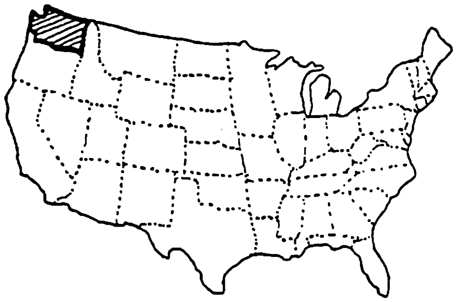
アメリカ・ニュージーランドだより

木 平 勇 吉*

上高地のウエストン祭も終り本格的な野外の季節を迎えられ，お変りなくお過ごしのことと存じます。大変ご無沙汰を致しておりますが私は目下ニュージーランドにて家族ともども元気に研究生活を送っています。晩秋のもやにつつまれたラジアータと温泉の町ロトルアから昨年を含めて近況をご報告致します。私達家族は昨年ワシントン大学で１年間を過ごし，正月に１度帰国後，折返し，今年はニュージーランド政府の招聘科学者として国立林業試験場に勤務しており，来年１月に信州大学に戻る予定にしております。



ワシントン州の位置

Ⅰ．アメリカの大学

アメリカでは，シアトルにあるワシントン大学で一般教授と同様に大学教育，教官の研究の進め方，大学の運営を広く経験し，そしてアメリカ林業を実地に知る機会に恵まれたと云えます。太平洋を越えたアメリカ西海岸は世界的な森林地帯で日本へ多くの木材が輸出されているのは衆知のとおりです。したがって，そこは林学研究のメッカの１つでもあり，北から南へ林学で有名な大学がカナダのブリティッシュ・コロンビア大学（バンクーバー），ワシントン大学（シアトル），オレゴン州立大学（クオバリス），フンボルト大学（北カルフォルニア），カルフォルニア大学（サンフランシスコ）と並んでいます。ワシントン大学は学生数45,000人で私の居た森林資源学部は林学，林業工学，林産，環境保全，野生動物の分野を持ち，教官数50名程度の信州大学農学部よりやや小さい組織です。

信州大学林学科と比較しての特徴としてカリキュラム選択の巾が広いこと，就職への結びつきが強いこと，そして大学院教育に重点があることが挙げられます。４学期生で学期毎に履修科目数に合わせて授業料を納めます。１学期は約２ヶ月半ですから集中度が高いといえます。教育施設は林学専門に限れば，教室，分析測定機，演習林などはさほど相異はありませんが，総合大学として図書館，スポーツ施設，寮，食堂，レクリエーション施設・病院など厚生施設，視聴覚教育施設，公開講座，イ

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ンフォーメーション，奨学金制度では圧倒的にワシントン大学の方が整備されているのが現状です。大学キャンパスの美しさ・大学らしさは大学にとって重要であるかどうかは議論もありますが，私が１年間を過した場所として何よりも誇りにする程美しい所です。

ところで，アメリカの学生あるいは外国の学生はよく勉強すると定評があり，実際にも評判以上にやります。その背景には２点あります。第１にはアメリカでは高校生頃から自立し始め大学の学資は自分で稼ぎます。若干の仕送りも受けていますが，必要な金は授業時間外か，休みかに働いて得るかあるいは貯金が出来てから大学へ来ます。だから多額の金を払った授業に出ない訳がないのです。第２は良い成績は奨学金，学内での研究アルバイト，そして就職口へ直接結びつきます。大学生活は自立生活の始まりであり，さらに充実した自立生活へのステップです。学生の生活は一般に忙しく１週間の日程表はぎっしりと詰り時間単位で生活しています。

大学の授業もこれらの背景に対応しています。授業スケジュールが明確で講義の内容は論旨明快・教材・スライドなど含めて方法は工夫されています。研究志向より知識伝達・基礎実力養成型でこれは大学院でも同じです。テストや宿題が多くそれらの客観材料で採点され，学期末になって受講科目の平均成績点が低いと退学，あるいはその勧告となり，一定以上でないと大学院へは進めません。教官の方も下手をすると受講生が少なくなるので大変です。講義を持つ学期は時間の多くを授業準備に割り当て自分の研究活動は出来ないようです。

Ⅱ、アメリカの林業

アメリカにおける今日の林学・林業の課題を挙げるなら，まず国際貿易と木材輸出に関する経済問題，林業の地域的盛衰に伴う林業労働力の雇用減少と地域社会の崩壊という社会問題，水資源とレクリェーション需要に対応した森林の多目的利用という経営問題，狩猟・野生動物・野鳥・川や湖の魚資源など動物管理のための自然保護問題があります。もちろん，大学の研究は既存の測樹，航空写真，育種，造林，生態，保護，伐出工学，林産などにも重点を置いています。

私の興味をとりわけひいた問題はやや専門的になりますが，「森林計画への市民の意向反映」という問題です。国有林であれ私有林であれ森林は私的な財産としての利用だけでなく，国土そのものであり，湖沼や川がそうであるように地域社会の生活基盤となっています。森林をどのように利用するかの計画を所有者や官庁の専門家が決めたとしても地域の人々の支持と理解が得られない場合はその計画は無意味になります。だから計画立案の時にどのようにして地域の人々の意向を取り入れるかということが大切な仕事となっています。これは言い易くして実に難しい問題です。それぞれの人の考え方や必要性が違い利害は反するからです。私の興味は，地域の人々の合意を得ることが何より計画立案上重要であることを林業サイドが明確に自覚するようになってきた事実にあります。このことは日本においても国有林，県市町村有林など公共林の経営計画の在り方を考えるのは大変参考になります。

