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Regression equations applicable to biomass components of stands of western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] were developed by destructive sampling of a thinned and an unthinned stand of western hemlock near Seaside, Oregon. Equations predicted more live-branch biomass and less dead-branch biomass per tree for the thinned stand, but equations for biomass of foliage, twigs, stem wood and stem bark did not differ significantly between stands. Concentrations of N, P, K, S, Ca, Mg, and Mn in tree components were determined and aboveground tree biomass and nutrient content were estimated for both stands.

The biomass data was used in conjunction with published data to modify an existing computer model in order to simulate growth and nutrient cycling of western hemlock stands. The FORCYTE computer model, originally developed for Douglas-fir forests in British Columbia by J. P. Kimmins and K. Scoullar, was used. Calibration runs indicated that yield in FORCYTE was extremely sensitive to the parameter defining the rate of mineralization of soil organic matter, a process which supplied the majority of N available for tree uptake. The mineralization rate was set initially so that yield remained constant in three succesive 90 year rotations, which resulted in a 4.1% loss of soil organic matter over the 270 year period. Simulations of 6 different 270 year management scenarios of varying intensity indicated that more intensive management (e.g., whole-tree harvesting and commercial thinning) caused faster depletion of soil organic matter and site N capital, resulting in an eventual decline in site productivity in later rotations. Simulations suggested that hemlock forests may not begin to accumulate soil organic matter until they approach old-growth status. Predicted declines in soil organic matter caused by intensive management were compared to documented losses of organic matter in agricultural systems. FORCYTE predicted soil organic matter would eventually equilibrate in about 1500 years when inputs to the soil organic matter pool balanced decomposition, resulting in an equilibrium yield level well below that of the first rotation, but sustainable in perpetuity. The strengths and weaknesses of the FORCYTE model are discussed. The predicted trends are based on currently available information, but it must be realized that as more information becomes available, predictions will inevitably change.

Management Effects on Nitrogen Nutrition
and Long-term Productivity of Western Hemlock Stands:
An Exercise in Simulation with FORCYTE

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TABLE OF CONTENTS

Page

I. INTRODUCTION 1

II. DISTRIBUTION OF BIOMASS, NUTRIENTS, AND AVAILABLE NITROGEN IN A THINNED AND AN UNTHINNED STAND OF WESTERN HEMLOCK 2

- Introduction 2
- Study site 3
- Methods 4
- Results and discussion 7

III. MANAGEMENT EFFECTS ON NITROGEN NUTRITION AND LONG-TERM PRODUCTIVITY OF WESTERN HEMLOCK STANDS: AN EXERCISE IN SIMULATION WITH FORCYTE 19

- Introduction 19
- Description of FORCYTE 20
- Calibration for western hemlock 21
- Results and discussion 27
- Conclusions 39

IV. BIBLIOGRAPHY 42

V. APPENDIX 49

LIST OF FIGURES

Figure		Page
1.	Distribution of N, P, and K in the aboveground tree biomass of an unthinned stand of western hemlock near Seaside, Oregon.	16
2.	Predicted levels of available N, stored N, and leaching of NO_3^- during a 90-year rotation.	28
3.	Predicted annual net primary production, biomass harvested, and biomass of forest floor plus soil organic matter during a 270-year simulation under six different management scenarios.	31
4.	Predicted yields over 40 rotations under management scenario D as described in Figure 3.	38

LIST OF TABLES

Table		Page
1.	Biomass components of a 30-cm tree as predicted with equations developed from data for trees at Haney British Columbia (Krumlik 1974) and at Seaside, Oregon.	9
2.	Biomass equations for coastal western hemlock.	10
3.	Nutrient concentrations (%) in tree components.	12
4.	Component biomass and nutrient content of thinned and unthinned stands of coastal western hemlock.	14
5.	Nitrogen status of the forest floor and mineral soil of a thinned and an unthinned stand of coastal western hemlock.	15
6.	Predicted biomass of forest floor components in a 90 year-old stand.	24
7.	Effects of alternate assumptions about the rate of N mineralization after clearcutting upon soil organic matter levels and yields.	35

MANAGEMENT EFFECTS ON NITROGEN NUTRITION AND LONG-TERM PRODUCTIVITY OF WESTERN HEMLOCK STANDS: AN EXERCISE IN SIMULATION WITH FORCYTE

INTRODUCTION

The major objective of this research was to investigate the long-term effects of intensive management on site productivity of Oregon coastal western hemlock forests. This was done with the aid of FORCYTE, a mangement-oriented simulation model of forest growth and nutrient cycling. FORCYTE was originally developed for Douglas-fir forests in British Columbia and required modification to simulate western hemlock forests. The first paper in this thesis describes the collection of data necessary for the modification of FORCYTE, including: development of biomass equations for western hemlock on the Oregon coast, determination of nutrient content of the various tree components, and measurement of mineralizable N, an index of N availability, in the soil and forest floor of the hemlock stands. The second paper details the modification of FORCYTE and the results of the simulation.

DISTRIBUTION OF BIOMASS, NUTRIENTS, AND AVAILABLE NITROGEN IN A THINNED AND AN UNTHINNED STAND OF WESTERN HEMLOCK

Introduction

As forest management intensifies and rotation lengths shorten, the concern is that removal of large amounts of nutrients from forests may adversely affect site productivity (e.g., Leaf 1979). Methods for quantifying the biomass and nutrient content of forest stands are needed for estimating the amounts removed by various harvest operations. Commonly, regression equations relating the biomass of tree components to diameter at breast height (dbh) are used to estimate forest biomass.

Gholz _et al._ (1979) developed equations for some Pacific Northwestern species of trees, shrubs, and herbs growing mainly in natural, unmanaged, old-growth forest stands. The equations for western hemlock [_Tsuga heterophylla_ (Raf.) Sarg.] combined data from three unmanaged stands--a young coastal stand near Otis, Oregon (Fujimori 1971), an old-growth stand near Haney, B.C. (Krumlik 1974), and an old-growth stand in the Oregon Cascades (Grier and Logan 1977). But because management practices such as thinning are known to affect stem form and crown development (Larson 1963; Assman 1970), thereby changing the partitioning of biomass within the tree, biomass equations developed for unmanaged stands may be inaccurate for thinned stands.

The objectives in this study were to develop biomass regression equations applicable to both thinned and unthinned stands of Coast

Range western hemlock, then to measure nutrient concentrations in tree components and use the data with the biomass equations for calculating amounts of biomass and nutrients removed during harvest. Available N in the soil and forest floor was measured in order to learn whether the stands were N limited and in order to assess the potential long-term effects of harvest practices on nutrient availability.

Study site

The two study sites were adjacent 52-year-old stands of western hemlock located on a gentle (0-10°) southwest slope at 250-m elevation in Crown Zellerbach's Clatsop Managed Forest near Seaside, Oregon (T.6 N., R.9 W., Sect. 16). Average minimum and maximum temperatures in this area are 0°C and 8.9°C in January, 11.1°C and 20°C in July. Annual precipitation averages 190 cm, 20 cm falling between May and September (National Oceanographic and Atmospheric Administration records for Seaside, Oregon). The soil is of the Hembre series (fine-loamy, mixed, isomesic, Typic Haplumbrept).

The present stands were established by natural regeneration after logging in the 1920's. One stand was thinned five times between 1960 and 1970 to maintain a basal area of 41 m^2/ha; the other remains unthinned. In 1980, the thinned stand had 700 trees/ha and 66.8 m^2/ha basal area, the unthinned stand 1,110 trees/ha and 81.8 m^2/ha basal area. The understory, dominated by western hemlock seedlings, also includes _Oxalis oregana_ Nutt., _Vaccinium parvifolium_ Smith, _V. ovalifolium_ Smith, _Viola sempervirens_ Greene, _Thelypteris_ phegopteris (L.) Slosson, Montia sibirica (L.) Howell, and Eurhynchium oreganum (Sull.) Jaeg.

Methods

Tree sampling

A diameter-frequency distribution of 5-cm-diameter classes was constructed for each stand from inventory data. The 11 trees selected for sampling in each stand spanned the diameter range and were allocated according to the diameter distribution. Random numbers were used to choose a pair of coordinates on a grid system established at each site, and the tree of the desired diameter class closest to the coordinate intersection was sampled.

In the field, diameter at breast height (1.3 m) of each sample tree was measured before and total height after a tree was felled. The main stem was marked at four points: at breast height, midway between breast height and the first live branch, at 5 cm below the first live branch, and midway in the live crown. The crown was divided into three strata of equal length and all branches were removed from the main stem. After dead branches, dead portions of live branches, and foliage-bearing twigs were separated from live branches, all components were weighed in the field.

In preparation for establishing dry-to-green-weight ratios, a sample branch selected randomly from each stratum was bagged, weighed, and returned to the laboratory for oven drying. Also, the main stem of each tree was cut at the marked points, and a disk removed from the base of each section was weighed and returned to the laboratory for oven drying. Stem sections from each of the smaller trees were further cut into sections approximately 1 m long before weighing in the field. The sub-neiloid formula (Dilworth 1973) was used to calculate volume of stem wood and bark from section length and minimum and maximum diameters of larger stems measured inside and outside the bark at each cut.

In the laboratory, bark and wood from the disks were separated and dried with sample branch components for 1 week at 60°C. Density of wood and bark of the larger stem sections was determined by dividing ovendry weight by green volume, which was measured by water displacement (Forest Products Laboratory 1952). We used the calculated wood and bark densities to convert volumes of large stem sections to ovendry weights. After foliage was separated from foliage-bearing twigs, the ratios of foliage dry weight and twig dry weight to green weight of twigs-plus-foliage were calculated. Dry-to-green weight ratios were calculated for live and dead branches and for wood and bark from smaller stem sections. Green weights of all branch components from each stratum and of bark and wood from small stem sections were converted to dry weights by multiplying by the appropriate dry-to-green-weight ratios.

Ovendry stem wood, stem bark, and sample branch components were ground in a Wiley mill to pass through a 40-mesh screen (0.419 mm opening). The diameter range was divided into three equal size classes and sample material was composited by class. Foliage was separated by sites and diameter classes (2 x 3 = 6 samples) and stem wood by stem sections and diameter classes (4 x 3 = 12 samples).

N and P were determined with an Autoanalyzer, Technicon method 334-74 A/A, after a standard Kjeldahl digest with a copper-selenium catalyst. Total S was determined by a turbidometric method after dry ashing (Tabatabi and Bremner 1970) and cations by standard methods of atomic absorption spectroscopy after a perchloric acid digest.

Soil and litter sampling

Soil and litter were sampled at six locations at 7-m intervals along a transect through each stand. At each location, all litter was removed from a 25- x 25-cm area and two soil cores were taken from the top 7.5 cm of the mineral soil. All samples were kept in a cooler during transport to the laboratory. Litter samples were weighed fresh, and a 10-g subsample of each was oven dried at 60°C for at least 4 days for determination of moisture content. One soil core from each location was oven dried similarly for bulk-density determination. Exchangeable NH^+_4 was determined by extracting triplicate 5-g subsamples of the remaining litter samples and soil cores with 1 N KCl, and N availability by measuring net NH^+_4 production during a 7-day anaerobic incubation at 40°C (Keeney and Bremner 1966). All NH^+_4-N measurements were made with an ion-selective HNU Systems ammonium electrode.

Regression procedure

Regression equations were of the form $\ln Y = a + b \ln X$, where Y = component biomass and X = dbh. Tree height was not included in the model as it did not significantly decrease the mean square residual for any tree component equation. Regression equations developed for each stand were compared by fitting a full model that included a separate slope and intercept for each stand. The hypothesis that the slopes did not differ significantly was tested by fitting a reduced model with a separate intercept but common slope for each stand and by testing for a significant reduction in the regression sum of squares (Cunia 1973). A similar approach was used to test for a common intercept and to compare regressions from this study with those developed from data taken by Krumlik (1974). All equations were checked for logarithmic bias with a computer program (developed by Bruce Ludwig, Department of Forest Management, Oregon State University) that calculates five correction factors according to methods reviewed by Flewelling and Pienaar (1981). All correction factors applied to the coefficients decreased the accuracy of prediction; therefore uncorrected coefficients are reported here.

Results and discussion

Regression equations

To test whether the development of local regression equations was justified, those from this study were compared with those developed from data taken in British Columbia by Krumlik (1974). Statistically significant differences between sites of the two studies were found in equations for stem wood, stem bark, and foliage biomass. For a tree of a given diameter, the equations from Krumlik's data predicted less biomass for stem wood and more for stem bark and foliage than did those from this study (Table 1).

The local equations for stem wood, stem bark, foliage, and twigs (Table 2) applied equally to both thinned and unthinned stands, with the exception that intercepts for live and dead branches differed significantly (thinned, $\alpha = 0.1$; unthinned, $\alpha = 0.01$). The equations predicted more live-branch and less dead-branch biomass for a given size tree in a thinned than in an unthinned stand. For example, a tree 30 cm in diameter in a thinned stand would have 23.4 kg of live-branch biomass and 7.3 kg of dead-branch biomass, but 17.4 kg and 11.7 kg in an unthinned stand. Such differences are reasonable. A tree in a thinned stand, with more growing space and less self-pruning, should support more live lower branches than a tree in an unthinned stand. Such a tree should also support more foliage biomass; however, thinning did not affect the foliage biomass equations. Nor did the measured ratio of foliar to live-branch biomass per tree differ between the stands (which would have accounted for the lack of difference in the equations). Possibly no difference appeared because the sample size was limited and foliage biomass per tree was highly variable, as evidenced by the foliage biomass equation, which had the highest mean square residual ($S^2_{y.x}$), thus the greatest uncertainty.

Tissue concentrations

The values for foliar N, P and K (Table 3) were similar to those reported by Radwan and DeBell (1980) and Gill and Lavender (1983a) for Coast Range western hemlock. However, the values for foliar Ca, Mg, and Mn were about twice those reported by Gill and Lavender, who

TABLE 1. Biomass components of a 30-cm tree as predicted with equations developed from data for trees at Haney, British Columbia (Krumlik 1974) and at Seaside, Oregon.

Tree component	Biomass, kg Haney	 Seaside
Stem wood	221.85	281.95
Stem bark	48.08	27.45
Foliage	29.13	12.43

TABLE 2. Biomass equations for coastal western hemlock

Component	Coefficients B_0	B_1	B_2	Number of trees sampled	r^2	$S^2y \cdot x$
Equations of the form $\ln Y = B_0 + B_2 (\ln X)$, where X is diameter at breast height (cm) and Y is component biomass (kg).						
Stemwood	-2.681	--	2.447	19	0.98	0.032
Stem bark	-4.371	--	2.259	19	0.97	0.035
Foliage	-6.524	--	2.659	21	0.91	0.157
Twigs	-6.611	--	2.431	21	0.91	0.123
Equations of the form $\ln Y = B_0 + B_1(X_1) + B_2(\ln X)$ where X = diameter at breast height, $X_1 = 1$ if site is thinned, $X_1 = 0$ if site is unthinned, and Y = component biomass (kg).						
Live branches	-4.876	0.306	2.271	21	0.89	0.139
Dead branches	-7.085	-0.474	2.805	21	0.93	0.134

used direct-reading spark-emission spectroscopy after dry ashing (Chaplin *et al.* 1974), a technique that often yields lower values for cation concentrations than the technique used in this study (D. Hanson, Department of Soil Science, Oregon State University, personal communication). Our data for concentrations of N, P, K, Ca, and Mg in most tree components agreed well with data for samples from a stand in the west-central Oregon Cascade Range analyzed with the same techniques (C. C. Grier, unpublished data). Discrepancies were in the concentrations of N, P, and Ca in dead branches, which were about twice as high at the coast sites as at the Cascade site.

