

The Crown Forest Assets Act 1989 provides for the establishment of a forestry rental trust. All licence fees payable under Crown forestry licences are to be paid into the forestry rental trust.

The Trust was established in April 1990 with two specific aims. First, to receive the rental proceeds from licences; and second, to make the interest earned from investment of those rental proceeds available to assist Maori in the preparation presentation and negotiation of claims before the Waitangi Tribunal which involve or could involve licence land [23].

The Trustees are appointed by Maori and Crown representative. Appointors have the power to remove and replace trustees at any time provided the number of trustees is always six. Any decision of the Trust must be made by a majority of the Trustees, comprising at least two Crown trustees and two Maori trustees. The Trust Deed

also gives the Trustees power to invest the trust funds.

Where money is to be paid to claimants the Trustees are to decide the criteria for the people applying for money and he basis for allocating funds to claimants; and, the machinery for ensuring confidentiality of information supplied to the trustees by claimants.

Where the Trustees decide to vary the criteria for applicants they must consult the New Zealand Maori Council and Federation of Maori Authorities.

The Trustees may only make payments for expenditure or activities which the Trustees have approval before the expenditure is incurred or the activity undertaken.

The Trust Deed also provides that where the Waitangi Tribunal recommends that land be returned to Maori ownership the successful claimants shall be entitled to receive from the capital of the Trust the amount of the Rental Proceeds received by the Trustees in respect of that licenced land since the commencement of the Licence.

THE DECISION

Once the Waitangi Tribunal has made an initial recommendation the claimant and Crown can negotiate and settle the matter. If the parties settle the claim the Waitangi Tribunal must cancel or modify the recommendation and if necessary make a final recommendation. Where no settlement has been reached after 90 days of the initial recommendation being made it becomes a final recommendation. Final recommendations are binding on the Crown.

Once a Waitangi Tribunal recommendation has become final the Crown is required to give the licensee a 35-year termination notice. From that point licence rentals are now to be paid to the Maori landowners. At this time the "Returned Area" clause of the Crown Forestry Licence will become significant. During the 35-year termination period the rights of the licensee are limited to forestry activities with respect to the tree crops standing on the land at the start of the termination period. Replanting during the termination period is not permitted.

Should the notice of termination be given within the initial 5, 10, or 20 year fixed term, the termination will not commence until the end of that fixed term. Licensees may continue to use all of the licensed land and to replant until the termination period commences and will then have 35 years in which to recover their investments from the forests.

Once the land is, however, no longer subject to claim for return to Maori ownership, there will be progressively no requirement to return it to the land owner during the termination period. The licensee will be able to use all of the land under the licence for any legitimate purpose until the date of the final expiry. To encourage full productive use, the licensee will be paid market value for any trees and nonremovable improvements which are on the land at the date of the expiry.

As hinted at above, the importance of the Waitangi Tribunal in the settlement process cannot be underestimated. The Tribunal has the power to make binding recommendations on State-Owned Enterprises assets requiring the Crown to return the licensed forest land and to pay any compensation by the end of the 90-day period. Counsel for the Aupouri tribe have asked for binding recommendations on the Aupouri State Forest and the Stony Creek station. These areas are currently where Juken Nissho Ltd. has large areas under plantation.

THE EFFECTIVENESS OF THE CROWN FOREST RENTAL TRUST

The New Zealand Crown Forest Assets Sale and related legislation makes an interesting case study of a complex problem. Although it goes a long way to resolve some of the challenges associated with Maori grievances resulting from the signing of the Treaty of Waitangi in 1840, it serves also to highlight the need for much greater research and planning to the dual challenge of appeasing Maori land rights and the transferring public assets to the private sector[24].

Since the establishment of the Crown Forest Rental Trust in April 1990 it has been the subject of much criticism from various sectors. The Crown Forest Rental Trust has been the cause of two Waitangi Tribunal claims. On 18 November 1991 an urgent hearing was held to enquire into the claims concerning alleged difficulties claimants were having in receiving funding from the Trust[25]. According to the claimants, as at November 1990 the Crown Forest Rental Trust had only distributed $NZ11,000 in research money to one tribe, while the Crown had disposed of $NZ 2 billion worth of forest assets. They argued that the Trust was unfairly withholding funding from Maori applicants. They also complained about the considerable costs involved in the application process.

The Trust Deed is inconsistent with the 1989 Agreement where Maori and the Crown agreed that money should be available for preparing a claim. Clearly the application process meant Maori were incurring large costs before they reached the Crown Forest Rental Trust. The advice of legal practitioners was often needed to assist Maori. The claimants argued that the absence of funding for the application process was contrary to the intentions of the parties to the original Agreement.

The claimants also pointed out that the role of the Trustees is to administer the Trust Fund and not to assess the validity of the applicant's claim. This rigorous application process seemed to contradict this [26].

As a result of the hearing the Tribunal issued a memorandum stating there is no argument that the disposal

of Crown assets without an adequate protective scheme was a matter within the Tribunal's purview; the central issue is whether the scheme is adequate in all circumstances.

As a result of the Waitangi Tribunal hearing the Trust employed Karen Wattereus as the Trust Secretary, set up a new office and approved funding for further groups. In February 1992 the claimants were satisfied that the Trust was operating in accordance with the Trust Deed. They subsequently adjourned the second hearing indefinitely.

Today there are now approximately 60 claimant groups being assisted by the Trust. Trust assistance to claimant groups for the year April 1993 to March 1994 amounted to $NZ3,806,731. This sum made up 60 percent of the Trust's gross income.

The Trustees have established a number of initiatives to assist Maori in presenting and researching claims. One of these initiatives included the establishment of a historical research unit. The purpose of the unit is "to assist claimants to prepare their historical evidence to the highest standard possible". The staff in the research unit can help claimants plan and undertake research, support claimant's own research efforts, assess claimants draft research reports before they are submitted to the Waitangi Tribunal and provide other professional support.

The Crown Forest Rental Trust has commissioned reports and studies including a report on the origins and implementation of the East Coast confiscation legislation and a study of gold mining legislation. A Waitangi Tribunal Report indexing project and an index of all the evidence presented to the Waitangi Tribunal by the Crown, claimants and Tribunal researchers, is also underway.

To enhance the Trust's relationship with claimants a claims facilitator has been appointed. The facilitator can help groups with their applications and the preparation of their claim. The facilitator also assists groups to understand the policies, services and requirements of the Trust in relation to their claim.

In summary, the Trust provides advice to claimants on the preparation a claim to the Waitangi Tribunal regarding Crown forest land; the establishment of appropriate management structures and processes to support the preparation of a claim; the application for legal aid; and, the maintenance of accountability to the claimant group and to the Trust.

The Trust has improved the services to Maori claimants. The number of claimants being assisted by the Trust has increased considerably since the Waitangi Tribunal hearing in 1990. A major concern, however, is that the Trust has been in operation for over six years and and as of 31 March 1995 only eight claims are in Proceedings. It is estimated that up to ten groups may be in a position to apply to the Waitangi Tribunal for hearing dates in the 1994/1995 year. Despite this, the Trust is not meeting the objective of the original negotiators to process claims within the "shortest reasonable period." The capital from the fund cannot be distributed until the Tribunal has made a recommendation for compensated to a claimant and the Tribunal cannot make recommendations until it receives claims from the Trust. Until that time the capital is locked up and the full benefits of the Crown Forest Assets Act 1989 will remain unrealized.

The Trust is without a doubt subject to a wide range of pressures: from the political agents who control the legislation membership and funding; from the courts, which dominate the judicial apparatus to which they precariously belong; from the grievants whom they have to attract; from the respondents, whose actions are on trial; and from the broader public, whose support, or at least acquiescence, they require. They are always walking on a tightrope that can be loosened or tightened as the circumstances and priorities of the time demand.

The effectiveness of the Crown Forest Rental Trust or the Waitangi Tribunal is often overstated. They lack the political clout of real courts and judges; they are usually chronically underfunded; and their slow progress in resolving disputes tends to undermine their credibility. Unless they are allocated more resources, their turnover can only be increased by decreasing the time and energy spent on each case. This reduces their appeal to the grievants even further. In the long run, these agencies might not actually accelerate the resolution of disputes; their lack of resources and power might even delay solutions.

CONCLUSION

Whether or not the Maori landowners undertake a joint ventures with Pacific Rim forestry investors depends once the land has been returned depends on the thinking of the different tribes. Joint ventures represent for the Maori a main avenue to obtain ready finance. Thus, joint ventures [27] with established forestry companies, whether they have their origin in New Zealand or elsewhere, makes sound commercial sense. The advantages of a joint venture would be compelling to the successful claimant.

For example:-

1. The successful claimant may have little experience in forest management. A joint venture with a committed and experience partner would provide the means to address this.
2. The size and age structure of the forest may mean that there are significant cash flow problems in planting and tending "Returned Areas" as they come stream.
3. The successful claimant may be persuaded to enter into a joint venture with the Licence Holder. For example, a Licence Holder with significant proces

sing facilities in the region, may for strategic wood supply reasons, be willing to enter in commitments not only in terms of employment opportunities for Maori within the growing cycle but also the processing cycle. Conversely, the successful claimant may wish to encourage a Licence Holder to remain with a region and move into processing activities.

4. The joint venture negotiations would allow considerable opportunity for innovative arrangements dealing with not only cost sharing, share of the produce, joint marketing activities but also with vertical integration of employment opportunities for Maori.

5. For completeness sake the final option is to maintain the existing status quo whereby the existing licensee is entitled to replant "Return Areas" for a rental under terms similar to the existing Crown Forestry Licence.

Whether or not the Pacific Rim forestry investors, on the other hand, will be prepared to undertake a joint ventures to manage the returned areas with successful claimant is, however, an unexplored issue.

While preparing for this research a number of executives of Japanese forestry industries [28] were approached and their views and preferences assessed. All indicated that they were considering assessing the viability and possibility of joint ventures with Maori landowning operations. Forestry executives clearly indicated that in order of preference they would respectively prefer to own the land involved; enter into joint ventures with a single landowner; and finally, enter into joint ventures involving multiple owned land.

This ranking was due in part to the difficulties in identifying exactly who had the say in Maori multiple landowning organizations; non-alienation of land; and a desire to use their land to bring about economic self determination for the greater group. This results in a lack of clear lines of authority, confusion, uncertainty, and delay in decision-making. However, where a forestry company already has forestry operations and/or processing complexes in a region, it may be interested in securing long-term access to wood supply within an immediate strategic region. The Korean forestry industry, Hansol, did, however, enter to a $NZ50 million agreement in February 1996 with the Ngati Porou tribe. Where a Maori landowning organization is fortunate enough to have landholdings in a strategic region, then a suitable discount may be applied to a forestry company's traditional reluctance to get involved with multiple owned land.

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FOOTNOTES

The author holds a Ph.D from the Law Faculty at Osaka University, Japan. Research was supported by the Japanese Department of Education and mainly arose out of her interest in foreign direct investment and resource management especially in forest management both in her home country of New Zealand and her 'adopted' country of Japan. It should be noted that this article fundamentally serves as a descriptive background piece of prose for the author's Ph.D dissertation in which a a prescriptive analysis will be undertaken. Although New Zealand's economic reforms are widely discussed in many circles in Japan, little is known out these discussions of New Zealand herself. This article hopes to remedy this lack of understanding.

The author wishes to thank Professor Y. Konohira from Tokyo University of Agriculture and Technology; and Pieter Berghout from the New Zealand Ministry of Forestry for their support and advice. She also gratefully acknowledges the helpful and constructive comments given by Professors Ed Bilek and Graham Whyte of the University of Canterbury, School of Forestry, New Zealand.

While every effort has been made to ensure that the accuracy of the information contained in this research, the information should not be relied upon as a substitute for professional advise in any specific situation. In such cases the services of a professional lawyer should be sought. The opinions expressed in this article are however those of the author and any errors or omissions remain the author's author's responsibility.

1) The current system of government in New Zealand exists partly because of the appropriation and colonization of these islands by the British Crown in the 19th century. By what right? Traditionally there have been three justifications for a country to appropriate new

lands: terra nullius, by force of conquest, and by treaty. Of the three justifications, the third is the most popular. Of course, this rests on the assumption that the original inhabitants freely consented to an appropriate agreement, then New Zealand governmental institutions have a legal and moral foothold, and provided they are operating justly, can rightly command the loyalty and obedience of all. It is this assumption that is under attack. One of the main grievances held by the Maori is that the sale of land was not alienation but the equivalent of a lease. The sale of land meant the permanent loss of land was not a concept in the Maori world view of the time.