アメリカでは森林計画に合理性を求める手法として，例えば適切な伐採量を決めるのに数学理論を

基礎にした計算機システムが多く応用されています。これらは数量化しうる項目だけを扱い，多くの人の納得を得る強力な手段として最適化という概念を発展させています。更にこの論理だけでは扱いにくい人間の多様な価値観を森林計画の中に取り入れて，その社会的な認知が欠かせなくなったのも時代の流れとでも云うべきでしょうか。

営林局次長をやっているJ.スペース氏からの手紙を借用すると，彼らの仕事や関心の一端をうかがうことが出来ます。Draft PlanとかPreferred Olternative あるいは Final Plan といった長く，手間のかかる立案過程を通じてPublic interest とAppeals を受け入れる様子が文面からも推察されます。関連資料が私の手元に文字通り山積みされているので利用していただければ幸です。

さて，アメリカの研究生活で得た私にとっての収穫は，この国において森林を扱う科学への期待の大きさを知ったことです。伝統的な木材育成伐出技術の枠から抜け出して，現代生活に欠かせない自然の恵みを最大限に，しかもより広く国民に提供することが今日の林学の課題であり，我々にとってやるべきことが山積していることを改めて知り精神的に大きな刺激を受けました。したがって，林学は科学の分野として明かるいことを実感し，また，それは難しく，やりがいがある職業だと思っています。日本では林業の産業としての地位低下は事実です。アメリカでも同じです。しかし，日常生活をはじめ，人類の生存にこの森林あるいはもう少し広く解釈して自然を安定して維持してゆくには大変な経営努力と研究とが欠かせません。したがって森林を世話する林業の地位は社会的に高まっていると言っても過言ではありません。

Dear Dr. Konohira:

I was pleased to receive your letter of August 25 and to hear that you are enjoying your stay in New Zealand. My wife, Helen, and I have visited New Zealand twice and really love the country and its people. I didn't get to the Forest Research Institute the last time I was there, but when I was there in 1980 I spent several days there, particularly with Dr. Madgwick. Please give him my regards.

Things are busy as ever here at the Forest Service in the Pacific Northwest. The focus at the present time is on the completion of draft Forest Plans for all of our National Forests. We just recently completed the selection of preferred alternatives for all the Plans, and they should all be published in draft form soon after the first of the year. The draft Plans that are presently out for review are generating public interest and many comments from the public. Much of our time over the next year or so will be spent dealing with the public comments, the revisions of the draft Plans, and the publication of the final Plans. Beyond that, we expect numerous appeals of our plans but hopefully, if we have done our job well, there will not be very many lawsuits or if there are, that we can deal with them successfully.

Unfortunately, I was unable to attend the IUFRO Congress in Yugoslavia this fall. I have been spending a great deal of time this past 6 months on a training program which will probably eventually lead to a promotion and transfer to a new post.

Keep me informed of the results of your research and, if you have occasion to visit the United States again, please let me know. If you do, I will try to arrange for a longer visit than we were able to have last time.

Sincerely,

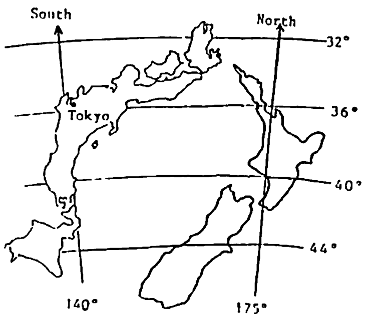
JAMES C. SPACE
Deputy Regional Forester

J．スペース氏の手紙

なおワシントン州の森林とその経営については「Orerview of Forests in Washington State,信大農学部紀要23巻 2，1986」を参考にして下さい。

Ⅲ、ニュージーランドの林業

話は北半球から南半球へ移ります。1986年１月よりニュージーランド政府の招きにより私は林業試験場に勤務しています。日本からは少し遠く感じる国ですが林学では非常によきライバルであり，その様子を述べてみます。この国は現在では世界第１の林業国といえます。国内の最重要産業として多くの人の生活がかかり，そして国内企業のトップ10社のうち殆どを木材会社が占めています。この国の森林の歴史をみると1,000 年前マオリ人が南太平洋からニュージーランドに移り住んだ時は全土が暖帯性の森林で覆われていました。やがて19世紀に始まるヨーロッパ人の移住は，この森林のほとんどを焼き尽くし，伐り尽して草地へ荒地へと変えたのです。天然林の中のカウリと言われる広葉樹の高級材は帆船時代のマストとして欠くことの出来ない材料であり世界中で重宝がられたようです。その結果，第１次大戦後には森林は国土面積の20%弱になり，それも利用価値のない荒廃した森となってしまいました。



