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Can FORECAST be used to predict the Sustainability of Norway Spruce Stands in Southern Sweden?

Master's Thesis
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Abstract

Swedish Norway spruce production forests are designed to have the largest yield of Norway spruce possible from a plot of land. This allows growers to maximise wood production in a specific sized plot of land based on the plot's fertility rating. This paper looks at the sustainability of growing these Norway spruce monoculture forests in Southern Sweden using preliminary results obtained from a forest simulation program called FORECAST. The question of sustainability is focused in the area of the soil and the dynamics of the nutrient nitrogen in the soil. A large amount of historical data was gathered on the growth properties of Norway spruce trees on three different levels of soil productivities as well as the physical and chemical properties of the soils at these different levels. The data was based on tree and soil sites located in Southern Sweden. This data was then entered into the FORECAST program, created by the University of British Columbia, in order to obtain a preliminary assessment of the nutrient dynamics based on the historical data. The preliminary result of the simulation showed that a Norway spruce monoculture forest located in Southern Sweden is unsustainable due to humus and, consequently, nutrient depletion.

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1.0 INTRODUCTION

Forestry is an important part of the economy in Sweden and contributes to a significant part of their export income. Sweden has a reputation of being involved with sustainable forestry principles and they have been committed to the practise of sustainable forestry for a number of years. Some people believe that the management practises in Sweden are perhaps the most advanced in the world with respect to sustainability. Currently, Sweden grows more wood than they use, harvesting about 70 % of the annual growth each year leaving a 30% increase in their forest production. (Fredman 1998 pp.5) At first glance, wood production in Sweden appears to be at a sustainable rate but this may not be the case when we take a closer look at the different systems being used in their forests.

If Sweden is going to remain or become truly sustainable in their forest production, they will have to consider many different elements that are related to forest growth. Perhaps one of the most easily overlooked factors is the level of nutrients in the soil. Since the chemical elements are not something that can be seen, it is easy to assume that they will remain for an infinite amount of time. Only chemical analysis of the soil can tell scientists the characteristics of the soil chemistry. Predicting the dynamics of these nutrients over a short time period is very difficult because of the nature of a forest's system dynamics and the long time-periods involved in growing a forest. Studying the dynamics of soil nutrients require decades in order to have reliable data upon which to base trends however, modern techniques such as computer modelling have shortened this time period significantly. (Botkin 1993; Kimmins 1997)

1.1 Aim

The aim of this paper is to determine if the program FORECAST is a suitable tool to study the sustainability of Norway spruce monocultures in Sweden by attempting to collect the necessary data required to run a simulation of Norway spruce forest growth in Southern Sweden. The paper will focus on what is required to run a simulation of FORECAST and preliminary simulations will be analysed to determine if this program has the potential to be used as a tool in the Swedish forestry industry.

1.2 Scope

The scope of this paper is the physical area of Southern Sweden shown in Figure 1. Data from four stands of trees were used as input data for the model. One dataset was from the Åsa forest, one was from the Aneboda area located near Åsa and some general data specific to Southern Sweden were used to fill in missing data from the other two sites.

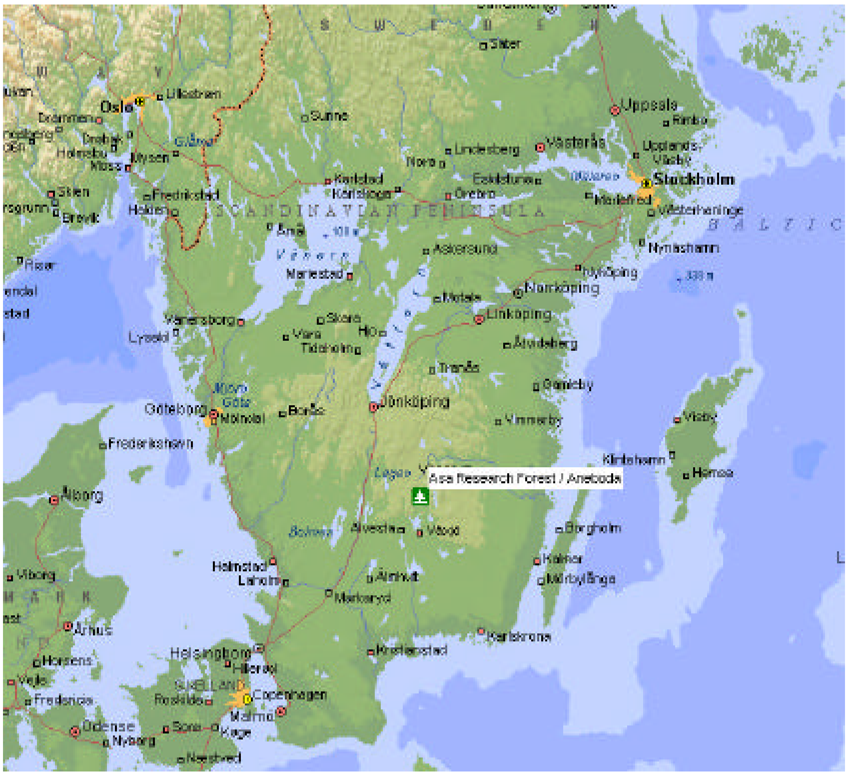

Figure 1:A map of southern Sweden showing the locations of the Asa Research Forest and the Aneboda Forest.

The data obtained from these stands were converted into the correct format and entered into the computer forest modelling software FORECAST to represent the Southern Sweden area. FORECAST then attempted to simulate the growth of a hypothetical forest with similar features to that of the stands used in the model.

1.3 Limitations and Assumptions

When using computer-modelling technology, there are always a large number of limitations. A significant complaint is that computer models cannot totally simulate real-life in every detail because of the huge number of variables and complex systems that are at work in real-life situations. Another general, but perhaps the most important limitation, is that the output of the model depends on the quality of the data used. Poor data will give poor results. Additionally, the quality of the output can be affected if the model is not used exactly as it was intended.

As seen in Section 5.3, a large amount of data is required to run FORECAST, and much of the data required is not readily available. In these cases, educated guesses or estimates were used from books or calculations in order to fill in some blanks. (See Section 6.0) It is important to note that the project was limited to 20 weeks full-time work and thus this report is not able to analyse FORECAST and the results obtained from FORECAST fully. However, it is possible to get an idea of the potential of this program looking at what was completed over the 20-week time span. The intention is that this report be used as a starting point for a more extensive study with FORECAST.

When looking at the FORECAST data sets, it is important to note that the bryophyte data file and the plant data file were excluded. These files were excluded for two reasons;

the first reason was due to the time constraint of finding the data required for the model, unessential data such as these two files, were omitted. The second reason was because in a mature Norway spruce monoculture, there is relatively little plant life on the forest floor and it is believed that the moss complex has only a small effect on the soil nutrients in comparison to the trees.

Another limitation of FORECAST is that the data required is typically from an unmanaged forest. In southern Sweden no such forest exists; all forests are, to some extent, managed. This situation made it very difficult to find the proper data for the model. The data used in the model were selected from the least managed areas of Åsa and Aneboda in order to comply with the original ideas behind the design of this modelling software. The small amount of management on these sites was in the form of thinning, therefore the thinning of trees was incorporated into the data supplied and cannot be removed. Likewise, more error would be introduced into the results if thinning was activated within the model.

It should be noted that this model does not represent “moisture limitations and moisture competition” (Kimmins, Mailly et al. 1999 pp.4) very well. This model assumes that the site will not have “severe site moisture deficits, or sever soil moisture competition.” (Kimmins, Mailly et al. 1999 pp.4) In addition to moisture figures, FORECAST does not make direct use of temperatures. Similar to the treatment of moisture, the model assumes that the temperature will not have any significant effects on the trees over the upcoming years and the trees will continue to grow as they have in the past.

2.0 BACKGROUND

Sweden supplies about three percent of the world’s sawn wood products and about six percent of the pulp production. (Fredman 1998 pp.5) This wood is supplied by a combination of small, private wood lot owners and larger forest company owned lots. In Southern Sweden, most of the wood lots are owned and run by small wood lot owners. This industry contributes approximately 70 billion SEK per year to the Swedish economy in the form of exports. (Ibid.)

2.1 Sweden’s Forestry Practises

In order to ensure a high yield of wood products, Swedish forests undergo very vigorous forest management practises. These include careful forest use planning, cutting trees at an optimum age, thinning the stands, clearing the low quality trees, spacing, cutting the lowest branches, etc. The whole system is designed to produce high quality trees at the fastest rate possible without using the obvious forest-depleting techniques such as slash and burn or clear cutting large areas. (Enström 1997 pp.52-105; Karlsson and Westman 1991)

Some of the newer management techniques include computer applications such as forestry production models. One example of this used in Sweden today is the HUGIN system. While the HUGIN system is not a new technique, is it one that is “at present capable of forecasting e.g. future volumes of biomass, distribution of logged trees into assortments, costs and revenues from silviculture and logging and effects of nature conservation to forestry." (Lind 1996) The model is based on the production trends of the past and uses historical data to forecast future production, in addition to costs and revenues. Similar techniques are practised using tables and charts in order to maximize production. (Hamilton and Björlesjö 1977; Karlsson and Westman 1991; Enström 1997)

3.0 Methods and Materials

The data required for this model was acquired from a number of major sources. The main sources originated from the Åsa research forest and a site involved with the Swedish Integrated Monitoring Programme in Aneboda. (Figure 1) Some supplemental data were acquired from the Plant Ecology Department and the Chemical Engineering Department at Lund University.

The raw data for the model were sorted, stored and analysed using Microsoft Excel 2000 and CurveExpert 1.3. Excel was used to store and sort the data based on the necessary properties required. To make use of the raw data in FORECAST, a number of regression analysis were performed using CurveExpert 1.3 in order to derive functions or equations needed to calculate the necessary parameters crucial for FORECAST. The specific calculations will be discussed in Section 6.0.

Other compulsory data that were not available, or that could be calculated from the available data, were derived from literature searches or an expert opinion was obtained in order to make a realistic assumption.

4.0 Theoretical Framework

4.1 Sustainable Forestry

In order to determine if FORECAST is a good tool to determine the sustainability of Norway spruce forests in Southern Sweden, the question 'what is meant by sustainability?' must be addressed and the results of the simulation must be consistent with this definition.

A good definition for sustainable forestry was found from an organisation called Sustainable Forestry in Southern Sweden (SUFOR). They define it as the idea of a balancing of three different systems in respect to forestry; these systems are the economic, social, and natural systems. More specifically, they believe that a sustainable forest should be:

1) Economically profitable and supply a steady number of jobs for the local people involved in the forestry industry.
2) Culturally acceptable to the majority of the people, specifically the local residents who reside in close proximity to the forest and use it in their recreational activities.

3) Naturally sustainable. The forest should produce trees, plant life and wildlife for an indefinite period without compromising the natural system of the forest. (Sverdrup and Stjernquist 2000 pp.22-23)

The National Board of Forestry (NBF) has a similar definition of a sustainable forest and has developed five targets that must be met in order for a forest to be considered sustainable. These targets are based on their definition of a sustainable forest, which is: "The forest and forest soil's value for biological production must be protected at the same time as biological diversity and cultural and social values are protected." (Wrådhe 2000) The NBF hopes to meet these targets by the year 2010. They say that these targets are relatively easy to meet, however there are some obstacles that may slow the implementation of these targets. The main obstacle is that the forests will not be able to meet their economic obligations. There may also be conflicts in regards to multiple-use forests. Companies and local people will have to agree on the uses of these forests and this may lead to some disagreements.

In the context of this paper, a sustainable forest is defined as an economically productive forest with a wide diversity of plants and animals that provides social value to people. The sustainable forest should also replicate nature in every way especially in terms of soil dynamics, which is often overlooked. As an example, a forest that has a constant humus layer due to management practises should not be considered a sustainable forest since the humus layer grows in a natural growth system. This definition may seem simple, but since people do not yet exactly know all of the dynamics of a forest system, the definition is as complex as the system we do not understand.

4.2 The Dynamics of Forests – What we know so far

In order for a forest to grow, many processes must take place. In addition, these processes must be balanced. If there is even a slight imbalance in any of the components, the forest will not grow to its potential nor will it be a healthy forest. (Thelin 2000) Report #3 The soil is the key component in a forest. "Soils build up over thousands of years through physical, chemical and biological processes as rock is weathered into minute fragments and incorporated together with the remains of dead plants and animals to form a medium that supports bigger plants and trees [...] these processes make the various types of soil found in different parts of the globe one of the most complex living systems on earth. [...] [S]oil is in effect a non-renewable resource." (Ponting 1993) pg. 15 When growing a forest for economic reasons, it is important to understand the major components of the forest so that it will yield the maximum sustainable growth possible.

Perhaps the most important components involve the nutrient levels in the soil. "Element cycling and nutrient supply in forest ecosystems are of vital importance not only for short-term productivity but also for longer-term land management, because lack of key nutrients may cause disturbances in regrowth and ecosystem development". (Walse 1998 pp.1) This also follows 'Liebig's Law of the minimum', which states that the growth of a tree is limited by the nutrient with the slowest supply rate. (Botkin 1993; Sverdrup and Stjernquist 2000 pp.64) Forests get their nutrients in three different ways. They get them from the geochemical cycling, biogeochemical cycling and biochemical cycling. (Kimmins 1997)

Geochemical cycling of nutrients includes chemical inputs from weathering of rocks, slope seepage, animals, gases, dust and precipitation. They can also lose nutrients by animals, gases, dust, soil erosion, and leaching. All of these factors are forces from outside of the forest itself. (Kimmins 1997)

Biogeochemical cycling of nutrients happens in the immediate area of the forest. This includes the ground, animals and plants in the forest. (Kimmins 1997) Biochemical cycling involves the individual's cycle, so this would be the specific cycle for each animal and plant in the entire forest. (Kimmins 1997)

Humus "is produced from microbial activity associated with lignin degradation." (Waring and Running 1998 pp.130) Humus is a key component in the composition of the soil. It "contains an overwhelming proportion of the total N, P, and S in forest soils. In coarse-textured soils, humus greatly increases the water holding capacity; in fine textured soils, humus reduces the bulk density, which improves conditions for drainage, root growth, and soil organisms." (Waring and Running 1998 pp.131) Nutrients are deposited from both the atmosphere and the tree to the forest floor. Here they are decomposed and turn into humus. The nutrients accumulate in the mineral soil where they are either leached deeper into the soil or used by the trees.