2) The texts accepted by Parliament as authoritative are set out in the First Schedule of the Treaty of Waitangi Act 1975 (as substituted by the Treaty of Waitangi Amendment Act 1985, s. 4). As to the Treaty's legal status, see, e.g., KEITH, K., 'International Law and New Zealand Muncipal Law' in DAVIS, A.G., Essays in Law (1965 ed. Northey) 130, 136-38, 146-8; MCKEAN S., 'The Treaty of Waitangi Revisited' in W.P. MORRELL; a Tribute (1973 ed. WOOD and O'CONNOR) 237 237. As to text interpretation, see, e.g., ROSS, B., 'Te Tiriti o Waitangi' (1972) 6 New Zealand Journal of History 129 and 'The Treaty on the Ground in The Treaty of Waitangi: its Origins and Significance (1972 V.U.W) 16.

3) A real philosophical problem presently facing the New Zealand Government is that present day non-Maori New Zealanders cannot be fairly excluded from their lands or from their place in New Zealand, whatever the original defects in title and in means of acquisition may have been. To render the Crown retroactively liable in law for past wrong dealings with Maori customary land, with some suggested possible consequences for private owners at least where they hold under purported Crown lease of land, see MCHUGH B., 'The Legal Basis for Maori Claims against the Crown' (1988) 1 VUWL Rev. 1 and more recent articles published in The Christchurch Press, Government's Handling of Land Claims Rapped: Farmers, Maori Leader Unite in Attack, 24 March 1996; and, 'Farmer Facing Financial Ruin: Land Claims Causing 'Strain'', 3 April 1996.

4) The Waitangi Tribunal is a quasi-autonomous government body which is charged with making recommendations to the Crown over Maori grievances relating to breeches of the principles of the Treaty of Waitangi.Waitangi Tribunal has, under section 8A(2)(a) of the Treaty of Waitangi 1975, to recommend the return to Maori ownership, land, or an interest in land transferred to a State enterprise under section 23 of the State-Owned Enterprises Act 1986. The Tribunal consists of three persons: the Chief Judge of the Maori Land Court, who was to be the chairman, and two others appointed by the Governor General, one on the recommendation of the Minister of Justice, the other (who was to be Maori) on the recommendation of the Minister of Maori Affairs. Further, the Crown Forest Assets Act 1989, amended the Treaty of Waitangi Act 1975, allows for the Waitangi Tribunal to make recommendations in regard to Crown forest land as defined under the Crown Forest Assets Act 1989. The Tribunal can recommend that the forest land be returned to Maori ownership. Where the Tribunal recommends that the claim is well founded and the land should be returned to Maori ownership, the recommendation shall be in the first instance an initial recommendation.

5) The Crown refers to the New Zealand government as a whole, including the Governor-General, Parliament, the Prime Minister and other Ministers, Crown departments, Crown entities, the Court of Appeals, the High Court, District Courts, and specialized courts whereas the Government refers to the Prime Minister and other Ministers who together constitute the Cabinet and perform the executive functions of the New Zealand state.

6) Apart from the obvious pressures of time restraints, as mentioned in the text, there is a lack of qualified staff employed by the Crown Forest Rental Trust. Moreover, the 'job' description of the Waitangi Tribunal, under the Treaty of Waitangi Act 1975, is not confined to the exclusive interpretation of the meaning, the principles, and the effect of the two versions of the Treaty of Waitangi. It has to examine the contemporary intellectual climate to assess what was in the minds of the men who made, negotiated, and signed the Treaty. That in turn required an investigation of the historical traditions of both sides: on the British side some centuries of jurisprudence and colonial policy; on the Maori side orally recorded traditions of lore and custom. There was no way of avoiding such historical analysis, despite the limitation of the Act excluding actions or omissions of the Crown before 1975.

7) Under the New Zealand Constitution Act 1852, all powers of sovereignty were vested in the Crown. This Act established a system of representative central government and divided the country into six provinces, presided over by provincial councils. Tribes and individual Maori were excluded from effective participation in these structures because of the right to vote was limited to males 21 years and over who owned or leased land to a certain stated minimum value. Minor cessions or recognition to the Moari were made at the central level by the creation of four Maori electorates as a means of 'franchising' Maori voters who, because of their communal ownership of land, "failed" the

property test. Four Maori seats were allocated to 50,000 potential Maori voters, compared with 72 Non-Maori seats for a population of 250,000.

8) In 1984 the New Zealand Treasury's briefing to the incoming government signaled an ideologically-driven onslaught against the dominance of the state in the New Zealand economy. The extensive welfare bureaucracy was one of the prime targets. With the enactment of the State-Owned Enterprises Act in December 1986 nine new government-owned corporations were established including forestry. The overriding statutory objective of each SOE was to run a successful business. Within that, the SOE had to be as profitable and efficient as a comparable private sector business, be a good employer and exhibit a sense of social responsibility.

9) See Greig J's observation in Ngai Tahu Maori Trust Board v Attorney-General (interim decision) (CP 559/87, 614/87: 12 December 1987) in respect of fisheries.

10) New Zealand Maori Council v Attorney-General [1987] 1 NZLR 641. The Treaty of Waitangi (State Enterprises Act) provides for the Waitangi Tribunal to make mandatory recommendations requiring the Crown to return land transferred to a State-Owned Enterprise to the relevant Maori claimant.

11) The Corporation is a limited liability company established under the State-Owned Enterprises Act 1986 and incorporated under the Companies Act 1955.

12) The Government announced the sale of the Forestry Corporation for just over $ NZ 2 billion to a Fletcher's led consortium on 21 August 1996 The main players are Brierley Investments and CITIC, a Chinese governmental group.

13) Supreme Court. At this stage in the hierarchy of courts, the citing of cases by counsel found in the reports from all relevant jurisdictions, and the detailed examination of case authorities, is expected. It is here that may be seen most commonly the intricacies and difficulties involved in the view that the decision of the court is binding upon other courts but only as to the ratio decidendi thereof.

14) New Zealand Maori Council v Attorney-General [1987] 1 NZLR 641, 673. On the central importance of good faith in the partnership between the Crown and Maori see also Cooke P. at pp. 664 and 667 and Richardson J at pp. 680-3. Judge Richardson also cites Article 2 of the UN Charter, Articles 26 and 31(1) of the Vienna Convention on the Law of Treaties 1969, and Virally in (1983) 77 AJIL 130.

15) The State-Owned Enterprises Act 1986, s. 329 came into force on 1 April 1987 and repealed the definition of "indigenous state forest land".

16) Clause 14 of the Agreement states that the Agreement covers exotic forests. No discussions had been made in regard to indigenous production forests or the two State sawmills.

17) Crown-Maori Agreement 1989, Clause 1.

18) New Zealand Maori Council v Attorney-General, Court Order, 28 August 1990.

19) The transfer of Crown forestry assets is pursuant to s. 11 of the Crown Forests Assets Act 1989. Crown Forest Assets Act 1989, s 2(1)(a) and (b), meaning of "Crown Forests Assets." Crown Forest Assets means every forest that comprises principally exotic trees growing or standing on Crown forest land, and all improvements on, or associated with, Crown forest land. All plant, equipment, vehicles, tools, logs, consumable supplies, raw materials, forest produce, and stores used or associated with the management of other Crown forest assets are also included.

20) Section 14 specifically outlines the three types of recommendations that may be made by the Waitangi Tribunal. These include either that all land be made not liable to be returned for Maori ownership; that the return of all the land to Maori ownership; and finally, that the return of part of the land to Maori ownership. Other provisions include the preservation and safeguarding the graves of Maori people; the collection of traditional medicines and foods; and, other recreational purposes.

21) Forestry Licence, Clause 10.1

22) Forestry Licence, Clause 16.3.

23) Crown Forest Rental Trust 1994-1995 Report to Appointors, 8.

24) Recent criticism have, for example, come from the farming sector. The Christchurch Press, "Farmers Facing 'Financial Ruin': Land Claims Causing Strain", 27 May 1996; The Christchurch Press, "Government's Handling of Land Claims Rapped", 18 July 1996.

25) "Te Manutukutuku" Waitangi Tribunal Division, Department of Justice newsletter, Number 13, December 1991.

26) The Christchurch Press, May 11, 1996.

27) In simple terms a joint venture is:
   1) an association of persons (or other legal entities);
   2) for the purposes of a particular undertaking or project;
   3) with a view to each participant making some agreed contribution; and
   4) sharing in an agreed proportion in the product and proceeds of the sale of the product.

28) One of the biggest Japanese forestry concerns in New Zealand is, for example, the Hiroshima-based company Juken Sangyo. The 22,660 hectares of Crown land on which it is currently renting in Aupouri is under claim by the Muriwhenua Forestry Claims Project.

(Received 28 July 1997)
(Accepted 18 November 1997)

Article

The History of Taungya Plantation Forestry and Its Rise and Fall in the Tharrawaddy Forest Division of Myanmar (1869-1994)

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ABSTRACT

In some areas of Myanmar (formerly Burma), trees are planted amongst agricultural crops in hill-farms (taungya). This "taungya system" is one method of restoring tree cover and can also be regarded as a forerunner of agroforestry. The system is widely believed to have originated in the Tharrawaddy forest division of Myanmar, but the actual location of its origin is likely to be the Kaboung forest area. The taungya system was first devised by Dr. DIETRICH BRANDIS, an early German botanist-turned-forester in Myanmar, in the mid-1800 s after he observed the taungya of the Karen hill people. Taungya teak plantations expanded in the Tharrawaddy forest division from 1869 as teak grows well there and the facilities for teak timber extraction are good. However, the annual establishment rate in Tharrawaddy has fluctuated greatly. The establishment of taungya plantations has gone through three periods of growth and decline. The growth phase of the first period began in 1869 when Imperial foresters succeeded in employing the hill Karen to plant teak in their taungyas, and was followed by a decline from 1906 when the scattered taungya plantations became difficult to manage. The second period began from 1918-19 when concentrated regeneration under the Uniform System was introduced into the division. This period's decline started in 1930 and was caused by the farmers' revolution. The third period began in 1948, but the thirty years to 1979 were politically and socially unstable, so there was very little planting throughout this time. The growth in plantation establishment began in early 1980 when the government focused on reforestation to boost timber production, but its decline came in the late 1980s and was primarily caused by socioeconomic and government policy changes. Higher wages for taungya workers and more productive agricultural techniques for taungya crops are now necessary if taungya plantation management is to be successful in the future.

Keyword : natural regeneration, plantations, taungya, teak

INTRODUCTION

The objective of this paper is to establish the possible origin of the taungya plantation system in Myanmar (formerly known as Burma) and to review the rise and fall of taungya plantations in the nation's Tharrawaddy forest division. The Tharrawaddy forest division[2] is located in southern Tharrawaddy district, one of the four districts in Pegu Division[3], some 125 km north of Rangoon (see Figs. 1 and 2). The division's forests can be classified simply along topographical lines into hill forests and plain forests. The former are mainly natural forests and are located in the eastern part of the district, while the latter are located in the central plain area of the district. Karen hill-tribes live in the hill forests, while the Bamar people and a few Karen live in the plain area.

The Tenasserim forests of Myanmar, which were occupied by the first British annexation war (1824-26), were devastated by the uncontrolled logging of private timber traders. This and other such experiences prompted the colonial government to more carefully manage the

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Pegu teak forests that were annexed in 1852, and in 1856, it appointed Dr. DIETRICH BRANDIS, a German botanist to manage these forests. BRANDIS introduced a Selection System[4] with the aims of producing a sustained supply of teak , and also started planting teak trees in taungya areas to increase the proportion of teak in forest areas.

The Tharrawaddy forest division is reputed to be the area where the taungya system originated. The Myanmar' s first Forestry School was established there in 1898, and the success of taungya plantations under the Uniform System introduced in 1918 led to a wave of enthusiasm for taungya plantations.

