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BOREAL MIXEDWOOD CHALLENGES: DO ECOSYSTEM MODELS LIKE FORCYTE-11 HAVE A ROLE?

by

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FOREWORD

ENFOR is the acronym for the ENergy from the FORest (ÉNergie de la FORet) program of Forestry Canada. This program of research and development is aimed at securing the knowledge and technical competence to facilitate in the medium- to long-term a greatly increased contribution from forest biomass to our nation's primary energy production. It is part of the federal government's efforts to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy sources.

The ENFOR program is concerned with the assessment and production of forest biomass with potential for energy conversions and deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (Biomass Conversion, dealing with the technology of converting biomass to energy or fuels, is the responsibility of the Renewable Energy Division of the Department of Energy, Mines and Resources). Most ENFOR projects, although developed by Forestry Canada scientists in the light of program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. This work was supported by the Federal Interdepartmental Panel on Energy Research and Development (PERD). For further information on the ENFOR Biomass Production program, contact:

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ABSTRACT

The present report is a result of a project that had two distinct objectives. The first primary objective was to identify stand-level boreal mixedwood problems based on interviews with federal, provincial and industrial forestry personnel who are currently involved in mixedwood forest management. The emphasis was on the identification of mixedwood challenges in Manitoba, Saskatchewan and Alberta, but several forest managers in northeastern British Columbia were also interviewed. That objective is addressed in a separate contractor's report prepared for the Northern Forestry Centre by E.B. Peterson, A. Kabzems, R.D. Kabzems and N.M. Peterson under the title, "Boreal Mixedwood Forest Management Challenges: A Synopsis of Opinions from 1988 interviews".

The second primary objective was to relate the identified mixedwood management challenges to a stand-level ecosystem modelling framework, FORCYTE-11, developed by Professor J.P. Kimmins and co-workers at the University of British Columbia for Forestry Canada under the ENFOR program. The present report addresses this second objective.

FORCYTE-11 was designed to simulate most forest management activities and to predict production, yield and ecosystem nutrient budgets. Applicability of FORCYTE-11 to the identified management concerns was judged from two vantage points - present applications and possible future applications. These assessments were based on professional knowledge of the modelling framework, tempered by judgements about how the model could find new applications in a setting where technical factors such as utilization, economics and climate, and social factors such as professional opinions and public perceptions, are rapidly changing.

For only one of 16 identified concerns - need to define mixedwood management regimes - was FORCYTE-11 judged to have high applicability both presently and potentially. For three concerns (difficulty of white spruce regeneration, uncertain ecological effects of site preparation equipment, and inadequate use of existing information) applicability of the model was considered to be medium, now and in the future. There were three concerns with presently low but potentially medium applicability (competition from shrubs and grasses, restrictions to herbicide use, and integration of softwood and hardwood harvests).

Concerns with presently low but potentially high application of FORCYTE-11 included: need to refine allowable annual cut calculations; nutrition management in boreal mixedwood ecosystems; energy production from mixedwood biomass; need for research to increase mixedwood productivity; development of short-rotation forestry; and the need to work with longer time horizons in forest planning. FORCYTE-11 was considered to have no present or foreseeable application for three identified concerns: management and use of decayed aspen; need for better inventory data for boreal hardwoods and understorey conifers; and the current lack of biophysical data at the scale at which operational decisions are made.

A shorter version of this report, co-authored by E.B. Peterson and M.J. Apps under the title, "Do Ecosystem Models Such as FORCYTE-11 Have a Role in Boreal Mixedwood Management?", was published in the proceedings of the Seventh Canadian Bioenergy R & D Seminar, Ottawa, 1989.

RÉSUMÉ

Le présent rapport découle d'un projet qui comportait deux objectifs distincts. Le premier consistait à identifier les problèmes rencontrés au niveau des peuplements dans la forêt mixte boréale à partir d'entrevues menées auprès de personnes oeuvrant actuellement en aménagement des forêts mixtes au fédéral, au provincial et dans l'industrie. Le but visé était l'identification des défis posés par la forêt mixte au Manitoba, en Saskatchewan et en Alberta, quoique plusieurs aménagistes du nord-est de la Colombie-Britannique aient été interrogés. Cet objectif est abordé dans un rapport distinct de l'entrepreneur préparé pour le Centre de foresterie du Nord par E.B. Peterson, A. Kabzems, R.D. Kabzems et N.M. Peterson et intitulé <u>Boreal Mixedwood Forest Management Challenges: A Synopsis of Opinions from 1988 interviews</u>.

Le deuxième objectif principal consistait à établir un rapport entre les défis qui ont été identifiés en matière d'aménagement des forêts mixtes et un modèle d'écosystème de peuplement, le FORCYTE-11, élaboré par le professeur J.P. Kimmins et des collègues de l'Université de la Colombie-Britannique pour Forêts Canada, dans le cadre du programme ENFOR. Le présent rapport aborde ce second objectif.