Concentrations of N, S, and Mg were higher in dead than in live branches; P, Ca, and Mn concentrations were slightly lower; and K was much lower. Apparently, K was translocated before death, or was leached afterwards. There was no evidence of translocation or leaching of other elements. Possibly the dead branches on the tree suffered a net carbon loss due to microbial respiration during decomposition, which would increase concentrations of the remaining nutrients.

Estimation of nutrient removal by harvest operations

The biomass equations and nutrient data made it possible to estimate biomass and nutrient pools in the Coast Range western hemlock stands from existing forest inventory data (Table 4). Data on total N concentrations in the surface mineral soil (0-20 cm) and forest floor at nearby sites on the Clatsop Managed Forest (J. R. Boyle, unpublished data) were used to calculate total N in the sur-

TABLE 3. Nutrient concentrations (%) in tree components. Standard errors are in parentheses.

Component	Numbers of samples*	N	P	K	S	Ca	Mg	Mn
Foliage	6	1.16(0.007)	0.162(0.013)	0.565(0.036)	0.113(0.007)	0.497(0.047)	0.168(0.015)	0.152(0.017)
Twigs	3	0.827(0.044)	0.116(0.006)	0.437(0.032)	0.084(0.003)	0.120(0.006)	0.120(0.006)	0.074(0.009)
Live branches	3	0.330(0.020)	0.045(0.002)	0.223(0.009)	0.027(0.001)	0.053(0.003)	0.053(0.003)	0.047(0.002)
Dead branches	3	0.373(0.020)	0.035(0.005)	0.030(0.012)	0.048(0.001)	0.063(0.003)	0.063(0.003)	0.044(0.009)
Stem wood	12	0.080(0.003)	0.021(0.001)	0.075(0.005)	0.010(0.001)	0.018(0.002)	0.018(0.002)	0.013(0.001)
Stem bark	3	0.320(0.021)	0.055(0.005)	0.257(0.023)	0.036(0.003)	0.053(0.009)	0.053(0.009)	0.045(0.008)

*Composite samples, see text.

face soil and the forest floor of both thinned and unthinned stands (Table 5). We based mineral-soil bulk density, 0.5 g/cm^3 for the top 20 cm, on data for other coastal Oregon sites (Grier 1976; J. Boyle and K. Baker, personal communications). Table 5 shows that the unthinned stand had accumulated significantly more litter ($\alpha = 0.01$) than the thinned stand. Repeated thinnings probably incorporated litter into the soil, temporarily increased the rate of litter decomposition, and undoubtedly removed most of the trees that would have died and subsequently added wood and foliage to the forest floor.

Data on biomass and nutrient content of stands can be used to estimate amounts of nutrients removed in various harvest operations. For example, a standard-stems-only clearcut would remove 379.8 (275.2 + 104.6) kg N/ha from the site, accounting for 51.2% (37.1 + 14.1) of the total N in the aboveground portions of the trees (Fig. 1). (Not all of this amount would be lost if some slash were left behind.) Whole-tree harvesting would remove nearly twice as much, 740.9 N kg/ha. Delaying removal of felled trees until most of the foliage had fallen could reduce the loss by as much as 181.2 kg/ha, though the reduction would probably be smaller due to some translocation of N back into the twigs before abscission.

Consequences of N and P removal

The N removed by clearcutting constitutes 5.0% of the total N in the aboveground tree biomass, forest floor, and top 20 cm of the mineral soil. A whole-tree harvest would remove 9.7% of the N capital. Though it seems unlikely that such removals would greatly

TABLE 4. Component biomass and nutrient content of thinned and unthinned stands of coastal western hemlock.

Component	Dry weight, Mg/ha	N	P ---------- kg/ha ----------	K
Unthinned stand				
Stem wood	344.0	275.2	72.6	258.0
Stem bark	32.7	104.6	17.8	84.0
Foliage	15.6	181.2	25.3	88.3
Twigs	6.4	52.8	7.4	27.9
Live branches	28.0	92.2	12.6	62.3
Dead branches	9.3	34.8	3.3	2.8
Total	436.0	740.8	139.0	523.3
Thinned stand				
Stem wood	300.6	240.5	63.1	225.4
Stem bark	27.8	88.9	15.3	71.4
Foliage	14.1	163.4	22.8	79.6
Twigs	5.6	46.0	6.5	24.3
Live branches	23.8	78.5	10.7	53.0
Dead branches	8.6	32.1	3.0	2.6
Total	380.4	649.4	121.4	456.3

TABLE 5. Nitrogen status of the forest floor and mineral soil of a thinned and an unthinned stand of coastal western hemlock. Standard errors are in parentheses.

Parameter	Unit	Unthinned stand	Thinned stand	Combined stands*
Forest floor mass	Mg/ha	62.9**(13.2)	17.8**(2.3)	--
Soil bulk density (0-7.5 cm)	g/cm^3	--	--	0.440 (0.43)
Exchangeable $NH_4{}^+$-N	μg/g			
Forest floor		--	--	71.4 (7.0)
Soil (0-7.5 cm)		--	--	20.5 (4.9)
Net mineralizable NH^4 + -N	μg/g			
Forest floor		--	--	363 (28)
Soil (0-7.5 cm)		--	--	151 (24)
Total N (see text)	kg/ha			
Forest floor		614**	173**	--
Soil (0-20 cm)		--	--	7,000

* Combined values are reported where means for thinned and unthinned stands did not differ significantly.

** Difference is significant at $\alpha = 0.01$.

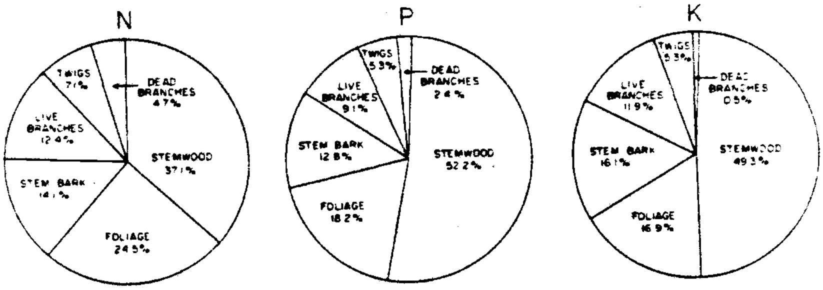

Figure 1. Distribution of N, P, and K in the aboveground tree biomass of an unthinned stand of western hemlock near Seaside, Oregon.

affect site productivity during the first several rotations, continued removals of organic matter might pose a long-term problem. However, the consequences of nutrient removal from coastal western hemlock sites depend on which element limits growth. There is substantial circumstantial evidence that P, not N, is limiting over much of the area. The amount of exchangeable $NH^+{}_4$-N in the forest floor (Table 5) is about twice the 31 μg/g reported by Vitousek *et al.* (1982) for a 120-year-old coastal stand of western hemlock-sitka spruce [*Picea sitchensis* (Bong.) Carr.] on the central Oregon coast, but agrees well with the 85 μg/g reported by Sidle and Shaw (in press) for a recently clearcut spruce-hemlock site in southeast Alaska and with values for 10 other sites near our study area (J. Boyle, personal communication). The value for exchangeable $NH^+{}_4$-N in the top 7.5 cm of the mineral soil (Table 5) is similar to those reported for the top 0-15 cm of the soil at other coastal sites (Vitousek *et al.* 1982; Sidle and Shaw in press; J. Boyle, personal communication).

Mineralizable N is also plentiful. Net $NH^+{}_4$ production (anaerobic incubation) averaged 363 μg N/g for the forest floor and 151 μg N/g for the surface soil (Table 5), and differences between the thinned and unthinned stands were not significant ($\alpha = 0.05$). Boyle (1982) reported similar values for 10 nearby stands. Net $NH^+{}_4$ production from surface soil (0-15 cm) ranged from 6 to 139 μg N/g for 16 stands of western hemlock in Washington--the average value for coastal sites significantly higher than that for the Cascade Range sites (Radwan and Shumway in press).

At both of our study sites and at 16 of the 18 sites in the studies just mentioned, levels of mineralizable N in the surface soil far exceeded the fertilization-response thresholds reported for Douglas-fir, 45 μg mineralizable N/g (Shumway and Atkinson 1978), and for true fir and ponderosa pine, 16 μg N/g (Powers 1980). These data suggest that western hemlock may not generally be N limited at coastal sites, and they may explain in part the lower and more highly variable response to N fertilization at coast sites than at Cascade sites (Olson _et al._ 1979).

P availability may limit growth of coastal western hemlock stands. In their study of 16 such stands, which included fertilizer test plots set up as part of the Regional Forest Nutrition Research Project (Olson _et al._ 1979), Radwan and Shumway (in press) examined correlations between the growth response to application of 224 kg/ha of N fertilizer and the levels of total and available N, total sulfate, mineralizable S, and extractable P. Extractable P in the forest floor correlated most significantly ($r = 0.77$, $\alpha = 0.001$). The mineral soil parameter that correlated best was the ratio of extractable P to mineralizable N ($r = 0.67$, $\alpha = 0.005$). Extractable P levels in both forest floor and surface mineral soil were significantly higher in Cascade than in coastal sites. In a greenhouse study by Heilman and Ekuan (1980), hemlock seedlings grown in Washington coastal soil responded significantly to P fertilization. Because of this evidence and the results of our study, we believe that P availability and dynamics should be emphasized in future research on western hemlock nutrition at Coast Range sites.

MANAGEMENT EFFECTS ON NITROGEN NUTRITION AND LONG-TERM PRODUCTIVITY OF WESTERN HEMLOCK STANDS: AN EXERCISE IN SIMULATION WITH FORCYTE

Introduction

It is difficult to estimate the long-term effects of forest management practices without actually monitoring yield over several rotations, which could, of course, take centuries. What is needed is a method of integrating current information from a wide variety of studies to predict long-term trends. This can be accomplished using simulation modeling. A management-oriented simulation model can be of value to land managers because it allows the prediciton of the long-term consequences of various silvicultural practices (Sollins et al. (in press)). Such models can also be useful to researchers by providing a mechanism for integrating and testing ideas and to direct and prioritize research (Van Veen et al. 1981). Through sensitivity analysis critical processes can be identified and research directed where the need is greatest.

In this study we worked with FORCYTE, a management-oriented simulation model of growth and nutrient cycling (Kimmins and Scoullar 1979, 1981, 1982). FORCYTE was originally developed for Douglas-fir forests in British Columbia, but can be adapted for any even-aged forest species. Our first objective was to adapt FORCYTE for use with western hemlock based in part on data we collected for two stands in Coastal northwest Oregon (Sachs and Sollins (in review)). We then used FORCYTE to gain insight into the consequences of silvicultural practices on long-term productivity of western hemlock stands at those sites. Nitrogen availability has often been cited as a growth-limiting factor although recent research has indicated that phosphorus may be limiting on some sites (Radwan and Shumway (in press), Sachs and Sollins (in review)). Proceeding under the assumption that N was limiting, we attempted to use FORCYTE to investigate the factors which regulate N availability.

Description of FORCYTE

FORCYTE is as management-oriented simulation model of forest growth and decomposition which includes nutrient cycling, nutrient limitation on growth and management intervention (Kimmins and Scoullar 1979, 1981, 1982). The model is designed to be adaptable to any even-aged forest with rotation lengths of less than 150 years. A major design criterion of FORCYTE is that it can be driven by inventory type data, collectable in one or two field seasons or available in the literature and that it not require detailed process information which could take years of research to gather.

Growth of stemwood in FORCYTE is driven by volume/age equations of the Chapman-Richards type (Pienaar and Turnbull, 1973) for each of five different site qualities, which can be developed from local yield tables. Growth of other tree components is calculated using a set of age-specific ratios of foliage, branch, stembark and root biomass to stemwood biomass. The model also requires information on the nutrient content of the various tree components.

Nutrient demand each year is calculated as the product of the predicted growth of each component and the nutrient content of that component. Predicted growth is then modified by nutrient availability. If nutrient demand exceeds availability in any year, growth in that year is reduced to a level at which all the available nutrient supply is utilized. Nutrients in excess of this level cause an increase in growth, although the increase is limited so that trees cannot respond unrealistically to a sudden increase in nutrient availability. Throughout the simulation, site quality can vary depending on the size of the available nutrient pool in relation to tree demand. When available nutrients are not sufficient to satisfy demand, site quality is reduced, resulting in less predicted growth and lower nutrient demand the following year. Conversely, an excess of available nutrients causes an increase in site quality resulting in increased predicted growth and nutrient demand the following year. FORCYTE can model the effects of any single nutrient on growth. The current version simulates nitrogen cycling because N is most often limiting and most research has focused on nitrogen. For a detailed description of FORCYTE see Kimmins and Scoullar (1979, 1981, 1982).

Calibration for Western Hemlock

Calibration of FORCYTE for western hemlock required collection of field data as well as a thorough search of the literature. Information on the growth of stemwood was taken from western hemlock yield tables by Wiley (1979) and Barnes (1962). This information was used to construct Chapman-Richards growth equations for each of five different site classes (I-V) for input to FORCYTE. Age-specific ratios of foliage, branch, stembark and root biomass to stemwood biomass were estimated using data from three Oregon coastal hemlock forests: a 26-year-old hemlock stand on the central Oregon coast (Fujimori 1971), a nearby 121-year-old stand (Grier 1976), a 52-year-old stand near Seaside, Oregon (Sachs and Sollins (in review)). All three studies provided information on biomass of stemwood, stembark, foliage, and branches. Grier and Fujimori also measured coarse root biomass. Additional data on root biomass came from a review by Santantonio et al. (1977).

Information on the nitrogen content of the various tree components was taken primarily from the site II stand of pure western hemlock that we studied (Sachs and Sollins (in review)). FORCYTE requires this information for all site classes. Some data for western hemlock on lower site classes in the Cascades was available (C.C. Grier, unpublished data). Data on foliar N concentrations in western hemlock stands on sites I-V were taken from a study by Radwan and DeBell (1980). Values for nitrogen concentrations of other tree components on poorer sites were estimated using the data from Sachs and Sollins and Grier (unpublished data).

Forest floor biomass data was taken from the studies of the three Oregon coastal hemlock forests. Additional information on the amounts of coarse woody debris in northwest forests was found in papers by Sollins (1982) and Graham and Cromack (1982). Estimates of total soil nitrogen and soil organic matter content were based on the studies by Grier (1976), Sachs and Sollins and unpublished data provided by J. R. Boyle.

Initial model calibration was accomplished by running FORCYTE with the nutrient feedback system turned off. Under this condition FORCYTE simulates the growth of a hemlock forest as described by the yield table without regard to nutrient limitations. We set the model to simulate a site II stand and ran it for 90 years. At the end of this period FORCYTES's predictions of the biomasss of various components of the forest floor were compared to the available data on the forest floor of hemlock stands. Decomposition rates for the various forest floor components were adjusted and the model run again. Through trial and error we were able to simulate a forest floor which was comparable to the data we had.