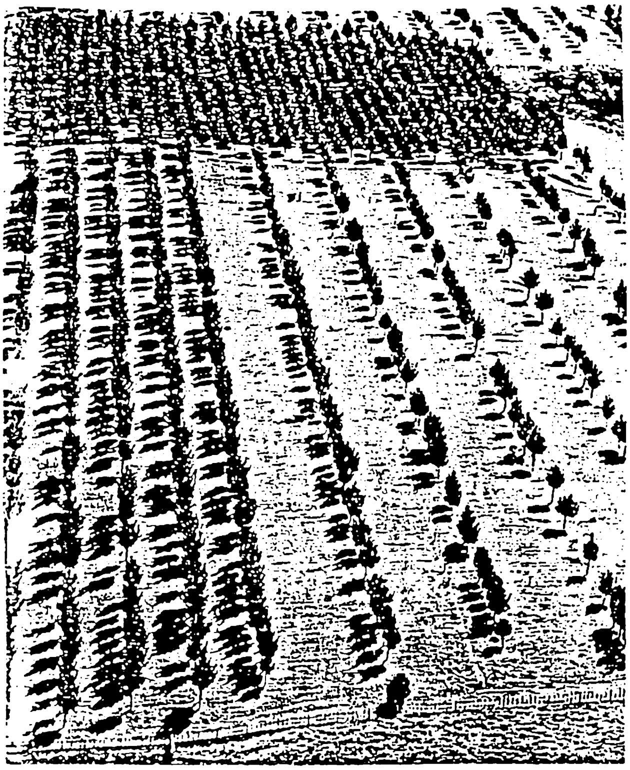
ニュージーランドの位置

将来の木材需要に備えて国を挙げての植林を1930年代から始めて現在まで続けています。現在の人工林面積は100 万haで（日本の人工林は1000万ha余）その大部分がラジアータ松で，その他ダグラスファー，ユーカリ，カラマツなど世界中の外来樹種の導入が試みられています。ラジアータは最も成功した樹種で生長は年平均20～30㎥/haでこれは10年で 200～300 ㎥/ha の蓄積になるわけです。これは信州カラマツの老令林の蓄積に相当します。この自然条件に恵まれた立地を生かして木材生産を産業として繁栄させるため国の組織・知識を集めてここ林業試験場を建設して林業研究を進めていまして研究者・職員あわせて約 500人の大企業です。ここへは毎週多くの外国研究者が来訪し，にぎやかです。

私はこの活発な林業環境を背景として実際林業への課題を国際共同で研究できることを誇りに思っています。私のやっていることは木材資源管理（伐採量の計画）で，それは長期計画（20～30年），中期計画（5 ～10年），短期計画（1 ～2 年）に大別されています。ニュージーランドには目下のところ，長期と短期計画の制度があります。この２つを調整する中期計画の設計を私は担当しています。その手法としてコンピュータによる地図手法の導入も設計しています。森林現場へも行きますが主として室内での設計と関係者との討議に時間は早く過ぎていきます。

ニュージーランドは最近10年間に次の分野で著しい研究成果をおさめています。（１）生長モデル（２）固定試験地設定（３）長期収穫規整モデル（４）育種事業（５）育林モデル（６）製材モデルとりわけ興味深いのは育林モデルです。これは育林方法（植付密度，枝打ち，間伐，最終伐採）によ

り，どのような木材が生産できるかのモデルです。とりわけ，枝打ち，間伐の方法により生長（太さ）と材質（無節）とが管理され市場価が決まるからです。次は製材モデルです。これは育林方法が林業の最終製品である製材品の量・質にどう関わるかのモデルです。伐期が30年ですので育林から商品化までの距離が近く，農産品の思考が入っています。したがって，ここでは人工林のことをTimber firmとも呼びます。在来の天然林の保護はきびしい反面 Forest Park制度によりレクリェーション利用が盛んに行われています。水の美しさ，鳥，野生動物，魚の豊さはこの国の何よりの誇りです。



ラジアータ　混牧林

Ⅳ、ニュージーランドの林業研究

日本の経済発展の様子が日本丸と呼ばれたのに対し，このニュージーランドの林業振興と林業研究のやり方はラジアータという旗を揚げたNZ丸と呼ぶのにふさわしいでしょう。林野省，森林会社，試験場，大学など林業にたずさわる人々は一致協力してラジアータ生産という統一目標に向って担当の分野を発展させています。すなわち官民の各分野を代表する委員会が国の研究開発の青写真を示し，定期的にふり返り次の目標を設定していくやり方を続けています。このやり方の長所は情報伝達，普及活動，現地からのフィード・バックなどを含めて総合的に研究の能率をあげるうることにあります。人口 300万人の小国が最近10年間に世界の林業をリードする水準にまで達したと言えます。反面，この方法の短所ではないかと私が危惧することは，大勢に流されて個々の研究の持つユニークさ，あるいは個人の創意が埋れやすいことです。ラジアータの高生産性，高収益性という鬼のように強い林業上の価値観にこの国が統一されすぎているという感じがします。

ところで過去10年間の研究成果を具体的に描いてみます。この国も1960年代までは伝統的な植栽・伐採の域を出なかったようです。ちょうどその頃，日本は「木材増産・拡大造林」の時代で林業家は森林からの高収益を享受し，林学者は産業発展に鼻が高かった時代です。ところが1975年に林野庁，会社，大学，試験場の実務家，研究者や多分野の専門家が集まり，Mensuration Project team（1976～78年）を創設して大きな飛躍の第一歩をふみだしました。この森林計測特別研究班は森林調査法，収穫表，保続計算法，材積表，測樹法など森林の経営と計画の基本的な手法をラジアータに適した形で開発し，すべてをコンピュータ化して森林現場がいつでもこのプログラムを容易に使いこなせる状況を作りました。そのために全国を結ぶコンピュータ網が1979年に完成しました。このプロジェクト・チームの成功に続いてラジアータ特別研究班（1979～82年）が作られ，育林方法と最終の林分内容との関係を明らかにするシステムが作り出されました。地位，育林方法，生長と収穫される木材の量・質，伐採方法，製材方法など多くの施業上の因果関係を説明するプログラロム群（Silviculture Stand Model)が出来ました。この研究を更に発展させたのが木材利用特別研究班（1983～1985年）で林産品の市場動向と施業とを結びつける大きなプログラム群（Conversion Model）を完成させ，さらにそれらのプログラムは年々改良が加えられ，あるいは適用地，適用樹種が拡大されて今日では日常業務に欠かせない用具として使われています。それぞれの内容は資料として添付しますので参照して下さい。特に各プログラムが体系的に組み立っている所に注目すれば面白さは倍増するかもしれません。