Le FORCYTE-11 a été conçu pour simuler la plupart des activités d'aménagement forestier et prédire la production, le rendement et les bilans nutritifs d'un écosystème. L'applicabilité du FORCYTE-11 aux préoccupations connues des intervenants en aménagement forestier a été jugée de deux points de vue - ses applications actuelles et ses applications futures éventuelles. Ces évaluations ont été menées par des personnes connaissant le cadre de modélisation et ayant des opinions sur la façon dont le modèle pourrait trouver de nouvelles applications dans un contexte où des facteurs techniques, comme l'utilisation, l'économie et le climat, ainsi que des facteurs sociaux, comme l'opinion des experts et les perceptions du public, évoluent rapidement.

L'applicabilité, tant actuelle que potentielle, du FORCYTE-11 n'a été jugée élevée que pour l'une des seize préoccupations identifiées - la nécessité de définir des régimes d'aménagement des forêts mixtes -. Son applicabilité actuelle et future a été jugée moyenne à l'égard de trois autres préoccupations (la difficulté de régénération de l'épinette blanche, les effets écologiques incertains du matériel de préparation du terrain et l'utilisation inadéquate des données disponibles). Son applicabilité à trois autres domaines de préoccupation a été jugée comme faible à l'heure actuelle, mais potentiellement moyenne (concurrence des arbustes et des graminées, restrictions de l'usage d'herbicides et intégration de la récolte des résineux et des feuillus).

Au nombre des préoccupations auxquelles le FORCYTE-11 s'appliquait peu à l'heure actuelle, mais offrait un fort potentiel futur, mentionnons la nécessité de mieux calculer les possibilités réalisables annuelles, la gestion des éléments nutritifs dans les écosystèmes de la forêt mixte boréale, la production d'énergie à partir de

la biomasse des forêts mixtes, la nécessité d'effectuer des recherches en vue d'accroître la productivité des forêts mixtes, le développement d'une foresterie à courte révolution et la nécessité d'utiliser des horizons de planification plus longs en foresterie. Le FORCYTE-11 a été jugé comme n'ayant aucune application actuelle ou future à l'égard de trois des préoccupations identifiées : l'aménagement et l'utilisation des peupliers faux-trembles en voie de décomposition, la nécessité de meilleures données d'inventaire sur les forêts feuillues boréales et les conifères du sous-étage et l'insuffisance actuelle de données biophysiques à une échelle correspondant à celle à laquelle des décisions opérationnelles sont prises.

Une version abrégée du présent rapport rédigé par E.B. Peterson et M.J. Apps et intitulé Do Ecosystem Models Such as FORCYTE-11 Have a Role in Boreal Mixedwood Management? a été publiée dans les comptes rendus du Septième séminaire R & D bioénergétique du Canada qui s'est tenu à Ottawa en 1989.

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A preliminary version of this contractor's report was reviewed by M.J. Apps and D.A. MacIsaac, Northern Forestry Centre. Their constructive suggestions and editorial advice resulted in a much improved report. We also wish to thank Michelle Kirkpatrick, Cadboro Bay Business Center, Victoria, for word processing several drafts of the report.

1. INTRODUCTION

As a result of the strong recent interest in boreal mixedwood forest management, reflected in a number of recent articles (Whitney and McClain 1981; Hagglund and Peterson 1985; Canadian Forestry Service 1988; Resource Development Council Education Foundation Inc. 1987; Samoil 1988), Forestry Canada selected the mixedwood region in 1988 as one of several areas in Canada in which to assess management and research roles for a stand-level ecosystem modelling framework, FORCYTE-11[1].

FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator) was originally developed as a tool to examine the nutritional aspects of growing forests as a renewable supply of energy. However, the model has evolved into a forest ecosystem management simulation predictor (Kimmins et al. 1986a) to a point where it was timely to examine it in relation to some examples of challenges currently faced by forest managers. The approach adopted was to identify concerns through a series of consultative meetings with mixedwood forest managers or researchers and then to subjectively evaluate the possible role of the FORCYTE modelling framework for addressing those concerns.

The present report is a result of a project that had two distinct objectives. The first primary objective was to identify stand-level boreal mixedwood problems based on interviews with federal, provincial and industrial forestry personnel who are currently involved in mixedwood forest management. The emphasis was on the identification of mixedwood challenges in Manitoba, Saskatchewan and Alberta, but several forest managers in northeastern British Columbia were also interviewed. That objective is addressed in a separate contractor's report prepared for the Northern Forestry Centre (Peterson et al. 1989).

The second primary objective was to relate the identified mixedwood management challenges to a stand-level ecosystem modelling framework, FORCYTE-11. The present report addresses this second objective. The FORCYTE-11 modelling framework is briefly described in Section 3.