The model's predictions of the forest floor biomass under a 90 year-old stand are shown in Table 6. FORCYTE predicts 222 Mg/ha of decomposing logs which agrees well with the 212 Mg/ha reported by Grier (1976) for a 121 year-old stand. The FORCYTE prediction is based upon a decay rate of 0.03 year^{-1}. Grier calculated a decay rate of 0.012 year^{-1} from the change in density of decaying logs over time. Sollins (1982) reported a decay rate of 0.028 year^{-1} for an old-growth Douglas-fir stand in Washington, calculated by assuming a steady state and dividing bole mortality by the amount present. He stated that rates calculated by this method are often 3-5 times those calculated directly from change in density alone which fail to include the large amount of material lost in fragmentation. FORCYTE predicts litterfall (including branches, but not boles) to average approximately 7.0 Mg/ha/yr which is similar to values reported by Grier (1976) and Fujimori (1971).

TABLE 6. Predicted biomass of forest floor components in a 90 year-old stand.

Component	Biomass (Mg/ha)
Logs	222
Bark	64
Foliage	11
Branches	37
Roots	53

We made one major design modification in the FORCYTE program. A parameter defining the rate of fine root turnover was added. In the original version of FORCYTE no more than 90% of the fine root biomass could die and be replaced in any given year. Our modification allows the user to set fine root turnover to much higher levels. Santantonio (1982) reported fine roots turned over 2.8, 2.0, and 1.7 times/year on dry, medium and wet examples of mature Douglas-fir forest in the Oregon Cascades. Lacking data for western hemlcok, we set fine root turnover at 2.0 times/year initially in FORCYTE.

Initial calibration runs of FORCYTE indicated that yield in the model was extremely sensitive to the parameter defining the rate of mineralization of soil organic matter. In FORCYTE there is one soil organic matter pool, which includes all soil o.m. plus the forest floor h layer. The nitrogen released during its mineralization provides the majority of the N available for uptake by trees each year and therefore regulates tree growth. Unfortunately, little is known about mineralization of soil organic matter and therefore we had only a vague idea as to what mineralization rate to use in FORCYTE. We first set the rate so that the starting level of soil o.m. would be maintained over a 270 year period under a management scenario of three 90 year rotations, with no thinnings and a clearcut at rotation age removing only stem wood and bark. We assumed this would simulate minimum management of the site; a situation in which soil o.m. levels might be expected to remain constant. Under these conditions FORCYTE predicted a 4% drop in yield in the second rotation and a 6% drop in the third. We then increased the mineralization rate until yield remained relatively constant over three rotations. This resulted in about a 4% drop in soil o.m. over the 270 year period. It was decided to leave the mineralization rate at this level to give a good base to which the effects of other, more intensive management scenarios could be compared.

One problem we encountered involved leaching of soil NO_3- and NH_4^+. The ratio of $NO_3^-:NH_4^+$ is user defined. At the end of each year, any NH_4+ not taken up by vegetation or immobilized during decomposition is stored as soil N, and any leftover NO_3^- is leached out of the soil. Therefore leaching is extremely sensitive to the parameter defining the ratio of $NO_3^-:NH_4^+$ in the soil, which had to be set to about 0.04 to keep leaching losses to a reasonable level (< 50 kg $ha^{-1}yr^{-1}$) during the first 10 years of the rotation. This proportion seems low. Grier (1976) measured about 25% of the extractable N in the top 15 cm of the soil at his hemlock site to be in the NO_3^- form.

The amounts of available soil N and stored soil N followed the same general pattern in all rotations (Figure 2). The initial pulse in soil N is due mainly to the input from mineralization of soil humus, which is assumed to occur at a constant rate. There is some uptake by herbs and shrubs, but little or none by trees. Simulated leaching losses during this stage are about 15-30 kg/ha/yr. As trees occupy the site, uptake by trees increases and both available and stored soil N decrease. Tree uptake is at maximum from about 10-30 years. During this time available soil N drops to about 100 kg/ha and all stored soil N is depleted. Leaching losses during this period are minimal, averaging less than 1 kg/ha/yr. N uptake by trees decreases after age 30, available soil N begins to increase again, and excess soil N is stored every year after about age 50. Rotation lengths of less than 50 years never allow the stand to reach this soil N building stage. Leaching losses begin to increase again after about age 70, reaching 3-4 kg/ha/yr by the rotation age of 90 years. This trend is in agreement with measurements made by Vitousek and Reiners (1975) who reported higher NO_3^- levels in stream runoff from mature spruce-fir forests in New Hampshire than from nearby 30-40 year old stands.

Results and Discussion

We simulated a number of different forest management scenarios with the revised FORCYTE model in order to gauge their long-term effects on site productivity. All simulations were for 270-year periods. These included management for sawlogs on both 90- and 45-year rotations with precommercial and commercial thinnings, and management for biomass with whole tree utilization on 30- and 45-year rotations with thinning. As expected under the assumptions we used, the more intensive management scenarios caused marked depletion of the soil o.m. pool over the 270-year period. Depletion of the soil o.m. eventually decreased N mineralization which reduced the amount of N available for tree growth and caused a decline in site productivity and yield after 150-200 years (Figures 3A and B). The most intensive management scenarios generally caused the greatest long-term decline

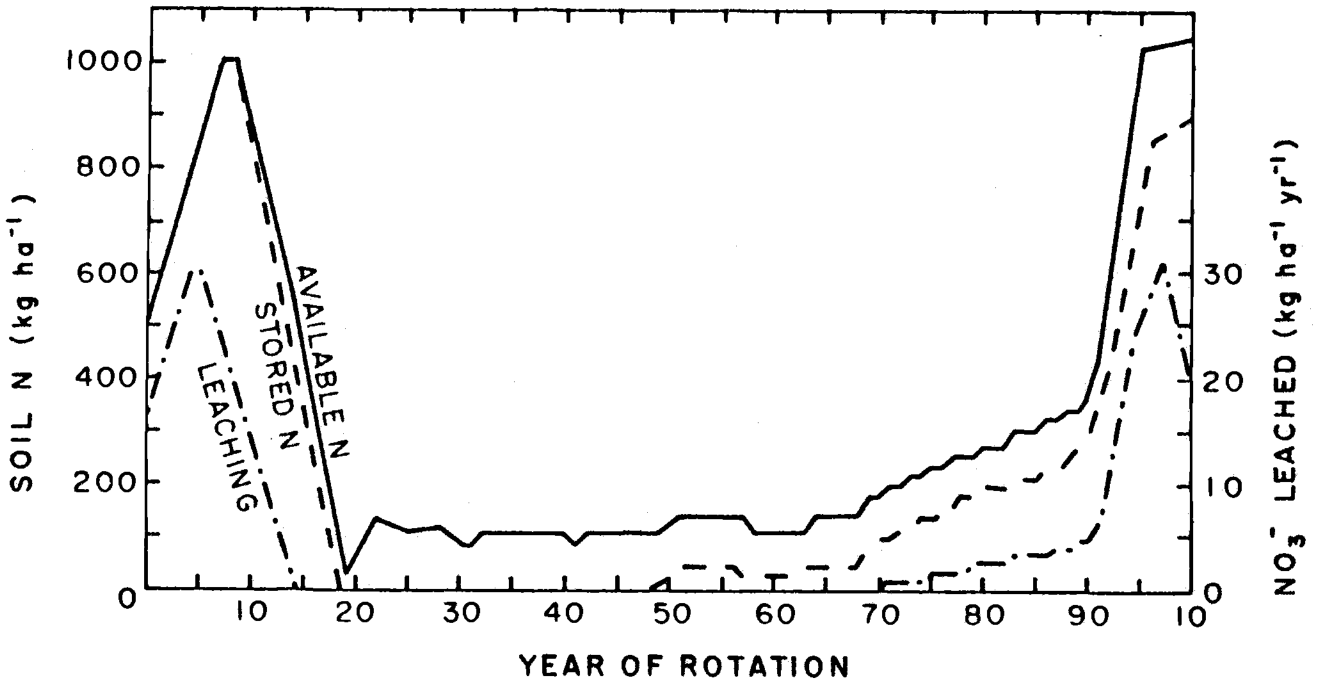

Figure 2. Predicted levels of available N, stored N, and leaching of NO_3^- during a 90-year rotation.

in productivity as indicated by predicted annual rates of production per rotation.

Predicted yields for the different regimes are shown in Figure 3B. Stemwood yield was maximum under 90-year rotation with thinning. Biomass yields from whole-tree harvesting were greatest under 45-year rotations. Apparently 30-year rotations are too short, harvesting the stand before culmination of mean annual increment. Intensive management caused initial increases in yield followed by rapid declines in later rotations due to depletion of soil o.m. and thus N capital.

The soil o.m. pool became depleted because the inputs to soil o.m. decreased. The only inputs to soil humus are through decomposition of forest floor materials and root death. Shorter rotations, commercial thinnings, and increased utilization remove more biomass from the site which would eventually have entered the forest floor through litterfall. The effects can be seen clearly in Figure 3C which depicts the predicted change in total forest floor biomass and soil o.m. over the 270-year simulation under the different management regimes. Notice that the additional removal caused by the commercial thinning of the stands during 90-year rotations increased loss of forest floor biomass and soil o.m. by about 24% over three rotations. When utilization was increased from stems-only to whole-tree under 45-year rotations, forest floor biomass and soil o.m. loss increased considerably; shortening the rotation to 30 years had the same effect.

Available soil N often increased temporarily for periods of 150-200 years under simulated intensive management, after which it decreased, often to levels well below those of the first rotation. This effect was due, in the model, to an interaction of two mechanisms. The initial increase in available N was due to increased removals of biomass, which resulted in a decreased forest floor biomass, which in turn initially decreased the amount of N immobilized each year by the forest floor and left more N available for uptake by plants. However, the increased biomass removals eventually decreased the input to the soil o.m. pool. As the soil o.m. pool decreased in size, the amount of N mineralized each year dropped and available N decreased in later rotations.

The initial increase in soil available N levels caused yield to increase for the first 150 - 200 years under short rotations (Fig. 3B). Later, yield dropped as soil N decreased in subsequent rotations due to depletion of the soil o.m. pool. FORCYTE predicted this initial yield increase because N availability is the only factor assumed to limit tree growth. If another factor such as P availability were to become limiting during this flush of N mineralization, then such increases in growth would be diminished or not occur at all. Future versions of the FORCYTE will be able to model the effects of two nutrients on tree growth (J.P. Kimmins, personal communication).

Fertilization briefly increased growth and therefore litterfall and root death and decreased the loss of soil o.m., but this effect only lasted one or two years. FORCYTE predicts a positive response

Figure 3. Predicted annual net primary production, biomass harvested, and biomass of forest floor plus soil organic matter during a 270-year simulation under six different management scenarios. All rotations start with a combination of planted and naturally established seedlings totaling 2400 per hectare. All final harvests are clearcuts. All scenarios except A include a precommercial thinning at age 15 years. Scenario F includes a fertilization at age 17 years.

Scenario	Rotation Length	No. Commercial Thinnings	Utilization Standard
A	90	0	Stems-only
B	90	2	Stems-only
C	45	2	Stems-only
D	45	2	Whole-tree
E	30	0	Whole-tree
F	30	0	Whole-tree

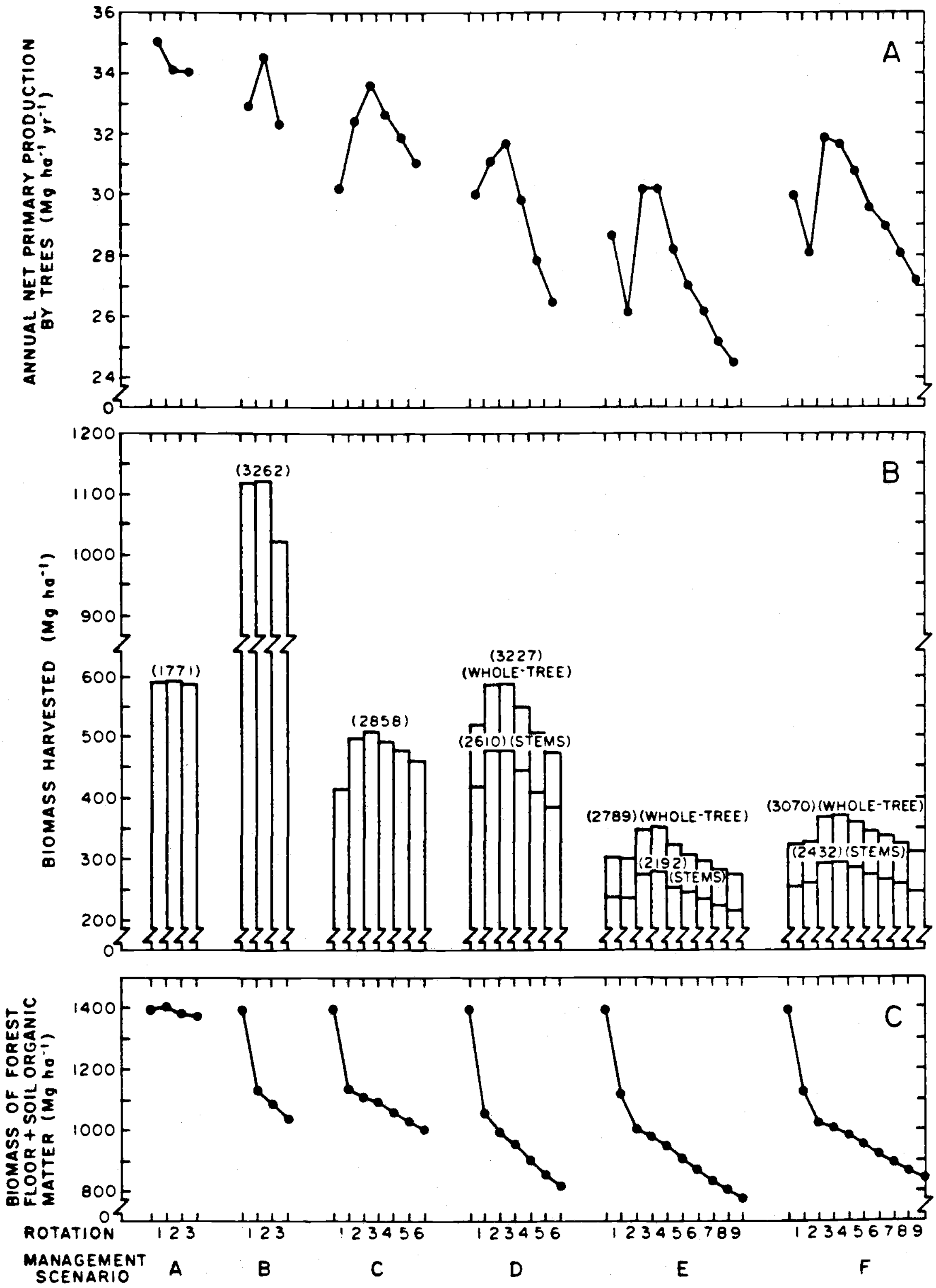
A
ANNUAL NET PRIMARY PRODUCTION BY TREES (Mg ha^{-1} yr^{-1})
36
34
32
30
28
26
24
0
B
BIOMASS HARVESTED (Mg ha^{-1})
1200
1100
1000
900
600
500
400
300
200
0
(1771)
(3262)
(2858)
(3227)
(WHOLE-TREE)
(2610) (STEMS)
(2789) (WHOLE-TREE)
(2192)
(STEMS)
(3070) (WHOLE-TREE)
(2432) (STEMS)
C
BIOMASS OF FOREST FLOOR + SOIL ORGANIC MATTER (Mg ha^{-1})
1400
1200
1000
800
0
ROTATION
1 2 3
1 2 3
1 2 3 4 5 6
1 2 3 4 5 6
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9
MANAGEMENT SCENARIO
A
B
C
D
E
F

Figure 3.

to fertilization whenever N is limiting. This may not be reasonable. The data on growth response of western hemlock to N fertilization are inconclusive with some stands showing negative response (Olson et al. 1979). This variable response has been attributed to several factors including possible P deficiency (Radwan and Shumway, in press) and fertilizer induced increases in mortality of mycorrhizae or changes in relative populations of mycorrhizal types associated with hemlock roots (Gill and Lavender, 1983b). However, FORCYTE is not presently capable of modeling these mechanisms. In any case, the response to fertilizer is short-lived, because simulated fertilization at typical levels only adds one or two years' supply of N. One would have to fertilize constantly at a rate comparable to uptake as is done in agriculture to produce a long-term effect.