THE TAUNGYA SYSTEM AND ITS VARIETIES

Taungya is a Bamar word meaning a hill-farm. *Taung* (hill) and *ya* (a farm area) give an exact translation of a farm on a hill. It is often translated as hill (*taung*) and cultivation (*ya*), but is most commonly translated as shifting cultivation. However, if this meaning is intended, the prefix *Shwe-pyaun* (a Bamar word meaning, "shifting") should be placed before taungya. The planting of trees in an area clearfelled for traditional taungya farming helps replace the forest cover, and thus this method of regeneration was given the name "taungya system" by Brandis (CHEIN HOE, 1969). Depending the techniques used, the taungya system is classified as natural or regular taungya.

Natural taungya: This kind of taungya was developed to exploit teak's need for light, and it can only be applied in areas where some teak stumps remain. Specifically, a number of six-foot square sample plots are established and if there is at least one teak stump in more than 40 % of the plots, "natural taungya" is used. Taungya farmers are then allowed into this area to grow agricultural crops in the first year. By the second year, teak seedlings would have coppiced from the remaining teak stumps (CHEIN HOE, 1979). "In theory no planting should be necessary though in practice some assistance may be given to avoid blanks" (FOREST DEPARTMENT 1957).

Regular taungya: The commonly known taungya system of growing trees and agricultural crops at the same location is called " regular taungya". In this paper, the origin and development of regular taungya will be examined.

UNDERSTANDING THE ORIGIN OF THE TAUNGYA SYSTEM

As will be seen, it is commonly thought that the

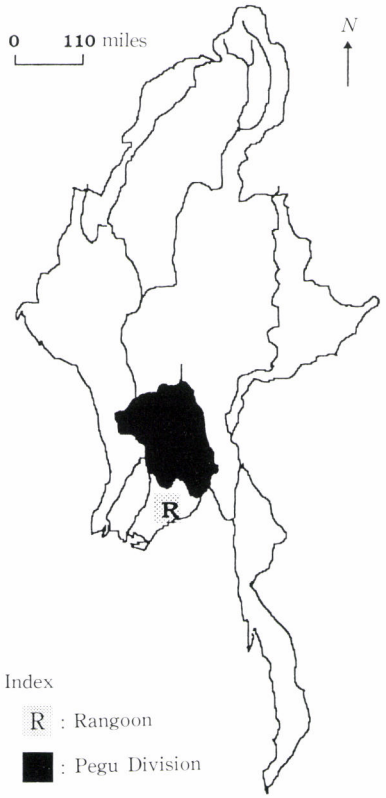

Fig. 1 The location of Pegu Division in Myanmar

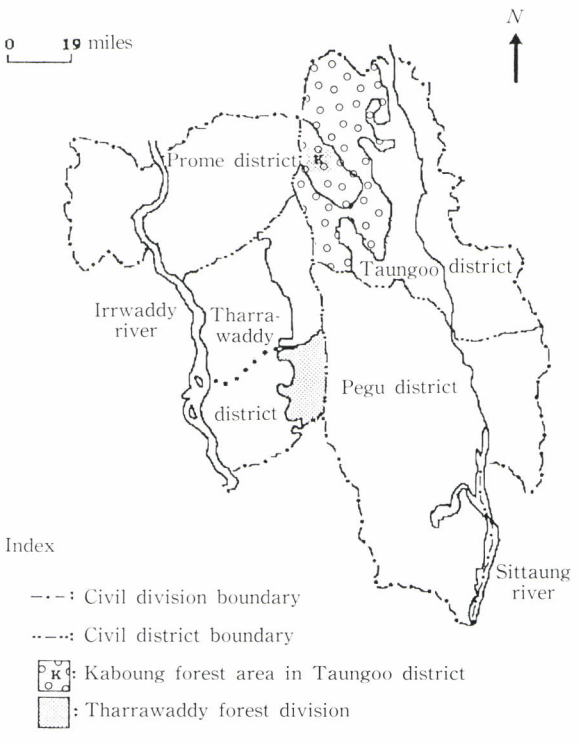

Fig. 2 The location of Tharrawaddy forest division and Kaboung reserved Forest

taungya system of teak plantation establishment originated in the Tharrawaddy forest division. However, it is the view of this writer that the system's origin is likely to be the Kaboung reserved forest in Myanmar's southern Taungoo forest division.

It is important to clarify the location and method of the system's origin, not just for the sake of technical accuracy, but also because it is an expression of the cultural and social conditions of the time, so is important historically. This will be done by examining a number of statements and opinions about the system's origin in relation to other published documents as well as the writer's own knowledge and experience gained by working in Myanmar's forests and taungya plantations. The writer spent 8 years in Tharrawaddy forest division and 6 of those years (1984-1989) were in the taungya plantations of Mokka, Kadinbilin, Konbilin and Thonze reserved forests working with the hill Karen and Bamars. One man was crucial to the development of the taungya system. He is Dr. DIETRICH BRANDIS, a German botanist who became a teacher of botany in 1849 after studying at the Universities of Copenhagen, Göettingen and Bonn. He continued studying botany in Germany for a number of years, and then through a train of circumstances which originated in the desire of the Government of India to find a man who could take charge of its forests, he was offered a position as forester in Burma in 1856 by Lord Dalhousie, the then Governer-General of British-India (PINCHOT 1908).

BRANDIS is credited with establishing the system after having seen the taungya of the Karen hill people, and the following statement is typical of those that assume BRANDIS's involvement in its establishment in the Tharrawaddy forest area:

"The first attempt at taungya teak plantation was made as early as 1856. It is recorded that actually the first plantation to be so made was formed by U Pan Hee, a Karen in the Thonze forests as a personal present to Brandis" (BLANDFORD 1958).

This view is also common in Myanmar's forestry profession (CHEIN HOE 1969). However,

the different dates given for the year when the U Pan Hee reportedly gave this taungya teak plantation to Brandis - 1856 (BLANDFORD 1958) and 1869 (Tharrawaddy Working Plan, 1946-47 to 1962-63) - are a sign that perhaps there is some doubt about the actual origin. WATANABE (1997) also considers that two stories about the origin of taungya seem credible.

1) "taungya" was first started at Tharrawaddy in the upper Burma by BRANDIS or by a

Karen tribesman, U Pan Hee, under the supervision of Brandis in 1856; and,

2) Colonel W. J. SEATON introduced "taungya" on a small-scale in 1869 in the Tharrawaddy area.

Taungya-like systems had been used in Europe (KERMODE 1964, KING 1968, STEBBING date unknown), and TAKEDA (1992) states that most accounts of the taungya system are credited to BRANDIS because he was a German forester, and was familiar with the "Waldfeldbau" system (a combined system of field crops and high forest), and with "Hackwaldbetrieb" or "Haubergswirtschaft" (a combined system of field crops and coppice). Thus, it seems logical that BRANDIS, knowing the efficiency of taungya style agroforestry in Germany, introduced the system and applied it to establish plantation forests in Burma.

The 1918 Working Plan for the Tharrawaddy forest division states that the idea of planting teak in taungya along with cereal crops was originated by BRANDIS, but BRYANT (1994b) puts the development of taungya forestry in a political context when he argues that it was one outcome of the antagonistic relationship between acquisitive British colonial rulers and the threatened indigenous people. Such a perspective is supported by BRANDIS's own admission that one of his objectives was to increase the amount of teak in the forests:

> "There was, however, no doubt in my mind from the outset that something more was wanted, and that it was not sufficient to protect and aid the teak which sprung up naturally, but that it would be necessary to increase the proportion of teak in the forests by sowing and planting" (BRANDIS 1896).

BRANDIS also saw the opportunity to do this by using the local people and co-opting their traditional agricultural system:

> "As soon as I had seen the first Karen toungya (sic) in 1856, I deter-mined to devise some method by which this mode of shifting cultivation might be utilized for planting Teak on a large scale in those regions where this species attains its most perfect development" (BRANDIS 1896).

Here it is interesting to speculate whether the Karen taungya seen by BRANDIS in 1856 was a traditional Karen taungya or a taungya containing deliberately planted teak trees. Karens in this hill forest traditionally do not plant teak trees in their taungyas for several reasons. Firstly, all teak trees in Myanmar have been the property of either royalty or governments since 1752. Thus even if a landowner grows teak on his/her own land, it will not be that person's property- "A standing teak tree wherever situated in the State is owned by the State" (GOVERNMENT OF MYANMAR 1992). Secondly, if the Karens grew teak in their taungya, the area would not become *Phonezo*[5] (an area where crops can be grown again) and so they could not return to farm it again. As well, they had little interest in the structural qualities of teak "building their homes entirely of bamboo" (BRYANT 1994).

Even if the Karen had wanted to give a teak plantation as a present to Brandis, the teak would have had to

have been planted in the taungya during 1855 at the latest, because BRANDIS took charge of the Pegu teak forests in January 1856 and set out on his first tour into the forests in early February, the beginning of the hot season[6] in Myanmar. To quickly establish a teak plantation in the hot season is impossible. However, when BRANDIS saw the Karen taungya he would have realized that there were inhabitants in the forest that could be used to plant teak.

It is also possible BRANDIS saw natural teak coppice in the Karen taungya. Teak grows on gentle slopes with good soil and Karens choose such places for taungya (Maling cited in Baillie as quoted in BRYANT (1994a), p: 131). Usually, teak coppices from already existing natural teak stock and grow quickly in taungya areas as the species is a light demander. The silviculturist KERMODE (1964) studied teak regeneration of various kinds in Myanmar forests and found that burning the forest for taungya cultivation in fact helps teak regeneration. It is also the writer's experience that teak coppice from already existing teak stocks will appear before the germination of planted teak seed.

The Pegu hills are part of Myanmar's "teak-heart", so it can be expected that teak coppice will grow well in the area's taungya. Thus what BRANDIS saw may have been a traditional Karen taungya with natural teak coppice, and as a result he decided to plant additional teak seedlings.

However, it seems that BRANDIS was reluctant to force the inhabitants to plant teak in their taungya because one of his three main objectives was to make friends of the inhabitants of the forests and surrounding areas. His other objectives were:

- to protect and, as far as possible, improve the forests, arranging the cuttings so as to stay well within the productive capacity of the forests thus ensuring a permanent and sustained yield of teak; and,
- as soon as possible produce an annual surplus revenue" (BRANDIS 1896).

Nevertheless he did realize that using the Karen to plant teak would be efficient, but that it would need some kind of inducement (ANON date unknown).

B*randis* states that he explained his idea to plant teak in taungya to a Bamar forester, Moung Tsaudoon, who was in charge of the Kaboung forest area, and that it was Tsaudoon who was the first to carry out the plan. "On a subsequent visit in 1868, I had the satisfaction to examine six small plantations made by him on toungyas (sic) in successive years, the oldest in 1856" (BRANDIS 1896).

This statement by BRANDIS is thus crucial to the history of taungya development as it supports the fact that he saw a Karen taungya on his tour during the dry season in 1856. It also shows that the first taungya plantation was established by a forester not a Karen, that this forester worked in the Kaboung forest area, and that BRANDIS did not receive the first taungya plantation from a Karen. In fact, it is also doubtful that a Karen gave a taungya teak plantation as a present to BRANDIS, an unknown newcomer, because the hill Karens are fond of seclusion. The Karen is not servile, and it has never been to their custom to *shiko* (worship or show respect to officials) (MARSHALL 1922).

Even if a Karen had given a taungya teak plantation as a present to BRANDIS in 1869, as stated in the Tharrawaddy Working Plan for the period of 1946-47 to 1962-63, this writer considers that it might have resulted from an official's suggestion or pressure as a way of convincing other hill-tribes to plant teak in their taungya. Such action is documented for other parts of the world. For example, in Tokugawa Japan (1600-1868), the practice of thanksgiving afforestation (*myogazorin*) involved people giving their lord a plantation that they had established and tended. It was, formally at least, a voluntary act that expressed thanks to the lord, but actually it was made in compliance with an official's suggestion or pressure (SHIOYA 1967).

