USING THE STEMS AND FORCYTE-11 COMPUTER MODELS FOR MIXEDWOOD FOREST MANAGEMENT

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There is an increasing need for management tools for forests of trembling aspen (Populus tremuloides Michx.) and white spruce (Picea glauca Moench [Voss]) in western Canada. Traditional growth and yield methods based on data from unmanaged stands may be inadequate for forecasting yields resulting from the expected new approaches to mixed stand management.

FORCYTE-11 is a large forest ecosystem simulation model that can be used to predict and to compare forest biomass growth and yield for alternative resource management strategies for which there may be little or no direct empirical data. It permits the inclusion of more than one tree species and accounts for inter- and intra- species competition for light and nutrients. However, the input data required to calibrate the model may not be easily available or may be expensive to collect. An alternative approach is described in which a traditional growth and yield model (STEMS) has been modified to provide the needed ecosystem description for FORCYTE-11. This method only requires the conventional stand parameters such as stand age, average stand Dbh, stand density, and site index.

Favourable preliminary results with calibrating FORCYTE-11 for aspen have encouraged us to extend this method to ecosystems. In this paper application of this approach to a range of site classes will be discussed. Because this approach requires only commonly available stand parameters, it can potentially provide a practical link of FORCYTE-11 to regional databases through geographic information systems.

On a de plus en plus besoin d'outils de gestion utilisables dans le cas des forêts mélangées de tremble (Populus tremuloides, Michx.) et d'épinette blanche (Picea glauca Moench [Voss]) dans l'ouest du Canada. Les méthodes traditionnelles de calcul de la croissance et du rendement basées sur des données recueillies à partir de peuplements non gérés peuvent se révéler inadéquates pour prévoir les rendements résultant de l'application de nouvelles approches de gestion des peuplements mélangés.

Le FORCYTE-11 est un important modèle de simulation de l'écosystème qui peut servir à prévoir et à comparer la croissance et le rendement de la biomasse forestière que l'on obtiendraient avec diverses stratégies de gestion des ressources sur lesquelles on ne possède pour ainsi dire pas de données empiriques directes. Ce modèle permet l'inclusion de plus d'une essence et tient compte de la compétition interspécifique et intraspécifique pour ce qui est de la lumière et des éléments nutritifs. Toutefois, l'obtention des données nécessaires pour étalonner le modèle peut se révéler difficile ou coûteuse. On décrit une autre aproche dans laquelle un modèle classique de croissance et de rendement (STEMS) a été modifié pour fournir la description de l'écessaire au FORCYTE-11. Avec cette méthode, il suffit de connaître les paramètres classiques liées au peuplement, comme l'âge du peuplement, le Dhh moyen pour le peuplement, la densité du peuplement et l'indice de station.

Les résultats préliminaires favorables obtenus avec l'étalonnage du FORCYTE-11 appliqué au tremble nous ont encouragés à appliquer cette méthode à des écosystèmes mélangés. Dans ce document, on traite de l'application de cette approche à une variété de classes de site. Comme cette approche ne nécessite que les paramètres relatifs aux peuplements dont on dispose normalement, elle pourrait servir de lien pratique entre le FORCYTE-11 et les bases de données régionales grâce à des systèmes d'information géographiques.

INTRODUCTION

The forests of the boreal mixedwood (MW) region contain a mix of heterogeneous ecosystems. Stand composition varies from pure hardwoods, dominated by aspen (Populus tremuloides Michx.), to pure softwoods, of which white spruce (Picea glauca Moench [Voss]) is commercially the most important. A full spectrum of mixtures of sizes and percentages of these two species exist between these extremes. The variation in stand composition is due mainly to site history (particularly the occurrence and severity of fires) as well as site and soil conditions.