このロトルアの試験場はもとより現場の事務所でも多くの職員はコンピュータと向かい合っているのが平常の勤務の姿となり，停電の日はオモチャを取りあげられた子供のようにガックリくるというのが実感です。このコンピュータ依存体制について日本育ちの私ははんぱつを感じることもありますが，研究成果が現場で使われ現場の要求が研究に反映されているという事実を高く評価すべきです。

V、おわりに

この研究所での私の仕事がニュージーランドにとって，そして私自身にとってどれ程の成果を残すかはこれからの問題ですが、ただ現在は言葉をはじめ何かと様子の違う環境の中で格闘中という現状です。外国では短期訪問の来客としては居心地が良くても実質組織メンバーとしてやるにはいささか心構えが要るようです。

さてわが町ロトルアは温泉とマオリ文化の中心地です。そして6月10日はこの地域を埋めつくしたタラウェア火山1886年大噴火の100 年記念日です。今は観光客もハレー彗星とともに去り、ひっそりと薪ストーブの煙が立ちのぼるロトルアは世界で最も平和で美しい町であると思えます。私は週末の家族ゴルフを始めてスコアは50が目前です。長女はこの町の高校の最終学年，家内はコミニティカレッジに通いマオリ工芸を習っています。長男のみ京都在住で大学生活を送っております。日本製品が沢山入っていますが豊かすぎる物質は精神を貧しくすることを改めて知らされます。この街で最も印象に残る風景は子供が戸外で遊びまわり賑やかな声が隣近所に満ちていることです。変速ギヤなしの

簡素な自転車が彼等の宝です。

おわりに日本では初夏を迎えられ新しい年の計画に着手される頃と思います。不在中に多くのご迷惑をおかけしておりますことをお詫びすると共に一層のご活躍を心よりお祈り致します。

注）この文は1986年６月10日付で大学関係者へ出した近況私信に加筆し資料を添付したものです。

（1986年10月）

資料

Ｉ　計測・生長モデル（Resource inventary and yield control systems)

Ⅱ　育林と林分モデル（Silvictual stand model)

Ⅲ　木材利用モデル　（Conversion planning)

Ⅳ　Y.Konohiraの研究計画（Stand specfic harvest scheduling)

注）Ｉ，Ⅱ，Ⅲは1986 Forestry Handbook（New Zealand Institute of Foresters Inc.)から引用した。

I. Resource inventory and yield control systems (R.Hancock , O. Garcia)

The New Zealand Forest Service has, over the past 10 years, expended considerable effort in developing the tools needed to forecast more accurately the future wood supply patterns from its plantation forests. The quantitative base was laid in the work of the Mensuration Project Team (1976–78) and its successor, the Resource Inventory Group. This base has been developed latterly by the Radiata Pine Task Force (1979–82) and is likely to be taken further by the present Conversion Planning Project Team (1983–85).

Resulting from this effort is a suite of computer packages now maintained by the Resource Inventory Group in Rotorua, in close liaison with the Forest Mensuration and Management Systems Section of the Forest Research Institute. These packages are available on the Government Computer Centre's ICL 2980 and on the New Zealand Forest Service network of DEC VAXs.

(1) The stand record system

The stand record system (SRS) is a computer-based management information system for plantation forest managers and planners. Information on areas and silvicultural treatments, as well as growing stock descriptions in mensurational terms, is stored in the system and is readily available through an information retrieval system. The system is designed primarily to assist those engaged in monitoring and planning the wood supply, by helping to organise, analyse, and summarise information describing forests in a manner useful for yield forecasting. However, other uses of the system by operational staff, draughting personnel and others are also possible.

Examples of the type of management enquiry that may be quickly answered by accessing the stand record system include:

- Has the radiata pine in Compartment 6, Karioi Forest been thinned?
- What is the total area of radiata pine in Golden Downs Forest?
- What is the age class distribution of Corsican pine on tractor country at Kaingaroa Forest?
- Locate radiata pine stands at Karioi Forest that are candidates for low pruning this year.
- Produce a yield forecast over the next 5 years for all radiata crops at Esk Forest that are aged 25 years or more.

The bring-up and powerful searching and sorting facilities developed to readily answer such queries obviously have the potential to aid forest management generally.

(2) The growth and yield system

The growth and yield system (GAYS) has been developed primarily to provide stand level growth and yield estimates for use in Forest Service yield-control procedures.

The system has two basic components, the growth and yield subsystems, and is characterised by a number of features, including:
- interactive input with screen and printer output;
- convenient and flexible yield table review facilities;
- an on-line HELP facility;
- creation of COMMAND files for easy editing and re-running;
- ability to specify a model via valid combinations of basal area increment, topheight, volume, diameter distribution, taper, and breakage equations;
- code shared with other components of the yield-control system facilitating easy maintenance and consistency;
- incorporation of the EARLY growth routines.