A Causal Loop Diagram (CLD), Figure 2, helps to illustrate the complex relationship between the various key components of the soil and their effect on tree growth. In this system, the limiting growth factor is usually the available nutrients that limit the growth of the trees. However, this is not always the case, temperature and water supply can also affect the growth rate of the trees.

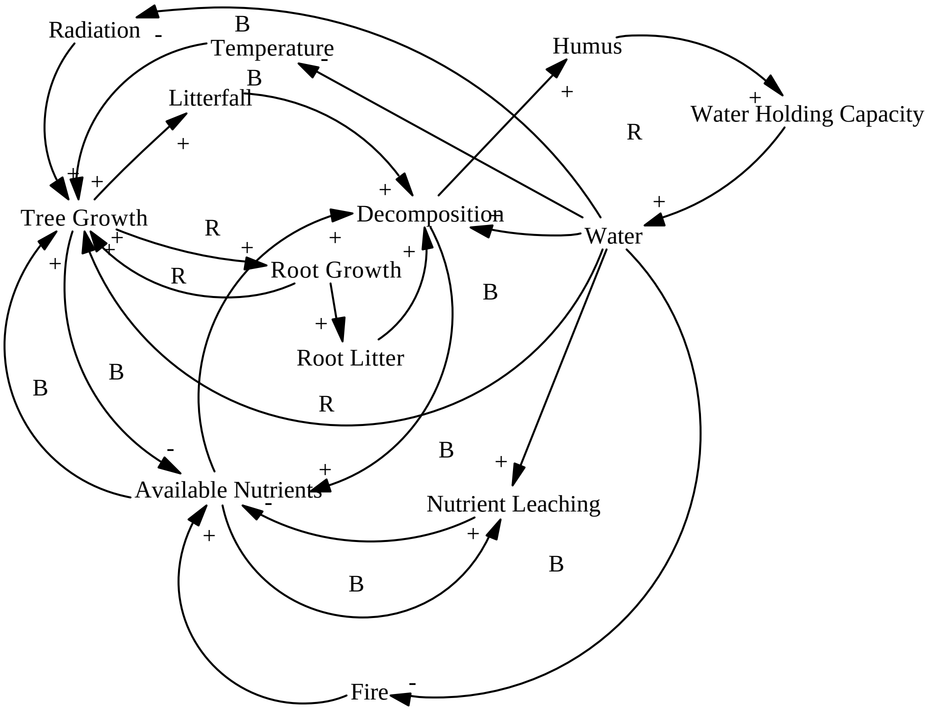

Figure 2: CLD of the soil properties of a forest.

In this CLD, it can be seen that a large number of factors can have an effect on a tree's growth. Water, available nutrients, temperature, radiation and to some extent root growth all have a say in how much the tree grows during the year. It is also possible to see that eventually the tree growth has some effect on all of these variables as well. An increase in tree growth will yield more litterfall, and in-turn increase the amount of decomposition taking place. This increased decomposition will contribute to the humus layer over the long-term as well as add nutrients to the available nutrient pool, which can be taken up by the trees in the future. An increase in humus will also allow the forest bed to hold more water, acting like a giant sponge. This will add to the amount of water available to the tree, dissolve more nutrients causing some to leach deeper into the soil. The water will also reduce fire risk, the temperature of the ground and the amount of radiation to hit the plants. The latter is because of the decrease in the clarity of the atmosphere. The more particles in it (water, aerosols etc.) the less solar radiation will be able to break through to the plant life.

The CLD in Figure 2 is similar to the figure in Appendix B in that most of the major systems of a forest are represented. However, Appendix B, which also represents the system used in FORECAST, does not contain all the elements contained in Figure 2. Specifically, FORECAST does not take into account solar radiation and temperature. They are assumed to be fixed in relation to the historical forest. This program cannot take into account some issues such as global warming, pollution (variation in solar radiation), or any events that decrease/increase the level of solar radiation to reach the forest. The program also does not model variable precipitation so there is not way to model events such as droughts or floods, both of which could have a significant impact on the economics part of the model.

4.3 Why Computer Models?

A computer model enables one person to accomplish a task that would require hundreds of people working long periods. More specifically, a forest growth model requires perhaps thousands of calculations just to simulate a short period. It would be virtually impossible to simulate an entire forest eco-system manually, so a computer model is required to complete the many calculations in a reasonable amount of time. It is also easier to produce trends or make minor changes to various scenarios using a specialized computer model.

4.4 Forestry Models

There are a number of forest-growth simulation models on the market today. Each model is designed with a specific use in mind. Many of these models simulate only one specific area, mainly the geographical location that they were constructed for. For example, SMAFS was designed for Acadian forests in Nova Scotia, FORSKA for boreal conifers in Sweden, and JABOWA-II for deciduous forests in eastern North America. (Kimmins 1997 pp.489)

In order to model the Norway spruce monoculture in Sweden, the required model needed to be flexible enough to be applied only to Sweden. Therefore, models that were constructed to be used in a specific location, for example the models mentioned above, were not considered. The advantage of FORECAST is that the design allows it to be used in every geographical location, but at the disadvantage of requiring the user to supply a massive amount of data.

5.0 FORECAST

5.1 What is FORECAST?

FORECAST is a powerful software package that is used for forest ecosystem management. It is mainly used as a decision tool to help forest managers produce sustainable wood. One of the strengths and weaknesses of the software package is that "the FORECAST software package is not a pre-calibrated, off-the-shelf decision support tool; it must be locally calibrated and tested with the aid of a forest scientist familiar with the ecological characteristics of the target ecosystem." (Seely, Kimmins et al. 1999 pp.5) Its strength lies in the ability of the model to be adapted to virtually any forest in the world, and it will yield accurate results. "FORECAST has the ability, if provided with appropriate calibration data, to forecast future values of:

?? Tree biomass, growth, nutrient content, and timber harvest yields.
?? Soil organic matter, nutrient capital and fertility.
?? Minor vegetation biomass growth and nutrient content.
?? Major pathways of nutrient cycling, ecosystem inputs and losses.
?? Ecosystem carbon budgets and carbon storage.
?? Stand-level economics, energy efficiency and employment.
?? Some limited wildlife habitat interpretations." (Waldie and Kimmins 1998 pp.4)

5.2 How FORECAST Works

FORECAST is based on a complex system that uses the ecosystem as its core. As shown in Appendix A, FORECAST has three main stages. These are the set-up stage, the ecosystem simulation and the output assessment. The set-up stage is where the user enters their data and fine-tunes the four programs so that they are representative of real-life. The ecosystem simulation is based on a very complex system (Appendix B) centred on the soil, the available nutrients and the plant biomass.

The first part of the set-up stage is data gathering and deciding what data shall be used in the simulation. The data is then entered into each of the proper files. After the user enters all the appropriate data, the first thing that the user must do is calibrate the model. This is accomplished by running the set-up programs for each data input file. This produces a series of simulation rules. These rules are used in the ecosystem simulation module to simulate the forest growth as if it were un-touched. This gives the program a background ecosystem that should represent how the forest would develop naturally. After this is set, the model must be run with the nutrient feedback off, in order to simulate the growth of the forest from a starting point equivalent to a 'parking lot' and allow it to build up nutrient levels and organic layers. In other words, the site of the simulated forest starts as a bare site and the software simulates the forest growth.

After a few runs, a state of equilibrium will emerge which can be compared to the historical growth of the actual forest. If the data sets are good, then the model should be consistent with the actual forest that will be managed with this software. The level of consistency can be tested by comparing the set-up curves with the real growth rates of forests with similar growth conditions. If they do not correlate with each other, it may be necessary to fine-tune the model until it reflects reality. Once it is determined that the model correlates to reality proving that the data sets are good, it is now possible to simulate the effects of various management techniques. (Seely, Kimmins et al. 1999) pg. 5-7 (Waldie and Kimmins 1998)

5.3 Required Data

FORECAST uses four data files with the data being in the form of historical empirical data. These four files can be seen on the left side of Figure 3. These files “are fed into ‘setup’ programs (TREEGROW, PLNTGROW, BRYOGROW, and SOILS) which use the information to derive a set of simulation rules and values for various process rates that are used in the ECOSYSTEM program to simulate the management of the ecosystem.” (Kimmins, Mailly et al. 1999 pp.5) This system allows the user to simulate a very large number of different ecosystems and management practises. “At first sight, the input data files appear somewhat intimidating. In reality, not all the data entries are required to run FORECAST. The complexity of the input files comes in part from the desire to enable the user to add detail to the simulation if the calibration data are available. The user can, at will, greatly simplify FORECAST, with corresponding reductions in calibration requirements. Remember, however, that omitting a process or compartment can result in a greater error in the simulation than including a well-based estimate of that process or compartment. The opposite may also be true. The user must make the final decision on the degree of detail to be included.” (Waldie and Kimmins 1998 pp.6) This project did not make use of a majority of the features of the program. This was due to the aim and time restrictions of this project.

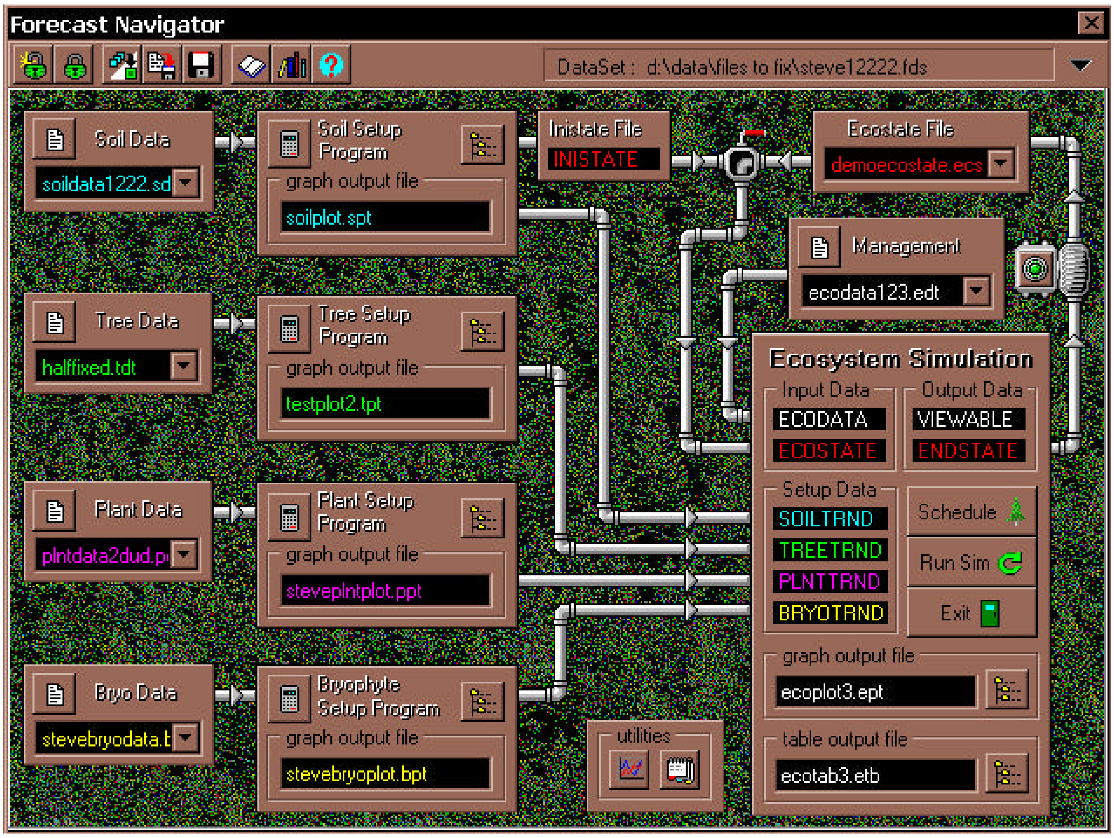

Figure 3: Overview of the FORECAST navigator.

With this potential power comes data requirements... and the requirements to run this program are "substantial". (Kimmins, Mailly et al. 1999 pp.6) "Data are required on height, stand density, stem size frequencies, biomass accumulation, nutrient concentrations in the various biomass components, atmospheric nutrient inputs, foliar leaching (optional), biomass to litterfall transfer rates, photosynthetic adaptations of foliage (e.g. photosynthetic light saturation curves for sun and shade foliage), and a variety of other stand and soil (physical and chemical properties) information from a chronosequence of stands on sites that vary in nutritional site quality." (Ibid.) In addition to this, the data must come from an unmanaged forest. This is so that the model can simulate the baseline growth of the forest, which it uses to more accurately simulate the effects of man's activities.

Unfortunately, the specific data required by the model does not exist in Sweden because almost 100% of the forested area in Southern Sweden is under some sort of management. (See section 1.3) However, since we wanted to see the effects that the Norway spruce monoculture is having on the nutrients in the soil, we used the data collected on this type tree as well as present soil data. We also chose sites with the least amount of management possible. (The best sites we could use had Norway spruce monocultures planted on them with minimal thinning.)