Traditionally, white spruce has been favoured by the forest industry while aspen was considered a "weed" species. Improvements in harvesting and processing technology, however, have increased the potential for aspen utilization as indicated by recent announcements of new mill projects in western Canada, particularly in the province of Alberta. Moreover, forecasted global wood supply shortages will increase the incentives to use all major boreal MW tree species as sources of wood, fibre and energy. These pressures are compounded by environmental concerns such as global climatic warming and acid rain. Counterbalancing the need to maximize economic return from the forest is a growing requirement to ensure long-term sustainability and to minimize undesired environmental effects.

These pressures, together with the complexity of the MW forest itself, present a cogent challenge to the manager of the MW forest; he truly must be armed with a powerful crystal ball. In the absence of such omniscience, simulation models may be the best tools for predicting the results of today's decisions on tomorrow's forests. With appropriate models, different scenarios (e.g., management alternatives to meet changing economic, political, or environmental objectives) may be examined for both short-term returns and their longer-term consequences. Such information will be increasingly needed to help the decision-maker make more informed choices.

In this paper preliminary work with two models which have potential application to MW forest management is presented. STEMS (Stand and Tree Evaluation and Modeling System, U.S.D.A. Forest Service, 1979) is a conventional growth and yield model built on a large empirical database. FORCYTE-11, discussed elsewhere in these proceedings, is a more flexible, but more complex, model which employs both process simulation and empirical biomass chronosequence data. We also describe initial attempts to use a modified PC version of STEMS (STEMS*, Grewal *et al.* 1989) to provide the empirical biomass data required to calibrate FORCYTE-11 for white spruce - aspen MW stands.

STEMS MODELING OF MIXEDWOOD STANDS

The projected development of a typical MW stand of fire origin was performed with STEMS. As a simple example of how the model might be used to assist management decisions, the effect of site quality on the relative performance of the two species was examined. Three sites, ranging from site index[1] 12m to 24m for spruce, were compared. Initial stand conditions emulate aspen with an understorey of spruce which is 10 to 20 years younger (Johnson 1986):

aspen: 2500 stems/ha, 9 cm average Dbh, at year 30
white spruce: 6200 stems/ha, 4 cm avg Dbh, year 30

Normal size class distributions were assumed for both species using the treelist generation program TREEGEN of TWIGS, the PC version of STEMS described by Miner *et al.* (1989).

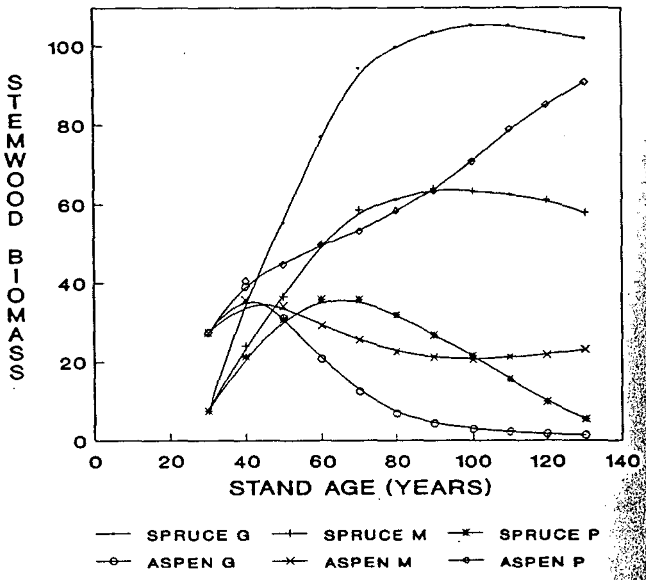

FIGURE 1: STEMS projections of stemwood biomass for white spruce and aspen on three sites. GOOD: SI-24M MEDIUM: SI-18M POOR: SI-12M. (biomass in t/ha)

The medium site shows the response often observed in MW stands - the aspen biomass peaks at about age 40 with the white spruce assuming dominance to reach its maximum 40 to 50 years later (Figure 1). This response is even more pronounced on the good site, but on a poor site, the spruce has a difficult time competing with the aspen over the entire rotation.

