USING FORCYTE-11 TO EXAMINE THE POTENTIAL EFFECTS OF INTENSIVE MANAGEMENT AND INCREASED UTILIZATION ON THE LONG-TERM PRODUCTIVITY OF DOUGLAS-FIR FORESTS

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As the demand for forest products escalates, forest managers are increasingly concerned about the possible detrimental effects of intensive management and increased biomass utilization on the long-term productivity of forest lands. The best estimate of the effects of current or planned management practices on future site productivity comes from multi-rotation long-term experiments. However, forest planners require more immediate estimates for allowable cut determinations. In addition, increased public awareness of the planning process requires that forest managers address the problem now. Simulation modeling can provide a means to integrate and project forward the results of current studies. The FORCYTE-11 computer simulation model has been calibrated for Douglas-fir forests using literature and inventory data. It is being used to examine the consequences of shorter rotations, increased biomass utilization, and slash burning on the long-term productivity of good and poor quality Douglas-fir sites. Current plans are to use the model to rank the projected effects of different management scenarios on long-term site productivity in preparing 10-year management plans for western Oregon.

Au fur et à mesure que la demande de produits forestiers monte en flèche, les gestionnaires forestiers sont de plus en plus préoccupés par les effets néfastes possibles de l'aménagement intensif et de l'utilisation accrue de la biomasse sur la productivité à long terme des forêts. La meilleure estimation de effets des pratiques de gestion actuelles ou prévues sur la productivité future des sites dont on dispose a été fournie par des expériences de multi-rotation à long terme. Toutefois, les planificateurs forestiers ont besoin d'évaluations plus immédiates pour déterminer quelles sont les coups permissibles. En outre, la conscientisation du public en ce qui concerne le processus de planification exige que les gestionnaires forestiers résolvent ce problème dès maintenant. Les modèles de simulation peuvent constituer un outil d'intégration et d'extrapolation à partir des résultats des études courantes. Le modèle de simulation par ordinateur FORCYTE-11 a été étalonné pour être applicable aux forêts de pin Douglas grâce à des données recueillies dans la documentation et dans des inventaires. Il servira à étudier les conséquences de rotations plus courtes, de l'utilisation accrue de la biomasse, et du brûlage de rémanents sur la productivité à long terme des forêts de pin Douglas de bonne et de mauvaise qualité. Actuellement, on cherche à utiliser le modèle pour classer les effets prévus de différents scénarios d'aménagement sur la productivité à long terme des sites, dans le cadre de la préparation de plans d'aménagement décennaux dans l'ouest de l'Orégon.

INTRODUCTION

In order to estimate the long-term effects of forest management practices without monitoring yield over several rotations, a method is needed to integrate and project forward the results of current and past studies. Simulation modeling can provide such a method and enable land managers to predict the long-term consequences of various silvicultural practices. In addition, models provide researchers a method to integrate existing knowledge and to test hypotheses.

In this study we worked with FORCYTE-11, a highly flexible modeling framework which can be used to simulate the growth, yield, and nutrient cycling in a wide variety of even-aged forests (Kimmins 1988; Kimmins and Scoullar 1984). FORCYTE-11 was calibrated to simulate the growth of Douglas-fir forests in Western Oregon using a combination of literature and inventory data. The growth and nutrient cycling of the understory vegetation was not simulated for this project.

FORCYTE-11 tracks the biomass and nutrient content of all decomposing tree and understory components separately. Each type of material begins with a specified nutrient content as litterfall and decomposes for a specified number of years after which the remaining material becomes soil organic matter (SOM). The nutrient content of decomposing material approaches that of SOM as it decays. Decomposition rates can vary with both the age of the material and site quality. The decomposition rates for forest floor materials and SOM, and the nutrient concentrations of all materials are slightly higher on better sites in our data set. In FORCYTE-11 the decomposition rates of all materials can change after clearcutting and gradually return to pre-harvest levels as crown closure is reached. Based on data from Erickson et al. (1985) we slowed the decomposition of branches by 20% after clearcutting. Lacking any other data, we set the remaining decomposition rates to remain constant after clearcutting.