The following sections will give a very brief overview of the data files. If more information is desired, then please refer to Kimmins, Mailly et al. (1999)

5.3.1 The Tree Data File

The tree data file requires many different parameters defining the biomass growth rate and other properties of the tree's growth related to the age of the tree and the soil site quality. It consists of data that defines the biomass accumulation, natural mortality, height, access to light, stand density, foliage data, death, decomposition nutrient concentrations of various components, and atmospheric inputs. It is possible to simulate a number of different tree species in order to produce a more realistic simulation of a forest, however it cannot simulate natural re-growth. Appendix C shows an example of the tree data file for a Norway spruce growing on a site with a soil quality #3, which, in this simulation, is equivalent to a soil site quality of G 32 as rated by the Norway spruce growth index for Southern Sweden. This index is based on the average height of 100 year-old trees. (Karlsson and Westman 1991) pg. 168

5.3.2 The Soil Data File

The soil data file requires many different parameters defining the chemical and physical properties of the soil. It requires data on the litterfall related to decomposition, humus types related to decomposition, nutrient concentration changes when litter is transformed into humus, worms, general nutrient dynamics for the tree's components and for the soil, and decomposition data. Using this data, FORECAST is able to run a simulation with a minimum of two levels of soil quality and it is capable of running with many more.

5.3.3 The Bryophyte Data File

The bryophyte data file is the data file that describes the moss complex, and what growth characteristics it has. It requires data on biomass accumulation, photosynthesis data, nutrient data and transfer of biomass rates for each type of moss to be simulated.

5.3.4 The Plant Data File

The plant data file can have the growth properties of a number of different plants that grow on the forest floor. The data requirements are similar to that of the tree data file and include biomass accumulation, natural mortality, height, access to light, stand density, foliage data, death, decomposition nutrient concentrations of various components, and atmospheric inputs.

5.4 Output of FORECAST

FORECAST has two main output formats. One is in graph form and the other is in table form. FORECAST enables the user to quickly look at the graphed output of data to determine any number of trends. This is a large advantage to the user if they are looking for a specific trend in the data. For example, the user may be interested in the amount of nitrogen in the soil; the graphed output can give a quick view of how the soil dynamics are affected by different management techniques. The user is also able to compare this trend with up to seven other trends, such as the productivity of a specific group of trees, other nutrient concentrations relative to time, plant trends, other soil trends etc.

The tables allow you to look at such things as the economics of the forest, the ecosystem and general overviews. Of particular interest are the tables showing the nutrient inputs and losses over the course of the forest rotation. For the person in the forest industry, the economic table are of particular interest. Here you can see the costs of your scenario, the amount of money that you will make or lose, and the amount of manpower required.

6.0 AVAILABLE AND CALCULATED DATA

6.1 The Tree Data File

The tree data file is the file that describes the properties of the trees in a historical sense. These trees must also have the corresponding soil data, or they are of no use. This type of data was, to some extent, available from the Åsa Research Forest and the Aneboda forests, however there were some considerable gaps that had to be filled in.

The first of many gaps was the question of stand density related to tree age and soil fertility level. The data available that was related to the correct soil fertility level from the experimental forests had very a limited range of age. FORECAST required data points showing the specific age of the forest in relation to stand density. The available data was inadequate to obtain the functions needed to calculate the specific stand densities. Specifically, the y-intercepts, or a forest age of 0 years, of the functions were undefined. Considering that these forests were minimally spaced and trimmed, the y-intercept was obtained from Enström's book (1997, 102), which shows the Swedish recommended stand density when planting a new forest in relation to soil quality. Next, the data from Åsa was entered into CurveExpert and the following functions were calculated:

Low soil fertility:	$Y ? \frac{a}{(1 ? e^{b ? c*x})^{\frac{1}{d}}}$	Y= number of trees x = tree age a = 9994,3617 b = 15,495124 c = -0,25090974 d = 12,385596
High soil fertility:	$Y ? (a ? b*x)^{\frac{?1}{c}}$	Y= number of trees x = tree age a = 0,0032057578 b = $9,4181409*10^{-5}$ c = -0,25090974

Using these functions it was then possible to calculate the stand density for a specific forest age for the FORECAST data file.

The next problem was to determine the biomass accumulation. For this the formulas from two reports were used. Lars Gunnar Marklund, from the Swedish University of Agricultural Sciences, wrote these reports in 1987 and 1988 and they contain the biomass functions for three species of trees; the Norway spruce, pine trees and birch trees in Sweden. As seen from the listed formulas in Appendix E, at least three variables were needed to complete these calculations. These were:

1. The diameter of the tree.
2. The height of the tree.
3. The age of the tree.

Unfortunately, the data set from Aneboda did not have the age of the trees. Åsa's data set lacked the tree diameter, and the age values were questionable. Anneboda's data did not have the tree diameter nor did it relate the trees to a standardised soil fertility level. This resulted in virtually no way to connect the two databases. A literature search for a connection did not turn up anything of use. However, a third file obtained from Christer Kalen from Lund University's Ecology Department had all three components needed. Despite this, it too did not relate the trees to a standardised soil fertility level but using this file, it became possible to salvage the data from Åsa by finding functions that would relate the diameter of a tree with its height. This was a vital factor, which enabled the use of the Åsa file. The Åsa file was the only file that accurately related the trees to the soil quality. Appendix F shows this relationship in more detail using Anneboda as verification data for the function calculated from the data obtained from the ecology department. This verification showed that the function was fairly accurate as both functions were almost identical. It is important to note that the ecology and Anneboda files were no longer considered useful due to a lack of vital data required for FORECAST.

Now that the three vital components were known for the Asa file, the biomass components listed in Appendix E were calculated for each of the three soil qualities. As mentioned previously, this data was not adequate for FORECAST because the modelling software required data specific to forest age. So, another function was derived relating the tree age to the biomass of each component and this function was used to calculate the specific biomass function related to age. The ages used in this function are the ages seen in the treedata file in Appendix C. Finally the biomass for each age and soil type was multiplied by the stand density for each age and specific soil type to determine the biomass in Tonnes per Hectare, which is the format required by FORECAST.

The maximum foliage in the stand, the tree's maximum mass and the maximum age of a tree were all estimated based on expert opinion. However, since the trees in the simulation are harvested every 80 years, these numbers will have only a minimum impact if they are not correct. This is because these numbers affect the space competition in the forest. This may be more significant if the forest were allowed to mature.

The tree canopy height data was inferred based on the data from Aneboda since the other two data sets did not include any canopy data. These values were largely based on Aneboda's data related to the age of the trees (as mentioned previously the ages were calculated values) and an estimated deviation from the average to compensate for the soil qualities.

The data defining the nutrient concentrations in tree biomass components were obtained from Patrik Wallman and Brad Seely. The remainder of the data for this file were based on the advice of Mr. Seely or data from the white spruce was assumed to be sufficient due to the similar physical characteristics between the Norway spruce and the White spruce.

6.2 The Soil Data File

The soil data file contains data describing the properties of the three different soil sites. All the data was derived from the Asa research Forest in southern Sweden.

The soil data file had many pieces of data that were unknown. These were primarily the decomposition properties of the Norway spruce and its effects on the soil. However, data on the chemical and physical properties of the soil were available from the Asa Research Forest. It was noted during this project that by comparing Mr. Seely's tree data file with the obtained data from the Anneboda and Åsa data files, the relationship of the White Spruce in western Canadian soil displayed very similar characteristics to the Norway spruce in southern Swedish soils. From this observation when data was unavailable for Sweden, the Canadian data was substituted even though the Canadian data would not perfectly match the Swedish data.

The data that were used from Åsa included the numbers needed to calculate the mass of mineral soil and humus in each area. The cation exchange capacity was also used from the Asa forest, however the units supplied were not in the correct format and were converted to the format needed by FORECAST. The number of days that nitrogen fixation can take place per year was found Asa's web site. We assumed that nitrogen fixation takes place around the same amount of days as vegetation growth takes place. These are the number of days with an air temperature of over 5 ?C. This web site can be found at http://www.afp.slu.se/klimat/year-a1/1999/a1year.htm.

All other data that was not mentioned above could not be found within the time frame of this project and was taken from the Canadian file. This included the proportion of nutrient change of litterfall to humus, the activity of the worms, the time dependant decomposition rates etc.

6.3 The Bryophyte Data and the Plant Data File

As stated earlier in this report, the bryophyte and plant data files were not used in the simulation, however it is not as simple as just excluding the files. A hypothetical plant and moss system must be created and this system must have a zero growth. These files must be set up to match the most basic criteria set by the other files. For example, these files are set to run for a specific number of time steps, which are the same as the other files, which in this case are 80 years. It also must contain the nutrient(s) that the user wishes to simulate so 1 nutrient was given, nitrogen. The only numbers that the user must input are the numbers showing the ages, and their corresponding values of zero to be certain that there will be no growth of this component in the simulation.

7.0 Preliminary Results and Discussion from the FORECAST Simulation

After the data files were completed, the simulation was fine-tuned so that it produced a realistic growth of trees. Next, the management file was set-up. For this project, the simulation was instructed to run three cycles of 80 years. The trees were harvested at the end of the 80 years, similar to Swedish practise. After the harvest, another forest was re-planted and the cycle was repeated.

The Management file was also instructed to send the stem wood, bark, branches and foliage to the market, which means that these materials were not allowed to naturally decompose back into the eco-system. This could also represent measures taken to produce biofuels from harvested forests. The roots and previously dead branches remained on the forest bottom and were allowed to decompose. No ash or fertilisers were added to the fields during the simulation.

Once this was achieved, the nutrient feedback was enabled and the preliminary results were analysed.

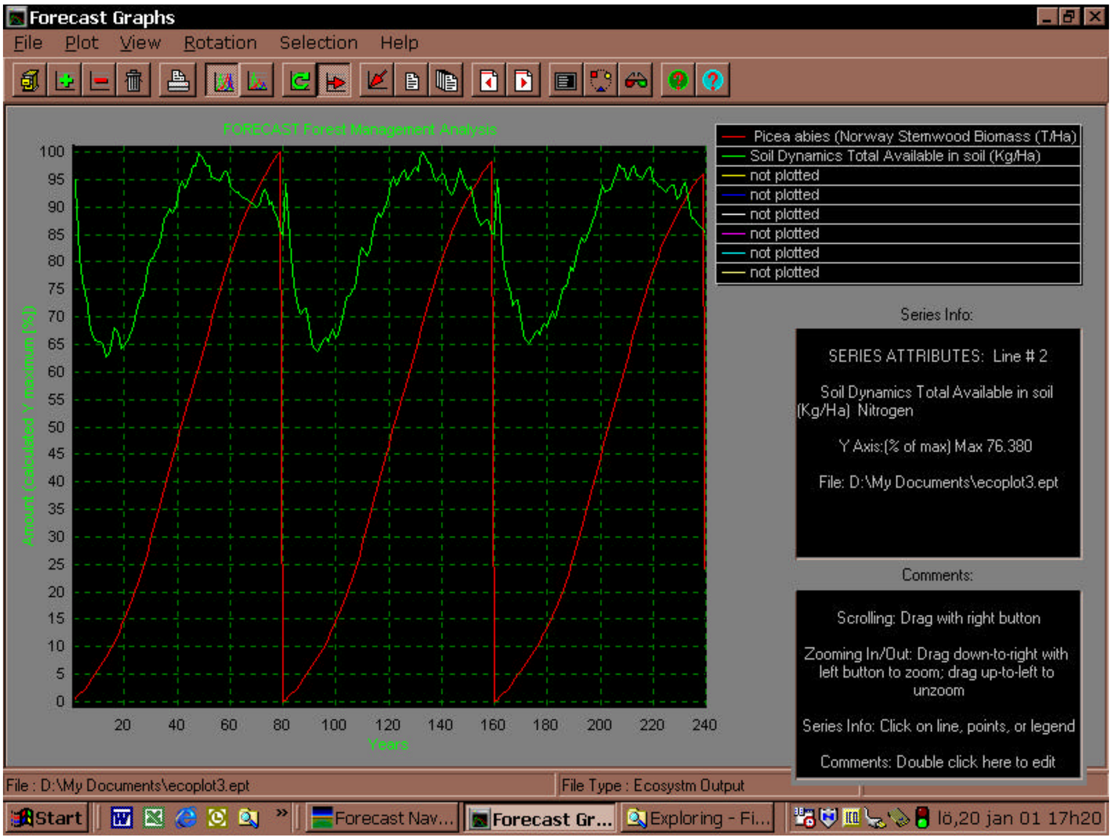

Figure 4: Stembiomass and total available nutrients.

The first thing checked was the relationship between the biomass produced over time and the level of nutrients. Figure 4 shows the stem wood biomass in red and the amount of nitrogen available in green. The graphs are shown on a scale that is based on 100% of the maximum Y value. They are shown in this way to make it easier to see the trends. Looking at the stem wood biomass, a very small decrease over the 240-year period can be seen. The Nitrogen level also appears to decrease a small amount based on the peaks. However, the trend of the minimum values is increasing a very small amount.

From these two trends, it is apparent that the stem wood biomass is decreasing but it is unclear why. The nitrogen levels appear to be reasonably stable so perhaps there is another factor.

In Figure 5, the total production trend as well as the stem wood biomass trend are shown. Looking at the production trend, it is clear that this forest is producing less biomass every year. It is unclear, however, when trying to determine which components are responsible for this decrease in production. For an explanation, we must look at some of the dynamics in the soil.