The growth subsystem enables future basal area, topheight and stems per hectare to be estimated from starting values, using equations developed from permanent sample plot data. The yield subsystem then calculates volumes either by using stand volume equations, or by use of the stand volume generator contained in program PROD. The link between the two subsystems is optional.

(3) Prediction of log assortments

Program PROD is a computer program to calculate stand tables and the assortment of logs expected from stands of known or predicted age, height, stocking, and basal area when particular cutting patterns are applied. The estimates of volume provided may subsequently form part of the input to forest modelling such as the Interactive Forest Simulator (IFS), or other long-term planning systems.

Input to the system consists of data containing the basic stand parameters for stands of interest, and one or more cutting patterns to be applied to individual stands.

Like many of the systems described in this paper, users may specify the tree volume volume equation, taper function, breakage function, and the predictive functions for the diameter distribution. to be used for a particular set of basic stand parameters. Standard equations are available within the system.

(4) Stand treatment and growth simulation

Stand treatment and growth simulation (STAGS) is the replacement for GAYS on the VAX. It is a stand level, growth simulation program akin to the growth and yield system, in that it incorporates the growth model package and several other mensuration packages, to generate yield tables.

The program operates in 3 phases:
- setting up models and tables;
- setting stand parameters;
- generating yield tables.

Stands are grown interactively and may be grown either to an age (and month), or a specified height. They may also be thinned and, in the case of some models, fertilised. Output in all instances is to both screen and file.

(5) Extraction thinning control

The Forest Service recognises the importance of routine management inventory procedures carried out in conjunction with silvicultural operations as a means of monitoring the state of the forest growing stock. The EXT. THIN. (Extraction Thinning) system is specifically concerned with the field and office procedures necessary to collect and process the information required for the control of extraction thinning operations.

Processed field data can then be used to formulate a written description of the work required and may also be used to set a production rate for the job using production standards from work study.

The system, whilst primarily designed for control of extraction thinning operations, is also applicable to quality control of waste-thinning operations where the field assessment is the last silvicultural assessment received by the stand.

(6) Assessment of recoverable volume by log type

A method for the assessment of recoverable volume by log types (MARVL) is a system for the preharvest inventory of single-species exotic stands.

The system recognises the potential of stands to yield different products (log assortments) when subjected to different cross-cutting patterns. The approach used is to observe and record stem quality and size on a sample of standing trees and then predict the results of cross-cutting these trees under the influence of a variety of log specifications and requirements as specified by the inventory officer. No merchantability factors are required.

The method has been designed to meet the needs of personnel involved in the planning and administration of harvest operations. It assists in marketing and logging planning by estimating the crop yield by different log types and by defining the quantity and location of high-value products such as peeler logs. As an aid in allocating logging equipment and setting bonus targets, it provides information on total recoverable volume, on average merchantable sizes for hauls and on numbers and sizes of individual logs. It can also be used to provide recoverable factors as a control for long-term yield forecasting.

(7) General purpose forest inventory

Program QADI is a general-purpose forest inventory system which provides growing stock information for a tree population. It replaces that part of the New Zealand Service "Standard Methods for Inventory and Growth Measurement of Exotic Forests", (Lees, 1976) concerned with extensive surveys to determine the current condition of forest areas.

In contrast to the MARVL inventory system which caters specifically for the intensive assessment of mature crops before harvesting, QADI is applicable to the more general, and often extensive, surveys in stands of any age.

The system describes the forest growing stock in terms of average age, stocking, basal area, top height, and total stem volume — information which can subsequently be input to forest modelling systems via yield tables, produced using growth models.

(8) Forest estate model

Simulation has long been used by foresters to answer "what if" questions about the effects of forest management. Essentially it consists of building a simplified abstract representation of the forest (a model), e.g., by a set of tables and rules, and using this to predict the consequences of different management alternatives. The ready availability of computers has reduced the work involved in carrying out these simulations, and so made it possible to analyse many more alternatives at a much higher level of detail.

There are 2 simulation systems in general use in New Zealand for long-term forest management planning: RMS80/RMS85 (Allison *et al.* 1979, Allison 1980, 1985), and IFS (Garcia 1981). Both simulators, in common with older non-computerised procedures, use a similar conceptual model of a forest estate.

The forest is described by a classification of areas into "crop types" and age classes. Stands are grouped into crop types according to growth, silvicultural regimes, harvesting methods, location, ownership, or other characteristics, as appropriate to the planning exercise. Events are recorded for time intervals ("periods") of length equal to the number of years in an age class.

Figure 1 illustrates the model for 1 crop type with 5-year age classes. The state of the forest at the beginning of a 5-year period is described by the area in each crop type and age class. During the period some of the area in each class may be cut, and the remaining area moves into the next age class at the beginning of the next period. The harvested areas may be replanted immediately into the same or different crop types, or left unplanted.

The areas cut from each class are multiplied by the appropriate entries in harvest product/resource tables, to compute volumes produced, or resources required or generated in the period. The residual areas may be multiplied by entries in the same product/resource tables to assess the growing stock, and by entries in another set of tables to account for intermediate products/resources such as thinning yields and silvicultural costs. It is also possible to transfer areas between crop types; this is useful for modelling alternative silvicultural regimes or changes of ownership.