Thus, while it is clear that BRANDIS was in fact the originator of the taungya system, contrary to previous thought, there is a strong evidence to show the first taungya teak plantation was started in Kaboung forest area of South Taungoo forest division in Taungoo district. According to the Working Plan for South Taungoo forest division for the period of 1933-34, there were 132 Karen taungya cutters living in the Kaboung forests. It seems that the Imperial foresters then chose Tharrawaddy as the area in which to expand teak plantations using the taungya system as teak grows well here. It also close to Rangoon and can be easily accessed for timber extraction by waterways as well as roads and railway. The Myitmaka river has been used for teak since the mid-19th century (CHEIN HOE 1969). Also the Rangoon-Prome railroad opened in 1877, was the first rail line in Myanmar (GOVERNMENT OF MYANMAR 1994) (see Fig. 3).

IMPERIAL FORESTER'S USE KARENS TO PLANT TEAK

The Imperial foresters[7] of the time wanted to increase the amount of teak growing stock in Burma and attempted experimental plantations even in open areas outside the hill forests. However, they were not successful producing only fluted and crooked teak stems. They realized that the hill forests were the best teak producing areas and so chose the Tharrawaddy hill forests in which to begin establish teak plantations. They also saw the local inhabitants, the Karen, as the main labour force and made concerted attempts to involve them in teak planting.

It seems that Imperial foresters tried planting teak in Karen taungya before 1869. However, the Karen were most unwilling to participate as they correctly saw that a

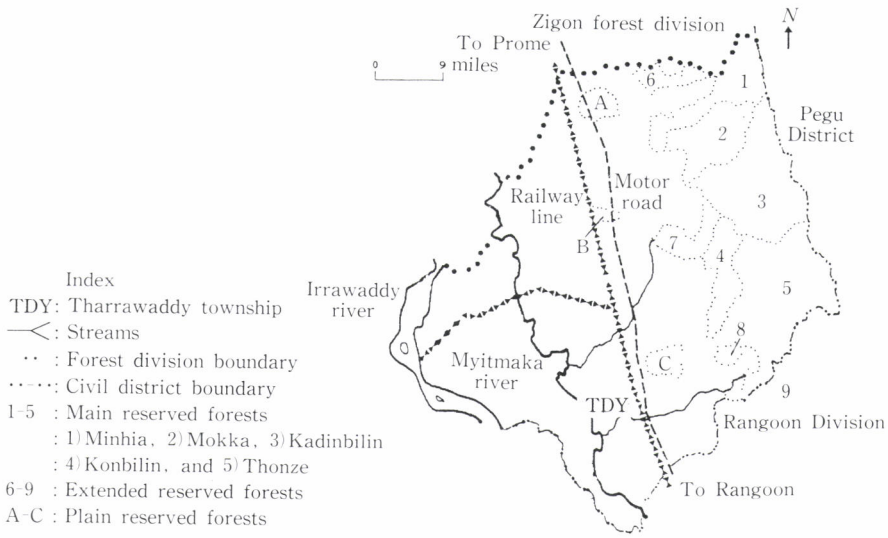

Fig. 3 Tharrawaddy forest division (southern Tharrawaddy District)

taungya so planted would not become phonezo, and could never be returned to again. As a consequence, only small areas of plantations were established in the Mokka forest. The foresters then turned to threatening the Karen, and this had the desired effect:

> "The beginning appears to have been attained by pointing out to them (Karen taungya cutters) that they destroyed a good many teak trees in their taungya every year and were liable to be prosecuted for this breach of forest rules. As an alternative they were allowed to plant teak in expiation of the offence" (Tharrawaddy Working Plan, 1918).

In 1869, the Conservator, Colonel Seaton used force to make the Karen plant teak in their taungya, as he knew that land for taungya is a prerequisite for the Karen way of life.

> "As soon as the intentions of Government are explained with reference to the formation of special reserves, and the abandonment of certain areas to the Karens for taungya ground, it is found they manifest aninterest in the whole question of forest improvement and are quite too ready to admit that the sooner the special reserves are converted to compact teak forests, the sooner will Government be in a position to exclude other areas from the operation of the Forest Rules" (Tharrawaddy Working Plan 1918).

Thus, if the Karen refused to convert the special forest reserve into compact teak forest (ie if they refused to plant teak in their taungya), then the government would not give land to them for their taungya. After the Conservator met with Karen headmen, no less than 8 Karen villages had to undertake the planting of teak in their taungya clearings. Also there was no difficulty in getting labour to plant teak in their taungya in return for being allowed to cut taungya within the reserves. It seemed that the Karen, finally, had to agree to plant teak trees in their taungya clearings after they were coerced, not merely persuaded, to do so by the Conservator of Forests. This was the start of the taungya plantation in this forest division. The Karen were employed for the benefit of the British colonial government, and this provided substantial financial benefits as BRANDIS (1896) notes:

> "The principle of planting teak on the same area with field crops was adopted in the case of plantations made by means of hired labour, called regular plantations, in order to reduce the cost of these under-takings; nevertheless, the expense per acre was always six to eight times that of toungya (sic) teak plantations made by the Karens in the forests".

In Tharrawaddy forest division, a regular plantation established in 1867 had cost the government 110 rupees per acre by 1880. However, the average cost of a taungya plantation over 40 years is about 31 rupees per acre (see Table 1).

THE LONG-TERM TRENDS IN TAUNGYA PLANTATIONS

Taungya farmers have established large areas of plantations in the Tharrawaddy forest division since 1869. Table 2 shows the total area established in the division up to 1994 by 10 year periods for the main reserved forests and also the lowland forests into which plantations extended. It is obvious that annual planted area fluctuated markedly. These fluctuations and their background will

Table 1 The average per acre cost of a taungya plantation over 40 years

Age	Operations	Cost/acre (Unit: rupees)
1	Clearing and planting	10
2	Weeding	2
3	Weeding	2
4	Weeding	1.5
7	Cleaning	2
10	Cleaning and thinning	2.5
15	Cleaning	2
20	Thinning	2
25	Cleaning	2
30	Thinning	2
40	Thinning	3
Total		31

Source: Working Plan for the Yoma (hill) forests in the Tharrawaddy Division, 1918, vol. I.

Table 2 Plantation establishment in the Tharrawaddy forest division

Unit: Acres

Year	hill reserved forests[a]						Others[9]	Total
	Minhla	Mokka	Konbilin	Kadinbilin	Thonze	Extended[10]		
1867-69	0.0	20.0	49.0	0.0	0.0	0.0	0.0	69.0
1870-79	140.6	802.9	0.0	40.9	70.0	0.0	0.0	1,054.4
1880-89	1,601.0	2,042.1	1,017.5	331.7	546.4	0.0	0.0	5,538.7
1890-09	2,083.0	1,386.8	113.1	447.9	877.4	0.0	0.0	4,908.2
1900-09	798.8	412.7	0.0	350.7	536.7	0.0	0.0	2,098.9
1910-19	86.0	94.0	53.0	120.5	821.6	194.0	58.0	1,427.1
1920-29	1,521.0	938.0	615.0	0.0	1,128.0	1,135.0	857.0	6,194.0
1930-39	321.0	481.0	363.0	50.0	213.0	627.0	1,052.0	3,107.0
1940-49	0.0	97.0	210.0	0.0	0.0	275.0	725.0	1,307.0
1950-59	0.0	0.0	0.0	0.0	0.0	0.0	585.0	585.0
1960-69	116.0	0.0	0.0	0.0	0.0	0.0	1,588.0	1,704.0
1970-79	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980-89	3,200.0	3,715.0	3,612.0	1,790.0	2,800.0	4,410.0	2,920.0	22,447.0
1990-94	1,924.0	1,917.0	1,830.0	900.0	1,620.0	2,800.0	50.0	11,041.0
Total	11,791.4	11,906.5	7,862.6	4,031.7	8,613.1	9,441.0	7,835.0	61,481.3

Sources: 1. From 1867 to 1917 (Tharrawaddy Working Plan, 1946-47 to 1962-63)
2. From 1918 to 1968 (Tharrawaddy Working Plan, 1946-47 to 1962-63, and 1963-64 to 1972-73
3. From 1980 to 1994: Tharrowaddy Forest Department documents unpublished

Notes:
(a) The location of these reserved forests is shown in Fig. 3
(b) Extended reserved forests adjoining the main hill forests, including Nyaungbinzin-Kyinichaung, Kanni, Teinmyok and Thewa
(c) Plantations established in Thindawyo, Sitkwin, Satpok and public forest
(d) This 49 acres were regular plantations

now be examined. The whole period of examination is divided into three shorter periods: 1) The first period (1867 to 1917); 2) The second period (1918 to 1947); and, 3) The third period (1948 to 1994).

THE FIRST PERIOD (1869 to 1917)

During this period, more than 14,000 acres of teak taungya plantations were established. Establishment began in 1869 when the Karen people were forced plant teak in their taungya. The fluctuations in plantation establishment in the Tharrawaddy forest division from 1867 to 1917 are seen in Fig. 4. The area of taungya plantations increased and first peaked in 1889. Planting in the one small regular plantation stopped by 1869 (Tharrawaddy Working Plan, 1919).

The Forest Department was very pleased, and made the remark that in the hills, the true habitat of the teak, where labour was both difficult to obtain as well as to control, the system of employing the Karen taungya cultivators was particularly suited to the work of consolidating the teak forests (Tharrawaddy Working Plan 1946-47 to 1962-63).

However, in this initial period, the Forest Department had to let the Karen cut taungya wherever they pleased, and as a consequence these plantations were of various sizes and scattered over wide areas. They were thus difficult for the Forest Department to adequately tend and supervise. This system of plantation establishment eventually fell into disfavour, and a policy of restricting plantations adopted in 1905 led to the almost entire cessation of this work (Tharrawaddy Working Plan, 1919). It was decided in 1911-12 to discontinue establishment of scattered taungya plantations, but this was not implemented and some planting continued (Tharrawaddy Working Plan, 1963-64 to 1972-73). These events are reflected in Fig. 4.

The beginning of the 20th century was the time of first decline in the division's taungya plantations programme. Experiments in an alternative method of inducing natural teak regeneration using improvement felling (IF) were conducted during 1908 in Mokka and Minhla reserved forests. However, the results were uncertain and uneven, while the costs were no less than those of taungya plantations which gave more assured results and complete stocking.

THE SECOND PERIOD (1918 to 1947)

Plantation establishment philosophy changed markedly in this period. It was decided to intensify teak production activities and a Uniform System using a concentrated regeneration method was introduced into the division during 1918. All hill forests were placed in one working circle and teak production still had priority with hill teak bearing forests being planned for replacement with plantations. The annual target rate for converting accessible teak forests was set at 1,100 acres, and forest villages were established at regeneration centres across the hill reserves. A second peak in plantation establishment was reached in 1920.

> "The immediate success of concentrated regeneration by taungya in the Tharrawaddy division led to a wave of enthusiasm for this method, and at one time proposals were made for working over the whole of Burma by planting up 1/R of the forest annually (R being the rotation considered necessary for plantations to come to maturity" (BLANFORD 1933).

However the annual target of 1,100 acres was not reached because it was impossible to dispose of all the wood left on the ground after felling. At first, the regeneration activities progressed well. Then, one regeneration

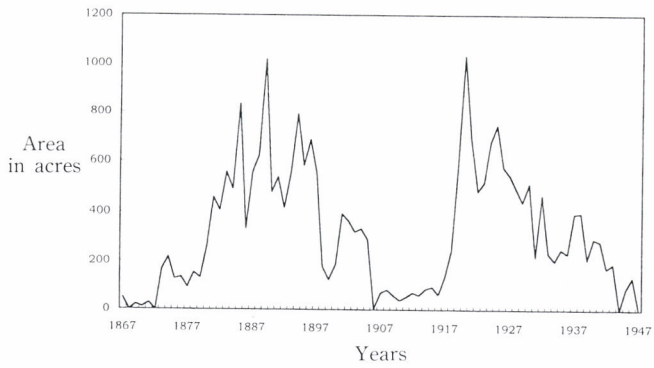

Fig. 4 Plantation establishment in Tharrawaddy forest division (1867 to 1947)

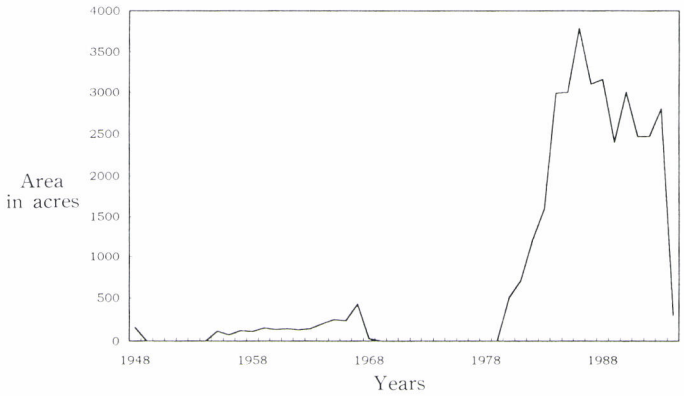

Fig. 5 Plantation establishment in Tharrawaddy forest division (1948 to 1994)

site was closed because of the 1930 Tharrawaddy farmers' revolt against British rule in which a Forest Conservator and some of his subordinates were killed. In 1931-32, four regeneration centres were also closed down because of financial stringencies. These closures might also have been influenced by the development of the then Chief Conservator of Forest's proposal, put forward in 1932-33, for a complete cessation of teak planting. He based his argument "on the assumption that the quality of plantation teak would be inferior to that of natural ones, as the former had been found to be three times more liable to be attacked by the bee - hole borers" (Tharrawaddy Working Plan, 1963-64 to 1972-73).