After comparisons of many different trends, one interesting trend was found that may provide an explanation for the decrease in biomass production. In Figure 6, a significant decrease in the mass of humus is shown. Since the humus is associated with the organic matter and stored nutrients on the forest floor, this could be interpreted as future loss of nitrogen and carbon. Perhaps this is one of the explanations for the decrease in production without a significant decrease in the total nitrogen available.

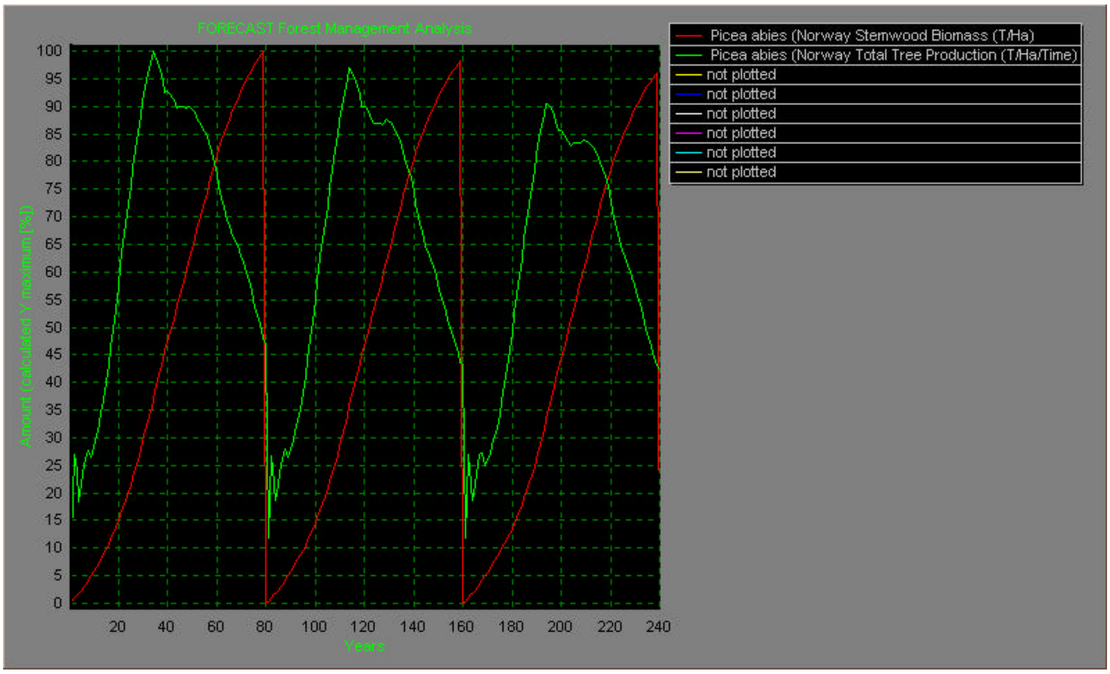

Figure 5: Stembiomass and total tree productivity.

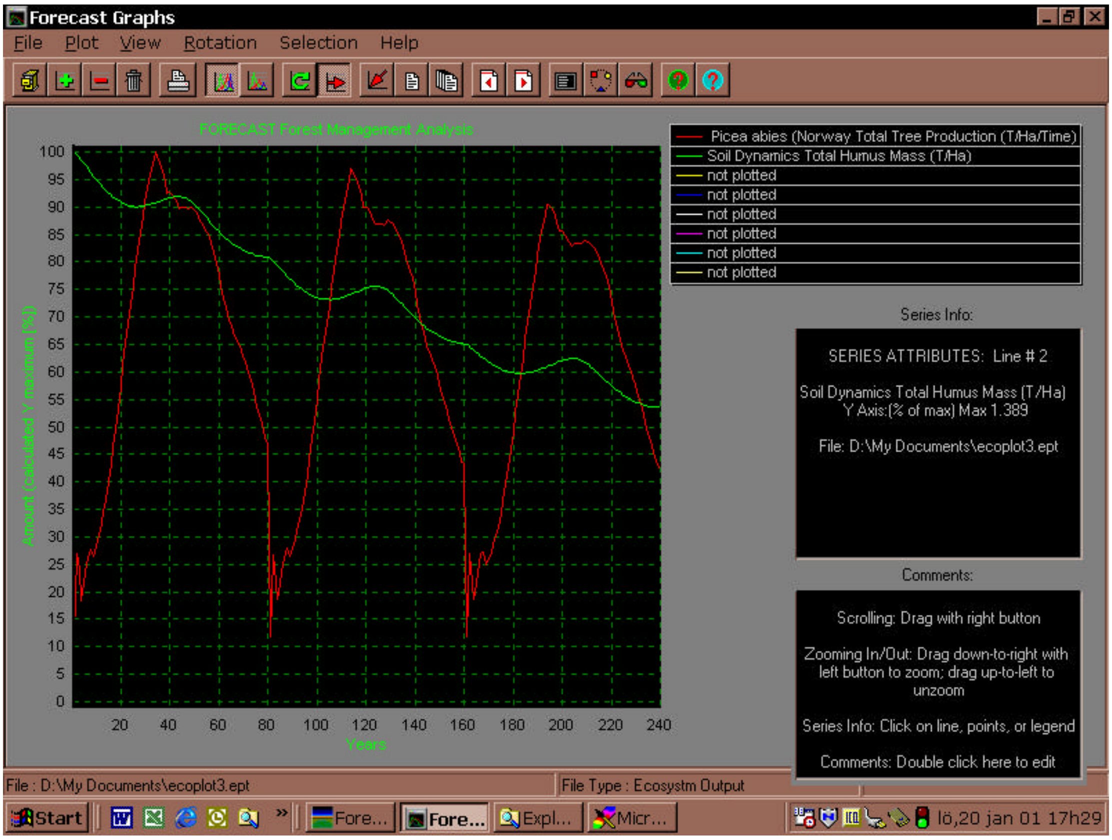

Figure 6: Productivity and the total amount of humus mass.

By looking at these preliminary results obtained from the FORECAST simulation, it suggests that a spruce monoculture might not be sustainable in southern Sweden. Perhaps this problem could be solved with different management techniques such as depositing the branches after harvesting, or by not harvesting everything in one cut. This may increase the humus trend, but it is not known by how much. These possibilities are all within the capabilities of FORECAST. This program appears to be very flexible and can simulate different scenarios for a forest in a matter of minutes by making changes to the management file. Once the program is calibrated and tested to reality it has a lot of potential for anywhere from government authorities to the small wood lot owner.

A wood lot owner might use FORECAST to predict future costs and earnings from a tree lot. Governments might use it for testing fertilisation methods and sustainability issues. FORECAST could also be used as a forestry management trouble-shooter to discover why something might be happening the way it is in nature.

Using all the data files would allow the growth of a multi-species forest with moss and plants. This could be used to determine if multi-species forests are sustainable in the long-term, and which trees grow best together.

Unfortunately, due to time restrictions it was not possible to conduct multiple studies of the effects of various management techniques. If a study were undertaken, it should include fertilisation, mixed species stands, animals, thinning versus no thinning, plants, moss complexes, etc. This type of project would require years of work, however they may reveal some insights into the role different trees have on Swedish soils and their synergetic effects on their ecosystem.

9.0 CONCLUSION

In this report, the preliminary results of the FORECAST model suggested that some of the current forestry methods pertaining to Norway spruce might be unsustainable. In this example, the model pointed towards a decrease in the humus layer over time leading to a decrease in wood biomass production. These preliminary results show the potential of the software and allow the conclusion that, yes; FORECAST could be used to predict the Sustainability of Norway Spruce Stands in Southern Sweden.

When considering the humus and organic parts of the forest ecosystem, this trend could lead to bigger problems than just the immediate forest. We can ask, “Is the Asa forest really a carbon sink?” Most people assume that a forest is, because trees are made up of carbon. However, the forest floor also contains a large amount of carbon and if this is decreasing, then it must be going somewhere else. This could also lead to concerns about Sweden in regards to the Kyoto Protocol. This protocol is about decreasing carbon emissions in the atmosphere on a global scale. How much more carbon is being released in Sweden due to a decreasing amount of humus in the forests? These questions may take years to answer, but perhaps a tool of this nature can help answer some of these questions or similar questions to these.

FORECAST is a powerful model that is accurately able to simulate many different management scenarios IF the correct data is supplied in the data files. However, its uses in Sweden are rather limited, mainly due to the lack of data in the correct format in Sweden. More specifically, Sweden has plenty of data, but it is not data on a natural growth system, and that is what the model requires. In order for it to be useful in Sweden, data would have to be collected on many different species of trees and plants in a natural growth system. However, once collected it could be used as a tool for predicting the specific effects of different management techniques on different types of soils in the southern Sweden region. It can also be used to predict monetary costs, labour costs and energy costs associated with the chosen management techniques, from thinning trees, to fertilisation and fire. One advantage of FORECAST is that once the tree data files are built they are finished and can be used all over the region.

A tool like this one, calibrated to the Swedish ecosystems, would be a very powerful tool that would be useful to many people in the forestry industry. By running a simulation such as this, they would be in a better position to plan their management techniques in a way that would maximize their productivity, minimize their effort and economic spending, knowing that they will be running a production forest in a truly sustainable manner.

10.0 References

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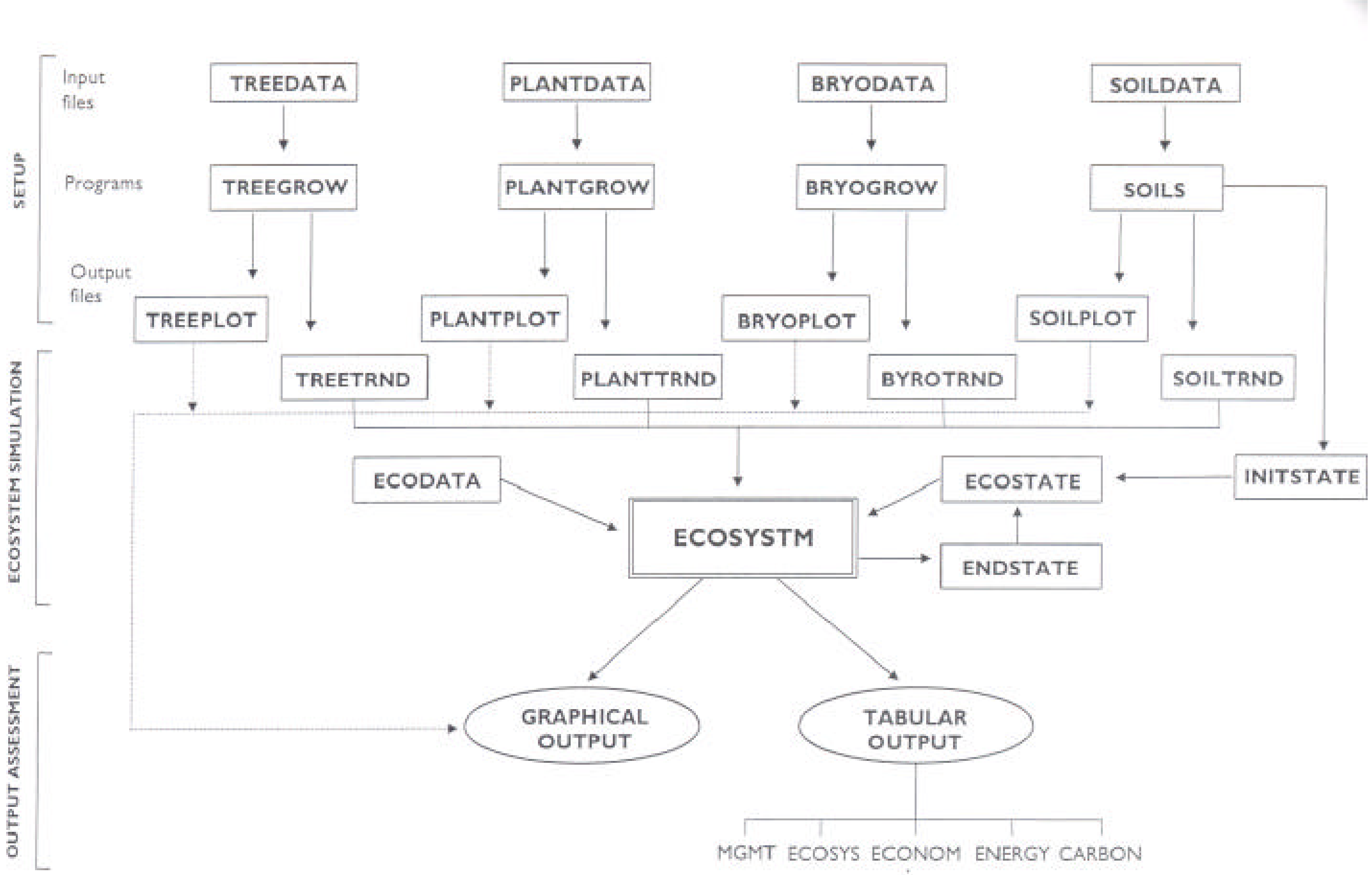
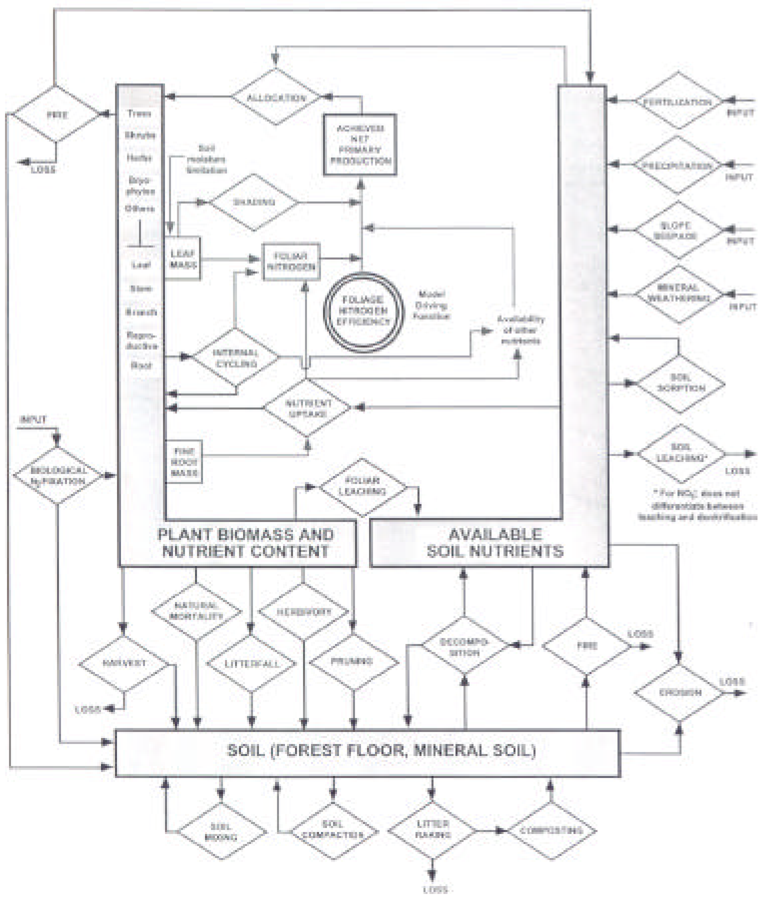
Appendix A – A flowchart of FORECAST **(KIMMINS, MAILLY ET AL. 1999)**