A recent review of boreal forest management (Baskerville 1983) made it clear that management only indirectly addresses present problems; management is undertaken to ensure future continuity of the forest uses, and to improve the future situation. With few exceptions, the benefits of forest management actions taken today will not be captured until several decades from now. It is not surprising, then, that there is much emphasis on the role of forecasting in today's forest management decision-making. There is, in fact, a constraint on management because of the need to forecast the development of many different types of stands, on different sites and in response to different kinds of interventions (Baskerville 1983). The emphasis on

[1] This model was developed by Prof. J.P. Kimmins and co-workers at the University of British Columbia under contract for Forestry Canada through support provided by the Energy from the Forest (ENFOR) program.

forecasting establishes a link with FORCYTE-11 which includes a Management Forecast Activity. The same forecasting need gave rise to the Forestry Canada development of FIDME (Forest Investment Decisions Made Easy), a model that focuses on long-term forestry investments that involve risk and uncertainty (Payandeh and Field 1985).

2. METHODS

Methods for assembly of opinions about today's boreal mixedwood management are described in a separate report (Peterson et al. 1989). The next step was to relate those viewpoints to the FORCYTE-11 modelling framework. This step required the contractor's judgement of whether each identified mixedwood management theme might be served by the FORCYTE modelling framework, in its present state of development. Although respondents were not specifically asked their opinions on FORCYTE's forecasting capabilities, the interviewers for this project were on the lookout for voluntarily offered concerns that revealed an interest in or a need for forecasts of the dynamic development of forest stands - which is what the FORCYTE modelling framework sets out to do. This objective was influenced by Baskerville's (1983) opinion that a major constraint to forest management is the inability to forecast the dynamic development of stands and forests.

The method adopted for this part of the project was very subjective. The recorded opinions about FORCYTE's applicability to a given mixedwood management concern are not the result of consensus-building during interviews because the latter focused on problem definition rather than detailed discussions of the model. Furthermore, this assessment is not a synthesis of discussions between the contractor and developers of FORCYTE; the opinions are those of the contractor, based on a general familiarity with the FORCYTE modelling framework. Reasons for the recorded opinions are presented in Section 4.

3. THE FORCYTE-11 MODELLING FRAMEWORK

The University of British Columbia developers of the FORCYTE-11 modelling framework have described it in several publications (Kimmins 1985; Kimmins et al. 1982; Kimmins and Scoullar 1988, 1989; Kimmins et al. 1986a,b; Kimmins et al. 1988; and Kurz et al. 1988). Excerpts from reports prepared by developers of the model are summarized below to highlight the main objectives of this modelling framework. The most detailed description for anyone intending to use FORCYTE-11 is the user's manual prepared by Kimmins and Scoullar (1989).

FORCYTE was originally developed as a tool to examine the nutritional consequences of using forests as a renewable supply of energy. For several reasons described by its developers, the modelling framework gradually evolved into a generalized forest ecosystem management simulator. Up to and including the development of FORCYTE-10, the only growth-regulating processes that were simulated were those dealing with forest biogeochemistry, nutrient cycling and plant nutrition. The initial emphasis on nutrients was appropriate to the model's original objectives, but it limited the model's usefulness. In particular, FORCYTE-10 was not able to represent architecture and function of the forest canopy, nor could it simulate the effects of live crown pruning or relate a tree's crown class to its growth performance. To rectify these shortcomings, a simulation of the architecture and function of the crown canopy was added to the model to create FORCYTE-11 (Kimmins et al. 1986b).

FORCYTE-11 is a multi-species, multi-nutrient modelling framework designed for even-aged single-species or mixed-species forest or agro-forestry crops. It simulates most types of forest management activities, including site preparation, regeneration, weed control, thinning, fertilization, rotation length and utilization regimes. It also simulates the effects of fire, light competition and herbivory on the production and yield of the simulated forest, and the growth effects associated with pruning of live branches. Predictions made by the model include estimates of production, yield, stand-level economics, ecosystem nutrient budgets and energy benefit/cost predictions on a site-specific and species-specific basis.

FORCYTE-11 consists of two major simulation activities. The first is a "setup" activity in which empirical data on biomass accumulation, tree heights, tree diameters, tissue nutrient concentrations, light intensities below the canopy, and various other plant and soil variables are assembled, ideally from chronosequences of stands on sites of different soil fertility. These empirical data are used to calculate soil process rates, canopy-increment relationships, and a variety of other variables about the plant populations being simulated. The second simulation is a management forecast activity (MANAFOR) in which output from the setup programs is used to simulate management of the ecosystem. A third activity involves output and analysis of results of the management simulation (Kimmins et al. 1986b).