The Government accepted this proposal and issued the first plantation policy in 1935. The main thrust of this policy was to plant teak not for export, but only for domestic use. Planting was not to be carried out in areas heavily infected by the "bee-hole borer", and was to be confined to teak and Pyinkado (*Xylia dolabriformis*). The policy laid stress on natural regeneration. The government issued another plantation policy in 1937 that reaffirmed the 1935 policy, but put a higher priority on plantations for local people. The 1937 policy limited the planting of teak and Pyinkado, and promoted species suitable for local people's needs. The area of forest regenerated each year progressively declined because of these policies. Other regeneration centres in hill forests were closed prior to the Second World War, and only small areas were planted in the plain reserved forests up to 1946- 47 (see Fig. 1).

THE THIRD PERIOD (1948 to 1994)

Myanmar gained its independence in 1948, and the rate of taungya planting stayed extremely low through to 1980 mainly because of civil unrest. The Forest Department of Burma was only able to establish an average of 330 acres a year between 1948 and 1962 throughout the whole country (WINT 1986).

The area of new plantations in Tharrawaddy forest division also decreased because of the civil unrest, which continued up to the mid-1970s in the Pegu hills. The rate of plantation established for the years 1948 to 1994 in Tharrawaddy forest division is shown in Fig. 5.

Only 2,448 acres of plantations were established in the Tharrawaddy forest area from 1948 to 1979, an average of 76.5 acres per year. Almost all of these (more than 95%) were established in the plain reserves, as the hill forests were in a state of unrest.

After 1980, the then Socialist government approved its policy on the forestry sector. The aim of this policy was to ensure the supply of forest products for domestic use and export and to introduce advanced planting and extraction techniques.

The government paid increased attention to plantations, and in 1983 a plantation scheme was adopted. Moderately large-scale plantings using the taungya method began in 1980 in the Tharrawaddy forest division. From 1980 to 1994, a large plantation area of 33,488 acres was established, of which 91.5% comprised commercial species - mainly teak and Pyinkado.

The agricultural trade policy prior to 1988 made growing rice unprofitable for farmers, so some began working in plantation areas where agricultural produce from taungya was not required to be sold to the government's crop purchasing centres. As a result, farmers and agricultural labourers (mostly Bamar) worked with Karen hill tribe labourers in the Tharrawaddy district, and plantation establishment here up to 1988 was very successful. The life of a Taungya cutter was better than that of a rice farmer in the lowlands and based on the writer's experience in Mokka and Kadinbilin reserved forests from 1984 to 1987, the Bamar population increased mark

edly to about three times that of the Karen taungya cutters.

However, Myanmar 's socioeconomic and political situation changed dramatically in 1988. The new government made considerable economic changes, especially in the agricultural sector. Its new economic policy provided strong price incentives to increase agricultural productivity. Farmers are now allowed to grow any crops they wish and sell them wherever possible (MAUNG 1992).

Rice growing has become profitable for farmers, and the wage of a worker in wetland rice farming has increased to more than that of taungya plantation worker. Farmers and agricultural workers have returned to their former work, but the hill tribe Karen continue to work in taungya. Other factors which contributed to this decline in taungya workers were: the increasing price of forest products (some taungya farmers entered the timber, bamboo, and charcoal industry as the pay is better than that from taungya farming, which cannot cover daily living costs); the poor social welfare and inadequate infrastructure provided to taungya cutters, even though the new plantation areas are further from their villages; the pegged payment for forestry work; and increased commodity prices.

The 1994-95 consumer price index was about 6 times that of 1985-86 (CENTRAL STATISTICAL ORGANIZATION 1995). However, the average per acre budgetary allocation for plantation establishment rose only 2.4 times over the same period. The annual plantation target has not been reduced in line with the changing costs and reduced workforce. The Forest Department has had to continue its heavy workload with less resources (WIN 1995).

A final fall in Tharrawaddy's taungya plantation establishment rate occurred in 1994-95. No concrete explanation for this abrupt fall has been identified. However, there was a slight fall in new plantation establishment over the country as a whole, while greater priority was given to plantation establishment for local people during 1994. Of these, the latter might be the main reason for the fall, as commercial plantation establishment dominated in the Tharrawaddy forest division for many years.

CONCLUSION

The available evidence shows that the taungya system of teak production was originated by Dr. DIETRICH BRANDIS in the Kaboung forest area of Taungoo, not in Tharrawaddy as stated by many researchers. Tharrawaddy was the area where the large-scale development of taungya plantations began. The taungya system that the botanist-turned-forester refrained from forcing on the inhabitants in the initial stages of colonial rule, was later imposed by the army officer-turned-forester as colonial rule became entrenched.

Three periods of growth and decline occurred in the Tharrawaddy's history of teak plantation establishment. The growth phase of the first period began in 1869 when Imperial foresters succeeded in coercing the hill Karen to plant teak in their taungyas, while its decline occurred in 1906 when the scattered taungya plantations became difficult to manage and natural regeneration was attempted by the improvement felling. The growth phase of second period began in 1919 when concentrated regeneration using the Uniform System was introduced. The decline of this growth phase began in 1930 with the farmers' revolt in Tharrawaddy and continued up to 1945 because of the both government financial stringencies and heavy beehole-borer attacks on planted teak. No large-scale plantations were established between 1948 and 1979 and the growth phase of this third period began in early 1980 when the government increased reforestation work to boost timber production. Plantation areas established during this last phase comprise more than half of all plantings since the taungya system was introduced. The final phase of decline was caused by a shift in government priorities during 1994.

The taungya system will certainly remain an important method of forest regeneration in Myanmar. However, if taungya plantations are to be successfully managed in the future, two great needs must be met: the provision of an adequate wage for forest workers; and the introduction of high yield production techniques for taungya agricultural crops. The former will enable the recruitment of necessary labour, and the latter will encourage them to work permanently in taungya areas. Currently there are no specially recruited forest workers, and such work relies mainly on using agricultural workers from nearby villages. Changes in the agricultural sector will thus impact on the forestry sector and its labour supply. If the Forest Department fails to provide a wage that is equal to or higher than that paid by the agricultural sector, attracting willing workers will be difficult.

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FOOTNOTES

1) In Myanmar, the older spelling of some towns, rivers, etc., have been changed. The following words in parentheses show the former spellings of modern place names used in this paper: Ayeyarwady (Irrawaddy), Bago (Pegu), Pyay (Prome), Taninthayi (Tenasserim), Taung gu (Taungoo), Thayarwady (Tharrawaddy). As the primary concern of this paper is the historical context of taungya plantation development, the older spellings are used for the sake of consistency.

2) This "division" means forest boundary division.

3) Here "Division" means a civil boundary division.

4) Selection system: Felling and regeneration are distributed uniformly over the whole area; the trees are thus uneven-aged. Uniform system: Opening up the canopy and regeneration is confined to certain portion of forest area while the timber crop is mostly even-aged and uniform.

5) A Bamar word meaning an abandoned farm area overgrown with trees and bushes where crops are grown again after a period of 8 to 10 years.

6) In Myanmar, February is the beginning of the hot period that includes the dry hot days of summer season, and finishes at the end of May when the monsoon rains set in.

7) Imperial foresters were mostly British and were high-ranking officials such as the Conservator of Forests, divisional forest officers, etc. On the other hand, Burmese foresters were lower ranking foresters who may have been responsible for a small forest area in a forest division.

(Received 29 September 1997)
(Accepted 4 February 1998)

Article

Estimation of Upper Bound Forest Protection Expenditures under Uncertainty

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ABSTRACT

The impact of different probabilities of avoidable stand loss on the optimal rotation age and the corresponding EPVs of aspen stands in Minnesota is examined in a geographic information system (GIS) framework. The monetary costs associated with reducing such probabilities over time are also estimated. Aspen stands were indentified as the species to be examined because it is the most dominant cover type in Minnesota and provides almost half of the statewide timber harvest. Integrating GIS technology with the aspen model highlighted spatial components of the overall analysis. The model output combined with the spatial data, provided information about potential future investments that can be used to protect aspen stands from such catastrophes as fire and disease. Given the current shortages as well as the age class imbalance in aspen supply and relative increase in aspen demand over time in Minnesota, the need to invest in protection of this cover type is further enhanced.

Keyword : aspen, expected present value, optimal rotation, risk reduction

INTRODUCTION

Typically, forest stands are susceptible to two kinds of losses which may be characterized as avoidable and unavoidable. Avoidable losses include forest fires resulting from human negligence or the destruction of a forest which could have been avoided by proper management or treatment. Unavoidable losses are generally attributed to natural events such as hurricanes, fires by lightening, or floods. Although it is impossible to eliminate such losses, forest managers can take steps to reduce the chances or risks of avoidable forest stand losses.

The lengthy production cycles associated with forestry projects make it necessary to evaluate and incorporate potential impacts of uncertainties in the forest planning and decision making process. The role of uncertainties in the forest planning process has long been a critical issue in public forest management, primarily because of the uncertainties surrounding avoidable losses and their impact on the optimal rotation age, expected present value (EPV) and economic feasibility of risk reduction.

The impact of different probabilities of avoidable stand loss on the optimal rotation age and the corresponding EPVs of aspen stands in Minnesota is examined. The monetary costs associated with reducing such probabilities over time are also estimated. Aspen stands were identified as the species to be examined because it is the most dominant covertype in Minnesota and provides almost half of the statewide timber harvest. Its economic significance to the forest industry along with its susceptibility to disease and stand break-up makes aspen a particularly suitable species to be evaluated in the context of uncertainty in management decisions.

A continuous time model is utilized to determine the EPVs of aspen stands incorporating age dependent stand-loss probabilities, and salvage values given infinite

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rotations. This model is linked to a geographic information stystem (GIS), ARCINFO, to examine the spatial dimensions of the problem. Until recently this was not possible because of limited techonology and a lack of digitized data. Advances in GIS technology and greater availability and accessibility to spatial data, has made it possible to integrate spatial components in previously theoretical models. The idea is to provide decision makers with concise visual and site specific information. New information over time and space is generated on the impact of stand-loss probabilities associated with the expected income stream generated by forest stands as well as the monetary expenditures required to reduce stand loss.

The theoretical aspects of this research are an extension of work conducted by REED (1984) and HAIGHT *et al.* (1995). Reed's pioneering work showed that the EPV of stands can be estimated by a slightly modified version of the Faustmann equation, provided that stand destructions occur independently over time. HAIGHT *et al.* (1995) estimated the EPV for loblolly pine plantaions for a single rotation assuming age dependent hurricane risk and salvage values.

This study area is located in Itasca County in northern Minnesota. The county consists of heavily forested areas, largely comprised of aspen stands. The attributes of aspen stands in Itasca are very similar to the overall state averages.