APPENDIX B – THE MAJOR ECOSYSTEM COMPARTMENTS (KIMMINS, MAILLY ET AL. 1999)



APPENDIX C – TREE DATA FILE

```
*******************     TDATA:   INPUT DATA FILE FOR THE TREES-     3.20 PROGRAM OF FORECAST   ***********************
                                                                                                                       :
 **********  FILE LABEL AND CONTENT STATEMENT                                                               OOOOOOOO    :
 Asa 1                                                        DATA FILE IDENTIFICATION                         OO      :
 Asa Experimental Forest                                      PROJECT NAME                                     OO      :
 Stephen Burke                                                USERS NAME(S)                                    OO      :
 Asa, Sweden                                                  LOCATION OF DATA SITE(S)                         OO      :
 Cool Mixed Forest                                            ECOLOGICAL ZONE OF DATA SITE(S)                          :
                                                                                                                       :
     1                                                        NUMBER OF TREE SPECIES                                   :
 Picea abies (Norway Spruce)                                  NAME OF TREE #1                                         T1
   120     0                                                  # OF TIME STEPS, AND SPROUTING ABILITY (0=NO 1=YES)     T1
                                                                                                                       :
     1                                                        NUMBER OF NUTRIENTS                                      :
 Nitrogen                                                     NAME OF NUTRIENT #1                                     N1
                                                                                                                       :
 **********  OUTPUT SELECTION PARAMETERS  *********************************************************************************
    1    1    1       OUTPUT SELECTION:  SCREEN (1=YES 0=NO)   GRAPHS (2=VIEWS 1=GRAPHS 0=NO)   TRENDS (1=YES 0=N0)    :
                                                                                                ~Tree 1               T1
 **********  SECTION T1:  DATA FOR TREE #1  T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1  TREE #1  T1T1T1T1T1T1T1T1T1T1
     3                                                        NUMBER OF DATA SITES                                    T1
     1     5    10    15    20    25    30    35    40    45 AGES FOR SAVING DATA                                     T1
    50    55    60    65    70    75    80    85    90    95                                                          T1
   100   105   110   111   112   113   114   115   117   120                                                          T1
                                                                                                ~T1-Q3             Q3 T1
 ******  SUBSECTION T1 Q3:  DATA FOR TREE #1 ON SITE #3   Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3  DATA SITE #3  Q3Q3Q3Q3Q3Q3 T1
   75.00                                                      SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE       Q3 T1
 ****  SUBDIVISION 1:  DATA DEFINING THE GROWTH OF TREES FROM SEEDLINGS                                            Q3 T1
 **  DATA PAIRS DEFINING BIOMASS ACCUMULATION                                                                      Q3 T1
    10                                                        STEMWOOD BIOMASS ACCUMULATION: # OF DATA PAIRS       Q3 T1
    5.   10.   30.   40.   60.   70.   80.  100.  110.  120.       STAND AGE                                       Q3 T1
10.220 14.75 76.5 118.6 191.5 222.8 251.9 301.0 322.7 341.4      BIOMASS (T/HA)                                  Q3 T1
    10                                                        STEMBARK BIOMASS ACCUMULATION: # OF DATA PAIRS       Q3 T1
    5.   10.   30.   40.   60.   70.   80.  100.  110.  120.       STAND AGE                                       Q3 T1
 1.460  1.98  8.47 11.15 14.97 16.40 17.65 19.80 20.74 21.55     BIOMASS (T/HA)                                  Q3 T1
    10                                                        BRANCH BIOMASS ACCUMULATION: # OF DATA PAIRS         Q3 T1
    5.   10.   30.   40.   60.   70.   80.  100.  110.  120.       STAND AGE                                       Q3 T1
 3.330  8.87 41.57 54.44 70.11 74.20 76.64 78.01 77.51 76.25     BIOMASS (T/HA)                                  Q3 T1
    10                                                        FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS        Q3 T1
    5.   10.   30.   40.   60.   70.   80.  100.  110.  120.       STAND AGE                                       Q3 T1
 2.180  4.41 16.34 19.54 25.28 26.78 27.15 25.36 23.84 22.16     BIOMASS (T/HA)                                  Q3 T1
     28.00       80.00     120.    20.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE  Q3 T1
    10                                                        LARGE ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q3 T1
    5.   10.   30.   40.   60.   70.   80.  100.  110.  120.       STAND AGE                                       Q3 T1
```

```
0.250  1.56 11.22 13.62 19.97 23.45 26.63 30.57 31.04 30.56      BIOMASS (T/HA)                                         Q3 T1
   10                                                       MEDIUM ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q3 T1
   5.   10.   30.   40.   60.   70.   80.  100.  110.  120.      STAND AGE                                              Q3 T1
1.960  3.12 19.85 29.30 42.77 47.27 50.65 54.79 55.85 56.22      BIOMASS (T/HA)                                         Q3 T1
   10                                                       SMALL ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS     Q3 T1
   5.   10.   30.   40.   60.   70.   80.  100.  110.  120.      STAND AGE                                              Q3 T1
1.180  2.62  8.34 10.43 12.65 13.02 13.09 12.70 12.36 11.92      BIOMASS (T/HA)                                         Q3 T1
   10                                                       FRUIT BIOMASS ACCUMULATION: # OF DATA PAIRS           Q3 T1
   5.   10.   30.   40.   60.   70.   80.  100.  110.  120.      STAND AGE                                              Q3 T1
0.000  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00      BIOMASS (T/HA)                                         Q3 T1
**  DATA DEFINING NATURAL MORTALITY AND HEIGHT GROWTH                                                                  Q3 T1
   10                                                       STAND DENSITY: # OF DATA QUADRUPLETS                  Q3 T1
    5.    10.    30.    40.    60.    70.    80.   100.   110.   120.  STAND AGE                                      Q3 T1
 2799.  2360.  1388.  1130.   806.   698.   613.   488.   441.   400.  STEMS/HA                                       Q3 T1
 1.000  1.000  0.500  0.010  0.010  0.010  0.010  0.010  0.010  0.010  PROPORTION MORTALITY DENSITY INDEPENDENT       Q3 T1
 0.250  0.250  0.250  0.250  0.250  0.250  0.250  0.250  0.250  0.250  CANOPY REDUCTION TO STOP SHADE MORTALITY       Q3 T1
   10                                                       TREE AND CANOPY HEIGHT DATA: # DATA QUADRUPLETS       Q3 T1
   5.   10.   30.   40.   60.   70.   80.  100.  110.  120.      STAND AGE                                              Q3 T1
 1.34  3.59 13.40 17.28 22.85 24.80 26.38 28.71 29.59 30.32      AVERAGE TOP HEIGHT OF DOMINANT TREES (M)               Q3 T1
 0.00  0.00  5.00  8.00 14.00 15.00 16.00 16.00 16.00 17.00      TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)            Q3 T1
 0.00  0.15  4.39  7.78 12.26 13.37 14.05 14.77 14.96 15.10      AVERAGE HEIGHT OF CANOPY BOTTOM (M)                    Q3 T1
 2.00  4.60  6.00  8.00  9.50 10.00 11.00 11.00 12.00 12.00 TREE CANOPY MAXIMUM DIAMETER (M)                           Q3 T1
 1.90  4.10 15.80 20.60 27.00 29.07 30.66 32.80 33.60 34.22 TREE STEM MAXIMUM DIAMETER (CM)                            Q3 T1
**  DATA DEFINING PHOTOSYNTHESIS AND SOIL OCCUPATION BY ROOTS                                                          Q3 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      PHOTO LIGHT SATURATION CURVE: .% FULL LIGHT *DNC*     Q3 T1
0.00 0.25 0.45 0.67 0.76 0.85 0.93 0.97 1.00 1.00 0.00           .% OF MAX. PHOTO: SUN FOLIAGE                    Q3 T1
0.00 0.40 0.65 0.80 0.85 0.85 0.85 0.83 0.80 0.75 0.70           .% OF MAX. PHOTO: SHADE FOLIAGE                  Q3 T1
  0.080                                                     SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)   Q3 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      SHAPE OF FOL.BIO.SHADING: .% OF MAX.FOLIAGE  *DNC*    Q3 T1
0.00 0.08 0.24 0.38 0.50 0.60 0.69 0.77 0.83 0.87 0.93                                .% OF MAX.SHADING           Q3 T1
 0.00  0.50                                       .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL     Q3 T1
1.00                                                        .% OF SOIL VOLUME OCCUPIED AT MAX. SMALL ROOT BIO.    Q3 T1
1.00  1.00  1.00   .     .                                  .% EFFICIENCY OF NUTRIENT CAPTURE FOR EACH NUTRIENT   Q3 T1
**  DATA DEFINING THE PROPORTION OF TREES IN UP TO TEN STEM BIOMASS CLASSES FOR UP TO 10 STAND AGES                    Q3 T1
   10                                                       # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN   Q3 T1
AGE   5.     3.0    3.1    3.2    3.3    3.4    3.5    3.6    3.7    3.8    3.9    4.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .01    .15    .20    .40    .15    .05    .01        .% OF STEMS IN EACH CLASS Q3 T1
AGE  10.     5.0    5.2    5.4    5.6    5.8    6.0    6.2    6.4    6.6    6.8    7.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .01    .15    .20    .40    .15    .05    .01        .% OF STEMS IN EACH CLASS Q3 T1
AGE  30.    50.0   51.0   52.0   53.0   54.0   55.0   56.0   57.0   58.0   59.0   60.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .15    .20    .40    .15    .05    .01    .01        .% OF STEMS IN EACH CLASS Q3 T1
AGE  40.    50.0   60.0   70.0   80.0   90.0  100.0  110.0  120.0  130.0  140.0  150.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .15    .20    .40    .15    .05    .01    .01        .% OF STEMS IN EACH CLASS Q3 T1
AGE  60.   200.0  210.0  220.0  230.0  240.0  250.0  260.0  270.0  280.0  290.0  300.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .15    .20    .40    .15    .05    .01    .01    .01    .01        .% OF STEMS IN EACH CLASS Q3 T1
AGE  70.   250.0  260.0  270.0  280.0  290.0  300.0  310.0  320.0  330.0  340.0  350.0   STEM BIOMASS CLASSES    Q3 T1
```

```
              .01    .01    .01    .01    .15    .20    .40    .15    .05    .01       .% OF STEMS IN EACH CLASS Q3 T1
AGE  80.   350.0  360.0  370.0  380.0  390.0  400.0  410.0  420.0  430.0  440.0  450.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .15    .20    .40    .15    .05    .01    .01       .% OF STEMS IN EACH CLASS Q3 T1
AGE 100.   550.0  560.0  570.0  580.0  590.0  600.0  610.0  620.0  630.0  640.0  650.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .01    .15    .20    .40    .15    .05    .01       .% OF STEMS IN EACH CLASS Q3 T1
AGE 110.   700.0  710.0  720.0  730.0  740.0  750.0  760.0  770.0  780.0  790.0  800.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .15    .20    .40    .15    .05    .01    .01    .01    .01       .% OF STEMS IN EACH CLASS Q3 T1
AGE 120.   800.0  810.0  820.0  830.0  840.0  850.0  860.0  870.0  880.0  890.0  900.0   STEM BIOMASS CLASSES    Q3 T1
              .01    .01    .01    .15    .30    .30    .15    .05    .01    .01       .% OF STEMS IN EACH CLASS Q3 T1
**  DATA DEFINING THE CONCENTRATIONS OF UP TO 5 NUTRIENTS IN TREE BIOMASS COMPONENTS                          Q3 T1
.002400  .000000  .000000  .000000  .000000     STEM SAPWOOD                .% NUTRIENT CONCENTRATIONS        Q3 T1
.001800  .000000  .000000  .000000  .000000     STEM HEARTWOOD                                                Q3 T1
.002400  .000000  .000000  .000000  .000000     LIVE BARK (PHLOEM)                                            Q3 T1
.001400  .000000  .000000  .000000  .000000     DEAD BARK                                                     Q3 T1
.005100  .000000  .000000  .000000  .000000     LIVE BRANCHES                                                 Q3 T1
.002750  .000000  .000000  .000000  .000000     DEAD BRANCHES                                                 Q3 T1
.017000  .000000  .000000  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                 Q3 T1
.016800  .000000  .000000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                   Q3 T1
.012100  .000000  .000000  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                     Q3 T1
.002400  .000000  .000000  .000000  .000000     LARGE ROOT SAPWOOD                                            Q3 T1
.001800  .000000  .000000  .000000  .000000     LARGE ROOT HEARTWOOD                                          Q3 T1
.002400  .000000  .000000  .000000  .000000     MEDIUM ROOT SAPWOOD                                           Q3 T1
.001200  .000000  .000000  .000000  .000000     MEDIUM ROOT HEARTWOOD                                         Q3 T1
.011400  .000000  .000000  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                             Q3 T1
.011400  .000000  .000000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                     Q3 T1
.013300  .000000  .000000  .000000  .000000     FRUIT                                                         Q3 T1
**  DATA DEFINING ATMOSPHERIC INPUTS, FOLIAGE LEACHING AND SYMBIOTIC FIXATION OF UP TO 5 NUTRIENTS            Q3 T1
 0.00  0.00  0.00   .     .            ATMOSPHERIC INPUTS: DUST AND PRECIPITATION (KG/HA)                     Q3 T1
 0.00  0.00  0.00   .     .            THROUGHFALL CONTENT (KG/HA)                                            Q3 T1
 0.00  0.00  0.00   .     .            FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (T/HA)                Q3 T1
.0000 .0000 .0000 .     .              SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                  Q3 T1
**  DATA DEFINING TRANSFER OF BIOMASS FROM LIVE TO DEAD COMPONENTS, AND TO LITTERFALL                         Q3 T1
 .100  .040  .100  .050  .050         .% OF LIVE STEMWOOD, BARK, BRANCHES, LARGE AND MEDIUM ROOTS TO DIE      Q3 T1
 .030 0.050  .150  .500 1.000         .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL           Q3 T1
    4   2.0   4.0                      RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE       Q3 T1
 .050  .050  .050  .050  .050  .050   .% WT CHANGE AT DEATH OF LIVE: STEM, BARK, BRANCHES, LRG, MED & SML ROOT Q3 T1
 .100  .050                           .% WT CHANGE WITH FOLIAGE AGING AND DEATH                               Q3 T1
CHECK OK                                                                                                      Q3 T1
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   The FORECAST  model has been developed using the concepts and
   modelling approaches developed by the authors for the FORCYTE series
   of models.  The FORCYTE models were developed with funding from
   Forestry Canada (the ENFOR Program).  FORECAST has been developed
   with funding from the Greater Vancouver Regional District,