FORCYTE-11 is a modelling framework rather than a specific model, because the user can assemble nominal values for a wide variety of forest, agro-forestry and agricultural crop management systems (Kimmins et al. 1988). The user controls almost all process rates through input data files. By appropriate use of these files, processes can be omitted and the modelling framework can be simplified as desired (Kimmins et al. 1986b). The management treatments and impacts that can be simulated by FORCYTE-11.3, the version developed up to early 1988, are summarized in Table 1. Ecological processes simulated by FORCYTE-11.3 are in Table 2.

TABLE 1

SUMMARY OF MANAGEMENT TREATMENTS AND IMPACTS THAT COULD BE SIMULATED IN THE EARLY 1988 VERSION OF FORCYTE-11 (RELEASE 11.3, AFTER KIMMINS AND SCOULLAR 1987)

	VERSION 11.3 (early 1988)
Site preparation	
Scarification	NO
Ploughing	NO
Windrowing	NO
Windrow and burn	NO
Broadcast slashburn	YES
Regeneration (uniform distribution)	
Planting	YES
Natural regeneration	YES
Coppice/root suckering	YES
Regeneration (non-uniform distribution)	NO
Weed competition and control	
Chemical control	YES
Manual control	YES
Crop stand density control (thinning: high, low, or random by size)	
Spacing (PCT)	YES
Thinning (CT)	YES
Spatially-represented thinning	NO
Harvesting	
Commercial thinning	YES
Fruit picking	YES
Pruning of branches	YES
Litter raking	YES
Soil removal	NO
Final clearcut harvest	YES
Fertilization (multi nutrients)	
Broadcast	YES
Banding/spot	YES
Pruning (for wood quality improvement)	YES
Defoliation (herbivory)	YES
Other insect/disease impacts	NO
Fire	
Site preparation (broadcast)	YES
Stand underburning	YES
Wildfire	YES
Soil impacts of management	
Compaction	NO
Erosion	NO

TABLE 2

SUMMARY OF ECOLOGICAL PROCESSES THAT COULD BE SIMULATED IN THE EARLY 1988 VERSION OF FORCYTE-11 (RELEASE 11.3, FROM KIMMINS AND SCOULLAR 1987)

	VERSION 11.3 (early 1988)
PLANT PROCESSES	
A. Photosynthesis	YES
Foliage light adaptation	YES
Differences in foliage light adaptation with height in crown	NO
B. Allocation of net growth	YES
Effects of nutrients on allocation	YES
Effects of moisture on allocation	NO
Effects of stand density on allocation	NO
C. Geochemical inputs	YES
Biogeochemical cycle (uptake, distribution in biomass, litterfall, reproductive losses foliage leaching, decomposition)	YES
Internal cycle (all tissue types)	YES
Geochemical outputs (harvest loss, soil leaching)	YES
D. Intraspecific competition for	
nutrients	YES
light	YES
moisture	NO
E. Interspecific competition for	
nutrients	YES
light	YES
moisture	NO
F. Spatial representation of competition	
Allelopathy (simple)	YES
(improved)	NO
G. Individual plant height, diameter and biomass growth (trees)	YES
H. Denitrification	NO
I. Ionic forms of nitrogen	YES
SOIL PROCESSES	
A. Decomposition	YES
B. Soil nutrient exchange capacities	NO
Soil moisture holding capacities	NO
C. Soil leaching processes	NO
D. Soil mixing processes	NO
E. Phosphorus sorption	YES
F. Soil temperature effects	NO
G. Soil moisture effects	NO
CLIMATIC EFFECTS	
Effects of microclimatic change after harvest	NO
Effects of regional climatic change	NO

4. IMPLICATIONS OF 1988 INTERVIEW INFORMATION FOR FORCYTE-11

Mixedwood management concerns expressed in the 1988 interviews (Peterson et al. 1989) involve two kinds of themes. One kind of theme expresses a problem by stating what should be done, as in "Appropriate management regimes need to be defined for boreal mixedwood stands". For such themes, the recorded opinion (nil, low, medium or high) expresses the contractor's judgement about FORCYTE's potential to help fill the recorded need.

The other kind of theme simply states a fact or a circumstance. An example is the theme that states "Planning time horizons remain very short for most mixedwood forest managers". If this circumstance persists, the potential applicability of the FORCYTE modelling framework is considered to be low; if there is a shift to long planning horizons the potential applicability of FORCYTE is considered to be high. Therefore, for some of the themes in this group it was more meaningful to express an opinion on both the present and potential applicability of FORCYTE.

The sixteen themes developed during the 1988 interviews are described below in order of decreasing applicability of FORCYTE-11. The opinions about potential applicability of FORCYTE to a given forest management problem were not influenced by the possible future evolution of the FORCYTE-11 modelling framework. Instead the assumption was that FORCYTE-11 in its present form is available for potential users and that the presently available software simulates all of the management options and ecological processes listed for FORCYTE-11 in Tables 1 and 2.