Initial model calibration requires building a simulated forest floor. This was accomplished by running the model with nutrient feedback disabled, allowing simulated growth to match that predicted by the input data. The model was run for seven consecutive 90-year rotations in this manner. At this point the forest floor contained litter in various stages of decomposition, including many logs, and the SOM pool reached steady state. The model was then used to test the effect of rotation length, increased biomass utilization, and slash burning on long-term site productivity. Rotation lengths of 90, 45, and 30 years were simulated for a period of 540 years. All rotations started with a planting of 1500 seedlings/ha. Two utilization levels were considered. Stems-only utilization removed 85% of stem wood and bark at harvest. Whole-tree harvesting removed 90% of the stem wood and bark and 70% of the branches and foliage from the site. The 90-year rotation was chosen to represent low intensity forestry. The 45-year rotation is similar to that being considered on forest industry lands in the Coast Range of Western Oregon. The 30-year rotation represents extreme biomass harvesting. Four management scenarios were tested:

1. 90-year rotations, pre-commercial thinning age 15 to 750 stems/ha, stems-only harvest
2. 45-year rotations, pre-commercial thinning age 15 to 750 stems/ha, stems-only harvest
3. 45-year rotations, whole-tree harvest
4. 30-year rotations, whole-tree harvest

In addition, scenario 4 was repeated with a moderate slash burn added prior to the initial rotation. This simulation was repeated with fertilization using 200 kg N/ha at age 20 in every rotation.

RESULTS AND DISCUSSION

As expected, the 90-year rotations resulted in fairly constant yields, a stable forest floor, and SOM pool (Figs. 1a,b,c). This was not surprising since the initial forest floor was built using 90-year rotations. The shorter rotations and whole-tree harvesting reduced both the amount of decomposing litter and the SOM pool (Figs. 1b,c). This seemed plausible since shorter rotations and increased utilization removed biomass that would have been deposited on the forest floor and eventually enter SOM

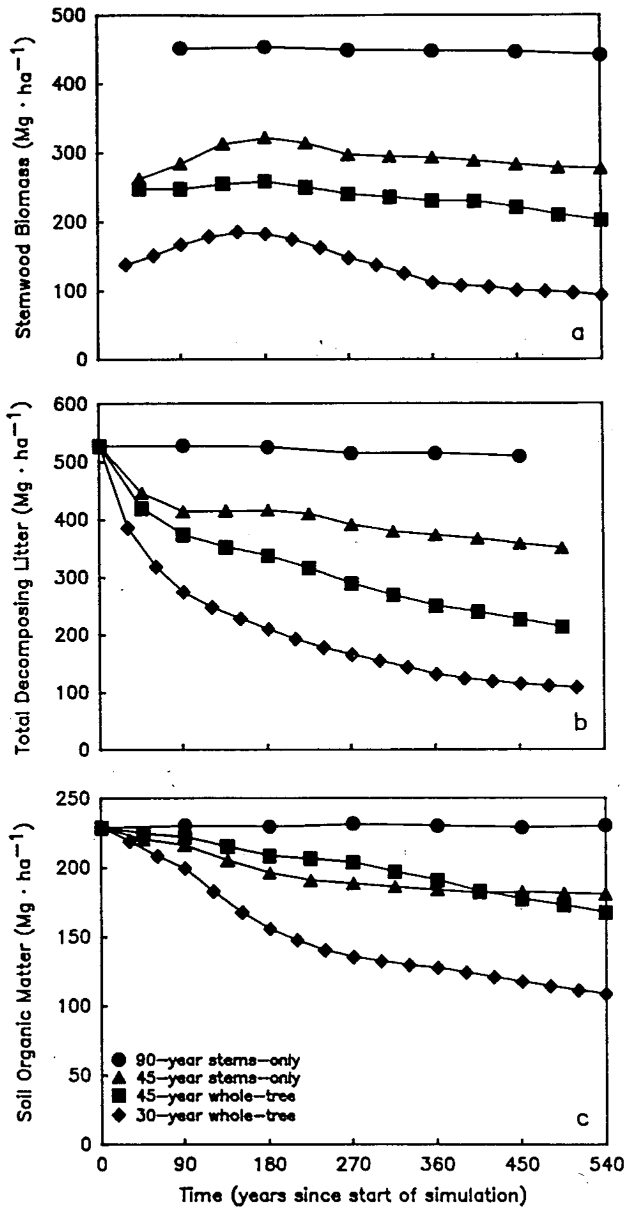

Figure 1. Projected effect of four management systems on forest system behavior over a 540-year simulation. (a) Stemwood biomass accumulation at the end of each rotation. (b) Total decomposing litter at the beginning of each rotation. (c) Total soil organic matter at the start of the simulation and the end of each rotation.

TABLE 1. Predicted cumulative stemwood and total yields for a 540-year simulation under the four management scenarios.

Management Scenario	Stemwood Yield (Mg/ha)	Total Yield (Mg/ha)
1.	2290	2570
2.	2980	3390
3.	2550	3150
4.	2220	2860

through decomposition. The whole-tree harvests also caused eventual declines in yield (Fig. 1a). The greatest cumulative biomass yield over the 540-year simulation came under 45-year rotations with stems-only harvesting (Table 1). The whole-tree harvest scenarios did not include a pre-commercial thinning. The difference in the predicted stemwood biomass production between the 45-year stems-only scenario and the whole-tree harvest scenario in the first rotation was due to the effect of pre-commercial thinning (Fig. 1a).