   NSERC grants, a grant from the B.C. Ministry of Forests, and
   various other sources.  The FORECAST models are the property
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of J.P. Kimmins and K.A. Scoullar.

APPENDIX D – SOIL DATA FILE

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********************    SDATA:  INPUT DATA FILE FOR SOILS     ****** FORECAST-  3.20 *******************************
                                                                                                                     :
 **********  SECTION 1                                                                                   OOOOO      :
 Asa 1                                                       DATA FILE IDENTIFICATION                   OO          :
 ******  SECTION 1.1:  FILE LABEL AND CONTENT STATEMENTS  *************************************         OOOOO      :
 Asa Experimental Forest                                     PROJECT NAME                                    OO     :
 Stephen Burke                                               USER IDENTIFICATION                        OOOOO      :
 Asa, Sweden                                                 LOCATION OF DATA SITES                                 :
 Cool Mixed Forest                                           ECOLOGICAL ZONE OF DATA SITES                          :
                                                                                                                     :
     1                                                       NUMBER OF TREE SPECIES                                 :
 Picea abies (Norway Spruce)                                    NAME OF TREE #1                                    T1
                                                                                                                     :
     1                                                       NUMBER OF PLANT SPECIES (SHRUBS, HERBS & SIMPLE TREES)  :
 Dud                                                            NAME OF PLANT #1                                   P1
                                                                                                                     :
     1                                                       NUMBER OF BRYOPHYTE SPECIES                            :
 Moss complex                                                   NAME OF MOSS #1                                    B1
                                                                                                                     :
     3                                                       NUMBER OF SOILS DATA SITES                             :
                                                                                                                     :
     1                                                       NUMBER OF NUTRIENTS                                    :
 Nitrogen                                                       NAME OF NUTRIENT #1                                N1
                                                                                                  ~General          :
 ******  SECTION 1.2:  ASSIGNMENT OF TYPE NUMBERS TO VARIOUS TYPES OF DECOMPOSING ORGANIC MATTER  ********************
 **  ASSIGNMENT OF TYPES OF PLANT LITTERFALL TO "DECOMPOSITION TYPES"  **                                            :
   34                                                        # OF DECOMPOSITION TYPES SIMULATED   (MIN=1   MAX=40)   :
  LITTERFALL TYPE AND ASSIGNED DECOMPOSITION TYPE #:                                SITE QUALITY DETERMINATION:      :
  WL 02  WD 01  BK 03  BN 04  FL 05  RL 06  RM 07  RS 08  FR 09        TREE#1                  1.00                T1
  ST 10  FL 11  RH 12  RT 13  FR 14                                    PLANT#1                 0.00                P1
  GR 18  BR 11                                                         BRYOPY#1                0.00                B1
  FR 32                                                                ANIMAL FAECES (INCLUDING INSECT FRASS)        :
  AS 19                                                                ASH                                           :
  CO 33                                                                COMPOST                                       :
  SD 34                                                                SLUDGE                                        :
 **  ASSIGNMENT OF "HUMUS TYPES" TO EACH OF THE DECOMPOSITION TYPES DEFINED ABOVE  **                                :
    2                                                   NUMBER OF HUMUS TYPES SIMULATED (MAX=40)                     :
  HUMUS TYPE # ASSIGNED TO EACH DECOMPOSITION TYPE DEFINED ABOVE (01=HUMUS TYPE #1, ETC.):                           :
   02   01   01   01   01   01   01   01   01   01      DECOMPOSITION TYPES  1-10                                    :
   01   01   01   01   01   01   01   01   01   01      DECOMPOSITION TYPES 11-20                                    :
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  01   01   01   01   01   01   01   01   01   01      DECOMPOSITION TYPES 21-30                                     :
  01   01   01   01   00   00   00   00   00   00      DECOMPOSITION TYPES 31-40                                     :
******  SECTION 1.3:  EFFECT OF THE PRESENCE OR ABSENCE OF SMALL ROOTS ON DECOMPOSITION RATES  **********************
**  USER MAY CHOSE NOT TO USE THIS SECTION.  SEE MANUAL FOR DESCRIPTION  **                                         :
1.00    1                                         TDKMDH  TDKMDW (1=DATA WITH)        TREE#1 ROOTS                 T1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 TDKMD(1...10) (2=DOUBLE, 1=NO CHANGE, 0.5=HALVE)                 T1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 TDKMD(11...20)                                                   T1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 TDKMD(21...30)                                                   T1
1.00 1.00 1.00 1.00  .    .    .    .    .    .   TDKMD(31...40)                                                   T1
1.00    1                                         PDKMDH  PDKMDW (1=DATA WITH)        PLANT#1 ROOTS                P1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 PDKMD(1...10) (2=DOUBLE, 1=NO CHANGE, 0.5=HALVE)                 P1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 PDKMD(11...20)                                                   P1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 PDKMD(21...30)                                                   P1
1.00 1.00 1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 PDKMD(31...40)                                                   P1
******  SECTION 1.4:  DEFINITION OF THE PATTERN OF CHANGE IN NUTRIENT CONCENTRATION FROM LITTER TO HUMUS  ***********
  10                                              NUMBER OF DATA PAIRS                                      ALL TYPES
.10  .20  .30  .40  .50  .60  .70  .80  .90  .00  PROPORTION OF TIME FOR FRESH LITTER TO BECOME HUMUS      ALL TYPES
**  PROPORTION OF THE CHANGE IN NUTRIENT CONCENTRATION BETWEEN LITTER AND HUMUS AT THE ABOVE TIME INTERVALS**      N1
.035 .120 .210 .288 .440 .510 .650 .760 .850 .000 DECOMPOSITION TYPE 01                                        #01 N1
.035 .120 .210 .300 .420 .530 .650 .760 .850 .000 DECOMPOSITION TYPE 02                                        #02 N1
.090 .135 .170 .230 .350 .450 .570 .840 .840 .000 DECOMPOSITION TYPE 03                                        #03 N1
.090 .100 .150 .200 .300 .500 .700 .800 .900 .000 DECOMPOSITION TYPE 04                                        #04 N1
.530 .720 .800 .900 .950 .960 .970 .980 .990 .000 DECOMPOSITION TYPE 05                                        #05 N1
.050 .147 .200 .270 .350 .450 .590 .750 .850 .000 DECOMPOSITION TYPE 06                                        #06 N1
.010 .015 .030 .081 .120 .180 .400 .600 .800 .000 DECOMPOSITION TYPE 07                                        #07 N1
.020 .040 .070 .100 .150 .250 .400 .750 .850 .000 DECOMPOSITION TYPE 08                                        #08 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 09                                        #09 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 10                                        #10 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 11                                        #11 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 12                                        #12 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 13                                        #13 N1
.450 .700 .800 .900 .950 .960 .970 .980 .990 .000 DECOMPOSITION TYPE 14                                        #14 N1
.450 .700 .800 .900 .950 .960 .970 .980 .990 .000 DECOMPOSITION TYPE 15                                        #15 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 16                                        #16 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 17                                        #17 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 18                                        #18 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 19                                        #19 N1
.450 .700 .800 .900 .950 .960 .970 .980 .990 .000 DECOMPOSITION TYPE 20                                        #20 N1
.450 .700 .800 .900 .950 .960 .970 .980 .990 .000 DECOMPOSITION TYPE 21                                        #21 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 22                                        #22 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 23                                        #23 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 24                                        #24 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 25                                        #25 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 26                                        #26 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 27                                        #27 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 28                                        #28 N1
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.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 29                                            #29 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 30                                            #30 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 31                                            #31 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 32                                            #32 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 33                                            #33 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .000 DECOMPOSITION TYPE 34                                            #34 N1
******  SECTION 1.5:  SOIL LAYERS AND SOIL MIXING  SLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSL
   3                                              NUMBER OF SOIL LAYERS (LAYER 1 IS LITTER)                            SL
**  WORMS   WMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWM SL
  0    1                                          WORMS:      (0=NO  1=YES)    CAST TO HUMUS TYPE (#)           WM SL
0.430 0.560 0.010  .     .     .     .     .     .     .      INGESTION OF ORGANIC MATTER FROM LAYERS (.%)      WM SL
0.150 0.840 0.010  .     .     .     .     .     .     .      EGESTION OF CASTS TO LAYERS  (.%)                 WM SL
  999   999   999   999   999   999   999   999   999   999   DECOMP TYPES YOUNGEST AGE USED  (TYPES 1 TO 10)   WM SL
  999   999   999   999   999   999   999   999   999   999                                   (TYPES 11 TO 20)  WM SL
  999   999   999   999   999   999   999   999   999   999                                   (TYPES 21 TO 30)  WM SL
  999   999   999   999     0     0     0     0     0     0                                   (TYPES 31 TO 40)  WM SL
******  SECTION 1.6:  NITROGEN FIXATION IN DECOMPOSING LITTER  ****************************************************:
  200.0                                           NUMBER OF DAYS PER YEAR WITH FIXATION ACTIVITY                       :
  3.0                                             CONVERSION FROM NITROGENASE ACTIVITY TO NITROGEN FIXATION RATES      :
CHECK OK                                                                                                                :
**********  OUTPUT SELECTION PARAMETERS  ***************************************************************************
   1    1    1       OUTPUT SELECTION:  SCREEN (1=YES 0=NO)   GRAPHS (2=VIEWS 1=GRAPHS 0=NO)   TRENDS (1=YES 0=N0)  :
                                                                                                                    :
 GRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGRGR GRAPH LABELS GRGRGRGRGRGRGRGRGRGR
                                                                                                                   GR
#01 TREE#1 HEARTWOOD                                 #11 MOSS BROWN                                                GR
#02 TREE#2 HEARTWOOD                                 #12 TREE#1 MEDIUM ROOTS                                       GR
#03 TREE#1 BARK                                      #13 TREE#2 MEDIUM ROOTS                                       GR
#04 TREE#2 BARK                                      #14 TREE#1 FOLIAGE                                            GR
#05 TREE#1 SAPWOOD                                   #15 TREE#2 FOLIAGE                                            GR
#06 TREE#2 SAPWOOD                                   #16 PLANT#1 SHOOTS                                            GR
#07 TREE#1 LARGE ROOTS                               #17 PLANT#2 SHOOTS                                            GR
#08 TREE#2 LARGE ROOTS                               #18 MOSS GREEN                                                GR
#09 TREE#1 BRANCHES                                  #19 ASH                                                       GR
#10 TREE#2 BRANCHES                                  #20 TREE#1 SMALL ROOTS                                        GR
                                                                                                                   GR
#21 TREE#2 SMALL ROOTS                               #31 PLANT#2 FRUIT                                             GR
#22 PLANT#1 FOLIAGE                                  #32 INSECT FRASS                                              GR
#23 PLANT#2 FOLIAGE                                  #33 COMPOST                                                   GR
#24 PLANT#1 ROOTS                                    #34 SLUDGE                                                    GR
#25 PLANT#2 ROOTS                                    NOT USED                                                      GR
#26 TREE#1 FRUIT                                     NOT USED                                                      GR
#27 TREE#2 FRUIT                                     NOT USED                                                      GR
#28 PLANT#1 TUBERS                                   NOT USED                                                      GR
#29 PLANT#2 TUBERS                                   NOT USED                                                      GR
#30 PLANT#1 FRUIT                                    NOT USED                                                      GR
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                                                                                                                                GR