The effects of alternate assumptions about the mineralization rate of soil o.m. must be considered. The predicted yields (Fig. 3B) are based on the soil o.m. mineralization rate we chose which kept yield constant over three 90 year rotations. If we had chosen a lower mineralization rate to maintain a constant soil o.m. pool under our minimum management plan, then yield would have decreased even more under the more intensive management scenarios. All of the management runs were made with the mineralization rate held constant, which may not be a valid assumption. The mineralization rate could increase after clearcutting due to more favorable temperature and moisture conditions (Binkley, in press). It could also decrease when there are no trees if fine roots are responsible for most or part of the mineralization of soil organic matter (Reid et al. 1982).

FORCYTE can simulate such changes. There is a parameter in the model which changes the mineralization rate by a certain percentage when there is little or no foliage on the site. As an experiment, we set the model to increase the mineralization rate by 50% under these circumstances and found that depletion of the soil o.m. pool under three 90-year rotations increased greatly. Yield increased in the second rotation and then dropped back to the first rotation level in the third as the soil o.m. pool was depleted. A fourth rotation would have shown decreased yield. We then set FORCYTE to decrease the mineralization rate by 50% when there was no foliage present. The soil o.m. pool decreased more slowly, but still decreased, and yield decreased considerably in the second and third rotations (Table 7).

FORCYTE predicts that soil o.m. levels observed in second growth stands cannot be maintained, even using rotations as long as 90 years. Production decreases consequently (Fig. 3A). Such a prediction is not all that surprising. The unmanaged coastal hemlock forests were subject to fire regimes characterized by crown fires at very long return intervals, quite possibly over 300 years (Kilgore, 1981). It is quite possible that large soil o.m. reserves only begin to accumulate after stands reach ages of several hundred years. In FORCYTE, soil o.m. never increased, even under 90-year rotations, unless the mineralization rate of soil o.m. was set so low as to severely limit tree growth, even during the first rotation. We suspect that soil o.m. will begin to accumulate in older stands, but we couldn't use FORCYTE to test this assumption because the model does not simulate old-growth forests accurately. This is because of

Table 7. Effects of alternate assumptions about the rate of N mineralization after clearcutting upon soil o.m. levels and yield. All runs were made using management scenario D as detailed in Fig. 3.

Change in mineralization rate	Yield (Mg/ha)			Loss of soil o.m.(%)
	Rotation			
	1	2	3	
Constant	543.14	545.32	541.00	4.1
Increased 50% when no foliage present	588.08	599.35	589.00	9.0
Decreased 50% when no foliage present	522.81	500.29	492.28	0.2

a lack of data on stocking, growth, mortality, and yield of old growth western hemlock stands across a range of site qualities, which causes tree mortality to cease in the model after about 110 years.

That shorter disturbance intervals caused by management may mine the soil o.m. pool is quite 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 with losses from the A horizon averaging 52%. Van Veen and Paul (1981) modelled organic C dynamics in grassland soils. The model showed sharp decreases in soil C as a result of cultivation of native grassland with C levels eventually stabilizing after 3-400 years. Losses are even more rapid under isomesic and warmer conditions (Fox 1980). Therefore, it is not unreasonable that FORCYTE should indicate a similar trend in soil organic matter levels for a hemlock forest ecosystem subjected to intensive management.

Soil o.m. levels in FORCYTE eventually approached a steady state, but this took about 1500 years. FORCYTE will only simulate 500-year periods, but the final output from one run can be used as input for another simulation. Using this technique we simulated successive 45-year rotations with commercial thinnings and whole-tree removal until soil o.m. levels stabilized as inputs to soil o.m. balanced annual decomposition. After about 1500 years, yield remained relatively constant due to a repeating pattern of N availability in successive rotations resulting from a stable soil o.m. pool (fig. 4).

FORCYTE predicts that first rotation yields cannot be maintained indefinitely except, perhaps, under extremely high levels of fertilization. Yields eventually stabilize however, and equilibrium yield levels can probably be increased with increasing inputs of energy. These predictions suggest that non-declining even flow (NDEF) may not be a biologically reasonable management strategy. NDEF is based upon the assumption that yield of forest stands can be maintained at or near present levels in perpetuity. FORCYTE suggests this assumption may be unreasonable for hemlock stands in coastal Oregon, but that a lower yield than the original second growth rotation may be readily sustainable in perpetuity. If true, then a major rethinking of management objectives and plans may be called for. For example, the optimum rotation length should perhaps be that which maximizes the energy benefit:cost ratio rather than short-term yield.

If declines are inevitable, but lower yield can be maintained in perpetuity, it could be argued that one should opt for short rotations and intensive utilization which would maximize short-term yield and cause soil o.m. and yield to equilibrate at lower but sustainable levels in the shortest time. However, our predictions are subject to uncertainty. It would seem more prudent to protect soil o.m. levels by using longer rotations and less intensive harvest methods until further research can refine our ability to predict future yields more quantitatively. It is much easier to lose soil o.m. than to build it.

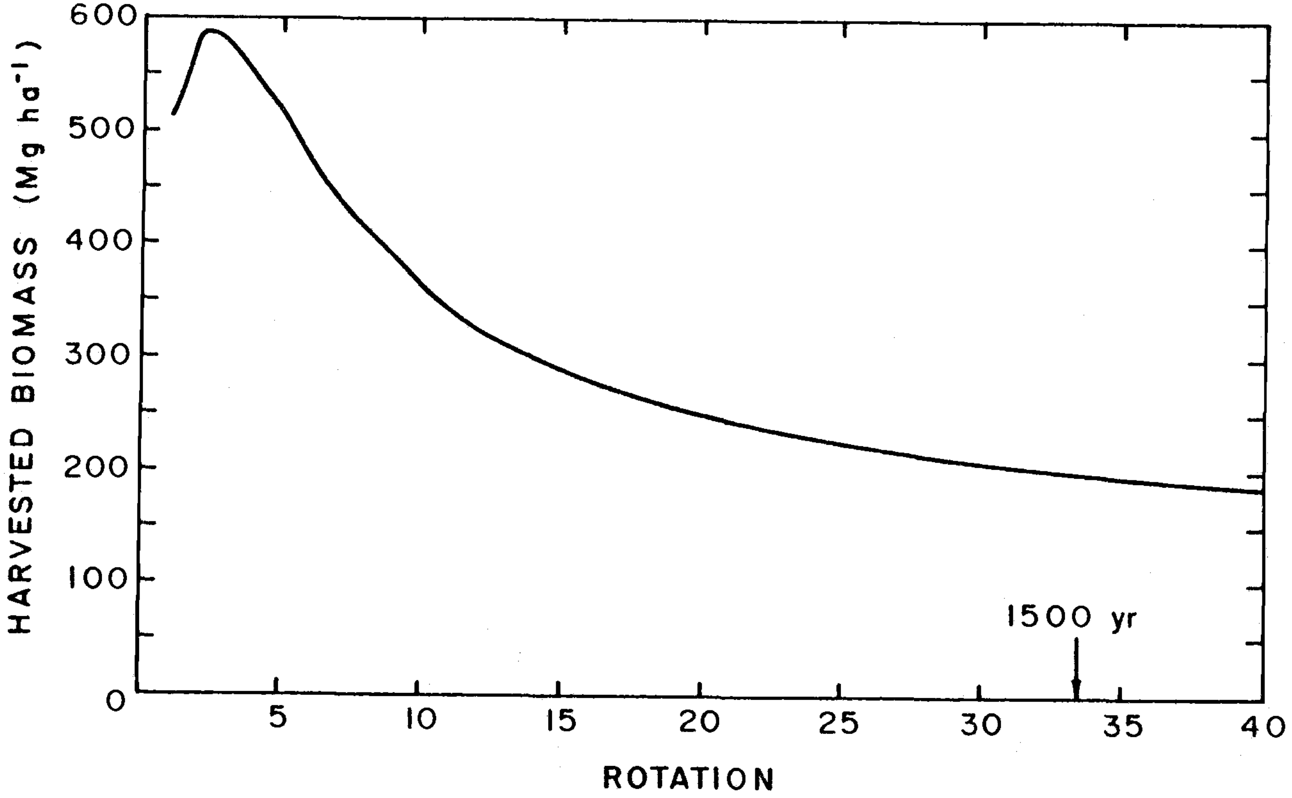

Figure 4. Predicted yields over 40 rotations under mangement scenario D as described in Figure 3.

Conclusions

Our work with FORCYTE has pointed out the model's strong points and a few weaknesses. FORCYTE is relatively easy to modify to model forest types other than the British Columbia Douglas-fir it was originally designed for, provided the necessary data is available. The model accurately tabulates the N cycle each year and regulates tree growth based on N availability. It produces output graphs of all ecosystem processes, which aid in checking the reality of its predictions. It should be emphasized that FORCYTE is very complex and several weeks can be required to decipher the reasons for its behavior.

The majority of the difficulties we encountered while working with FORCYTE did not involve problems associated with model structure, but rather a lack of data about the system being modelled. Examples include information about N mineralization rates, soil NO_3^- levels and leaching rates, and fine root turnover. FORCYTE is capable of simulating all of these processes, but data on them in hemlock forests is sketchy or non-existent.

We discovered two major weaknesses in the design of the model. The soil o.m. and forest floor humus are combined into a single pool, which is too simple an approach. There should be several soil organic pools including a forest floor humus pool and several soil layers with transfers between them. There should also be some modeling of physical protection of soil organic matter (Tisdall and Oades 1982, Van Veen and Paul 1981). The other problem involves decomposition of large woody debris. Respiration losses need to be separated from fragmentation losses (Lambert et al. 1980, Sollins 1982). These problems are being addressed in the next version of FORCYTE to be released in the summer of 1983 (J.P. Kimmins, personal communication).

A major value of a model such as FORCYTE lies in its ability to pinpoint key processes and test hypotheses concerning them thereby increasing our understanding of the system and prioritizing research. Work with FORCYTE has indicated a need for further research into the factors which regulate soil N availability, most notably the mineralization of soil organic matter. More information on soil NO_3^- levels and leaching rates in western hemlock stands is also required.

FORCYTE is the acronym for Forest Cycling Trend Evaluator. The model's major purpose is to predict trends. Its predictions of future yields are not to be taken as quantitative. They are only as accurate as the yield table information and other data used in the calibration of the model. FORCYTE's method of regulating tree growth by changing site quality may not be completely realistic, but no better method has been proposed. The model's predictions are based upon the most current available knowledge. Further research will undoubtedly modify these predicitons, but to ignore them now could prove costly.

Our results indicate that soil organic matter is as precious a resource in hemlock forests as in agricultural soils and subject to the same losses during intensive management. Yield can be maintained in agricutlure by yearly fertilization, but this is generally not feasible in forest ecosystems. It is quite possible that initial second rotation yields will not be sustainable in perpetuity under current management practices, but that yield could be readily sustainable at a lower level.

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APPENDIX

APPENDIX

The following are the input files for FORCETUP and FORCYCLE, the end-of-run state file used as the starting of the ecosystem for all management simulations, and copies of the code modifications to FORCETUP and FORCYCLE.