The amount of available soil N often increased during the first 150-180 years under the more intensive management scenarios, after which it decreased, often to levels below those of the first rotation. The initial increase in available soil N caused yield to increase for the first several rotations under short rotation management (Fig. 1a), and then eventually drop in later rotations as available N decreased. This effect in the model was caused by an interaction between two factors. Increased removal of tree biomass decreased forest floor biomass (Fig. 1b) which reduced the amount of N immobilized annually by forest floor decomposition. This left more available N for uptake by plants (cf. Vitousek and Matson, 1984). However, the increased biomass removals eventually lowered the input to SOM. As the amount of SOM decreased, the amount of N mineralized by SOM decomposition dropped, causing a decrease in available N in later rotations.

We simulated a moderate burn before the initial rotation of management scenario 4. The model predicted an earlier peak and more rapid decline in yield than with no burn (Fig. 2). The burn immediately removed a portion of the forest floor causing a decrease in N immobilization and increased N availability for tree growth. However, the decline in SOM was more rapid causing a faster decline in yield than with no burn.

We repeated the initial burn and 30-year rotation scenario with the addition of 200 kg/ha N in fertilizer at age 20. The fertilizer increased growth dramatically, but a slight downward trend in yield due to loss of SOM was evident (Fig. 2).

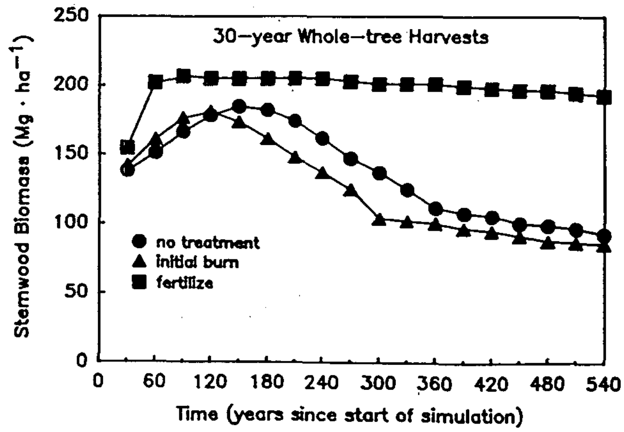

Figure 2. Predicted stemwood biomass accumulation at the end of each 30-year rotation under three management scenarios. All scenarios included whole-tree harvests. 1. No other treatment. 2. Moderate slash burn before initial rotation. 3. Same as 2., but fertilization with 200 kg N/ha at age 20 in each rotation.

In our simulations N availability varied by as much as 30 kg/ha between the highest and lowest yielding rotations. In a simulation exercise to examine the response of northern forests to climatic change, Pastor and Post (1988) found that their LINKAGES model predicted changes in forest vegetation type which altered soil N availability by as much as 40 kg/ha over a 500-year period. Hence, the changes in forest floor mass caused by shorter rotations and whole-tree harvests predicted by FORCYTE-11 might also affect N availability.

The predictions of increased yields during the first several rotations under more intensive management or from fertilization were a direct result of the underlying assumption that N was the only nutrient limiting tree growth. If another factor were to become limiting during the flush of increased N availability such growth responses would be diminished or perhaps not occur at all. The FORCYTE-11 model can simulate the cycling of several nutrients simultaneously and we plan to include other nutrients in future simulations. Certainly factors other than nutrient availability, such as soil moisture, can limit growth, but these are beyond the present scope of FORCYTE-11.

The model projections indicate that large woody debris from the last rotation can have a legacy often lasting many years. Decomposing logs provide a source of nitrogen and SOM often lasting in excess of 300 years (Sollins et al. 1987). It is the large woody debris from the original forest floor which is a long term input to SOM in the model. This prevents SOM levels from declining rapidly for at least 100 years under intensive management.

Model predictions of declining SOM levels caused by shorter rotations and increased utilization are consistent with agricultural experience. Voroney et al. (1981) measured losses of organic C resulting from 70 years of cultivation of the native Saskatchewan prairie. They reported an average of 38% of the organic C was lost from the soil profile. Van Veen and Paul (1981) modelled organic C dynamics in grassland soils. Their model showed sharp decreases in soil C as a result of cultivation of native grassland with C levels eventually stabilizing after 300-400 years.

CONCLUSIONS

The FORCYTE-11 model provides a plausible simulation of the growth and N cycling of a western Oregon Douglas-fir stand on a moderate site. Low intensity management characterized by 90-year rotations are projected as maintaining yield levels and site productivity. The model predicts that rotations of 45 years do not seriously degrade site productivity. Short rotations and whole-tree harvests are predicted to cause eventual declines in long-term productivity.