In using these simulators, the user specifies (or accepts defaults for) the actions to be taken in each period. Decisions include the areas to be harvested from each crop type and age class, areas which will be replanted, and areas to be transferred across crop types. There are various alternative ways of specifying these actions. For example, the user may just give the total volume to be produced in the period, and the program automatically distributes the necessary cut among crop types and age classes according to predetermined rules. A number of different reports can be produced to describe the results of applying a particular management strategy.

RMS80 was developed by NZ Forest Products Limited, and has been used mainly by the largest private companies (NZ Forest Products and Tasman Forestry), and by the School of Forestry of the University of Canterbury. It operates in batch mode and is written in Fortran. A distinctive feature is the computation of a number of "forest mass" measures developed by Allison (1978). These measures indicate similarity of the current state of the forest to a normal forest; they have been found useful in communicating with top management, and for some valuation and yield control and analysis purposes.

IFS, developed at the Forest Research Institute, has been largely used by the New Zealand Forest Service and by some smaller forestry organisations and forestry consultants. It is primarily an interactive system, although it can also be used in a batch mode. Versions in several Basic dialects are available for ICL and VAX mainframes and for a number of microcomputers.

Simulation uses trial-and-error to search for an acceptable management strategy. Only a limited number of possible alternatives can be tried, and in many instances much superior solutions may be overlooked. Given a clear statement of objectives and constraints, optimisation techniques can be used to find a "best" solution. It must be recognised, however, that the objectives and constraints used in optimisation models are often gross oversimplifications, and many relevant factors that are difficult to quantify are ignored. Also, currently available optimisation methods are not suitable for handling as high a level of detail as the simulators.

By far the most commonly used optimisation technique for long-term forestry planning is linear programming (LP). Several applications of LP have been carried out in New Zealand. Some of them were developed by operational research experts in collaboration with management for modelling a specific situation (e.g., White and Baird 1983). Two general-purpose LP-based systems for use by forest managers are CPLAN (Shirley 1979) and FOLPI (Garcia 1984).

CPLAN, like most LP forest management systems, follows the so-called Model I formulation (see, for example, Clutter *et al.* 1983). Individual stands are grouped into "cutting units", which correspond approximately to age classes within crop types. For each cutting unit, a number of management alternatives are nominated. These alternatives specify the management of stands over the whole planning period, and should cover all the reasonable combinations of silvicultural treatments and successive harvesting ages. The flows of the relevant products, resources, costs, and revenues for each management alternative must be provided. The manager specifies an "objective function" or end result to be maximised or minimised, for example, present net value, and a series of constraints on the flow of products and/or resources. CPLAN then generates the best over-all management strategy by determining how much of each cutting unit should be treated according to each management alternative. Solution of the model may be followed by post-optimal analysis, where the effects of changes in constraints, alternatives, and resource flows are investigated.

FOLPI does not use the Model I formulation. Instead, it is based on a model of the forest identical to that used by the simulators described above. Given an objective function and a set of constraints, LP is used to calculate for each period the areas to be cut from each crop type and age class, the areas and destination crops for replanting, and any transfers of area across crop types. The same input data files are used by IFS and FOLPI, and reports identical to those produced by IFS can be generated interactively. Objectives and constraints are specified in a form that does not require any detailed knowledge of LP.

(9) Weight/volume conversion

Program CONV is a system which describes the collection and processing of sectional measurement data in order to determine weight/volume conversion factors for individual truckloads of logs. Measurement of diameter and bark thickness at predetermined intervals along the log are used to calculate log volumes using Smalian's formula. Log volumes are summed to give truckload volumes in cubic metres. Division of the load volume by the load weight in tonnes gives the conversion factor in cubic metres per tonne.

The system also has an optional facility for segregating the total load volume into predefined product classes labelled "sawlog" and "pulplog".

(10) Logging waste assessment

Assessments of the waste wood on cutover areas and landings are required for a variety of reasons such as the reconciliation of standing-crop-volume estimates with volume outturn, and for short- and long-term yield control. They also provide logging management with information about the standard of logging operations, and in some cases logging organisations may be charged for recoverable waste.

The logging waste assessment system (LWAS) describes the field and computer procedures required to enable the assessment and recording of waste-wood volumes on cutovers and landings, by way of either cutover assessments, skid assessments, or stacked wood assessments. The system is designed to operate on an annual cycle coinciding with the financial year. Waste-wood assessments are performed throughout the year and progress reports are produced at convenient intervals.

(11) Mensuration packages

A series of these procedures, called the mensuration subroutine packages, have been implemented on the New Zealand Forest Service network of VAX computers for use by any person writing programs, whether a local forester, or an EDP specialist. The modular design allows the subroutines to be incorporated easily into any applications program. The routines are efficient, fully tested and documented. They increase the effectiveness of the applications programmer, and the mathematical description provides a standard mensurational definition. On-line help is available and a hard copy reference manual can be obtained either from the computer, or as an internal Forest Research Institute report. Subroutines are available in the following areas:

— Tree heights (calculations from angles and distances).
— Height/dbh curves (fitted to data and for making estimates).
— Mean top diameter (as derived from plot measurements).
— Tree volume and taper.
— Log scaling (sectional measurements).
— Special functions (Weibull distribution, random normal numbers etc.).
— Stand volume tables (functions of basal area, height and stocking).
— Scattergrams (for generating low-resolution plots).
— Breakage (estimating tree-break height).
— Growth models (prediction of stand growth over time).
— Products (derivation of dbh distribution and yield by log types).