One major modification was made to both the FORCETUP and FORCYCLE programs involving the addition of a parameter defining fine root turnover. This parameter is named TURN in the FORCETUP input file and FINE ROOT TURNOVER in the FORCYCLE input file.

```
 349.61062 -0.0301614  3.1143738               TREB1  TREB2  TREB3             ... TREE GROWTH ... VERY POOR ...
    10                                         NSTEMS                          ...                           ...
 .001 .085 .330 .459 .573 .669 .808 .855 .891 .919 STEMSX(1...NSTEMS)          ...                           ...
9999.3706.4868.3088.2372.1927.1408.1260.1112.1038. STEMSY(1...NSTEMS)          ...                           ...
    10                                         NRBRK                           ...                           ...
 .001 .065 .330 .459 .573 .669 .808 .855 .891 .919 RABRK(1...NRBRK)           ...                           ...
 .300 .123 .102 .096 .092 .090 .087 .086 .085 .084 RRBRK(1...NRBRK)           ...                           ...
    10                                         NRFOL                           ...                           ...
 .001 .085 .330 .459 .573 .669 .808 .855 .891 .919 RAFOL(1...NRFOL)           ...                           ...
 .271 .210 .102 .055 .041 .032 .023 .021 .019 .013 RRFOL(1...NRFOL)           ...                           ...
    10                                         NRBRN                           ...                           ...
 .001 .085 .330 .459 .573 .669 .808 .855 .891 .919 RABRN(1...NRBRN)           ...                           ...
 .794 .170 .110 .096 .092 .081 .071 .070 .070 .065 RRBRN(1...NRBRN)           ...                           ...
    10                                         NRROT                           ...                           ...
 .001 .085 .330 .459 .573 .669 .808 .855 .891 .915 RAROT(1...NRROT)           ...                           ...
1.30  .380 .360 .350 .345 .340 .330 .325 .320 .315 RRROT(1...NRROT)           ...                           ...
  .0007  .0007  .0030  .0030                   CNSAP  CNHRT  CNLBRK  CNDBRK    ...                           ...
  .0033  .0010                                 CNLBRN  CNDBRN                  ...                           ...
  .0110  .0110  .0030                          CNNFOL  CNOFOL  CNDFOL          ...                           ...
  .0010  .0008  .0013  .0008                   CNRTL  CNDRTL  CNRTM  CNDRTM    ...                           ...
  .0060  .0025 1.0000                          CNRTS  CNDRTS  PERRTS           ...                           ...
    8   20   50   25   10   2   2.0            NSAP NBRL NBRD NBNL NBND NFOL TURN...                         ...
..............................................................................................................

   3000.00    -0.110         6.500             SHRB1   SHRB2   SHRB3           ... SHRUB GROWTH .. VERY POOR ...
     9                                         NRSHFL                          ...                           ...
 .006 .035 .125 .337 .630 .874 .895 .950 .999  RSHFLX(1...NRSHFL)              ...                           ...
2.50 1.75 1.450 .750 .350 .250 .200 .200 .200  RSHFLY(1...NRSHFL)              ...                           ...
    10                                         NRSHRT                          ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RSHRTX(1...NRSHRT)          ...                           ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RSHRTY(1...NRSHRT)          ...                           ...
  .0050  .0050  .0040                          CNSHTW  CNSHNF  CNSHDF          ...                           ...
  .0050  .0035                                 CNSHNR  CNSHDR                  ...                           ...
  .2500  .2500                                 PERSHT  PERSHR                  ...                           ...
..............................................................................................................

   500.00    -0.2          1.000               HRBB1   HRBB2   HRBB3           ... HERB GROWTH ... VERY POOR ...
    10                                         NRHRRT                          ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RHRRTX(1...NRHRRT)          ...                           ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RHRRTY(1...NRHRRT)          ...                           ...
  .0150  .0070  .0080  .0040                   CNHRNF  CNHRDF  CNHRNR  CNHRDR  ...                           ...
  .3000                                        PERHRB                          ...                           ...
..............................................................................................................

VERY POOR SITE          GRAPH #1               VERY POOR SITE          GRAPH #2
.............................................  ...............................................
TREE STEMWOOD BIOMASS                          TREE SAPWOOD INCREMNT           *** LABELS FOR PRINTER PLOTS ***
TREE BARK BIOMASS                              TREE BARK INCREMENT
TREE BRANCH BIOMASS                            TREE BRANCH INCREMENT
TREE FOLIAGE BIOMASS                           TREE FOLIAGE INCREMNT
TREE LARGE ROOT BIOMA                          TREE LARGE ROOT INCRM
TREE MEDIUM ROOT BIOM                          TREE MEDIUM ROOT INCR
TREE SMALL ROOT BIOMA                          TREE SMALL ROOT INCRM
NUMBER OF TREE STEMS                           TOTAL TREE PRODUCTION
TOTAL TREE BIOMASS                             NUMBER OF STEMS DYING
TOTAL TREE NITROGEN                            PERCENT STEMS DYING
VERY POOR SITE          GRAPH #3               VERY POOR SITE          GRAPH #4
.............................................  ...............................................
# YEARS ACCUM UPTAKE                           TREE STEM INTER CYCL
TREE DEAD BARK LITTER                          TREE BARK INTER CYCL
TREE LIV BRANCH DEATH                          TREE BRANCH INTR CYCL
TREE FOLIAGE LITTER                            TREE FOLIAGE INT CYCL
TREE SMAL ROOT LITTER                          TREE LARGE ROOT CYCL
TOTAL TREE LITTER                              TREE MEDIUM ROOT CYCL
TOTAL LITTER NITROGEN                          TREE SMALL ROOT CYCL
TOTAL TREE NATUR MORT                          TOTAL TREE INTER CYCL
TOTAL NITROGN IN MORT                          TOTAL TREE NIT DEMAND
TREE ACCUM UPTAKE                              TOTAL TREE NIT UPTAKE
VERY POOR SITE          GRAPH #5               VERY POOR SITE          GRAPH #6
.............................................  ...............................................
SHRUB TWIG BIOMASS                             TOTAL SHRUB LITTER
SHRUB FOLIAGE BIOMASS                          SHRUB LITTER NITROGEN
SHRUB ROOT BIOMASS                             TOTAL HERB LITTER
HERB FOLIAGE BIOMASS                           HERB LITTER NITROGEN
HERB ROOT BIOMASS                              TOTAL SHRUB INT CYCL
SHRUB TWIG INCREMENT                           TOTAL HERB INTR CYCL
SHRUB FOLIAGE INCREMT                          TOTAL SHRUB N DEMAND
SHRUB ROOT INCREMENT                           TOTAL HERB NIT DEMAND
HERB FOLIAGE INCREMNT                          TOTAL SHRUB N UPTAKE
HERB ROOT INCREMENT                            TOTAL HERB NIT UPTAKE
.......................                        .......................
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423.44603 -0.0372619  3.7346560              TREB1  TREB2  TREB3                ... TREE GROWTH ... POOR SITE ...
  10                                         NSTEMS                             ...                      ...
.001 .090 .228 .386 .533 .656 .823 .876 .913 .958 STEMSX(1...NSTEMS)           ...                      ...
9800.8105.4720.2446.1408.1037. 692. 593. 526. 432. STEMSY(1...NSTEMS)           ...                      ...
  10                                         NRBRK                              ...                      ...
.001 .090 .228 .386 .533 .656 .823 .876 .913 .958 RABRK(1...NRBRK)             ...                      ...
.300 .123 .111 .102 .096 .092 .088 .087 .086 .084 RRBRK(1...NRBRK)             ...                      ...
  10                                         NRFOL                              ...                      ...
.001 .090 .228 .386 .533 .656 .823 .876 .913 .958 RAFOL(1...NRFOL)             ...                      ...
.271 .210 .120 .076 .045 .031 .024 .021 .018 .010 RRFOL(1...NRFOL)             ...                      ...
  10                                         NRBRN                              ...                      ...
.001 .090 .228 .386 .533 .656 .823 .876 .913 .958 RABRN(1...NRBRN)             ...                      ...
.794 .165 .130 .100 .095 .080 .071 .070 .070 .059 RRBRN(1...NRBRN)             ...                      ...
  10                                         NRROT                              ...                      ...
.001 .090 .228 .386 .533 .656 .823 .876 .913 .958 RAROT(1...NRROT)             ...                      ...
1.10 .360 .350 .340 .330 .325 .315 .310 .305 .300 RRROT(1...NRROT)             ...                      ...
 .0008   .0006   .0032   .0032               CNSAP  CNHRT  CNLBRK  CNDBRK       ...                      ...
 .0033   .0012                               CNLBRN  CNDBRN                     ...                      ...
 .0112   .0112   .0050                       CNNFOL  CNOFOL  CNDFOL             ...                      ...
 .0010   .0008   .0015   .0010               CNRTL  CNDRTL  CNRTM  CNDRTM       ...                      ...
 .0060   .0025 1.8000                        CNRTS  CNDRTS  PERRTS              ...                      ...
   8   20   50   25   10    2    2.0         NSAP NBKL NBKD NBNL NBND NFOL TURN...                      ...
........................................................................................................

   3000.00   -0.110        6.500             SHRB1   SHRB2   SHRB3              ... SHRUB GROWTH .. POOR SITE ...
    9                                        NRSHFL                             ...                      ...
 .006 .035 .125 .337 .630 .874 .895 .950 .999     RSHFLX(1...NRSHFL)            ...                      ...
2.50 1.75 1.450 .750 .350 .250 .200 .200 .200     RSHFLY(1...NRSHFL)            ...                      ...
  10                                         NRSHRT                             ...                      ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RSHRTX(1...NRSHRT)          ...                      ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RSHRTY(1...NRSHRT)          ...                      ...
 .0050   .0100   .0060                       CNSHTW   CNSHNF   CNSHDF           ...                      ...
 .0050   .0040                               CNSHNR   CNSHDR                    ...                      ...
 .2500   .2500                               PERSHT   PERSHR                    ...                      ...
........................................................................................................
   500.00   -0.2           1.000             HRBB1   HRBB2   HRBB3              ... HERB GROWTH ... POOR SITE ...
  10                                         NRHRRT                             ...                      ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RHRRTX(1...NRHRRT)          ...                      ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RHRRTY(1...NRHRRT)          ...                      ...
 .0150   .0070   .0080   .0040               CNHRNF   CNHRDF   CNHRNR   CNHRDR  ...                      ...
 .3000                                       PERHRB                             ...                      ...
........................................................................................................

POOR SITE            GRAPH #1               POOR SITE            GRAPH #2
.........................................   ..........................................
TREE STEMWOOD BIOMASS                       TREE SAPWOOD INCREMNT              ... LABELS FOR PRINTER PLOTS ...
TREE BARK BIOMASS                           TREE BARK INCREMENT
TREE BRANCH BIOMASS                         TREE BRANCH INCREMENT
TREE FOLIAGE BIOMASS                        TREE FOLIAGE INCREMNT
TREE LARGE ROOT BIOMA                       TREE LARGE ROOT INCRM
TREE MEDIUM ROOT BIOM                       TREE MEDIUM ROOT INCR
TREE SMALL ROOT BIOMA                       TREE SMALL ROOT INCRM
NUMBER OF TREE STEMS                        TOTAL TREE PRODUCTION
TOTAL TREE BIOMASS                          NUMBER OF STEMS DYING
TOTAL TREE NITROGEN                         PERCENT STEMS DYING
POOR SITE            GRAPH #3               POOR SITE            GRAPH #4
.........................................   ..........................................
# YEARS ACCUM UPTAKE                        TREE STEM INTER CYCL
TREE DEAD BARK LITTER                       TREE BARK INTER CYCL
TREE LIV BRANCH DEATH                       TREE BRANCH INTR CYCL
TREE FOLIAGE LITTER                         TREE FOLIAGE INT CYCL
TREE SMAL ROOT LITTER                       TREE LARGE ROOT CYCL
TOTAL TREE LITTER                           TREE MEDIUM ROOT CYCL
TOTAL LITTER NITROGEN                       TREE SMALL ROOT CYCL
TOTAL TREE NATUR MORT                       TOTAL TREE INTER CYCL
TOTAL NITROGN IN MORT                       TOTAL TREE NIT DEMAND
TREE ACCUM UPTAKE                           TOTAL TREE NIT UPTAKE
POOR SITE            GRAPH #5               POOR SITE            GRAPH #6
.........................................   ..........................................
SHRUB TWIG BIOMASS                          TOTAL SHRUB LITTER
SHRUB FOLIAGE BIOMASS                       SHRUB LITTER NITROGEN
SHRUB ROOT BIOMASS                          TOTAL HERB LITTER
HERB FOLIAGE BIOMASS                        HERB LITTER NITROGEN
HERB ROOT BIOMASS                           TOTAL SHRUB INT CYCL
SHRUB TWIG INCREMENT                        TOTAL HERB INTR CYCL
SHRUB FOLIAGE INCRCMT                       TOTAL SHRUB N DEMAND
SHRUB ROOT INCREMENT                        TOTAL HERB NIT DEMAND
HERB FOLIAGE INCREMNT                       TOTAL SHRUB N UPTAKE
HERB ROOT INCREMENT                         TOTAL HERB NIT UPTAKE
.....................                       .....................
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552.28634  -0.037977   3.612058                           TREB1  TREB2  TREB3                ... TREE GROWTH - MEDIUM SITE ...
  10                                                      NSTEMS                             ...                           ...
.001 .102 .248 .410 .557 .677 .769 .887 .921 .963 STEMSX(1...NSTEMS)                         ...                           ...
9700.7290.3929.1858.1162. 776. 630. 465. 400. 331. STEMSY(1...NSTEMS)                        ...                           ...
  10                                                      NRBRK                              ...                           ...
.001 .102 .248 .410 .557 .677 .769 .887 .921 .963 RABRK(1...NRBRK)                           ...                           ...
.300 .123 .111 .102 .096 .092 .050 .087 .086 .084 RRBRK(1...NRBRK)                           ...                           ...
  10                                                        NRFOL                             ...                           ...
.001 .102 .248 .410 .557 .677 .769 .887 .921 .963 RAFOL(1...NRFOL)                           ...                           ...
.271 .200 .113 .061 .045 .031 .026 .021 .016 .010 RRFOL(1...NRFOL)                           ...                           ...
  10                                                        NRBRN                             ...                           ...
.001 .102 .248 .410 .557 .677 .769 .887 .921 .963 RABRN(1...NRBRN)                           ...                           ...
.794 .160 .130 .093 .092 .079 .072 .070 .070 .058 RRBRN(1...NRBRN)                           ...                           ...
  10                                                      NRROT                              ...                           ...
.001 .102 .248 .410 .557 .677 .769 .887 .921 .963 RAROT(1...NRROT)                           ...                           ...
.90  .320 .310 .300 .295 .290 .280 .260 .250 .230 RRROT(1...NRROT)                           ...                           ...
  .0008   .0008   .0032  .0032                            CNSAP   CNHRT  CNLBRK   CNDBRK     ...                           ...
  .0033   .0015                                           CNLBRN   CNDBRN                    ...                           ...
  .0114   .0114   .0060                                   CNNFOL   CNOFOL   CNDFOL           ...                           ...
  .0010   .0009   .0015   .0010                           CNRTL   CNDRTL   CNRTM   CNDRTM    ...                           ...
  .0062   .0030 2.9000                                    CNRTS   CNDRTS   PERRTS            ...                           ...
    8    20    50    25     10     3    2.0               NSAP NBKL NBKD NBNL NBND NFOL TURN...                           ...
........................................................................................................................

   5000.00    -0.110          6.500                       SHRB1    SHRB2    SHRB3            ... SHRUB GROWTH  MEDIUM SITE ...
    9                                                     NRSHFL                             ...                           ...
 .006 .035 .125 .337 .630 .874 .895 .958 .999             RSHFLX(1...NRSHFL)                 ...                           ...
2.50 1.75 1.450 .750 .350 .250 .200 .200 .200             RSHFLY(1...NRSHFL)                 ...                           ...
  10                                                      NRSHRT                             ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RSHRTX(1...NRSHRT)                        ...                           ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .398 .385 RSHRTY(1...NRSHRT)                        ...                           ...
  .0050   .0150   .0080                                   CNSHTW   CNSHNF   CNSHDF           ...                           ...
  .0050   .0045                                           CNSHNR   CNSHDR                    ...                           ...
  .2500   .2500                                           PERSHT   PERSHR                    ...                           ...
........................................................................................................................
   1500.00    -0.2            1.000                       HRBB1    HRBB2    HRBB3            ... HERB GROWTH - MEDIUM SITE ...
  10                                                      NRHRRT                             ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RHRRTX(1...NRHRRT)                        ...                           ...
5.70 2.50 1.70 1.108 .780 .500 .435 .400 .390 .385 RHRRTY(1...NRHRRT)                        ...                           ...
  .0150   .0070   .0080   .0040                           CNHRNF   CNHRDF   CNHRNK   CNHRDR  ...                           ...
  .3000                                                   PERHRB                             ...                           ...
........................................................................................................................

MEDIUM SITE               GRAPH #1                        MEDIUM SITE               GRAPH #2
.......................................................   ...........................................
TREE STEMWOOD BIOMASS                                     TREE SAPWOOD INCREMNT              ... LABELS FOR PRINTER PLOTS ...
TREE BARK BIOMASS                                         TREE BARK INCREMENT
TREE BRANCH BIOMASS                                       TREE BRANCH INCREMENT
TREE FOLIAGE BIOMASS                                      TREE FOLIAGE INCREMNT
TREE LARGE ROOT BIOMA                                     TREE LARGE ROOT INCRM
TREE MEDIUM ROOT BIOM                                     TREE MEDIUM ROOT INCR
TREE SMALL ROOT BIOMA                                     TREE SMALL ROOT INCRM
NUMBER OF TREE STEMS                                      TOTAL TREE PRODUCTION
TOTAL TREE BIOMASS                                        NUMBER OF STEMS DYING
TOTAL TREE NITROGEN                                       PERCENT STEMS DYING
MEDIUM SITE               GRAPH #3                        MEDIUM SITE               GRAPH #4
.......................................................   ...........................................
# YEARS ACCUM UPTAKE                                      TREE STEM INTER CYCL
TREE DEAD BARK LITTER                                     TREE BARK INTER CYCL
TREE LIV BRANCH DEATH                                     TREE BRANCH INTR CYCL
TREE FOLIAGE LITTER                                       TREE FOLIAGE INT CYCL
TREE SMAL ROOT LITTER                                     TREE LARGE ROOT CYCL
TOTAL TREE LITTER                                         TREE MEDIUM ROOT CYCL
TOTAL LITTER NITROGEN                                     TREE SMALL ROOT CYCL
TOTAL TREE NATUR MORT                                     TOTAL TREE INTER CYCL
TOTAL NITROGN IN MORT                                     TOTAL TREE NIT DEMAND
TREE ACCUM UPTAKE                                         TOTAL TREE NIT UPTAKE
MEDIUM SITE               GRAPH #5                        MEDIUM SITE               GRAPH #6
.......................................................   ...........................................
SHRUB TWIG BIOMASS                                        TOTAL SHRUB LITTER
SHRUB FOLIAGE BIOMASS                                     SHRUB LITTER NITROGEN
SHRUB ROOT BIOMASS                                        TOTAL HERB LITTER
HERB FOLIAGE BIOMASS                                      HERB LITTER NITROGEN
HERB ROOT BIOMASS                                         TOTAL SHRUB INT CYCL