MODEL

Suppose $S(t)$ is the stumpage value of a stand which is dependent on the prices and the volume at time t. Let stand volume be a function of basal area, diameter, height, volume, age, and site index which can be calculated using the following set of equations developed by WALTERS and EK (1993).

$$BA = 0.6036\ SI^{0.7735} A^{0.4459} \quad (1.1)$$

$$DIA = 1.3762 + 0.0532A + 0.0326SI \quad (1.2)$$

$$HT = 11.4804 SI^{0.5039}(1 - \exp(-0.0281\ A))^{m} \quad (1.3)$$

where: $m = 105.9678\ SI^{-1.059}$ (HAHN 1984)

$$VOL = 3.1206\ BA^{0.9241}\ HT^{0.5449} \quad (1.4)$$

$$PVOL = (VOL \exp(-0.0005\ T^{3.5} - 0.2662\ (T/(1+DIA)))) / 79 \quad (1.5)$$

$$SVOL = PVOL\ (0.1202 + 0.0054\ A) / 98.484 \quad (1.6)$$

where:

SI = site index (ft)
A = stand age (yrs)
BA = basal area (ft²/ac)
DIA = mean diameter of a stand (in)
HT = average height of trees (ft)
VOL = gross volume (ft³/ac)
$PVOL$ = pulpwood gross merchantable volume (cords/ac)
$SVOL$ = sawtimber gross merchantable volume (mbf/ac)
T = top diameter outside bark (in)

After the estimation of the pulpwood and sawtimber proportions of the stand volume, the stumpage value can be calculated by using the appropriate prices in the following fashion:

$$S(t) = PP\ PVOL(t) + PS\ SVOL(t) \quad (1.7)$$

where:

$S(t)$ = stumpage value at time t
PP = average pulpwood price ($/cord)
PS = average sawtimber price ($/MBF)

If we assume that a stand will be harvested at age T, then the total net present value of all future harvests of a given species is:

$$V = \frac{(S(T) + k - w)}{(e^{rT} - 1)} \quad (2)$$

where r is the instantaneous discount rate, k is the monetary value of other benefits associated with a given site, and w is the replanting costs for the next rotation starting immediately after harvest. Equation (2) is simply the discounted value of an infinite series of harvests at T year intervals. The optimal rotation period T is calculated by setting $dV/dT = 0$; i. e., when the impact of a marginal increase in the rotation period T on the net revenue is equal to zero (Equation 3).

$$\frac{S'(T)}{S(T) + k - w} = \frac{r}{(1 - e^{-rT})} \quad (3)$$

In order to incorporate uncertainty, following REED (1984) suppose that a random variable z whose distribution is given by $F_z(t) = Pr(z \leq t)$ indicates the time intervals between successive stand harvest or total or partial destruction. Further assume that each stand loss occurs independently of each other but is a function of the stand age. Note that if the probability of destruction during an infinitesimal time interval of length λ after year t is $g(t)\ \lambda$, then stand loss occurrence follows a nonhomogeneous Poisson process (ROSS 1970, HAIGHT *et al.* 1995). Assuming that $l(t) = \int_0^t g(u)du$ is the average rate of stand destruction per unit time interval, then the cumulative distribution of $F_z(t)$ is as follows:

$$Pr(z \leq t) = F_z(t) = 1 - e^{-l(t)} \quad \text{for } t < T$$
$$Pr(z \leq t) = F_z(t) = 1 \quad \text{for } t \geq T \quad (4)$$

The second equation reflects the fact that if the stand is not destroyed prior to the optimal rotation period T, it will be harvested at that point. Therefore, the net revenue at each z can be defined as follows:

$$R_n = G(z)S(z) + k - d \quad \text{if } z_n < T$$
$$= S(T) + k - w \quad \text{if } z_n = T$$

where d is the cost of clearing and replanting the site after a destruction, k is the monetary value of non timber benefits associated with a site, and $G(z)\ S(z)$ is the salvage value in case that a destruction occurs before harvest time. The expected present value of all future harvests can be

determined by using equation (5).

$$V=E[\sum_{n=1}^{\infty} e^{-r(z_1+z_2+\cdots\cdots+z_n)}R_n] \tag{5}$$

Utilizing the independence property of z_n, equation (5) is rewritten as follows:

$$V=\sum_{n=1}^{\infty} E[e^{-r(z_1+z_2+\cdots\cdots+z_{n-1})}]E[e^{-rz_n}R_n]$$

$$V=E[e^{-rz_n}R_n]\sum_{n=1}^{\infty}\prod_{i=1}^{n-1}[E(e^{-rz_i})]$$

$$V=\frac{E[e^{-rz}R]}{[1-E(e^{-rz})]} \tag{6}$$

Furthermore, from equation (6):

$$\begin{aligned}E(e^{-rz})&=\int_0^{\infty} e^{-rt}dF_z(t)\\&=\int_0^{T} e^{-l(t)-rt}g(t)dt+e^{-l(T)-rT}\\&=1-r\int_0^{T} e^{-l(t)-rt}dt\end{aligned} \tag{7}$$

Similarly,

$$\begin{aligned}E(e^{-rz}R)&=\int_0^{T}[G(z)S(z)+k-d]\\&\qquad g(t)e^{-l(t)-rt}dt+(S(T)+k-w)e^{-l(T)-rT}\\E(e^{-rz}R)&=(S(T)+k-w)e^{-l(T)-rT}+\phi(T)\\&\quad+[k-d][1-e^{-l(T)-rT}]-r[k-d]\int_0^{T} e^{-l(t)-rt}dt\end{aligned} \tag{8}$$

where:

$$\phi(T)=\int_0^{T} G(t)S(t)g(t)e^{-l(t)-rt}dt$$

Combining equations (6), (7), and (8), we obtain:

$$V=\frac{(S(T)+k-w)e^{-l(T)-rT}+\phi(T)+[k-d][1-e^{-l(T)-rT}]}{r\int_0^{T} e^{-l(t)-rt}dt}-[k-d] \tag{9}$$

Note that if we assume damage to be independent of the stand age and no salvage value so that $G(t)=0$, $g(t)=\lambda$ such that $l(t)=\int_0^t \lambda du$ then equation (9) reduces to equation (10) which is the same as equation (14) in Reed(1984).

$$V=\frac{(\lambda+r)(S(T)-w)e^{-T(\lambda+r)}}{r(1-e^{-T(\lambda+r)})}-d\frac{\lambda}{r} \tag{10}$$

We are now in a position to calculate the investment justifiable to reduce the probability of stand destruction. Suppose that continuous costs are incurred at the rate of P dollars per unit time in order to reduce the average probability of destruction from $l_2(t)$ to $l_1(t)$ where $l_2(t)>l_1(t)$. Then the total discounted costs can be calculated as follows:

$$\int_0^{\infty} Pe^{-r}dt=\frac{P}{r} \tag{11}$$

On the other hand, the change in EPV, given the same discount rate but the different probabilities of destruction, becomes:

$$V_{\max}(l_1(t);r)-V_{\max}(l_2(t);r) \tag{12}$$

Equating (11) and (12), i. e., cost of "risk reduction" and EPV of benefits, we get:

$$\frac{P}{r}=\max(V_{\max}(l_1(t);r),0)-V_{\max}(l_2(t);r) \tag{13}$$

The maximum condition in equation (13) ensures that the EPV associated with the lower level of risk is non-negative. Without this condition, it is possible that the cost of risk reduction might be over estimated.

From equation (9) using T_1 and T_2 to represent optimal rotation periods given $l_1(t)$ and $l_2(t)$ respectively, we obtain:

Table 1 Itasca Country DNR CSA stands by covertype

ACES Covertype	No. of Stands	Acres	Percent
Red Pine	1,304	23,230	7.26
Jack Pine	844	12,029	3.76
Balsam Fir	1,287	16,644	5.20
Aspen	7,805	179,051	55.98
N WH Cedar	1,482	24,092	7.53
Tamarack	1,619	50,846	15.90
Paper Birch	1,033	12,975	4.06
Oak-Hickory	384	7,780	2.43
Black Spruce	3,070	58,050	18.15
Balm of Gilead	309	4,014	1.25
White Pine	37	398	0.12
White Spruce	180	2,733	0.85
Total Forest	19,355	319,842	100

$$P=\frac{(S(T_1)+k-w)e^{-l_1(T_1)-rT_1}+\phi(T_1)+[k-d][1-e^{-l_1(T_1)-rT_1}]}{\int_0^{T_1}e^{-l_1(t)-rt}dt}$$
$$-\frac{(S(T_2)+k-w)e^{-l_2(T_2)-rT_2}+\phi(T_2)+[k-d][1-e^{-l_2(T_2)-rT_2}]}{\int_0^{T_2}e^{-l_2(t)-rt}dt} \quad (14)$$

If all variables in equation (14) are known, then it can be used to estimate the maximum investment necessary for a given level of risk reduction. In other words, we can find the upper bound on cost of decreasing the probability of a destructive event to a desired level. It would be economically infeasible to exceed this upper bound. Using the same assumptions as in equation (10), REED's version of equation (14) is as follows:

$$P=(\lambda_2-\lambda_1)d+\frac{(\lambda_1+r)(S(T_1)-w)e^{-T_1(\lambda_1+r)}}{1-e^{-T_1(\lambda_1+r)}}$$
$$-\frac{(\lambda_2+r)(S(T_2)-w)e^{-T_2(\lambda_2+r)}}{1-e^{-T_2(\lambda_2+r)}} \quad (15)$$

STUDY DATA

The data for the study were retrieved from the Continuous Stand Assessment (CSA) digitized data set of the Minnesota Department of Natural Resources (MDNR). This data base of state-owned forest lands in Itasca County contained 32,596 stand records of which 19,355 were commercial stands. The distribution of the commercial stands by covertype is presented in Table 1. Aspen is the most dominant covertype covering over 55 percent of the total forest land. This is also true for the entire state of Minnesota where aspen covers about half of the total forest lands.

The pulp and sawlog yields for each stand were updated to 1997 using the biometric portion of the above model. A custom program was utilized to fill in missing values in the CSA data set and to project each stand from its year of measurement to 1997 (ROSE 1996). Fig. 1 shows the updated initial ages for all aspen stands in the analysis area. Approximately 63,000 acres of aspen stands are below age 20 and almost 88,000 acres are over 80 years old. The age class imbalance of aspen stands is evident. The data validates the concerns of the forest industry that the current stands are either too young or too old for industrial use. Another interesting issue that becomes readily apparent from examining this figure is that the younger stands are spread out over the entire study area, while the older stands are relatively clustered.

The site indexes of the aspen stands were classified in five unit intervals to avoid clustering within the figures. For example, a site index of 50 represents all stands which are within the site classes 47.5 and 52.5. The majority of the aspen stands (110,886 acres) have a site index of 75. There is also a significant acreage of aspen in the site classes 70 (27,770 acres), 80 (17,246 acres), and 65 (13,951

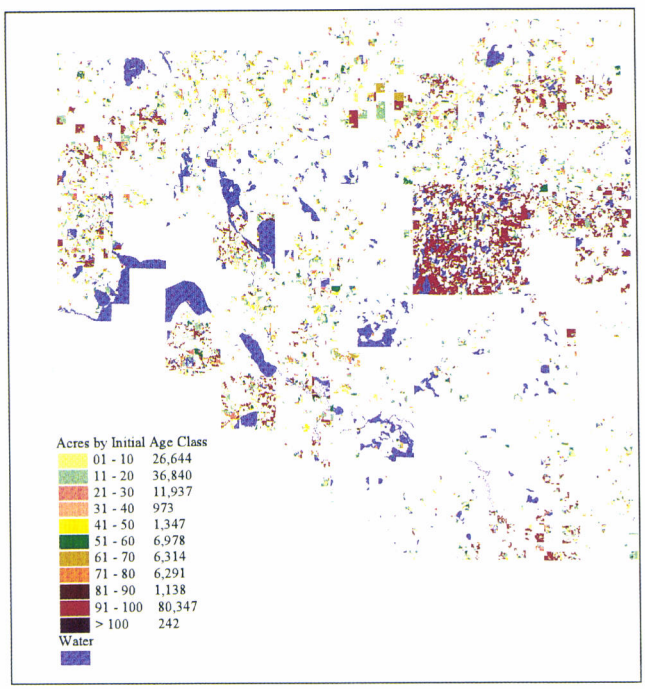

Fig. 1 State-owned aspen acreage by initial age class in Itasca County

acres) respectively.