II Silvicultural stand model (F.J.N.Williams)

The Silvicultural Stand Model (SILMOD) is a package of computer-based mathematical models. It is designed as an indicative tool to help forest managers evaluate alternative silvicultural regimes for stand management of radiata pine. To achieve this it is necessary to account for the quite complex relationships between the various factors expressing site, silviculture, stand growth, log quantity and quality, the harvesting and milling processes, and the sawn timber and residues produced.

Thus the model simulates the growth, harvesting, and processing of a stand. It can be used to evaluate the effects on relative stand productivity and, using cash flow analysis, relative stand profitability of varying:

(1) Site variables — site productivity, topography, distance to mill, wood density, internode length, and incidence of sweep and resin pockets.
(2) Silvicultural regimes — initial spacing, pruning, thinning, and rotation age.
(3) Processing variables — minimum sawlog diameter, sawing pattern, conversion standard, grading routine, sawing cost, and prices for sawn timber and residues.

The package currently consists of 10 programs, 5 of which (denoted below with an asterisk) were in existence before the model was developed:

EARLY	This program predicts the growth of young stands from about mean crop height 3 m through to 18 m. It allows for the effects of pruning and thinning on growth and predicts the diameter-over-stubs for each pruning lift.
*KGM2 *AGM1 *SGM1 *BEEK GDNS AGM2	One of these growth models is then used to predict stand growth from the point at which EARLY terminates, to clearfelling. Except for BEEK (a national model), they are each appropriate to different regions
*PROD	This program uses data from the growth model to estimate the distribution of tree sizes (diameter and

height) in the stand and simulate the cutting of trees into logs at production thinning and/or clearfelling. The log assortment from the stand is predicted by log height class, small end diameter and volume.

HARPCE This program estimates the costs of extracting the predicted log assortment using either skidder, tractor, or hauler and of loading and trucking the logs to the mill.

PREVAL The final program first estimates the log quality variables: density, sweep, and internode index. It then predicts the quality variables branch index and defect core using data from the first 2 programs. Growing costs and the processing method are then specified. Using the estimates of log volumes, diameters, and taper from PROD, log conversions and hence gross sawlog values are then predicted along with the distribution of sawn timber grades. Finally, net log values, stand net worth, and the (discounted) present net worth are calculated.

Using the package involves:

(1) Defining the alternative strategies to be evaluated.
(2) Collecting the necessary data required to enable these to be simulated.
(3) Interpreting the results, taking into account management objectives and the known limitations of the input data and of the simulation package.

SILMOD has been developed at the Forest Research Institute and is currently implemented on 2 computer networks, belonging to the New Zealand Forest Service and Datacom Systems Ltd.

III Conversion planning (B.Manley)

The Conversion Planning Project Team has developed an integrated modelling system consisting of a portfolio of models, methods, and databases. The components can be used individually or linked together to help decision-makers address a wide range of conversion planning issues including:

— stand assessment and prediction;
— log evaluation;
— plant management and design;
— process selection;
— stand economic modelling;
— forest estate modelling;
— future market opportunities.

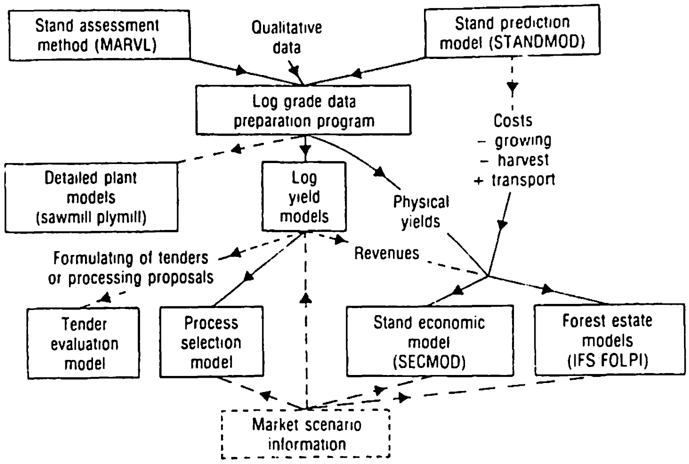
The Conversion Planning Project was set up at the Forest Research Institute to incorporate and extend the previous work of the Mensuration Project Team and Radiata Pine Task Force in the development of a conversion planning model system linking the output of the forest and the various processing options to market requirements for a full range of forest products.

An outline of the model system is given in Figure 1. The components of the system are shown together with the main linkages between the components. Solid lines are used to depict the formal linkages (i.e., output of 1 component is used directly as input by another component). Other linkages are shown as broken lines.

Details of the model system were presented at the FRI Conversion Planning Project Team general meeting in April 1986. The proceedings of this meeting are to be published.

An integral feature of the model system is the use of the standard set of log grades proposed by Whiteside and Manley (1985) for resource descriptions purposes.

Figure 1: Conversion Planning Project Team Model System



1. Stand Assessment Method

A set of standard quality codes has been developed and incorporated into a cruising decision tree to allow the assessment of stands in terms of the proposed standard log grades using the MARVL (Deadman and Goulding 1979) preharvest inventory system.

As the MARVL method involves cruising of external tree features only, it provides no information on the internal quality of pruned logs. A complementary assessment is required to evaluate pruned log quality (see Somerville, Park, and Goulding 1986).