SHRUB TWIG INCREMENT                                      TOTAL HERB INTR CYCL
SHRUB FOLIAGE INCREMT                                     TOTAL SHRUB N DEMAND
SHRUB ROOT INCREMENT                                      TOTAL HERB NIT DEMAND
HERB FOLIAGE INCREMNT                                     TOTAL SHRUB N UPTAKE
HERB ROOT INCREMENT                                       TOTAL HERB NIT UPTAKE
........................                                  ........................
```

```
 665.56096 -0.0393008  3.5859380                   TREB1  TREB2  TREB3               ... TREE GROWTH ... GOOD SITE ...
   10                                              NSTEMS                            ...                            ...
 .002 .113 .268 .434 .582 .700 .789 .854 .931 .968 STEMSX(I...NSTEMS)                ...                            ...
9600.6721.3459.1581. 502. 655. 531. 445. 339. 282. STEMSY(I...NSTEMS)                ...                            ...
   10                                              NRBRK                             ...                            ...
 .002 .113 .268 .434 .582 .700 .789 .854 .931 .968 RABRK(I...NRBRK)                  ...                            ...
 .300 .123 .111 .102 .096 .092 .090 .088 .086 .084 RRBRK(I...NRBRK)                  ...                            ...
   10                                              NRFOL                             ...                            ...
 .002 .113 .268 .434 .582 .700 .789 .854 .931 .968 RAFOL(I...NRFOL)                  ...                            ...
 .271 .200 .113 .061 .045 .031 .026 .022 .016 .010 RRFOL(I...NRFOL)                  ...                            ...
   10                                              NRBRN                             ...                            ...
 .002 .113 .268 .434 .582 .700 .789 .854 .931 .968 RABRN(I...NRBRN)                  ...                            ...
 .794 .160 .130 .093 .092 .079 .072 .070 .070 .053 RRBRN(I...NRBRN)                  ...                            ...
   10                                              NRROT                             ...                            ...
 .002 .113 .268 .434 .582 .700 .789 .854 .931 .968 RAROT(I...NRROT)                  ...                            ...
 .800 .260 .2540.250 .250 .240 .230 .220 .200 .180 RRROT(I...NRROT)                  ...                            ...
  .0008  .0008  .0032  .0032                       CNSAP  CNHRT  CNLBRK  CNDBRK      ...                            ...
  .0033  .0020                                     CNLBRN  CNDBRN                    ...                            ...
  .0116  .0116  .0008                              CNNFOL  CNOFOL  CNDFOL            ...                            ...
  .0010  .0009  .0015  .0010                       CNRTL  CNDRTL  CNRTM  CNDRTM      ...                            ...
  .0065  .0032 2.9000                              CNRTS  CNDRTS  PERRTS             ...                            ...
    8   20   50   25   10    3  2.0                NSAP NBKL NBKD NBNL NBND NFOL TURN...                            ...
.......................................................................................................................

  10000.00   -0.110      6.500                     SHRB1   SHRB2   SHRB3             ... SHRUB GROWTH .. GOOD SITE ...
    9                                              NRSHFL                            ...                            ...
 .006 .035 .125 .337 .630 .874 .895 .950 .999      RSHFLX(I...NRSHFL)                ...                            ...
2.50 1.75 1.450 .750 .350 .250 .200 .200 .200      RSHFLY(I...NRSHFL)                ...                            ...
   10                                              NRSHRT                            ...                            ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RSHRTX(I...NRSHRT)                ...                            ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RSHRTY(I...NRSHRT)                ...                            ...
  .0050  .0200  .0100                              CNSHTW  CNSHNF   CNSHDF           ...                            ...
  .0050  .0050                                     CNSHNR  CNSHDR                    ...                            ...
  .2500  .2500                                     PERSHT  PERSHR                    ...                            ...
.......................................................................................................................

   2000.00   -0.2         1.800                    HRBB1   HRBB2   HRBB3             ... HERB GROWTH ... GOOD SITE ...
   10                                              NRHRRT                            ...                            ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RHRRTX(I...NRHRRT)                ...                            ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RHRRTY(I...NRHRRT)                ...                            ...
  .0150  .0070  .0080  .0040                       CNHRNF  CNHRDF  CNHRNR  CNHRDR    ...                            ...
  .3000                                            PERHRB                            ...                            ...
.......................................................................................................................

 GOOD SITE               GRAPH #1                  GOOD SITE               GRAPH #2
 ................................................. .................................................
 TREE STEMWOOD BIOMASS                             TREE SAFWOOD INCREMNT             ... LABELS FOR PRINTER PLOTS  ...
 TREE BARK BIOMASS                                 TREE BARK INCREMENT
 TREE BRANCH BIOMASS                               TREE BRANCH INCREMENT
 TREE FOLIAGE BIOMASS                              TREE FOLIAGE INCREMNT
 TREE LARGE ROOT BIOMA                             TREE LARGE ROOT INCRM
 TREE MEDIUM ROOT BIOM                             TREE MEDIUM ROOT INCR
 TREE SMALL ROOT BIOMA                             TREE SMALL ROOT INCRM
 NUMBER OF TREE STEMS                              TOTAL TREE PRODUCTION
 TOTAL TREE BIOMASS                                NUMBER OF STEMS DYING
 TOTAL TREE NITROGEN                               PERCENT STEMS DYING
 GOOD SITE               GRAPH #3                  GOOD SITE               GRAPH #4
 ................................................. .................................................
 # YEARS ACCUM UPTAKE                              TREE STEM INTER CYCL
 TREE DEAD BARK LITTLR                             TREE BARK INTER CYCL
 TREE LIV BRANCH DEATH                             TREE BRANCH INTR CYCL
 TREE FOLIAGE LITTER                               TREE FOLIAGE INT CYCL
 TREE SMAL ROOT LITTER                             TREE LARGE ROOT CYCL
 TOTAL TREE LITTER                                 TREE MEDIUM ROOT CYCL
 TOTAL LITTER NITROGEN                             TREE SMALL ROOT CYCL
 TOTAL TREE NATUR MORT                             TOTAL TREE INTER CYCL
 TOTAL NITROGN IN MONT                             TOTAL TREE NIT DEMAND
 TREE ACCUM UPTAKE                                 TOTAL TREE NIT UPTAKE
 GOOD SITE               GRAPH #5                  GOOD SITE               GRAPH #6
 ................................................. .................................................
 SHRUB TWIG BIOMASS                                TOTAL SHRUB LITTER
 SHRUB FOLIAGE BIOMASS                             SHRUB LITTLR NITROGEN
 SHRUB ROOT BIOMASS                                TOTAL HERB LITTER
 HERB FOLIAGE BIOMASS                              HERB LITTER NITROGEN
 HERB ROOT BIOMASS                                 TOTAL SHRUB INT CYCL
 SHRUB TWIG INCREMENT                              TOTAL HERB INTR CYCL
 SHRUB FOLIAGE INCREMNT                            TOTAL SHRUB N DEMAND
 SHRUB ROOT INCREMENT                              TOTAL HERB NIT DEMAND
 HERB FOLIAGE INCREMNT                             TOTAL SHRUB N UPTAKE
 HERB ROOT INCREMENT                               TOTAL HERB NIT UPTAKE
 ........................                          ........................
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    784.712 -0.0397646      3.5418                 TREB1  TREB2  TREB3                 ... TREE GROWTH ... VERY GOOD ...
     10                                            NSTEMS                              ...                           ...
 .002 .119 .277 .445 .593 .710 .797 .860 .935 .970 STEMSX(I...NSTEMS)                  ...                           ...
9400.6301.3136.1396. 803. 581. 462. 390. 299. 247. STEMSY(I...NSTEMS)                  ...                           ...
     10                                            NRBRK                               ...                           ...
 .002 .119 .277 .445 .593 .710 .797 .860 .935 .970 RABRK(I...NRBRK)                    ...                           ...
 .300 .123 .111 .102 .096 .092 .090 .088 .086 .084 RRBRK(I...NRBRK)                    ...                           ...
     10                                            NRFOL                               ...                           ...
 .002 .119 .277 .445 .593 .710 .797 .860 .935 .970 RAFOL(I...NRFOL)                    ...                           ...
 .271 .200 .113 .061 .045 .031 .026 .022 .016 .010 RRFOL(I...NRFOL)                    ...                           ...
     10                                            NRBRN                               ...                           ...
 .002 .119 .277 .445 .593 .710 .797 .860 .935 .970 RABRN(I...NRBRN)                    ...                           ...
 .794 .160 .130 .093 .092 .079 .072 .070 .070 .053 RRBRN(I...NRBRN)                    ...                           ...
     10                                            NRROT                               ...                           ...
 .002 .119 .277 .445 .593 .710 .797 .860 .935 .970 RAROT(I...NRROT)                    ...                           ...
 .80  .260 .254 .250 .250 .240 .230 .220 .200 .180 RRROT(I...NRROT)                    ...                           ...
  .0008   .0008   .0032   .0032                    CNSAP   CNHRT   CNLBRK   CNDBRK     ...                           ...
  .0033   .0020                                    CNLBRN   CNDBRN                     ...                           ...
  .0120   .0120   .0100                            CNNFOL   CNOFOL   CNDFOL            ...                           ...
  .0010   .0009   .0015   .0010                    CNRTL   CNDRTL   CNRTM   CNDRTM     ...                           ...
  .0065   .0032 2.9000                             CNRTS   CNDRTS   PERRTS             ...                           ...
    8    20    50    25    10     3      2.0       NSAP NBKL NBKO NBNL NBNO NFOL TURN...                           ...
.....................................................................................................................

  10000.00    -0.110          6.500                SHRB1    SHRB2    SHRB3             ... SHRUB GROWTH .. VERY GOOD ...
     9                                             NRSHFL                              ...                           ...
 .006 .035 .125 .337 .630 .874 .895 .950 .999      RSHFLX(I...NRSHFL)                  ...                           ...
2.50 1.75 1.450 .750 .350 .250 .200 .200 .200      RSHFLY(I...NRSHFL)                  ...                           ...
     10                                            NRSHRT                              ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RSHRTX(I...NRSHRT)                  ...                           ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RSHRTY(I...NRSHRT)                  ...                           ...
  .0050   .0250   .0120                            CNSHTW   CNSHNF   CNSHOF            ...                           ...
  .0050   .0055                                    CNSHNR   CNSHOR                     ...                           ...
  .2500   .2500                                    PERSHT   PERSHR                     ...
.....................................................................................................................

   2000.00    -0.2            1.000                HRBB1    HRBB2    HRBB3             ... HERB GROWTH ... VERY GOOD ...
     10                                            NRHRRT                              ...                           ...
 .006 .035 .063 .125 .337 .684 .790 .895 .950 .999 RHRRTX(I...NRHRRT)                  ...                           ...
5.70 2.50 1.70 1.100 .700 .500 .435 .400 .390 .385 RHRRTY(I...NRHRRT)                  ...                           ...
  .0150   .0070   .0080   .0040                    CNHRNF   CNHROF   CNHRNR   CNHROR   ...                           ...
  .3000                                            PERHRB                              ...                           ...
.....................................................................................................................

VERY GOOD SITE          GRAPH #1                  VERY GOOD SITE          GRAPH #2
.................................................. .........................................................
TREE STEMWOOD BIOMASS                             TREE SAPWOOD INCREMNT                ... LABELS FOR PRINTER PLOTS  ...
TREE BARK BIOMASS                                 TREE BARK INCREMENT
TREE BRANCH BIOMASS                               TREE BRANCH INCREMENT
TREE FOLIAGE BIOMASS                              TREE FOLIAGE INCREMNT
TREE LARGE ROOT BIOMA                             TREE LARGE ROOT INCRM
TREE MEDIUM ROOT BIOM                             TREE MEDIUM ROOT INCR
TREE SMALL ROOT BIOMA                             TREE SMALL ROOT INCRM
NUMBER OF TREE STEMS                              TOTAL TREE PRODUCTION
TOTAL TREE BIOMASS                                NUMBER OF STEMS DYING
TOTAL TREE NITROGEN                               PERCENT STEMS DYING
VERY GOOD SITE          GRAPH #3                  VERY GOOD SITE          GRAPH #4
.................................................. .........................................................
# YEARS ACCUM UPTAKE                              TREE STEM INTER CYCL
TREE DEAD BARK LITTER                             TREE BARK INTER CYCL
TREE LIV BRANCH DEATH                             TREE BRANCH INTR CYCL
TREE FOLIAGE LITTER                               TREE FOLIAGE INT CYCL
TREE SMAL ROOT LITTER                             TREE LARGE ROOT CYCL
TOTAL TREE LITTER                                 TREE MEDIUM ROOT CYCL
TOTAL LITTER NITROGEN                             TREE SMALL ROOT CYCL
TOTAL TREE NATUR MORT                             TOTAL TREE INTER CYCL
TOTAL NITROGN IN MORT                             TOTAL TREE NIT DEMAND
TREE ACCUM UPTAKE                                 TOTAL TREE NIT UPTAKE
VERY GOOD SITE          GRAPH #5                  VERY GOOD SITE          GRAPH #6
.................................................. .........................................................
SHRUB TWIG BIOMASS                                TOTAL SHRUB LITTER
SHRUB FOLIAGE BIOMASS                             SHRUB LITTER NITROGEN
SHRUB ROOT BIOMASS                                TOTAL HERB LITTER
HERB FOLIAGE BIOMASS                              HERB LITTER NITROGEN
HERB ROOT BIOMASS                                 TOTAL SHRUB INT CYCL
SHRUB TWIG INCREMENT                              TOTAL HERB INTR CYCL
SHRUB FOLIAGE INCREMT                             TOTAL SHRUB N DEMAND
SHRUB ROOT INCREMENT                              TOTAL HERB NIT DEMAND
HERB FOLIAGE INCREMNT                             TOTAL SHRUB N UPTAKE
HERB ROOT INCREMENT                               TOTAL HERB NIT UPTAKE
.........................                         .........................

END OF DATA
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*****  INPUT DATA FILE FOR FORCYCLE-10 HEMLOCK VERSION  ***************************************

TITLE OF PROJECT       :SETUP RUN            ;   RUN #  5
NAME OF OPERATOR       :SACHS                ;
NUTRIENT SIMULATED     :NITROGEN             ;
TREE SPECIES SIMULATED:WESTERN HEMLOCK       ;
GEOGRAPHICAL REGION    :NORTHERN OREGON COAST          ;
ECOLOGICAL ZONE        :COASTAL WESTERN HEMLOCK        ;

*****  RUN PARAMETERS AND MANAGEMENT SCENARIO  ******************************

NUMBER OF YEARS TO BE SIMULATED          450
SITE QUALITY AT THE START OF THE RUN      28
ROTATION LENGTH (YEARS)                   90
NUMBER OF TREES PLANTED AFTER HARVEST 2400    (0=NATURAL REGEN)
PERCENTAGE OF DIFFERENT TREE COMPONENTS REMOVED AT FINAL HARVEST:
STEMWOOD .95  STEMBARK .95  BRANCHES .00  FOLIAGE .00  ROOTS .00
YEARS OF THINNING        999     999     999    9999    9999
PROPORTION STEMS CUT  0.00    0.00    0.00    0.00    0.00
# OF STEMS REMAINING   750     450     300    0000    0000
THINNING CODE:           2       4       4       3       3
   1=SPACING BY % STEMS CUT;    2=SPACING TO GIVEN STEMS/HA
   3=COMMERCIAL THINNING BY %;  4=COMMERCIAL THINNING TO STEMS/HA
PERCENTAGE OF DIFFERENT TREE COMPONENTS REMOVED AT THINNING:
STEMWOOD .95  STEMBARK .95  BRANCHES .00  FOLIAGE .00  ROOTS .00
YEAR OF FERTILIZATION 999 999 999 999 999 999 999 999 999 999
AMOUNT OF FERTILIZER  100 100 100 000 000 000 000 000 000 000

*****  PARAMETERS DEFINING NUMBER OF AGE CLASSES OF BIOMASS COMPONENTS  ********

   SAPWOOD     8
   LIVE BARK  20              DEAD BARK  50
   DEAD BRANCHES RETAINED ON THE TREE  10
   FOLIAGE  GOOD SITE  3      POOR SITE  2   FINE ROOT TURNOVER  2.0

*****  PARAMETERS CONTROLLING HERB AND SHRUB LITTERFALL  **********************

PROPORTION OF SHRUB ROOTS AND TWIGS WHICH DIE EACH YEAR  .250
PROPORTION OF HERB ROOTS WHICH DIE EACH YEAR             .300

*****  PARAMETERS CONTROLLING SHADING EFFECTS ON SHRUBS AND HERBS *************

% OF MAXIMUM TREE FOLIAGE TO FULLY SHADE OUT SHRUBS  1.250
% OF MAXIMUM TREE FOLIAGE TO FULLY SHADE OUT HERBS   1.000
% OF MAXIMUM SHRUB FOLIAGE TO FULLY SHADE OUT HERBS  0.800

***** PARAMETERS CONTROLLING GEOCHEMICAL INPUTS  *****************************

ANNUAL INPUTS OF NITROGEN IN PRECIPITATION    5.0  KG/HA
                             WEATHERING       0.0  KG/HA
                             SEEPAGE          1.0  KG/HA
BIOLOGICAL FIXATION OF NITROGEN (CONSTANT)    1.0  KG/HA
BIOLOGICAL FIXATION OF NITROGEN BY TREES    0.001  KG/KG FOLIAGE/YR
                                   SHRUBS   0.020  KG/KG FOLIAGE/YR
                                   HERBS    0.050  KG/KG FOLIAGE/YR
PROPORTION OF POPULATION FIXING NITROGEN     0.01  TREES
                                             0.00  SHRUBS
                                             0.05  HERBS

*****  ECONOMIC PARAMETERS  ($ VALUE AT START OF SIMULATION)  *****************

ASSETS AT START OF RUN         000000.00
INTEREST CHARGED ON LOANS    (%)     3.0
         EARNED ON REVENUE   (%)     3.0
DISCOUNT RATE                (%)     5.0
COST OF PLANTING        ($/HA)      250.
        SPACING         ($/HA)      250.
        THINNING        ($/HA)      800.
        FERTILIZATION   ($/HA)      100.
        FINAL HARVEST   ($/HA)     2500.
VALUE OF TREE BIOMASS COMPONENTS EXTRACTED AT THINNINGS ($ PER T)
STEMWOOD  50  STEMBARK    0  BRANCHES    0  FOLIAGE    0  ROOTS    0
VALUE OF TREE BIOMASS COMPONENTS EXTRACTED AT FINAL HARVEST ($/T)
STEMWOOD 150  STEMBARK    0  BRANCHES    0  FOLIAGE    0  ROOTS    0
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***** ENERGY PARAMETERS  ****************************************************

ENERGY BENIFITS (MILLION CALORIES PER TON)
                 STEMWOOD            4000
                 STEMBARK            4000
                 BRANCHES            4000
                 FOLIAGE             4000
                 ROOTS               4000
ENERGY COSTS (MILLION CALORIES PER HA)
                 PLANTING             630
                 SPACING              210
                 THINNING           20000
                 FERTILIZATION       9460
                 HARVESTING        100000

*****  NITROGEN CONCENTRATIONS IN TREE BIOMASS  *******************************
0.0008 0.0008 0.0007 0.0007                    CNGSAP CNPSAP CNGHRT CNPHRT      *** TREE GROWTH ***
0.0032 0.0032 0.0032 0.0032                    CNGLBK CNPLBK CNGDBK CNPDBK
0.0033 0.0033 0.002  0.0012                    CNGLBN CNPLBN CNGDBN CNPDBN
0.0116 0.0116 0.008                            CNNFLG  CNOFLG  CNDFLG
0.0112 0.0112 0.005                            CNNFLP  CNOFLP  CNDFLP
0.001  0.001  0.0009 0.0008                    CNGRTL CNPRTL CNGDRL CNPDRL
0.0015 0.0015 0.0010 0.0010                    CNGRTM CNPRTM CNGDRM CNPDRM
0.0065 0.0060 0.0032 0.0025                    CNGRTS CNPRTS CNGDRS CNPDRS

*****  NITROGEN CONCENTRATIONS IN SHRUB BIOMASS  ******************************
0.005  0.005                                   CNGSHT CNPSHT                    *** SHRUB GROWTH ***
0.020  0.010  0.010  0.006                     CNGSNF CNPSNF CNGSDF CNPSDF
0.005  0.005  0.005  0.004                     CNGSNR CNPSNR CNGSDR CNPSDR

*****  NITROGEN CONCENTRATIONS IN HERB BIOMASS  *******************************
0.015  0.015  0.007  0.007                     CNGHNF CNPHNF CNGHDF CNPHDF      *** HERB GROWTH ***
0.008  0.008  0.004  0.004                     CNGHNR CNPHNR CNGHDR CNPHDR

*****  PARAMETERS CONTROLLING DECOMPOSITION  **********************************

A.  NUMBER OF AGE CLASSES OF EACH DECOMPOSING PLANT BIOMASS COMPONENT
  70   70   20   10                            NDKSTM  NDKBRK  NDKBRN  NDKFOL   *** DECOMPOSITION ***
   2   10   50   10                            NDKRTS  NDKRTM  NDKRTL  NDKSHT
   5   10    2    3                            NDKSHF  NDKSHR  NDKHRF  NDKHRR

B.  TIME-DEPENDENT DECAY RATES FOR GOOD AND POOR SITES, BY COMPONENTS
    5                                          NDGSTM
    1.  30.  66. 120. 150.    .    .    .    . DGSTMX(1...NDGSTM)
.035 .035 .035 .035 .035 .    .    .    .    . DGSTMY(1...NDGSTM)
    5                                          NDPSTM
    1.  30.  66. 120. 150.    .    .    .    . DPSTMX(1...NDPSTM)