The 45-year, stems-only management scenario is projected as causing a 21% decline in site SOM while the 30-year whole-tree harvesting scenario caused a 53% decline over a 540-year period. The shorter, more intensive management scenarios also caused a major decline in the forest floor biomass, especially large woody debris. Both SOM and large woody debris serve functions in the forest ecosystem which are not thoroughly understood and not simulated in FORCYTE-11. For example, decaying logs can provide habitat for small mammals, including species important in dispersal of mycorrhizal spores critical for stand reestablishment (Maser et al. 1978;Franklin et al. 1981). Therefore, it may be more prudent to use more moderate rotations to protect SOM levels and provide some forest floor diversity until further research and improved models can sharpen our predictive abilities. It certainly appears that very short, whole-tree harvests should be avoided.

The model predictions should be viewed with caution. Actual numbers are only reported to indicate trends and compare alternatives. The model has not been validated against any long term experimental data. Hence, the precision and accuracy of the results are unknown.

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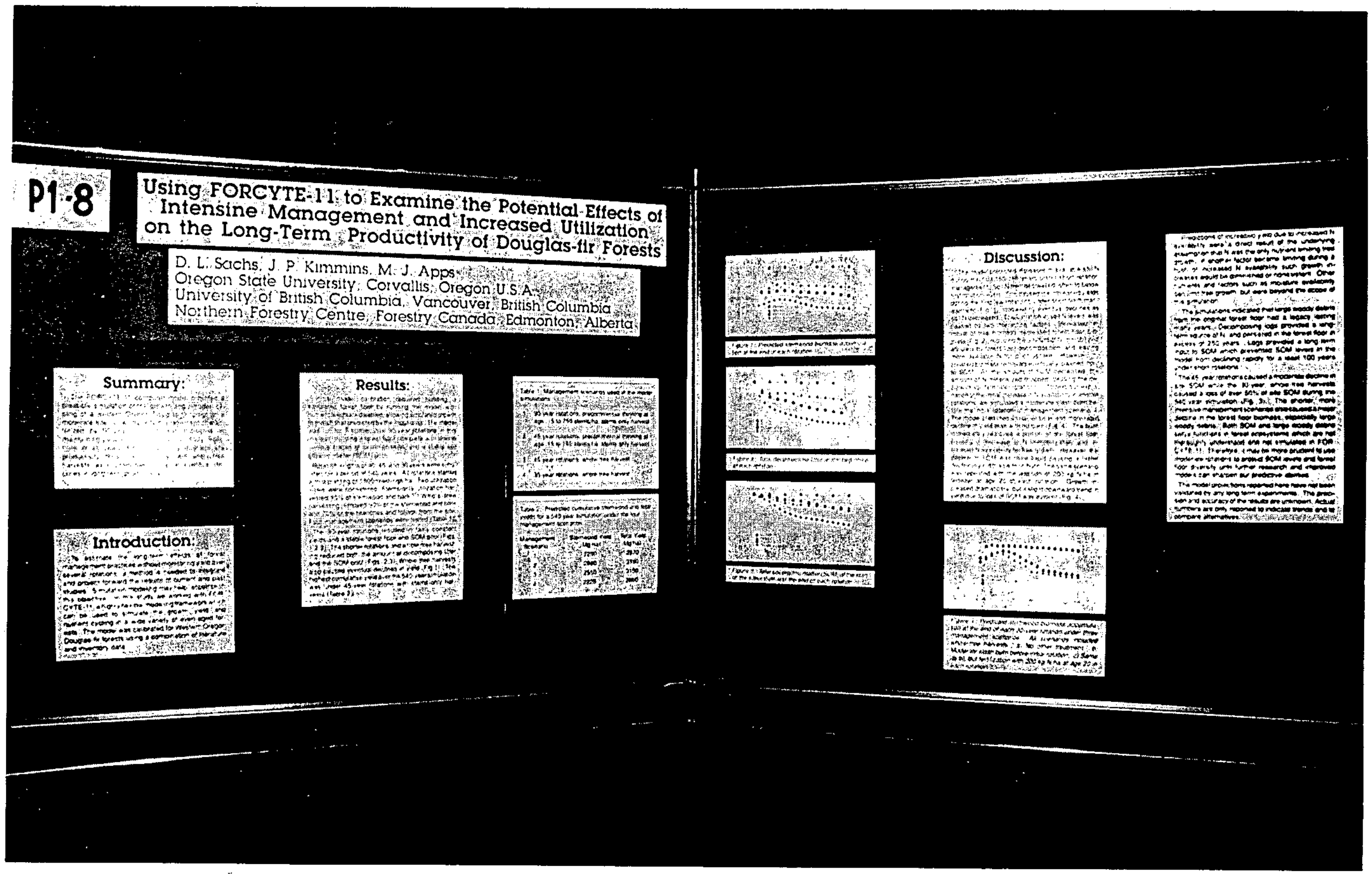
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Summary:
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Results:
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