THEME 1: APPROPRIATE MIXEDWOOD MANAGEMENT REGIMES

Applicability to FORCYTE-11: high

Reasons for opinion: FORCYTE-11 is designed to simulate competition and the dynamics involved in two-species stands. The model's highest present and potential applicability lies in the many specific concerns about optimum management of spruce and aspen in mixed stands. These problems involve planning periods of several decades, a time horizon that matches the intended purpose of FORCYTE-11.

THEME 2: CONIFEROUS REGENERATION

Applicability of FORCYTE-11: medium

Reasons for opinion: Coniferous regeneration in mixedwood ecosystems is amenable to FORCYTE-11 simulation because in many cases it involves competition between two tree species (spruce and aspen). Furthermore, it is a challenge of longer duration than the shrub-grass problem described in theme 11. Some respondents stressed that spruce regeneration is largely under the control of microsite differences which are at a spatial scale that cannot be addressed by a stand-level model such as FORCYTE; this is the reason for a medium rather than a high rating in the estimation of FORCYTE's potential role for this mixedwood regeneration problem.

THEME 3: ECOLOGICAL EFFECTS OF SITE PREPARATION

Applicability of FORCYTE-11: medium

Reasons for opinion: Slash management and the influences of site preparation activities on decomposition rates and nutrient cycling are subjects that can be simulated by FORCYTE-11. For those topics FORCYTE's present and potential applicability was rated as medium, rather than high because respondents who expressed concern over site preparation effects focused on variables that FORCYTE-11 does not address, such as changes to bulk density, aeration in the rooting zone, soil moisture and soil temperature, as well as successional changes in post-treatment vegetation.

THEME 4: BETTER USE OF EXISTING INFORMATION BASE

Applicability of FORCYTE-11: medium

Reasons for opinion: FORCYTE-11 is considered to have a role here, presently and in the future, because its calibration and use requires the user to assemble data and ecological information which might otherwise remain unapplied.

THEME 5: BOREAL HARDWOODS AND SHORTER ROTATIONS

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: Because there is presently very little interest in short rotation management, it is premature to suggest a high applicability of FORCYTE. However, if there is a trend towards shorter rotations, the nutrient cycling and productivity consequences of such a trend are precisely the kinds of changes that FORCYTE was designed to simulate.

THEME 6: ALLOWABLE ANNUAL CUT CALCULATIONS

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: At present, this concern reflects a data collection need which cannot be served by a simulation model such as FORCYTE. Management of stands for regulation of even flow is a problem that some respondents suggested could be aided by modelling, but they had in mind simulations to help determine how much land area is needed to produce a given softwood allowable annual cut and a given hardwood allowable annual cut, a goal for which FORCYTE-11 was not specifically designed. However, if long-range yield predictions become integral parts of allowable annual cut calculations for sustainable forestry then the simulations possible with FORCYTE will have a high applicability in the calculations.

THEME 7: SHORT TIME HORIZONS FOR PLANNING

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: With short time horizons there is no reason for forest managers to be interested in the multi-rotation predictions that can be made with a calibrated FORCYTE dataset. However, the potential applicability of the model will be high once managers need to have forecasts of circumstances in the next rotation.

There were indirect indications during interviews that the forecasting abilities of models such as FORCYTE could be of interest in the near future. For example, in Alberta after about 1990 all of that province's allowable annual cut will be committed and this suggests a need for models to help answer what to harvest and when to harvest it. Admittedly, this interest probably relates more to timber supply models than to a stand-level model such as FORCYTE, but it does indicate that present-day managers acknowledge a role for models in decision-making, even though they are not yet in widespread use.

In an unpublished memorandum prepared by the British Columbia Ministry of Forests for the Dawson Creek, Fort St. John and Fort Nelson timber supply areas, one of the suggested activities is modelling the management of mixedwood forest types. That proposed modelling, although not underway at the time of this 1988 review, was planned as part of a timber supply analysis designed to establish both short-term and long-term timber production objectives for coniferous and deciduous harvests. An example of a model that is now in use is Weyerhaeuser's high yield forestry model in which the objective is to assist planning for accelerated recovery of over-mature inventory, demonstrate the allowable annual cut effect of past silvicultural practices, and identify the species and product mixes expected from the future forest (Smith 1988). The operational use of timber supply models is expected to provide synergistic support for models such as FORCYTE-11 because the latter will be able to add refinements at the geographic scale at which productivity classes are differentiated through site classification.

THEME 8: NUTRITION MANAGEMENT

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: Nutrition management is the centrepiece of FORCYTE's original intent. Its applicability to nutrition management will obviously be high once nutrients become a concern amongst boreal mixedwood managers and researchers. Although there is little interest now in fertilization of mixedwood stands there are several unanswered questions that could be researched with the aid of FORCYTE. For example, even if there is consensus that fertilization is not needed to increase growth during the present rotation, will fertilizers be required to sustain productivity during subsequent rotations?