The stumpage value for each stand was derived using equation (1.7). The data on sawtimber prices (SP = $71.22/MBF) and pulpwood prices (PP=$16.09/cord) was obtained from MINNESOTA DEPARTMENT OF NATURAL RESOURCES (MDNR) PRICE REPORT (1997). An annual discount rate of 4 percent was used in all calculations. It was converted into a continuous discount rate by the equation $r=\ln(1+i)$. Unfortunately, there are no available data on actual probabilities of forest destruction. For present purposes, the assumption was made that these probabilities range from 0 to 5 percent in 1 percent increments. Due to the ability of aspen to naturally regenerate, the replanting costs after harvest were assumed to be zero. It was further assumed that clearing costs after a destruction would be $50/acre.

All protection cost estimates are purely based on the current stumpage values and do not account for any other benefits such as wildlife or recreational potential. Due to lack of data, the upper bound protection costs derived in this paper are purely based on the timber production potential of aspen. However, the model has the ability to easily incorporate additional attributes without any loss of generality. In the following section the results corresponding to a 4 percent discount rate and a 4 percent stand -loss probability with no salvage value and age independent damage probability are presented.

RESULTS

The estimated optimal rotation ages and the corresponding EPVs for all site classes in the Itasca County are presented in Fig. 2 and Fig. 3 respectively. These figures were generated under the assumption of a 4 percent annual discount rate with zero (state 1) and four (state 2) percent probabilities of stand loss. The difference between the EPVs corresponding with state 1 and state 2 when annualized over an infinite horizon provides an estimate of expected amount of annual expenditures over time necessary to reduce stand loss probabilities.

Fig. 2 shows the optimal rotation ages and EPV by site class for state 1. The optimal rotation ages range between 32 and 37 years. The higher rotation ages are associated with relatively lower site classes and somewhat shorter rotation ages are attributed to higher site classes. This can be explained by the fact that higher site classes correspond to high productivity areas which provide superior yields in relatively short time periods. This is also evident by observing the EPVs in the site classes. Note that in the higher site classes the EPVs are relatively high even though the rotation periods are small when compared to the lower site classes. The EPVs range between $31 and $70 respectively. The EPVs jump in about $5 increments as the site class values are increased.

In state 2 when the stand loss probability is 4 percent, the optimal rotation ages and the EPVs drastically reduce

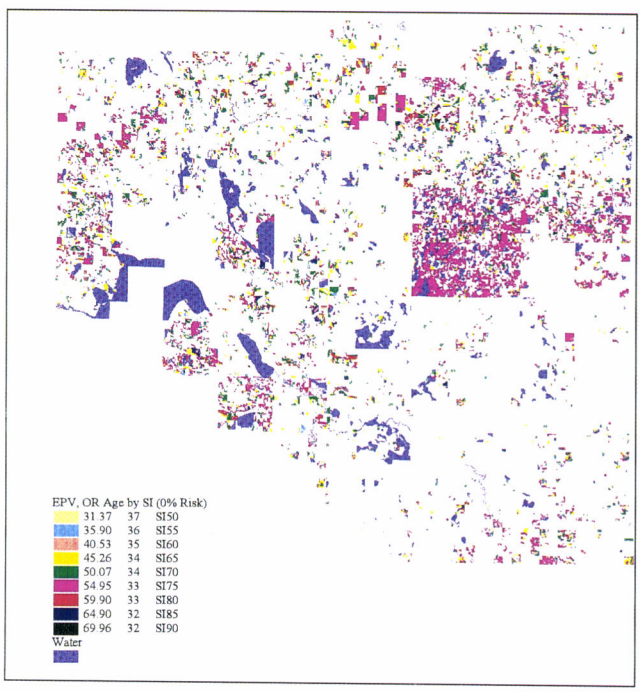

Fig. 2 Expected present value and optimal rotation age by site index with no risk

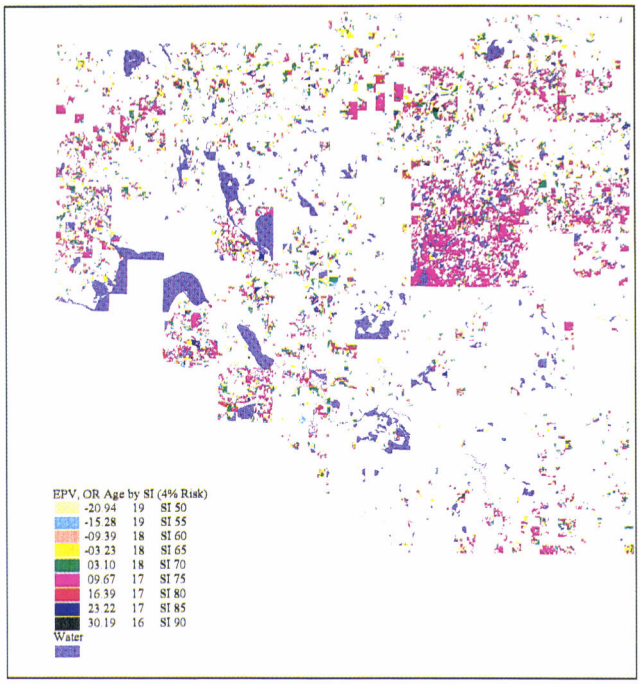

Fig. 3 Expected present value and optimal rotation age by site index with 4 percent risk

as illustrated in Fig 3. The rotation ages range between 16 and 19 years which is about 16 to 18 years shorter than its counterpart in state 1. The EPVs significantly decreased and remained negative for the first four lower site classes. The difference between the state 1 and state 2 EPVs is high but as the site classes increase, the difference begins to decline. However, as expected the pattern exhibited by the rotation periods and the associated EPVs in both states remains the same, i. e., shorter rotations and higher EPVs correspond with higher site class and vice versa.

It is apparent from the preceding discussion that accounting for the probability of destruction can significantly affect estimates of economic value. Therefore, it is important to estimate the upper bounds on the protection costs which would be required in order to reduce such probabilities. In general, estimates of protection costs will be downward biased when compared to estimates which incorporate other potential benefits and costs. However, lack of data limits our ability to incorporate these variables at this point in time.

The estimated maximum per acre protection costs for each site class are presented in Fig. 4. The annual investment in protection activities range between $1.56 and $2.05 per acre per year. Higher protection expenditures are associated with lower site classes and as the site classes increase the protection expenditures decrease. This is primarily because the difference between the EPVs for state 1 and state 2 begin to decline as the site classes increase. The step increment in the protection expenditures by site class is approximately $0.06 per acre per year.

CONCLUSIONS

Integrating GIS technology with the aspen model highlighted spatial components of the overall analysis. For instance, the model results indicate that the stands are considerably older than the optimal rotation ages, either with or without risk. Therefore, a harvesting decision based on the optimal rotation ages, though economically desirable, is not necessarily justified, particularly when the spatial distribution of these stands is considered. When these older stands were examined in a GIS framework, it was evident that these stands are clustered in relatively small areas rather than evenly distributed across the study area. If these stands were harvested, spatial ramifications would have to be considered that may include nontimber resources such as wildlife (game and nongame) and recreation uses.

The protection expenditures derived in this research are based on aspen stumpage values and do not recognize any other market or non-market values associated with these stands. If such values, however were included then the upper bound protection expenditures might be higher. Nevertheless, these economic results combined with the spatial data, can provide policy makers with information about management actions that will be necessary to protect aspen stands from such catastrophes as fire and disease. Given the current shortages, as well as the age class imbalance in aspen supply and relative increase in aspen demand over time in Minnesota, the need to invest in pro

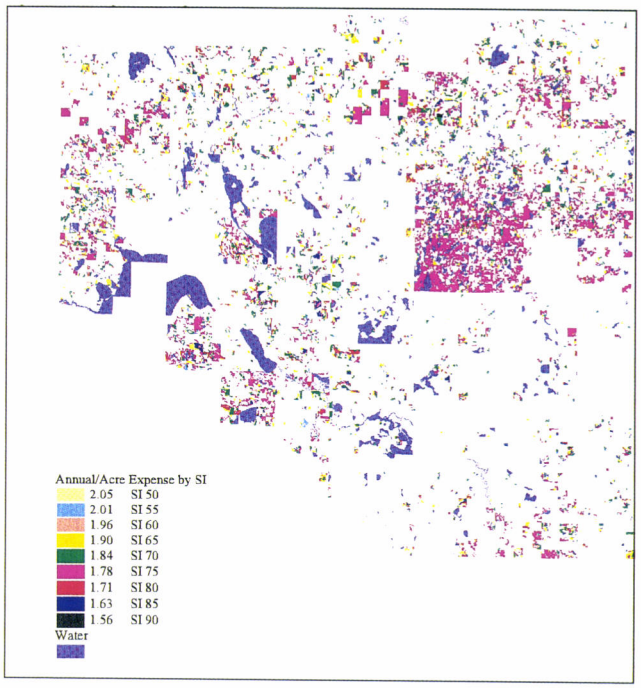

Fig. 4 Annual per acre expenditures for risk reduction from 4 to 0 percent

tection of this covertype is further enhanced.

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(Received 12 November 1997)
(Accepted 9 March 1998)

Short communication

A New Method for Analyzing Forest Stratification Based on Discriminant Criteria

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ABSTRACT

We applied the discriminant analysis method (DAM), which was originally proposed for image analysis, to stratifying a forest stand into some strata and discussed its validity. The results showed that DAM has the following merits ; 1) The forest stand can be stratified statistically. ; 2) The number of strata can be arbitrarily selected. ; 3) The optimum number of strata to be stratified can be estimated. These features make DAM one of the most effective methods for analyzing forest stratification.

Keyword : forest stratification, discriminant analysis method (DAM)

INTRODUCTION

Stratifying a forest stand into some strata based on its vertical structure is one of the fundamental concepts in forest ecological studies, and various methods of stratifying have been proposed. OGAWA *et al.* (1965) developed the crown depth diagram, which is based on the relationship between tree height and clear bole length. HOZUMI (1975) proposed a numerical method using *M-w* diagrams, which is based on an individual tree's weight distribution. YAMAKURA (1987) proposed a method using symmetric type difference diagrams, which is based on an individual tree's height distribution. All of these methods are graphical ones in which the points plotted on a diagram can be visually discerned by a few segmental lines or groups, each of which corresponds to a stratum of the forest stand.

INOUE *et al.* (1997) newly applied discriminant analysis method (DAM), which was proposed for image analysis by OTSU (1979; 1980), to stratifying a forest stand. Using DAM, threshold between upper- and lower-stratum tree height classes can be determined not visually but statistically, and the degree of separation between two strata can be quantified (INOUE *et al.* 1997). The purpose of this paper is to show that DAM can be applied to stratifying a stand into more than two strata statistically and to estimating the optimum number of strata to be stratified.

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A NEW METHOD FOR ANALYZING FOREST STRATIFICATION BASED ON DISCRIMINANT CRITERIA

Stratifying a forest stand into some strata requires determination of the "threshold(s)" on the tree height histogram (INOUE *et al.* 1997). If a stand is stratified into M strata, for example, $M-1$ thresholds are required. In this study, the thresholds are determined by discriminant analysis method (DAM) (OTSU 1979; 1980).

The tree height histogram is denoted by $n_1, n_2, \cdots, n_L$, where n_i is the number of trees in the stand with tree height class i, and L is the maximum tree height class. The total number of trees is expressed as N, where $N=\Sigma n_i$. The average tree height class μ_T and the variance of tree height class in the stand σ_T^2 are calculated by the following functions, respectively:

$$\mu_T = \sum_{i=1}^{L} in_i/N$$

$$\sigma_T^2 = \sum_{i=1}^{L} (i-\mu_T)^2 n_i/N$$

Here, let k_j denote the thresholds, where $j=1, 2, \cdots, (M-1)$. Using the zeroth- and the first-order cumulative moment, $\omega(k_j)$ and $\mu(k_j)$:

$$\omega(k_j) = \sum_{i=1}^{kj} n_i/N \quad (\omega(0)=0,\ \omega(L)=1)$$

$$\mu(k_j) = \sum_{i=1}^{kj} i n_i/N \quad (\mu(0)=0,\ \mu(L)=\mu_T)$$

we obtain the following values:

$$\omega_j = \omega(k_j) - \omega(k_{j-1})$$
$$\mu_j = [\mu(k_j) - \mu(k_{j-1})]/\omega_j$$

where $k_0=0$ and $k_M=L$.