Although these results are in keeping with current management thinking (i.e., spruce regeneration on poor MW sites is uneconomic), they must be qualified. For simplicity, we have ignored early stand development and assumed the same stocking densities and size classes at year 30, a situation that is unlikely in reality. STEMS is limited by the availability of suitable regression equations used and the paucity of good regression coefficients for

[1] Site index, a common measure of site productivity and one of the parameters used in STEMS, is the average height of the dominant and co-dominant tree at the reference age of 50 years.

small biomass classes impedes its use for very young stands. Unfortunately, there is good evidence that the early development and inter-species competition in multiple species stands can be very significant to the eventual development of the stand. Correcting this difficulty in STEMS is beyond the scope of this paper.

STEMS assumes that the site productivity (site fertility conditions) does not change when management treatments (e.g., harvest, release of spruce from aspen, etc) are carried out. Its projections are based on the historically observed tree growth patterns, averaged over many stands and not on simulation of processes such as nutrient dynamics. It is thus not well suited to investigate long-term impacts on the site, or to predict the results of new silvicultural or harvest treatments which might create growth conditions for which there may not be empirical data.

FORCYTE-11 DATA NEEDS FOR MIXEDWOOD FORESTS

In contrast to STEMS, FORCYTE-11 is a complex model requiring considerable initial set up and calibration effort by the user. A hybrid stand-level yield simulation model, it bases its predictions on empirical data that describe the observed patterns of biomass accumulation in existing stands (historical bioassay (HB) data, Kimmins and Scoullar 1989). For a two species MW stand, such HB data is required separately for each tree species to be modelled in the management simulator MANAFOR and for a suite of site nutrient qualities representing the range of managed stand growth conditions. Additional nutrient and soils data is also required for each site as discussed in Grewal *et al.* (1989) and Kimmins and Scoullar (1989). These references also discuss the standard methods for calibrating FORCYTE-11, and the reasons and rationale for the use of STEMS* to short-cut this process.

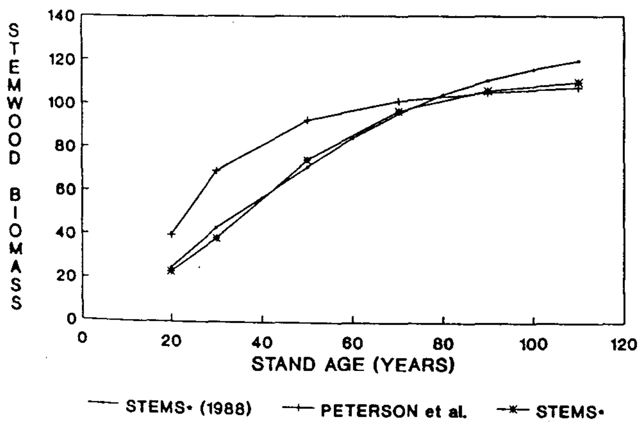

FIGURE 2: STEMS* projections vs data set from Peterson *et al.* 1988 for aspen stemwood biomass. STEMS* SI-17M Peterson Site Quality- 50
1988 STEMS* from Grewal *et al.* (1989) (biomass in t/ha)

Aspen Data Set

Since initially reported, STEMS* has been improved by inclusion of a new diameter adjustment function (Holdaway 1985). It now generates biomass accumulation curves which more closely match with the quasi-empirical (literature based) data assembled by Peterson *et al.* (1988). Data for stemwood biomass are shown in Figure 2 for a stand of 9900 stems/ha, average Dbh of 4.5 cm at age 20, and site index of 17m at age 50 years.