**********  SECTION 2                                                                                             ~Site 1        DK1
DK1DK1DK1DK1DK1   DATA FOR SOILS SITE #1  DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1   DATA SITE #1   DK1DK1DK1DK1
  25.00                                        NUTRIENT STATUS OF THE SITE - EDAPHIC GRID NUTRIENT AXIS         DK1
******  SECTION 2.1:  RATES OF INPUT OF UP TO FIVE NUTRIENTS FROM THE GEOCHEMICAL CYCLE  *************************DK1
 7.10   .     .     .     .                    PRECIPITATION INPUT       (KG/HA/TIME STEP)                      DK1
 0.00   .     .     .     .                    SEEPAGE INPUT             (KG/HA/TIME STEP)                      DK1
 0.00   .     .     .     .                    WEATHERING INPUT          (KG/HA/TIME STEP)                      DK1
 0.00   .     .     .     .                    NON-SYMBIOTIC FIXATION    (KG/HA/TIME STEP)                      DK1
******  SECTION 2.2:  SORPTION/DESORPTION OF UP TO FIVE NUTRIENTS BY MINERAL SOIL  *******************************DK1
1.000  .     .     .     .                     DESORPTION RATE (PROPORTION OF WAY TO EQUILIBRIUM/TIME STEP)    DK1
    1   0.0            NUTRIENT #1:    # DATA PAIRS DEFINING SORPTION     AMOUNT IRREVERSIBLY BOUND (KG/HA)   N1 DK1
  1.0    .     .     .     .     .     .     .    AMOUNT OF NUTRIENT ADDED (KG/HA)                            N1 DK1
  1.0    .     .     .     .     .     .     .    AMOUNT OF NUTRIENT IN SOLUTION (KG/HA)                      N1 DK1
**  CALIBRATION OF EXPERIMENT TO TEST THE SORPTION/DESORPTION SIMULATION USING ABOVE DATA  (KG/HA)  **          DK1
   0.    0.    0.    0.  1.00     NUTRIENT #1:   INIT SOL CONTENT   FERT#1   FERT#2   FERT#3   RELEASE RATE    N1 DK1
******  SECTION 2.3:  IONIC FORMS OF NUTRIENTS, AND THE EFFECT OF ROOTS AND LITTER TYPE ON NUTRIENT #1 FORMS *****DK1
0.050  .     .     .     .                PROPORTION OF SOIL NUTRIENTS IN ANIONIC FORM FOR UP TO FIVE NUTRIENTS     DK1
**  EFFECT OF THE PRESENCE OF FINE ROOTS ON THE PROPORTION OF NUTRIENT #1 IN ANIONIC FORM  **                    DK1
 1.00                                                TREE#1 ROOT EFFECT  (.%)            1.00=NO CHANGE    T1 DK1
 1.00                                                PLANT#1 ROOT EFFECT (.%)            2.00=DOUBLE       P1 DK1
 1.00                                                BRYOPHYTE#1 EFFECT  (.%)            0.50=HALVE        B1 DK1
**  EFFECT OF DECOMPOSITION TYPE ON THE PROPORTION OF NUTRIENT #1 IN ANIONIC FORM  **                           DK1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00        DECOMPOSITION TYPES 1 TO 10         1.00=NO CHANGE      DK1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00        DECOMPOSITION TYPES 11 TO 20        2.00=DOUBLE         DK1
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00        DECOMPOSITION TYPES 21 TO 30        0.50=HALVE          DK1
1.00 1.00 1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00        DECOMPOSITION TYPES 31 TO 40                            DK1
******  SECTION 2.4:  CATION AND ANION EXCHANGE CAPACITIES OF MINERAL SOIL AND SURFACE ORGANIC MATTER  ***********DK1
  30.0      .       .       .       .          MINERAL SOIL CATION EXCHANGE CAPACITY    (KG/HA)                 DK1
   0.2      .       .       .       .          FOREST FLOOR CEC (KG/T)                                          DK1
   0.2      .       .       .       .          HUMUS  CEC (KG/T)                                                DK1
   0.0      .       .       .       .          MINERAL SOIL ANION EXCHANGE CAPACITY     (KG/HA)                 DK1
   0.0      .       .       .       .          FOREST FLOOR AEC (KG/T)                                          DK1
   0.0      .       .       .       .          HUMUS AEC (KG/T)                                                 DK1
******  SECTION 2.5:  HUMUS CHEMISTRY AND DECOMPOSITION RATES  ***************************************************DK1
  .010   2.00     2.     HUMUS #1:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM1 DK1
  .01400  .       .       .       .          CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM1 DK1
  .005   1.50     7.     HUMUS #2:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM2 DK1
  .01000  .       .       .       .          CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM2 DK1
******  SECTION 2.6:  NUTRIENT CONCENTRATIONS AND WEIGHT LOSS FOR FAECES, ASH AND COMPOST  ***********************DK1
  .00500  .       .       .       .          CONCENTRATION OF UP TO FIVE NUTRIENTS IN ANIMAL FAECES   (.%)          DK1
  .500                                  KG FAECES PRODUCED PER  KG FOLIAGE CONSUMED   (KG/KG)                   DK1
  .00010  .       .       .       .          CONCENTRATION OF UP TO FIVE NUTRIENTS IN ASHED MATERIAL  (.%)          DK1
  .015                                  KG ASH PRODUCED PER KG MATERIAL BURNED        (KG/KG)                   DK1
  .00500  .       .       .       .          CONCENTRATION OF UP TO FIVE NUTRIENTS IN COMPOST         (.%)          DK1
  .500                                  KG COMPOST PRODUCED PER KG MATERIAL COMPOSTED (KG/KG)                   DK1
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******  SECTION 2.7:  CONCENTRATION OF UP TO FIVE NUTRIENTS IN LITTERFALL ENTERING EACH DECOMPOSITION TYPE  ******DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 01       USED FOR DIAGNOSTIC PURPOSES ONLY      #01 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 02                                              #02 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 03                                              #03 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 04                                              #04 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 05                                              #05 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 06                                              #06 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 07                                              #07 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 08                                              #08 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 09                                              #09 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 10                                              #10 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 11                                              #11 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 12                                              #12 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 13                                              #13 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 14                                              #14 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 15                                              #15 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 16                                              #16 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 17                                              #17 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 18                                              #18 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 19                                              #19 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 20                                              #20 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 21                                              #21 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 22                                              #22 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 23                                              #23 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 24                                              #24 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 25                                              #25 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 26                                              #26 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 27                                              #27 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 28                                              #28 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 29                                              #29 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 30                                              #30 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 31                                              #31 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 32                                              #32 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 33                                              #33 DK1
  .00200  .       .       .       .        DECOMPOSITION TYPE 34                                              #34 DK1
******  SECTION 2.8:  TIME-DEPENDENT DECOMPOSITION RATES FOR EACH DECOMPOSITION TYPE (.% WT. LOSS/TIME STEP) *****DK1
   5                                  DECOMPOSITION TYPE 01     # DATA PAIRS                                  #01 DK1
  1.  30.  45.  70. 100.    .    .    .    .    .              AGE:  LAST AGE IS MAX AGE FOR TYPE             #01 DK1
.002 .050 .080 .050 .010 .    .    .    .    .                 DECAY RATE                                     #01 DK1
1.52 2.22 2.22 3.88 2.41  .    .    .    .    .                NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)    #01 DK1
   4                                  DECOMPOSITION TYPE 02     # DATA PAIRS                                  #02 DK1
  1.  10.  20.  30.    .    .    .    .    .    .              AGE:  LAST AGE IS MAX AGE FOR TYPE             #02 DK1
.150 .200 .300 .020 .    .    .    .    .    .                 DECAY RATE                                     #02 DK1
1.52 2.22 3.88 2.41  .    .    .    .    .    .                NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)    #02 DK1
   4                                  DECOMPOSITION TYPE 03     # DATA PAIRS                                  #03 DK1
  1.  10.  50. 100.    .    .    .    .    .    .              AGE:  LAST AGE IS MAX AGE FOR TYPE             #03 DK1
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.010 .060 .100 .020 .    .    .    .    .    .               DECAY RATE                                       #03 DK1
2.00 3.00 3.00 4.00  .    .    .    .    .    .              NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #03 DK1
   4                                     DECOMPOSITION TYPE 04   # DATA PAIRS                                     #04 DK1
  1.  10.  20.  30.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #04 DK1
.200 .400 .350 .020 .    .    .    .    .    .               DECAY RATE                                       #04 DK1
2.00 3.00 3.00 4.00  .    .    .    .    .    .              NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #04 DK1
   5                                     DECOMPOSITION TYPE 05   # DATA PAIRS                                     #05 DK1
  1.  10.  25.  40.  50.    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #05 DK1
.010 .080 .150 .100 .020 .    .    .    .    .               DECAY RATE                                       #05 DK1
3.50 3.00 5.25 5.25 10.9   .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #05 DK1
   4                                     DECOMPOSITION TYPE 06   # DATA PAIRS                                     #06 DK1
  1.  10.  25.  30.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #06 DK1
.100 .300 .400 .020 .    .    .    .    .    .               DECAY RATE                                       #06 DK1
3.50 5.25 5.25 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #06 DK1
   5                                     DECOMPOSITION TYPE 07   # DATA PAIRS                                     #07 DK1
  1.   3.  10.  30.  50.    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #07 DK1
.040 .080 .150 .200 .020 .    .    .    .    .               DECAY RATE                                       #07 DK1
3.50 5.25 5.25 10.9 10.9   .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #07 DK1
   4                                     DECOMPOSITION TYPE 08   # DATA PAIRS                                     #08 DK1
  1.   3.  10.  20.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #08 DK1
.200 .300 .600 .020 .    .    .    .    .    .               DECAY RATE                                       #08 DK1
3.50 5.25 5.25 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #08 DK1
   4                                     DECOMPOSITION TYPE 09   # DATA PAIRS                                     #09 DK1
  1.  10.  30.  50.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #09 DK1
.050 .200 .150 .020 .    .    .    .    .    .               DECAY RATE                                       #09 DK1
3.50 5.25 5.25 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #09 DK1
   4                                     DECOMPOSITION TYPE 10   # DATA PAIRS                                     #10 DK1
  1.   5.  10.  15.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #10 DK1
.300 .600 .500 .020 .    .    .    .    .    .               DECAY RATE                                       #10 DK1
3.50 5.25 5.25 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #10 DK1
   4                                     DECOMPOSITION TYPE 11   # DATA PAIRS                                     #11 DK1
  1.   3.  10.  40.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #11 DK1
.100 .300 .200 .020 .    .    .    .    .    .               DECAY RATE                                       #11 DK1
70.0 70.0 70.0 70.0   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #11 DK1
   4                                     DECOMPOSITION TYPE 12   # DATA PAIRS                                     #12 DK1
  1.  10.  20.  50.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #12 DK1
.080 .200 .300 .020 .    .    .    .    .    .               DECAY RATE                                       #12 DK1
3.50 5.50 5.50 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #12 DK1
   4                                     DECOMPOSITION TYPE 13   # DATA PAIRS                                     #13 DK1
  1.   5.  10.  15.    .    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #13 DK1
.300 .500 .600 .020 .    .    .    .    .    .               DECAY RATE                                       #13 DK1
3.50 5.50 5.50 10.9   .    .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #13 DK1
   5                                     DECOMPOSITION TYPE 14   # DATA PAIRS                                     #14 DK1
  1.   2.  10.  15.  20.    .    .    .    .    .             AGE:  LAST AGE IS MAX AGE FOR TYPE               #14 DK1
.200 .300 .400 .200 .020 .    .    .    .    .               DECAY RATE                                       #14 DK1
3.50 5.50 5.50 10.9 10.9   .    .    .    .    .             NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)      #14 DK1
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   4                                          DECOMPOSITION TYPE 15     # DATA PAIRS                                    #15 DK1
  1.   2.   4.   6.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #15 DK1
.700 .700 .500 .020 .    .    .    .    .    .                          DECAY RATE                                      #15 DK1
3.50 5.50 5.50 10.9   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #15 DK1
   4                                          DECOMPOSITION TYPE 16     # DATA PAIRS                                    #16 DK1
  1.   2.   5.  10.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #16 DK1