THEME 9: ENERGY PRODUCTION FROM BOREAL MIXEDWOOD BIOMASS

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: Energy values can be attached to any of the biomass components simulated by FORCYTE. The model can also compile the energy cost of silvicultural operations to produce the biomass. Potential applicability of the model for prediction of energy production, based on prediction of biomass production, could be important in the future even if it is not now.

At present, there are several possible fates for mill residues: stockpile at the mill site; waste burn the residue as is the present practice in several operations in the Mixedwood Section; use the residue as an energy source for kiln-drying or for heating greenhouses; or return the residue to forest production sites as a step in nutrition management. Ecological consequences of the latter alternative could be forecast by FORCYTE.

THEME 10: RESEARCH AND DEMONSTRATION FOR INCREASED MIXEDWOOD PRODUCTIVITY

Applicability of FORCYTE-11: presently low / potential high

Reasons for opinion: FORCYTE-11 may find its greatest application as an education tool or as a research planning tool. Many models serve a useful purpose by forcing researchers to develop new hypotheses about ecological processes in their search for model refinements.

THEME 11: COMPETITION FROM SHRUBS AND GRASSES AFTER CLEARCUTTING

Applicability of FORCYTE-11: presently low / potential medium

Reasons for opinion: This is a short-duration problem in the overall life of a forest stand. Seasonal events or short-term dynamic changes that can be assessed directly by field observations and measurements are not high priority topics for a modelling approach; for this reason

FORCYTE is considered to have only a medium rather than a high potential applicability. The present applicability is judged to be low because calibration of the model for simulation of competition for nutrients or competition from shading is hampered by lack of data. Furthermore, FORCYTE-11 does not simulate competition from moisture, nor is it designed to portray spatial representation, a feature involved in most competition indices developed to date.

THEME 12: HERBICIDE USE IN MIXEDWOOD MANAGEMENT

Applicability of FORCYTE-11: presently low / potential medium

Reasons for opinion: Although FORCYTE could be calibrated to simulate the ecological effects of removing shrub or herb understorey species, such information is more readily attainable by direct measurement rather than modelling, because it is part of the same short-term phenomenon referred to in Theme 11. In any case, the herbicide concern expressed by respondents is a public relations and regulatory problem, not an ecological problem for which FORCYTE-11 was designed. For these reasons, the present applicability of FORCYTE-11 is considered to be low. However, if one views herbicide use as a management practice similar to thinning, in the sense that it is a way of reducing or eliminating interspecific competition, then FORCYTE-11 has potential for simulating subsequent growth in the presence or absence of herbicides.

If there was a strong interest in using herbicides to kill mature aspen for spruce release then FORCYTE-11 would have high potential applicability because one would be dealing with interspecific competition that spanned several decades. However, that use of herbicides is not anticipated. Current interest in herbicides is mainly for control of shrub and grass competition in the few years following harvest. As in theme 11, short-term phenomena are probably better addressed by a direct experimental approach rather than by simulation through ecosystem models.

THEME 13: INTEGRATION OF SOFTWOOD AND HARDWOOD HARVESTS

Applicability of FORCYTE-11: presently low / potential medium

Reasons for opinion: This concern presently involves questions of costs, scheduling, and administrative or regulatory arrangements that seemingly have no relationship to the simulation capabilities of FORCYTE. However, the model is assumed to have some potential application for this problem because of its ability to simulate sizes of individual stems and to attach economic values to biomass components of various sizes. Diameters of raw materials and the economic values associated with logs of various sizes can help define optimal uses of softwood and hardwood components of mixedwood harvest operations.

THEME 14: SPATIAL SCALE

Applicability of FORCYTE-11: presently nil / potential medium

Reasons for opinion: This concern is considered to be a data collection problem as in theme 16, with no obvious contributions from a modelling approach. However, if FORCYTE is used in the future as a trend evaluator for certain biomass or nutrient variables that are recorded in a geographic information system, then the model could help to identify data collection needs.

THEME 15: ASPEN DECAY

Applicability of FORCYTE-11: nil

Reasons for opinion: Decay management involves silvicultural and clonal manipulation, genetic selection and changing utilization standards, none of which have obvious relationships to FORCYTE's present simulation capabilities.

THEME 16: FOREST INVENTORY DATA

Applicability of FORCYTE-11: nil

Reasons for opinion: This concern is a data collection requirement for which FORCYTE is not applicable.