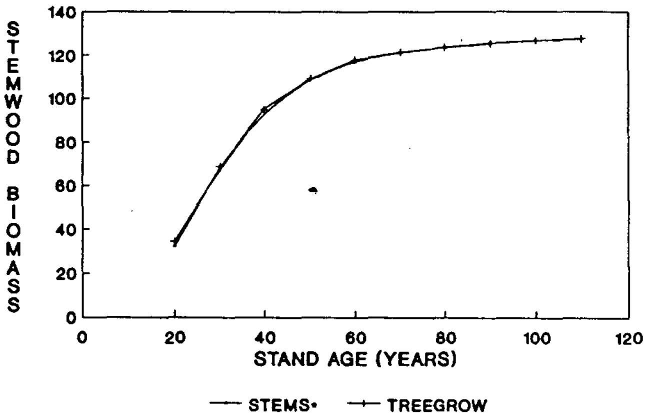

FIGURE 3: STEMS* vs TREEGROW projection for medium site white spruce stemwood biomass. (biomass in t/ha).

White Spruce Data Set

In the absence of an empirical calibration of FORCYTE-11 for white spruce, the STEMS* approach was used as follows. STEMS growth and mortality functions for white spruce, together with biomass equations for stemwood, stembark, foliage, and crown biomass components from Baskerville (1965), were incorporated in the modified white spruce STEMS* model. Initial monoculture stand conditions, from plantation data (Stiell and Berry, 1973), were used in STEMS* to generate the required biomass HB data from 20 to 115 years. The foliage biomass predicted by the Baskerville regression equations were unrealistically high, and were reduced using ratio factors obtained from Yarie's (1988) white spruce data set for FORCYTE-10. Other input parameters (photosynthesis, light saturation curves, tree heights, canopy thickness, etc.) were estimated from values in the literature and from the calibration of FORCYTE-11 for another conifer (Douglas-fir).

While the values obtained by the above process appear credible, the result must be considered a <u>prototype</u> calibration data set only. FORCYTE-11's TREEGROW subprogram uses these data to effectively parameterize the tree growth simulation sub-model. It also uses these calibrated routines to generate output diagnostic curves of simulated biomass, and other ecosystem component dynamics. When the prototype spruce data was used (Figure 3), most simulated biomass components appeared to track the original data quite reasonably. This agreement does not validate the simulation; it does however indicate that the simulations are working plausibly.

FORCYTE-11 MIXEDWOOD SIMULATIONS

Simulation of a MW ecosystem using FORCYTE-11 is accomplished with the management simulator MANAFOR which combines the process simulation sub-models (calibrated within FORSOILS, TREEGROW, etc.). MANAFOR also requires a file called ECOSTATE which defines the initial state of the soil resource: ECOSTATE effectively integrates the site history prior to the start of the simulation. This pre-management set up activity (Kimmins 1988, Kimmins and Scoullar 1989) can complicate evaluation and verification of MANAFOR results. Uncertainties and errors in ECOSTATE, or any of the sub-model calibrations, can propagate through the MANAFOR program and confound interpretation of its predictions.

TREEGROW was calibrated by combining the aspen and white spruce data sets into a two-species TREEDATA file. Calibration of the FORSOILS sub-model used the soil data from the pre-existing aspen data set (Peterson *et al.* 1988) which was developed for the MW ecoregion in Alberta (the two species sharing the same soil stratum are assumed to compete for the available nutrients). The ECOSTATE file was constructed with a spruce-aspen simulation covering 3 rotations of 80 years each. In order to simulate the build-up of soil nutrient capital, about 30% of the biomass was left to decompose in the forest floor after each rotation.