From these values, we obtain the variance between strata σ_B^2:

$$\sigma_B^2 = \sum_{j=1}^{M} \omega_j(\mu_j-\mu_T)^2$$
$$= \sum_{j=1}^{M} \omega_j\mu_j^2 - \mu_T^2$$

The thresholds for stratifying are determined when σ_B^2 is maximized (OTSU 1979; 1980).

Let η denote the ratio of σ_B^2 to σ_T^2, η is a measure of the degree of separation between each strata, within the following range (OTSU 1979; OTSU 1980; INOUE *et al.* 1997):

$$0 \leq \eta \leq 1$$

We can also estimate the optimum number of strata to be stratified using DAM. Let η_M denote the variance ratio when the stand is stratified into M strata. Since η_M is the ratio of σ_B^2 to σ_T^2, η_M has a natural bias (OTSU 1980) such that η_M is increased if M increases. This natural bias must be removed to obtain a significant measure for comparison. The Q_M value, proposed by OTSU (1980) to remove the bias, is expressed by the following function:

$$Q_M = \log[\eta_M/(1-\eta_M)] - \log(M^2-1)$$

The optimum number of strata to be stratified is determined when the Q_M value is maximized.

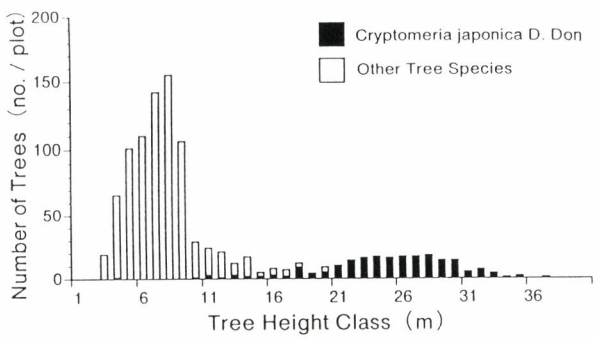

Fig. 1 Tree height histogram in a Sugi natural forest stand on Yakushima, Japan

RESULTS

In the first case, DAM was applied to a Sugi (*Cryptomeria japonica* D. DON) natural forest on Yakushima, an island off the south coast of Kyushu, Japan's southern most main island (YOSHIDA and IMANAGA 1990). The tree height histogram for this stand is shown in Fig.1. The black and white bars represent Sugi and other tree species, respectively. The plot in this stand was 100m long and 100m wide. The height of 1,020 trees in this plot with 4.0cm and more in DBH were measured. According to YOSHIDA and IMANAGA (1990), Sugi occupied the upper stratum of this stand and there was no regeneration and ingrowth of Sugi in the stand.

The thresholds (k_j), variance ratio (η_M) and Q_M values for the forest stand as determined by DAM, are shown in Table 1. Firstly, we shall consider the threshold values. If the stand is stratified into two strata ($M=2$), the threshold (k_1) is 16m. In this case, the first (taller) stratum consists of those individuals in the 17m or taller height classes, and the second (lower) stratum is the 16m or lower in height classes. If M is three, the thresholds k_1 and k_2 are at the 12m and 22m height classes. If M is four, k_1, k_2 and k_3 are at the 8m, 16m and 25m in height classes. This shows that we can arbitrarily select the number of strata to be stratified using DAM.

Secondly, we would like to consider Q_M. The maximum Q_M is $Q_2=0.283$. Therefore, the optimum number of strata to be stratified for this stand is two, with the threshold at the 16m height class.

In the second case, DAM was applied to a dry-evergreen forest stand, in Sakaerat in the northeastern region in Thailand. Tree heights for this stand were read from the forest profile diagram drawn by YAMAKURA (1987). The tree height histogram in this stand, as read

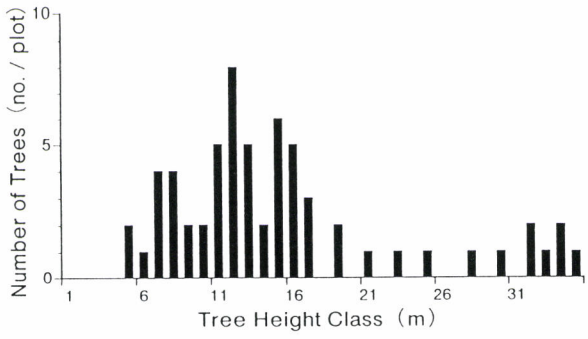

Fig. 2 Tree height histogram in a dry evergreen forest in Sakaerat, Thailand

Note: Tree height records were read from the profile diagram drawn by YAMAKURA (1987).

from the profile diagram, is shown in Fig.2. According to YAMAKURA (1987), the size of the plot was 50m long and 10 m wide, and 75 living trees and one dead *Hopea ferrea* tree were drawn in the profile diagram. However, only 63 trees were found on the profile diagram. This difference 12 individuals resulted from either some individuals being hidden in the diagram-drawing or errors in tree-height-reading from the diagram. Because of the lack of original records, however, we could not check this difference.

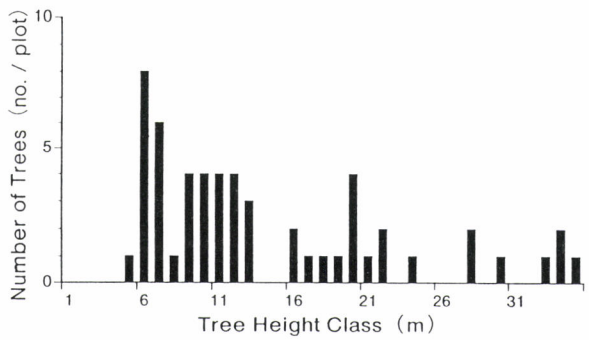

Fig. 3 Tree height histogram in a primary mixed forest, Moraballi creek, British Guiana
Note: Tree height records were read from the profile diagram drawn by DAVIS and RICHARDS (1933).

The values of k_j, η_M and Q_M for the dry-evergreen forest stand are shown in Table 2. The maximum Q_M is $Q_2=0.000$. This result indicates that the optimum number of strata in this stand is two, with a threshold at the 19m height class.

In the third case, DAM was applied to a primary mixed forest stand at Moraballi Creek, British Guiana. Tree height records in this stand were also read from a forest profile diagram drawn by DAVIS and RICHARDS (1933). The tree height histogram in this stand, as read from the profile diagram, is shown in Fig.3. According to DAVIS and RICHARDS (1933), there were 66 living trees in the profile diagram. However, only 55 trees were found on the profile diagram.

The values of k_j0, η_M and Q_M for the primary mixed forest stand are shown in Table 3. The maximum Q_M is $Q_4=0.151$, indicating that the optimum number of strata in this primary mixed stand is four, and the thresholds are at the 10m, 16m and 26m in height classes.

DISCUSSION

OTSU (1979; 1980) developed DAM for image analysis, and used the technique to analyze the thickness histogram

Table 1 Result for a Sugi natural forest stand obtained by DAM

number of strata (M)	thresholds (k_j)	variance ratio (η_M)	Q-value (Q_M)
2	16	0.852	0.283
3	12, 22	0.911	0.107
4	8, 16, 25	0.944	0.051

Table 2 Result for a dry-evergreen forest stand obtained by DAM

number of strata (M)	thresholds (k_j)	variance ratio (η_M)	Q-value (Q_M)
2	19	0.750	0.000
3	15, 25	0.868	−0.085
4	10, 15, 25	0.937	−0.004

Table 3 Result for a primary mixed forest stand obtained by DAM

number of strata (M)	thresholds (k_j)	variance ratio (η_M)	Q-value (Q_M)
2	17	0.752	0.005
3	14, 26	0.913	0.118
4	10, 16, 26	0.955	0.151

of the image. In this study, we used DAM to stratify a forest stand into strata, based on a simply changing the subject of analysis from the thickness histogram to the tree height histogram.

The results of this study showed that the merits of DAM are ; 1) The forest stand can be stratified statistically. ; 2) The number of strata can be arbitrarily selected. ; and 3) The optimum number of strata to be stratified can be estimated. Furthermore, the degree of separation between each strata can be quantified using DAM (Otsu 1979; Otsu 1980; Inoue *et al.* 1997). These features make DAM one of the most effective methods for analyzing forest stratification.

ACKNOWLEDGMENT

We would like to thank the members of the Department of Forestry, Faculty of Agriculture, Kyushu University for their valuable advice and discussion.

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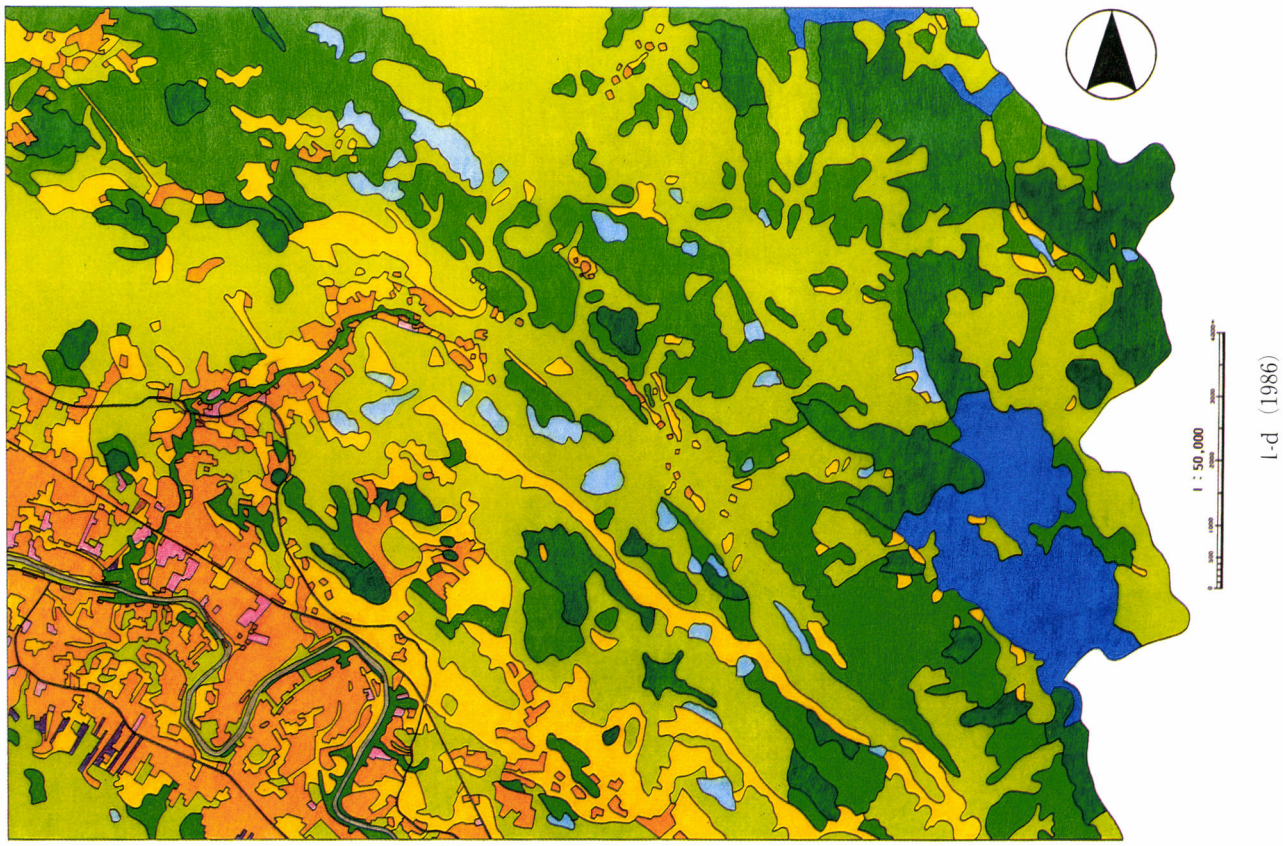
(Received 2 Decenver 1997)
(Accepted 14 January 1998)

Correction

Vol.3 No.2, 1997

Historical Changes of Forest Area in Thailand-A Case Study of Mae Klong Watershed Research Station-Lintin, Kanchanaburi - Suchat KALYAWONGSA, Masahiro AMANO, Komon PRATONG, Teunchai LAKHAVIWATTANAKUL, Adisorn NOOCHDUMRON, Hirofumi KUBOYAMA and Hiroyasu OKA

Page 69 Fig.1-d(1986) should be replaced by following figure.



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