.033 .033 .033 .033 .033 .    .    .    .    . DPSTMY(1...NDPSTM)
    4                                          NDGBRK
    1.  10.  50. 100.    .    .    .    .    . DGBRKX(1...NDGBRK)
.0048.0048.0048.0048.    .    .    .    .    . DGBRKY(1...NDGBRK)
    4                                          NDPBRK
    1.  10.  50. 100.    .    .    .    .    . DPBRKX(1...NDPBRK)
.0045.0045.0045.0045.    .    .    .    .    . DPBRKY(1...NDPBRK)
.03                                            DBND
    4                                          NDGBRN
    1.   5.  15.  20.    .    .    .    .    . DGBRNX(1...NDGBRN)
.0805.0805.0805.0805.    .    .    .    .    . DGBRNY(1...NDGBRN)
    4                                          NDPBRN
    1.   5.  15.  20.    .    .    .    .    . DPBRNX(1...NDPBRN)
.0800.0800.0800.0800.    .    .    .    .    . DPBRNY(1...NDPBRN)
    4                                          NDGFOL
    1.   2.  10.  20.    .    .    .    .    . DGFOLX(1...NDGFOL)
.2303.2303.2303.2303.    .    .    .    .    . DGFOLY(1...NDGFOL)
    4                                          NDPFOL
    1.   2.  10.  20.    .    .    .    .    . DPFOLX(1...NDPFOL)
.2250.2250.2250.2250.    .    .    .    .    . DPFOLY(1...NDPFOL)
    4                                          NDGRTS
    1.   3.  10.  20.    .    .    .    .    . DGRTSX(1...NDGRTS)
.1783.1783.1783.1783.    .    .    .    .    . DGRTSY(1...NDGRTS)
    4                                          NDPRTS
    1.   3.  10.  20.    .    .    .    .    . DPRTSX(1...NDPRTS)
.17  .17  .17  .17  .    .    .    .    .    . DPRTSY(1...NDPRTS)
    4                                          NDGRTM
    1.  10.  20.  30.    .    .    .    .    . DGRTMX(1...NDGRTM)
.139 .139 .139 .139 .    .    .    .    .    . DGRTMY(1...NDGRTM)
    4                                          NDPRTM
    1.  10.  20.  30.    .    .    .    .    . DPRTMX(1...NDPRTM)
.136 .136 .136 .136 .    .    .    .    .    . DPRTMY(1...NDPRTM)
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    4                                                        NDGRTL
    1.  10.  20.  50.      .     .     .     .     .         DGRTLX(1...NDGRTL)
.024 .024 .024 .024 .      .     .     .     .     .         DGRTLY(1...NDGRTL)
    4                                                        NDPRTL
    1.  10.  20.  50.      .     .     .     .     .         DPRTLX(1...NDPRTL)
.0210.0210.0210.0210.      .     .     .     .     .         DPRTLY(1...NDPRTL)
    4                                                        NDGSHT
    1.   3.   6.  10.      .     .     .     .     .         DGSHTX(1...NDGSHT)
.50  .50  .40  .30  .      .     .     .     .     .         DGSHTY(1...NDGSHT)
    4                                                        NDPSHT
    1.   3.   6.  10.      .     .     .     .     .         DPSHTX(1...NDPSHT)
.35  .35  .30  .20  .      .     .     .     .     .         DPSHTY(1...NDPSHT)
    4                                                        NDGSHF
    1.   2.   3.   5.      .     .     .     .     .         DGSHFX(1...NDGSHF)
.99  .60  .50  .40  .      .     .     .     .     .         DGSHFY(1...NDGSHF)
    4                                                        NDPSHF
    1.   2.   3.   5.      .     .     .     .     .         DPSHFX(1...NDPSHF
.30  .40  .40  .30  .      .     .     .     .     .         DPSHFY(1...NDPSHF)
    4                                                        NDGSHR
    1.   3.   6.  10.      .     .     .     .     .         DGSHRX(1...NDGSHR)
.40  .50  .40  .30  .      .     .     .     .     .         DGSHRY(1...NDGSHR)
    4                                                        NDPSHR
    1.   3.   6.  10.      .     .     .     .     .         DPSHRX(1...NDPSHR)
.30  .35  .30  .20  .      .     .     .     .     .         DPSHRY(1...NDPSHR)
    4                                                        NDGHRF
    1.   2.   3.   4.      .     .     .     .     .         DGHRFX(1...NDGHRF)
.90  .90  .90  .90  .      .     .     .     .     .         DGHRFY(1...NDGHRF)
    4                                                        NDPHRF
    1.   2.   3.   4.      .     .     .     .     .         DPHRFX(1...NDPHRF)
.60  .60  .40  .40  .      .     .     .     .     .         DPHRFY(1...NDPHRF
    4                                                        NDGHRR
    0.   1.   3.   4.      .     .     .     .     .         DGHRRX(1...NDGHRR)
.80  .70  .40  .40  .      .     .     .     .     .         DGHRRY(1...NDGHRR)
    4                                                        NDPHRR
    1.   2.   3.   4.      .     .     .     .     .         DPHRRX(1...NDPHRR)
.70  .60  .50  .30  .      .     .     .     .     .         DPHRRY(1...NDPHRR)
 .....  PARAMETERS CONTROLLING THE DECAY RATE OF HUMUS  .........................
  .0094  .0079   0.00   .025   .023   1.25          DGHUM  DPHUM  DKHEXP  CNGHUM  CNPHUM  TRDKMD

 .....  MISCELLANEOUS PARAMETERS  ..........................................
  -1.0   -1.0  -0.5   1.0  -0.5   0.0               DSPSTM DSPBRK DSPBRN DSPFOL DSPRTS DSPRTM
  -1.0    0.0   1.0   1.0   1.0   1.0               DSPRTL DSPSHT DSPSHF DSPSHR DSPHRF DSPHRR
    1   .02  .02                                    IFEEDB  RSPCU  RSPCO              *** NITROGEN FEEDBACK ***
  .05   .00  .10                                    RSPCTR  RSPCSH  RSPCHR
        .200       .010      0.010                  AVLGTR  AVLPTR  AVLHRB
        .040       .020                             PNO3G   PNO3P

 .....  LABELS FOR GRAPHICAL OUTPUT  ..........................................
                          GRAPH #1                                           GRAPH #2
 ** VARIABLE PLOTTED ............... MAXIMUM ***  ** VARIABLE PLOTTED ............... MAXIMUM ***
 TREE STEMWOOD BIOMASS                            TREE STEMWOOD INCREMENT
 TREE BARK BIOMASS                                TREE BARK INCREMENT
 TREE BRANCH BIOMASS                              TREE BRANCH INCREMENT
 TREE FOLIAGE BIOMASS                             TREE FOLIAGE INCREMENT
 TREE ROOT BIOMASS                                TREE ROOT INCREMENT
 SHRUB TWIG BIOMASS                               SHRUB TWIG INCREMENT
 SHRUB FOLIAGE BIOMASS                            SHRUB ANNUL FOL PRODUCTN
 SHRUB ROOT BIOMASS                               SHRUB ROOT INCREMENT
 HERB FOLIAGE BIOMASS                             HERB ANNUL FOL PRODUCTN
 HERB ROOT BIOMASS                                HERB ROOT INCREMENT
                          GRAPH #3                                           GRAPH #4
 ** VARIABLE PLOTTED ............... MAXIMUM ***  ** VARIABLE PLOTTED ............... MAXIMUM ***
 TREE STEMWOOD N CONTENT                          DECOMPOSING STEMWOOD BIO
 TREE STEMBARK N CONTENT                          DECOMPOSING BARK BIOMASS
 TREE BRANCH   N CONTENT                          DECOMPOSING BRANCH BIOMS
 TREE FOLIAGE  N CONTENT                          DECOMPOSING FOLIAGE BIOM
 TREE ROOT     N CONTENT                          DECOMPOSING ROOT BIOMASS
 SHRUB TWIG    N CONTENT                          DECOMP SHRUB TWIG BIOMAS
 SHRUB FOLIAGE N CONTENT                          DECOMP SHRUB FOLIAGE BIO
 SHRUB ROOT    N CONTENT                          DECOMP SHRUB ROOT BIOMAS
 HERB FOLIAGE  N CONTENT                          DECOMP HERB FOLIAGE BIOM
 HERB ROOT     N CONTENT                          DECOMP HERB ROOT BIOMASS
                          GRAPH #5                                           GRAPH #6
 ** VARIABLE PLOTTED ............... MAXIMUM ***  ** VARIABLE PLOTTED ............... MAXIMUM ***
 TREE STEM INTRNL CYCLING                         HUMUS BIOMASS
 TREE BARK INTRNL CYCLING                         HUMUS NITROGEN CONTENT
 TREE BRANCH INTL CYCLING                         HUMUS ANNU BIOMASS INCRM
 TREE FOLIAGE INT CYCLING                         HUMUS ANNU NITROGN INPUT
 TREE ROOT INTRNL CYCLING                         TOTAL FOREST FLOOR BIOMA
 TREE TOTAL INTRN CYCLING                         FOREST FLOOR NITR CONTNT
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                        GRAPH #7                                                      GRAPH #8
** VARIABLE PLOTTED ****************** MAXIMUM *** ** VARIABLE PLOTTED ****************** MAXIMUM ***
AVE TREE STEMWOOD BIOMAS                           TREE STEMWOOD LITTERFALL
AVE TREE BARK BIOMASS                              TREE BARK LITTERFALL
AVE TREE BRANCH BIOMASS                            TREE BRANCH LITTERFALL
AVE TREE FOLIAGE BIOMASS                           TREE FOLIAGE LITTERFALL
AVE TREE LRG ROOT BIOMAS                           TREE ROOT LITTERFALL
AVE TREE MED ROOT BIOMAS                           SHRUB TWIG LITTERFALL
AVE TREE SML ROOT BIOMAS                           SHRUB FOLIAGE LITTERFALL
TREE DENSITY (STEMS/HA)                            SHRUB ROOT LITTERFALL
TREE DENSITY CHANGE                                HERB FOLIAGE LITTERFALL
% TREE DENSITY CHANGE                              HERB ROOT LITTERFALL
                        GRAPH #9                                                      GRAPH #10
** VARIABLE PLOTTED ****************** MAXIMUM *** ** VARIABLE PLOTTED ****************** MAXIMUM ***
TOTAL AVAILABLE NITROGEN                           HERB DEMAND NITROGEN
TREMOD OF PERCENT NO3                              SHRUB DEMAND NITROGEN
HRBMOD OF PERCENT NO3                              TREE DEMAND NITROGEN
TOTAL AVAILABLE NO3                                TOTAL POTEN HERB NITRO
TOTAL AVAILABLE NH4                                TOTAL POTEN SHRUB NITRO
POTENTIAL SHRUB NH4                                TOTAL POTEN TREE NITRO
POTENTIAL TREE NH4                                 HERB UPTAKE NITROGEN
POTENTIAL HERB NO3                                 SHRUB UPTAKE NITROGEN
POTENTIAL SHRUB NO3                                TREE UPTAKE NITROGEN
POTENTIAL TREE NO3                                 SITE QUALITY
                        GRAPH #11                                                     GRAPH #12
** VARIABLE PLOTTED ****************** MAXIMUM *** ** VARIABLE PLOTTED ****************** MAXIMUM ***
DECOMP AND INPUTS NITROG                           TREE STEMWOOD LITTER NIT
TOTAL SOIL NITROGEN                                TREE BARK LITTER NITROGN
STORED SOIL NITROGEN                               TREE BRANCH LITTER NITRO
SOIL LEACHING NITROGEN                             TREE FOLIAGE LITTER NITR
DECOMPOSITION NITROGEN                             TREE ROOT LITTER NITTROG
TOTAL NITROGEN FIXATION                            SHRUB TWIG LITTER NITROG
FIXATION BY TREES                                  SHRUB FOLIAGE LITTER NIT
FIXATION BY SHRUBS                                 SHRUB ROOT LITTER NITROG
FIXATION BY HERBS                                  HERB FOLIAGE LITTER NITR
# LIVE BRANCH CLASSES                              HERB ROOT LITTER NITROGN
END OF DATA
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1                                                                  END-OF-RUN STATE

TABLE DESCRIBING THE STATE OF EACH COMPONENT OF THE ECOSYSTEM AT THE END OF THE RUN (KG/HA).
THIS STATE CAN BE USED AS THE INITIAL STATE OF SOME FUTURE RUN IF SO DESIRED.
          BHRT      HRTNIT        BRTL      RTLNIT        BRTM      RTMNIT        BRTS      RTSNIT
            .1        .001          .1        .001          .1        .001          .1        .001
BSAP(1...20)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
SAPNIT(1...20)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
BBKL(1...20)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
BKLNIT(1...20)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
BBKD(1...100)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
BKDNIT(1...100)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
BBNL(1...60)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
BNLNIT(1...60)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
BBND(1...40)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
BNDNIT(1...40)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
BFOL(1...20)
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
           .01         .01         .01         .01         .01         .01         .01         .01         .01         .01
FOLNIT(1...20)
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
         .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001       .0001
          OSTM        OBRK        OBRN        OFOL        ORTL        ORTM        ORTS        NBNL       STEMS
      597894.4     51369.3     41265.5      9390.8    114420.7      7941.5      5396.7           0          0.
        BSHTWG      SHTNIT      BSHFOL      SHFNIT      BSHROT      SHRNIT
        1098.4       5.492       492.9       9.366       596.2       2.981
        BHRFOL      HRFNIT      BHRROT      HRRNIT
         202.4       3.035        77.9        .623
        OSHTWG      OSHFOL      OSHROT      OHRFOL      OHRROT
        1013.6       465.5       545.6       210.1        80.9
        TOTSAP      TTSAPN      TOTBKL      TTBKLN      TOTBKD      TTBKDN
            .1         .00          .2         .00          .5         .00
        TOTBNL      TTBNLN      TOTBND      TTBNDN      TOTFOL      TTFOLN
            .1         .00          .1         .00          .2         .00
DKSTM(1...150)
      36513.03     6448.01     6110.83     5990.71     5907.55     5822.45     5735.43     5646.53     5555.79     5463.29
       5369.13     5232.94     4794.78     4709.16     4622.12     4533.72     4444.04     4353.15     4261.15     4168.11
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DKSTH(1...150)
    36513.03      6446.01      6110.03      5990.71      5907.55      5622.45      5735.43      5646.53      5555.79      5463.29
     5319.13      5222.94      4794.78      4709.16      4622.12      4533.72      4444.04      4353.15      4261.15      4168.11
     4073.25      3473.96      3762.03      3669.78      3576.92      3483.54      3389.72      3295.58      3201.21      3106.70
     3012.17      2917.71      3025.27      2927.06      2822.51      2718.60      2616.08      2514.56      2169.63      2038.74
     1885.65      3025.08      2854.18      2668.57      2486.91      2308.92      2134.20      1960.25      1785.00      1603.76
     3723.26      3319.13      2933.81      2589.99      2275.07      1984.84      1712.41      1447.04      1173.75      3144.04
     2595.25      2132.40      1740.33      1399.57       375.32       494.35       173.22          .00          .00       157.61
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
DKSTMN(1...150)
     25.8021       4.6225       4.4740       4.5107       4.6029       4.7219       4.6672       5.0380       5.2332       5.4520
      5.6934       5.9105       5.7800       6.0677       6.3724       6.6927       7.0274       7.3750       7.7340       6.1027
      8.4776       8.8508       8.9609       9.3422       9.7247      10.1066      10.4861      10.8613      11.2302      11.5911
     11.9420      12.2811      13.5074      13.8513      14.1445      14.4166      14.6667      14.8931      13.6587      13.4452
     13.1074      22.1454      21.9902      21.6239      21.1806      20.6552      20.0411      19.3105      18.4356      17.3555
     42.1874      39.2382      36.3862      33.5604      30.8211      28.0821      25.2901      22.2977      18.8619      52.6616
     45.2895      38.7545      32.9263      27.5544       7.6861      10.5268       3.8339        .0001        .0001       3.9137
       .0001        .0001        .0001        .0001        .0001        .0001        .0001        .0001        .0001        .0001
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
DKBAK(1...100)
     3776.18      1195.68      1163.01      1150.22      1140.38      1108.49      1081.12      1057.53      1038.29      1021.36
     1005.98       966.91       929.99       919.13       889.54       866.70       849.37       835.27       823.57       815.07
      887.38       798.95       771.62       765.66       756.59       749.57       744.14       740.78       737.35       733.80
      730.64       727.20       772.78       768.50       762.20       755.84       749.22       742.40       665.90       642.68
      614.86      1018.21       994.60       963.32       930.41       895.52       858.33       819.48       775.51       723.79
     1743.68      1608.67      1480.91      1362.55      1247.50      1134.07      1019.24       897.61       761.97      2131.48
     1838.67      1579.37      1347.21      1133.42       318.43       440.78       161.01          .03          .03       168.27
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
DKBRKN(1...100)
     12.8838       3.8366       3.7478       3.7278       3.7225       3.6499       3.5961       3.5588       3.5403       3.5337
      3.5367       3.5307       3.3903       3.4189       3.3806       3.3694       3.3819       3.4102       3.4514       3.5899
      3.5761       3.6432       3.6256       3.7898       3.7831       3.8705       3.9706       4.0868       4.2081       4.3343
      4.4685       4.6067       5.0728       5.2284       5.3760       5.5262       5.6635       5.6420       5.4363       5.4438
      5.4043       9.2867       9.4134       9.4613       9.4826       9.4709       9.4192       9.3307       9.1610       8.8698
     22.1649      21.2090      20.7482      19.3180      18.3374      17.2810      16.0981      14.6923      12.9233      37.4529
     33.4662      29.7721      26.2974      22.9060       6.6615       9.5436       3.6076        .0007        .0007       4.1738
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
DKBRN(1...50)
    89061.45      3676.18      3307.59      2997.71      2720.71      2469.57      2241.79      2035.51      1850.15      1680.38
     1526.89      1364.74      1236.14      1123.87      1022.19       929.35       845.18       770.83       702.70       640.24
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
DKBRNN(1...50)
    243.9097      13.7998      14.6401      15.4273      16.0938      16.6322      17.0532      17.3706      17.6060      17.7455
     17.8107      17.7700      17.3877      17.2738      17.1171      16.9101      16.6655      16.4425      16.1778      15.8778
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
DKFOL(1...50)
    12179.92      2255.44      1722.46      1293.20       971.51       731.12       550.44       414.47       313.04       236.18
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
DKFOLN(1...50)
    139.7033      31.9568      27.9603      23.5255      19.2791      15.5237      12.3257       9.6802       7.5599       5.8572
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
      0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000       0.0000
DKRTS(1...50)
     8109.20      2379.81         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
        0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00         0.00
DKRTSN(1...50)
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DKRTSN(1...50)
     58.9804     59.0193      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
DKRTM(1...50)
     7927.40       66.31       55.30       47.71       41.40       35.91       31.13       26.96       23.34       20.19
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
DKRTMN(1...50)
     12.0677       .4085       .4695       .5162       .5444       .5559       .5544       .5430       .5244       .5008
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
DKRTL(1...50)
   115336.20     1259.83     1208.29     1199.12     1196.91     1194.26     1191.13     1187.52     1183.41     1178.79
     1173.67     1159.05     1076.24     1071.59     1065.98     1059.85     1053.23     1046.20     1036.77     1030.88
     1022.53     1012.81      971.44      960.28      948.62      936.48      923.66      910.80      897.22      863.26
      868.92      854.33      697.36      879.61      859.46      839.02      818.35      797.50      702.35      665.12
      624.35     1014.05      968.71      916.71      864.73      812.68      760.41      708.05      653.64      595.29
DKRTLN(1...50)
    101.9420      1.1458      1.1350      1.1751      1.2349      1.3079      1.3943      1.4945      1.6087      1.7372
      1.8803      2.0223      2.0476      2.2248      2.4156      2.6206      2.8399      3.0738      3.3222      3.5849
      3.8617      4.1486      4.3100      4.6085      4.9179      5.2375      5.5666      5.9047      6.2504      6.6037
      6.9635      7.3302      8.2334      8.6207      8.9876      9.3519      9.7126     10.0686      9.4236      9.4751
      9.4350     16.2412     16.4300     16.4517     16.4081     16.2917     16.0936     15.8094     15.3863     14.7631
DKSHT(1...50)
      114.10       47.40       19.68        8.81        4.21        2.14        1.14         .63         .37         .22
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
DKSHTN(1...50)
       .7964       .4247       .2153       .1138       .0627       .0362       .0215       .0132       .0084       .0055
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
DKSHF(1...25)
        4.65        1.51         .64         .31         .16        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00
DKSHFN(1...25)
       .0730       .0292       .0140       .0073       .0040      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
DKSHR(1...50)
       76.10       36.19       15.30        6.87        3.35        1.72         .94         .53         .31         .19
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
DKSHRN(1...50)
       .6758       .4366       .2259       .1172       .0637       .0354       .0207       .0123       .0074       .0047
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
DKHRF(1...25)
        2.91         .05        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00
DKHRFN(1...25)
       .0723       .0013      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000
DKHRR(1...40)
        5.01        1.98        1.13        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
DKHRRN(1...40)
       .0896       .0446       .0281      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
       HUMUS      HUMUSN      SOLNIT
     750000.      10000.        500.
```