5. DISCUSSION AND CONCLUSIONS

5.1 A Forest Management Context for Evaluation of FORCYTE-11

Although there are many concepts of what makes up forest management, Baskerville's recent review of management of boreal forest ecosystems was a helpful context for the present assessment of FORCYTE-11. An important feature of forest management, as defined by Baskerville (1983), is that it requires the integration of four basic kinds of action that regulate forest dynamics: scheduling the harvest; distributing the harvest; renewing the resource; and protection of the resource. The ultimate test of a simulation model like FORCYTE-11 will be the assessment of its role in management planning, which requires the integration of these components in a specific geographic area and over time. In Baskerville's words:

> "These four tools, or tactics, are the means by which forest dynamics are controlled. Management planning therefore attempts to use these tools in the right amount, in the right places, in the right years, so that over a long period of time the desired management goals for the forest are obtained. No one of these tools constitutes management in itself, and none of them is an instant cure for any management problem. Management is achieved by the integration of all four kinds of action over the entire management area and over a time horizon of at least 40 years."

This view of forest management is the context in which the present review was conducted. Baskerville's suggested time horizon of 40 years is noteworthy, because interviews during this study (Peterson et al. 1989) revealed that challenges foremost in the minds of today's mixedwood forest managers appear to be mostly short-term problems associated with the first 10 to 20 years after harvesting.

5.2 FORCYTE-11 and Today's Time Horizons for Forest Planning

Although sustainable forestry is advocated by an increasing number of analysts, the 1988 interviews did not reveal much interest amongst managers for long planning horizons. The FORCYTE-11 modelling framework will be of limited interest as long as forest managers are unconcerned about the next rotation and site quality during the next rotation. Comments from several respondents (Peterson et al. 1989) did reveal an understanding that if we are to manage the mixedwood forest it is important to know something about the genetic and ecological blueprint that sustained these ecosystems up to now. But no respondents want the extra step to encourage the use of models such as FORCYTE-11 for prediction of how simulated management alternatives relate to the basic blueprint.

Interestingly, it was the oldest managed plantations in the prairie provinces - the pine plantations of southeastern Manitoba - that several respondents pointed to as the most likely candidate sites for use and evaluation of models such as FORCYTE-11. Maybe this is because boreal mixedwood foresters have been involved mainly with unmanaged forests up to now and this experience has not forced them to visualize or model the changed forests of the future. In contrast, where there are now plantations of harvestable size, as in southeastern Manitoba, it seems easier to make the conceptual link between a man-made forest and a forest that one can simulate with a model such as FORCYTE.

5.3 Links Between FORCYTE-11 and Forest Site Classification

Interviews revealed potential links between the geographically-oriented focus of forest site classification and the time-oriented focus of ecologically-based computer simulations such as FORCYTE-11. Foresters are often responsible for management of large land areas that include a wide variety of sites and forest ecosystem types that differ in their ability to grow trees and in their response to management. Developers of the FORCYTE-11 modelling framework (Kimmins and Scoullar 1984) recognized that to deal with the variability that exists over large management areas it is necessary for forest managers to consider variation in space as well as variation in time. To aid in the understanding of spatial variation, ecosystem classification systems such as those developed for west-central Alberta (Corns and Annas 1986) and Saskatchewan (Kabzems et al. 1986) are used. A site classification system is a measure of conditions, for example productivity or nutrient status, at the time that the data were gathered. For this reason the other dimension - variation in time - also needs to be considered by forest managers.

For reasons outlined above, developers of the FORCYTE modelling framework pointed to ecological land classification and ecologically-based computer simulation modelling as the two key management tools that will increasingly be used in forestry. However, at least one respondent in 1988 expressed doubts that FORCYTE could be used to predict future stand conditions when it is calibrated with historical growth and yield data. A reason for this scepticism is that the yields one would expect from managed stands would be different than the yields from natural stands. However, others suggested that these potential differences should not be a deterrent to a modelling approach because, first of all, adjustments can be made as experience is gained and, secondly, reasonable predictions are better than complete lack of knowledge.

The FORCYTE-11 modelling framework requires the user to provide vegetational and soil data on a site-specific basis. Up to five different site qualities or ecosystem types can be calibrated in the input files. Thus, use of FORCYTE-11 establishes an obvious link with site classification data. To calibrate the model, empirical data are required on plant growth, plant nutrient content, soil nutrient content and several biogeochemical processes for at least three site quality classes. This means that the modelling framework requires data from sites that vary in quality, defined primarily in terms of soil fertility. Although the required data will in many cases come from sources other than site classification work, it is to site classification and permanent sample plot data that a FORCYTE-11 user would look first for information.