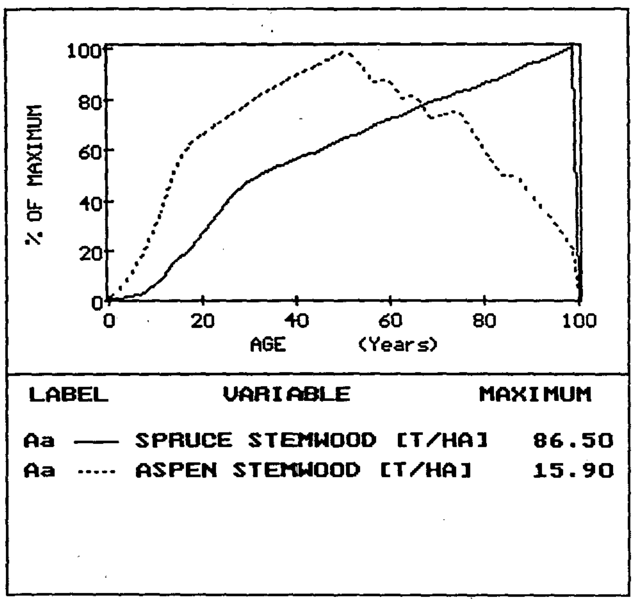

FIGURE 4: Aspen and white spruce stemwood biomass simulated by MANAFOR. Graph produced by PROBE Display Manager (MacIsaac *et al.* 1989.

To demonstrate model performance, a 100 year MW rotation was simulated. During the first year, 5 000 white spruce seedlings were planted and 90 000 aspen suckers were allowed to sprout. The spruce eventually dominates over aspen through competition for light and nutrients (Figure 4), in agreement with expected MW stand development. In addition, although the absolute values are of unknown accuracy, they are of the right magnitude. The model which is driven by the photosynthetic process through foliar nitrogen content, permits the success of the low density spruce through at least four mechanisms:- 1) longer retention of spruce foliage; 2) deeper spruce canopy development; 3) shade tolerant spruce foliage; and 4) less shade tolerant foliage for aspen.

In this simulation there was inadequate self-thinning of the spruce which may be related to the relative initial densities of the two species. This problem was significantly reduced when simulations were performed with nutrient limitation to growth disabled. It thus appears that the model (calibrated with the prototype MW data) puts more emphasis on competition for nutrients than for light.

We cannot unambiguously differentiate between data set errors or model inadequacies from the results to date. Before MW management simulations (planting regimes, release of spruce, thinning, etc.) can be attempted, further refinements of the prototype calibration must be made. In addition, the benchmark version of the FORCYTE-11 model was received after this manuscript was prepared and many of our concerns may be resolved when it is tested.

CONCLUSIONS

Preliminary investigations of two very different models, one an empirically-based conventional growth and yield model, and the other a hybrid simulator, have been performed. While both models can be used to assist forest managers in forecasting the results of today's actions on tomorrow's MW stands, they provide different levels of information, with different levels of certainty, and require different levels of user effort.

STEMS is easier to use and more believable in the short-term. However, it cannot account for changing site fertility conditions which could arise from intensive management or other factors such as climate change. In addition shortage of good regression equations for small biomass classes hinders its application to early stand development and inter-species competition, a problem of current MW management concern.

FORCYTE-11 permits greater flexibility for changing site growth conditions by including process simulation of competition for light and nutrients. However, it is both more complex to run and requires considerable site specific data. In addition, an assessment of the accuracy of its predictions has not yet been performed.

The preliminary use of STEMS* to provide part of the site-specific calibration data for FORCYTE-11 MW applications has been encouraging, but further work is needed before an adequately calibrated model is ready for application and evaluation.