Modifications to FORCETUP program (underlined).

```
C   SMALL ROOTS
C   SMALL ROOT DEATH LIKE FOLIAGE LITTERFALL
      RATE=PERRTS*FOLLIT/(TOTFOL+FOLLIT)
      IF(RATE.GT.0.9)RATE=0.9
      RTSLIT=BRTS*(TURN/(TURN+1.0))
C   NITROGEN TRANSFER TO LITTER AND INTERNAL CYCLING
      TRANSN=RTSNIT*RTSLIT/BRTS
      RTSLTN=RTSLIT*CNDRTS
      IF(RTSLTN.GT.TRANSN)RTSLTN=TRANSN
      CYNRTS=TRANSN-RTSLTN
```

```
      IF(GRTM.LT.0.001)GRTM=0.001
      GRTMN=GRTM*CNRTM
      PRTS=PROT*PFOL/(PSTM+PBRN+PFOL)
      PRTS=PRTS*(TURN+1.0)
      RTSNET=PRTS-ORTS
      GRTS=RTSNET+RTSLIT+RTSDIE
      IF(GRTS.LT.0.001)GRTS=0.001
      GRTSN=GRTS*CNRTS
```

Modification to FORCYCLE program (underlined).

```
C  SMALL ROOTS
C  SMALL ROOT DEATH LIKE FOLIAGE LITTERFALL
       RTSLIT=BRTS*FOLLIT/(TOTFOL+FOLLIT)
       RTSLIT=BRTS*(TURN/(TURN+1.0))
C  NITROGEN TRANSFER TO LITTER AND INTERNAL CYCLING
       TRANSN=RTSNIT*RTSLIT/BRTS
       RTSLTN=RTSLIT*CNDRTS
       IF(RTSLTN.GT.TRANSN)RTSLTN=TRANSN
```