A site classification system normally provides information on species composition productivity and nutrient status of ecosystems that make up the various classes of the system (Corns and Annas 1986). Sometimes information on variation in function between different ecosystem types or site classes is also available, although functional relationships are normally not described for each type. Instead, such relationships tend to be subjectively incorporated into criteria for management interpretations. The latter provide a potential link with FORCYTE-11. Management practices that can be simulated by FORCYTE's management simulation program

(MANAFOR) include variables such as site preparation options, regeneration delay, species mixture, brush competition, brush control, thinning, fertilization, pruning, utilization level of different plant components, burning and rotation length. These variables do not specifically match the management variables used in the Corns and Annas (1986) field guide which include: season of harvest; logging method; site preparation intensity; soil compaction hazard; soil puddling hazard; soil water erosion hazard; species, method, limitations and frost heave hazards for reforestation; type and severity of vegetation competition; windthrow hazard; and snowshoe hare damage hazard. Most of these variables cannot be directly simulated by FORCYTE-11 but there are some overlapping spheres of interest. To fully evaluate the potential role of FORCYTE-11 in boreal mixedwood management it would be necessary to assess the degree to which MANAFOR simulations can contribute directly to management interpretations such as those suggested by Corns and Annas (1986). For example, FORCYTE-11 produces output files that describe biomass and nutrient accumulation over time in various plant components. The output from MANAFOR includes predictive tables on yield, site biogeochemistry and ecosystem processes. The potential for site quality to decline or improve as a result of management practices can be simulated by FORCYTE-11 and this provides a link with site quality at a given time as defined by a classification system.

5.4 The Prospect for Use of FORCYTE-11 by Forest Managers

The 1988 interviews led to the general conclusion that a modelling framework such as FORCYTE-11 will not be applied operationally until site classification systems are in place and in widespread use. This will not happen quickly because site classification faces its own problems of acceptance by potential users (Corns 1988). The latter author listed the following deterrents to widespread use of site classification in mixedwood forest management: information is often not available or it is not yet mapped; users may be uncomfortable with the classification system; it takes time to quantify management responses before they can be applied; and forest management is not yet intensive, so some managers question the need for site classification. Once site classification is more widely used there will be more interest in developing new techniques for forecasting potential changes to ecosystem units that are defined by the site classification system. Amongst the new techniques that will aid this evolution are expert systems such as ASPENEX which provide an interface between predictive models and a geographic information system for aspen management (White and Morse 1987).

Quite apart from its dependency on the acceptance of site classification, FORCYTE faces two other deterrents to its use: a relative lack of interest, amongst mixedwood forest managers, in the processes that the model simulates; and the model's complexity. The FORCYTE-11 modelling framework was designed to simulate several forest management activities that do not appear to be of much interest yet to managers in the Mixedwood Section-fertilization and thinning are the most obvious examples. This poses at least temporary limitations on the degree to which FORCYTE can be evaluated in the boreal mixedwood context.

Predictions from complex models are difficult to check because of limited data on actual events over several decades of forest ecosystem development. This limitation will remain as long as there is little activity or interest in nutrition management in boreal mixedwoods; without such interest there will not be information and experience with which to judge the reasonableness of FORCYTE's predictions. FORCYTE's intended roles of simulating forest nutrient cycles and predicting possible long-term consequences of intensive biomass harvesting will be more readily evaluated in forest regions where fertilization and nutrition management are now operationally implemented. For example, those forest ecosystems in British Columbia and the Pacific Northwest in which fertilization is now a part of forest management are better sites for evaluation of FORCYTE-11 than are the less intensively managed boreal mixedwoods.

Despite these present deterrents to use of models such as FORCYTE by managers in the Mixedwood Section, it is important for someone to plan for the longer term for which forecasts are needed. An example of this need is the unforeseen ecological consequences of specific policies to convert mixedwood stands to conifer plantations in Sweden (Gamlin 1988). The rethinking of intensive forestry practices, including the ecological consequences of fertilization, that is now occurring in this Swedish example is a foretaste of the kinds of assessments that Canada's boreal mixedwood managers may face in the near future. Such a forecasting need is one reason why there should be continuing efforts to bring ecosystem models and trend evaluators such as FORCYTE-11 from their present research role to a broader planning role.

5.5 Modification of FORCYTE-11 to Address Specific Mixedwood Management Problems

The persons interviewed in 1988 were not specifically asked how FORCYTE-11 might be modified to make it more responsive to their present forest management concerns. However, if the present review stimulates others to search for mutually beneficial interactions between ecologically-based computer simulation of productivity processes and present site classification work in the Mixedwood Section, then there should be serious consideration of how the FORCYTE modelling framework should be amended to improve its acceptance as a trend evaluator. For example, it is possible that FORCYTE-11 would become a more accurate simulator if soil moisture and temperature were added as input parameters. However, for management purposes there is considerable incentive to simplify the model rather than make it more complex. Developers of the model have cautioned that, even if simplified, FORCYTE remains a predictive model; unlike explanatory or retrospective models, predictive models are encumbered by the difficulty of obtaining information with which to validate the model's predictions over long time scales (pers. comm., J.P. Kimmins, University of British Columbia, November, 1987). An important point in relation to predictive models, especially those that attempt to incorporate ecological as well as economic criteria, is that the setting that one attempts to simulate is often very changeable. It was evident even in the short period of this review in 1988 that technical factors such as utilization, economics and climate, as well as social factors such as professional opinions and public perceptions, are rapidly changing.

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