2. Stand Prediction Model

The stand prediction model, STANDMOD, predicts stand outturn by log grade of different silvicultural regimes.

Inputs to the stand prediction model specify stand conditions at the simulation starting point (e.g., initial age, stocking) and the silvicultural regime to be applied (e.g., pruning, thinning).

Outputs include stand composition by log grade at any specified age together with parameters for each log grade.

This model predicts at the single hectare or stand level and is primarily intended for use over the medium to long term (5 to 50 years).

3. Log-grade Data Preparation Program

This program allows the merging, aggregation, and editing of resource data to be input into the processing models.

4. Detailed Plant Models

Detailed plant-level models have been developed for sawmilling and plymilling. These operational models are primarily designed for short-term plant design and management problems.

5. Log-Yield Models

Log-yield models predict the products of log grades when they are utilised in different processing plants, and the costs and revenues associated with this processing. They attempt to measure the worth of logs to the processor under given assumptions.

Log-yield models have been developed for the following products or processes:

— sawmilling;
— plywood;

— export logs:
— export chips (whole log chipping);
— panel products — medium density fibreboard,
— hardboard,
— particleboard;
— pulp and paper — bleached kraft pulp,
— newsprint,
— linerboard;
— hydrolysis (ethanol).

6. Tender-evaluation Model

The tender-evaluation model finds the allocation of logs that maximises a seller's revenue while meeting buyers' requirements. It allows the seller of logs to evaluate buyers' bids and take into account their log-mix requirements.

7. Process-selection Model

The process-selection model can indicate likely processing options under perceived market opportunities. It allocates a specified resource of logs and residues to processes on the basis of relative log and residue values subject to market demand constraints. The relative allocations of logs and residues give an indication of the relative merits of the processes for the particular log supply and market scenario.

8. Stand Economic Model

The stand economic model (SECMOD) provides a discounted cash flow analysis at the single hectare or stand level. Stand physical-yield data can be obtained from the stand prediction model. Costs associated with growing, harvesting, and log transportation are user-specified as are log revenues. The user is required to specify a unit price for each log grade (or log-grade aggregation).

The pathway through the model system incorporating the stand economic model will replace SILMOD

9. Forest Estate Models

The forest estate models, IFS (Garcia 1981) and FOLPI (Garcia 1984), allow the forest manager to explore alternative forest management strategies. FOLPI can be used to model forestry problems involving a single forest or a number of forests. FOLPI can model yield-control/log-allocation problems involving forest management, forest harvesting, and the transportation of logs to processing plants with specified demands.

10. Market-scenario Information

As part of the conversion planning project research has been carried out on the medium- to long-term market prospects for a range of forest products. A range of market scenarios were developed based on this research.

The Conversion Planning Project Team Model System as it currently stands does not represent an end point. It will continue to be developed and enhanced. Some components such as those developed by the Mensuration Project Team or the Radiata Pine Task Force (e.g., MARVL; parts of STANDMOD) have been used for some time. Other components represent first-generation versions which may well be modified and improved as further research is done.

IV Stand specific harvest scheduling assisted by computer maps (Y. Konohira)

—— Development of a mid-term planning system ——

Objectives: The objective of this work plan is to develop a computer based mid-term harvest scheduling system which can function to coordinate the long term plan's goal and the direction of the short term plan. The plan will cover harvesting during the next five to ten years. The system can support the planners in making better decisions when they specify the stands to be cut in each year following the direction of the long term plan, the Harvesting and Marketing Strategy. With this specification of the stands, the system provides information about timber volume and quality, stand location and income/expense which are essential to marketing, logging-silvicultural operations and financial management. This system can work effectively when the scale of harvest is extended, profitability is emphasized and the regulations become more strict. The goal of the work plan is to establish a planning tool on the Vax computer network which the planners can easily handle to revise the mid-term plans.

Advantages: The system will be of use to logging planners controlling more than fifty stands to be cut each year. By computerizing the calculations of the volumes, revenues and costs of future harvests, the system will allow the logging planners more time and scope for testing different alternatives to maximize profit.

Methods: This system consists of three processes. (1)Listing the candidate stands ready to be cut, (2)specification of the stands scheduled to be cut and (3)report writing. At first, the system lists the candidate stands with the data of harvest volume, timber grades, terrain and income/expense etc. Most of these data are provided by the existent computer files or tools, for example, Stand Record System, Growth Model and Stand Model. Additional data are given to the system by the planners which are collected in the field, market, or routine operations.

Secondly, stand specification is processed by the planners interactively with computer assistance including the map information. The criteria of the selection are flexible because they mostly depend on the management requirement of the forests. The computer provides enough information to the planners in order to satisfy the given criteria, however, the final decision is made by the planners not by a mathematical optimization.

Lastly, after the specification of the stands scheduled to be cut, a report writing program makes several reports to meet the management requirements.

Schedule: This work plan consists of two parts, the development of main frame and a mapping option. The main frame can be developed by the following steps. (1)Exploring the potential requirements for the mid-term planning processes, (2)design details with the user's participation considering the hardware and data availability, (3)prototype programming, review and application test, and (4)finalizing and documentation. The development of the main frame is temporarily scheduled from July of 1986 to July of 1987.

The mapping option can be a gateway to the total mapping system and a basic discussion how to introduce a geographical information system is necessary. The mapping of this system should be developed paralleled with the discussion. The schedule is temporarily set from 1986 to 1988.