ACKNOWLEDGMENTS

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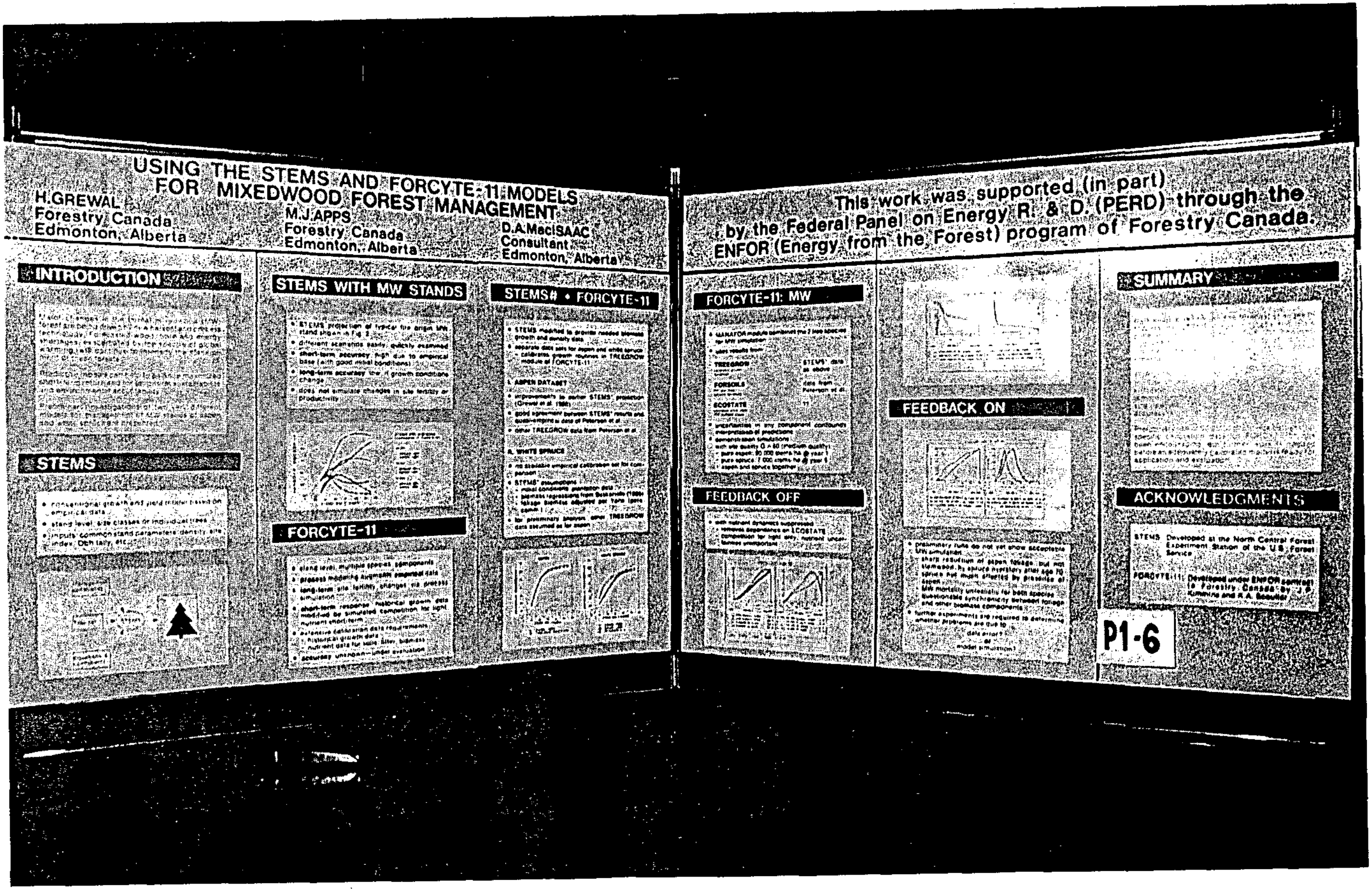
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INTRODUCTION
STEMS
STEMS WITH MW STANDS
different scenarios easily, quickly examined
short-term accuracy high due to empirical base (with good initial conditions)
long-term accuracy low if growth conditions change
does not simulate changes in site fertility or productivity
FORCYTE-11
STEMS# • FORCYTE-11
I. ASPEN DATASET
II. WHITE SPRUCE
FORCYTE-11: MW
TREEGROW
FORSOILS
ECOSTATE
FEEDBACK OFF
FEEDBACK ON
SUMMARY
ACKNOWLEDGMENTS
STEMS Developed at the North Central Forest Experiment Station of the U.S. Forest Service
P1-6

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