.200 .300 .600 .020 .    .    .    .    .    .                          DECAY RATE                                      #16 DK1
10.0 10.0 10.0 10.0   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #16 DK1
   5                                          DECOMPOSITION TYPE 17     # DATA PAIRS                                    #17 DK1
  1.   2.   3.   4.  10.    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #17 DK1
.200 .300 .600 .400 .020 .    .    .    .    .                          DECAY RATE                                      #17 DK1
10.0 10.0 10.0 10.0 10.0   .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #17 DK1
   4                                          DECOMPOSITION TYPE 18     # DATA PAIRS                                    #18 DK1
  1.   2.  10.  15.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #18 DK1
.200 .250 .400 .020 .    .    .    .    .    .                          DECAY RATE                                      #18 DK1
70.0 70.0 70.0 70.0   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #18 DK1
   4                                          DECOMPOSITION TYPE 19     # DATA PAIRS                                    #19 DK1
  1.   2.   3.   5.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #19 DK1
.950 .600 .500 .020 .    .    .    .    .    .                          DECAY RATE                                      #19 DK1
70.0 70.0 70.0 70.0   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #19 DK1
   4                                          DECOMPOSITION TYPE 20     # DATA PAIRS                                    #20 DK1
  1.   3.   6.  10.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #20 DK1
.100 .250 .500 .020 .    .    .    .    .    .                          DECAY RATE                                      #20 DK1
3.50 5.50 5.50 10.9   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #20 DK1
   4                                          DECOMPOSITION TYPE 21     # DATA PAIRS                                    #21 DK1
  1.   2.   3.   5.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #21 DK1
.400 .600 .800 .020 .    .    .    .    .    .                          DECAY RATE                                      #21 DK1
3.50 5.50 5.50 10.5   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #21 DK1
   4                                          DECOMPOSITION TYPE 22     # DATA PAIRS                                    #22 DK1
  1.   3.   6.  10.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #22 DK1
.300 .400 .600 .020 .    .    .    .    .    .                          DECAY RATE                                      #22 DK1
3.50 5.50 5.50 10.5   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #22 DK1
   4                                          DECOMPOSITION TYPE 23     # DATA PAIRS                                    #23 DK1
  1.   2.   3.   5.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #23 DK1
.800 .600 .500 .020 .    .    .    .    .    .                          DECAY RATE                                      #23 DK1
3.50 5.50 5.50 10.5   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #23 DK1
   4                                          DECOMPOSITION TYPE 24     # DATA PAIRS                                    #24 DK1
  1.   3.   6.  10.    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #24 DK1
.200 .300 .500 .020 .    .    .    .    .    .                          DECAY RATE                                      #24 DK1
3.50 5.50 5.50 10.9   .    .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #24 DK1
   5                                          DECOMPOSITION TYPE 25     # DATA PAIRS                                    #25 DK1
  1.   2.   3.   4.   5.    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #25 DK1
.300 .600 .700 .400 .020 .    .    .    .    .                          DECAY RATE                                      #25 DK1
3.50 5.50 5.50 10.9 10.9   .    .    .    .    .                        NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)     #25 DK1
   3                                          DECOMPOSITION TYPE 26     # DATA PAIRS                                    #26 DK1
  1.   2.   3.    .    .    .    .    .    .    .                       AGE:  LAST AGE IS MAX AGE FOR TYPE              #26 DK1
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.950 .950 .020 .    .    .    .    .    .    .                   DECAY RATE                                      #26 DK1
10.0 10.0 10.0    .    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #26 DK1
   3                                      DECOMPOSITION TYPE 27     # DATA PAIRS                                    #27 DK1
  1.   2.   3.    .    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #27 DK1
.950 .950 .020 .    .    .    .    .    .    .                   DECAY RATE                                      #27 DK1
10.0 10.0 10.0    .    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #27 DK1
   4                                      DECOMPOSITION TYPE 28     # DATA PAIRS                                    #28 DK1
  1.   2.   3.   5.    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #28 DK1
.500 .700 .800 .020 .    .    .    .    .    .                   DECAY RATE                                      #28 DK1
20.0 20.0 20.0 20.0    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #28 DK1
   4                                      DECOMPOSITION TYPE 29     # DATA PAIRS                                    #29 DK1
  1.   2.   3.   4.    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #29 DK1
.600 .800 .900 .020 .    .    .    .    .    .                   DECAY RATE                                      #29 DK1
20.0 20.0 20.0 20.0    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #29 DK1
   3                                      DECOMPOSITION TYPE 30     # DATA PAIRS                                    #30 DK1
  1.   2.   3.    .    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #30 DK1
.990 .990 .020 .    .    .    .    .    .    .                   DECAY RATE                                      #30 DK1
10.0 10.0 10.0    .    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #30 DK1
   3                                      DECOMPOSITION TYPE 31     # DATA PAIRS                                    #31 DK1
  1.   2.   3.    .    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #31 DK1
.990 .990 .020 .    .    .    .    .    .    .                   DECAY RATE                                      #31 DK1
10.0 10.0 10.0    .    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #31 DK1
   3                                      DECOMPOSITION TYPE 32     # DATA PAIRS                                    #32 DK1
  1.   2.   3.    .    .    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #32 DK1
.950 .900 .020 .    .    .    .    .    .    .                   DECAY RATE                                      #32 DK1
20.0 20.0 20.0    .    .    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #32 DK1
   5                                      DECOMPOSITION TYPE 33     # DATA PAIRS                                    #33 DK1
  1.   5.  10.  15.  30.    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #33 DK1
.200 .500 .300 .200 .020 .    .    .    .    .                   DECAY RATE                                      #33 DK1
20.0 20.0 20.0 20.0 20.0    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #33 DK1
   5                                      DECOMPOSITION TYPE 34     # DATA PAIRS                                    #34 DK1
  1.   2.   3.   4.   5.    .    .    .    .    .                 AGE:  LAST AGE IS MAX AGE FOR TYPE              #34 DK1
.600 .500 .300 .200 .120 .    .    .    .    .                   DECAY RATE                                      #34 DK1
20.0 20.0 20.0 20.0 20.0    .    .    .    .    .                 NITROGEN FIXATION (NMOLES C2H4/GR MASS/DAY)   #34 DK1
**  DEFINITION OF DELAY IN CONVERSION OF FRESH TREE LOG HEARTWOOD TO DECOMPOSING MATTER     **********************DK1
  10                                      TREE#1              # DATA PAIRS                                         T1 DK1
 10.  30.  40.  60.  70.  80.  90. 100. 110. 120.         TREE AGE AT DEATH                                    T1 DK1
  0.   0.  10.  20.  30.  35.  40.  43.  45.  46.         TIME FOR ALL HEARTWOOD TO START DECOMPOSITION        T1 DK1
******  SECTION 2.9:  EFFECT OF EXPOSURE ON DECOMPOSITION RATE OF DIFF AGE CLASSES FOR EACH DECOMP. TYPE  ********DK1
YOUNGEST   INTERMEDIATE   AGE OF INTER.    OLDEST         AGE CLASS                 .20  .% LIGHT AT GROUND        DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 01                                #01 DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 02                                #02 DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 03                                #03 DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 04                                #04 DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 05                                #05 DK1
 1.000         1.000          1.           1.000          DECOMPOSITION TYPE 06                                #06 DK1
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 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 07                              #07 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 08                              #08 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 09                              #09 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 10                              #10 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 11                              #11 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 12                              #12 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 13                              #13 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 14                              #14 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 15                              #15 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 16                              #16 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 17                              #17 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 18                              #18 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 19                              #19 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 20                              #20 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 21                              #21 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 22                              #22 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 23                              #23 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 24                              #24 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 25                              #25 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 26                              #26 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 27                              #27 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 28                              #28 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 29                              #29 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 30                              #30 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 31                              #31 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 32                              #32 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 33                              #33 DK1
 1.000         1.000          1.         1.000         DECOMPOSITION TYPE 34                              #34 DK1
******  SECTION 2.10:  SOIL LAYERS AND SOIL MIXING   SLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSLSL DK1
   0.0  1650.0  2000.0     0.0     0.0          MASS OF MINERAL SOIL IN LAYERS 1 TO 5  (T/HA)             SL DK1
   0.0     0.0     0.0     0.0     0.0          MASS OF MINERAL SOIL IN LAYERS 6 TO 10 (T/HA)             SL DK1
  100.      0.  42000.      0.      0.          MASS OF HUMUS #1 IN LAYERS 1 TO 5  (KG/HA)            HM1 SL DK1
    0.      0.      0.      0.      0.          MASS OF HUMUS #1 IN LAYERS 6 TO 10 (KG/HA)            HM1 SL DK1
35000.      0.      0.      0.      0.          MASS OF HUMUS #2 IN LAYERS 1 TO 5  (KG/HA)            HM1 SL DK1
    0.      0.      0.      0.      0.          MASS OF HUMUS #2 IN LAYERS 6 TO 10 (KG/HA)            HM1 SL DK1
**  WORMS   WMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWMWM SL DK1
  600.0     5.0                 WORMS:  MAXIMUM WORM MASS (KG/HA)   POPULATION RECOVERY (# TIME STEPS)   WM SL DK1
   25.0  1000.0                         INGESTION (KG OM/KG WM/TIME)  MAX THROUGHPUT (KG MIX/KG WM/TIME)  WM SL DK1
  0.050   0.050                         ASSIMILATION RATE    HUMUS (.%)     LITTER (.%)              WM SL DK1
  590.0      45       0           EXPERIMENT:  WORMS (KG/HA)    # TIME STEPS   POP. DYNAMICS (1=YES 0=NO)  WM SL DK1
 2335.0       5                         LEAF LITTER (KG/HA/TIME)    DECOMPOSION TYPE (#)              WM SL DK1
  780.0       8                         FINE ROOT LITTER (KG/HA/TIME)   DECOMPOSITION TYPE (#)        WM SL DK1
0.000 0.600 0.400  .     .     .     .     .     .     .        ROOT LITTER DISTRIBUTION TO LAYERS (.%)     WM SL DK1
CHECK OK                                                                                                     DK1
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The FORECAST model has been developed using the concepts and modelling approaches developed by the authors for the FORCYTE series of models. The FORCYTE models were developed with funding from Forestry Canada (the ENFOR Program). FORECAST has been developed with funding from the Greater Vancouver Regional District, NSERC grants, a grant from the B.C. Ministry of Forests, and various other sources. The FORECAST models are the property of J.P. Kimmins and K.A. Scoullar.

APPENDIX E – TREE DATA FUNCTIONS

The fertile soil stand density was based on the following function:

$Density=(a+b*age)^{(-1/c)}$
a=0,0032057578
$b=9,4181409*10^{-5}$
c=0,70627441

The least fertile soil stand density was based on the following function:

$Density=a/((1+e^{b-c*age})^{(1/d)}$
a=9994,3617
b=15,495124
c=-0,25090974
d= 12,385596

The middle soil quality stand density was the average of the maximum and minimum values from the previous two functions.

The following formulas were used to calculate the biomass components:

1 – Stem Biomass over bark pg. 49[1]:
ln(DWstem)= 7,4471*(d/(d+14))+0,0203*h+0,7256*(ln(h))+0,0517(ln(t))-2,3389

2 – Stem Wood Biomass pg. 52[1]:
ln(DWstemwood)= 7,0394*(d/d+14)+0,0391*h+0,6493*(ln(h))+0,0737*(ln(t))-2,4029

3 – Stem Bark Biomass pg. 58[1]:
ln(DWstembark)= 9,8364*(d/(d+15))-3,4216

4 – Living Branches Biomass pg. 63[1]:
ln(DW living branches)= 8,6040*(d/(d+13))-1,3858

5 – Needle Biomass pg. 67[1]:

Nomenclature:
DW() = Dry Weight in kg of the specific component
d= the tree's diameter in cm
h= the tree's height in meters
t= the tree's age in years

$\ln(\mathrm{DWneedles}) = 7{,}8171*(d/(d+12))-2{,}0330$

6- Dead Branches Biomass pg. 71[1]:
$\ln(\mathrm{DWdead\ branches}) = 9{,}9550*(d/(d+18)-4{,}6654$

7 – Stump Root System Biomass pg. 52[2]:
$\ln(\mathrm{DWstump\ roots}) = 10{,}5381*(d/(d+14))-2{,}4447$

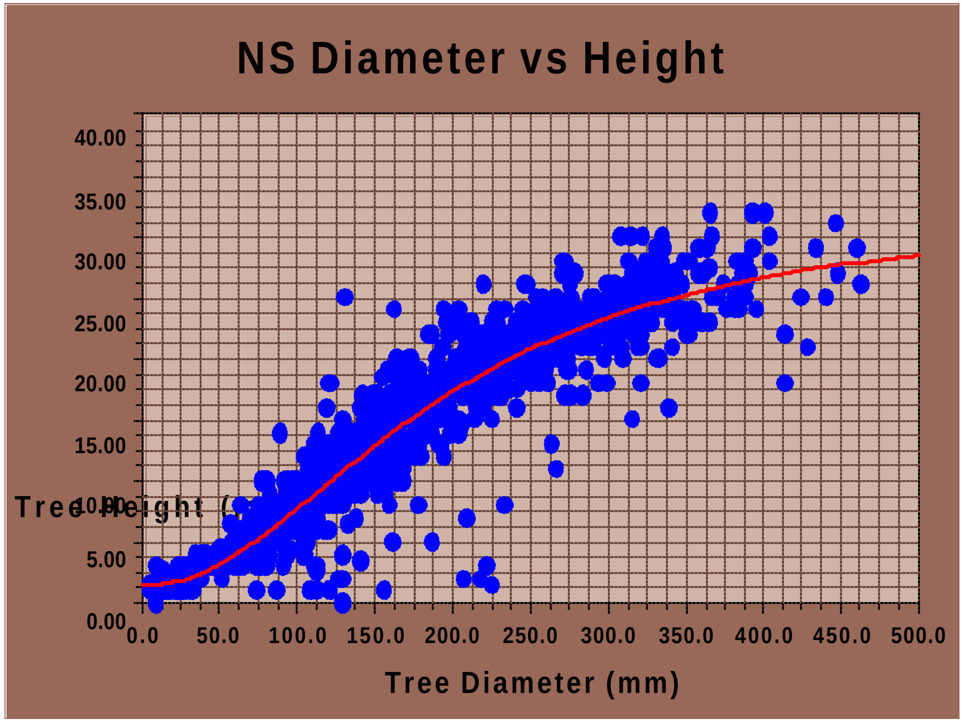
8 – Stump Biomass pg. 54[2]:
$\ln(\mathrm{DWstump}) = 10{,}6686*(d/(d+17))-3{,}3645$

9 – Roots >= 5cm pg. 55[2]:
$\ln(\mathrm{DWroots}>=5\mathrm{cm}) = 13{,}3703*(d/(d+8))-6{,}3851$

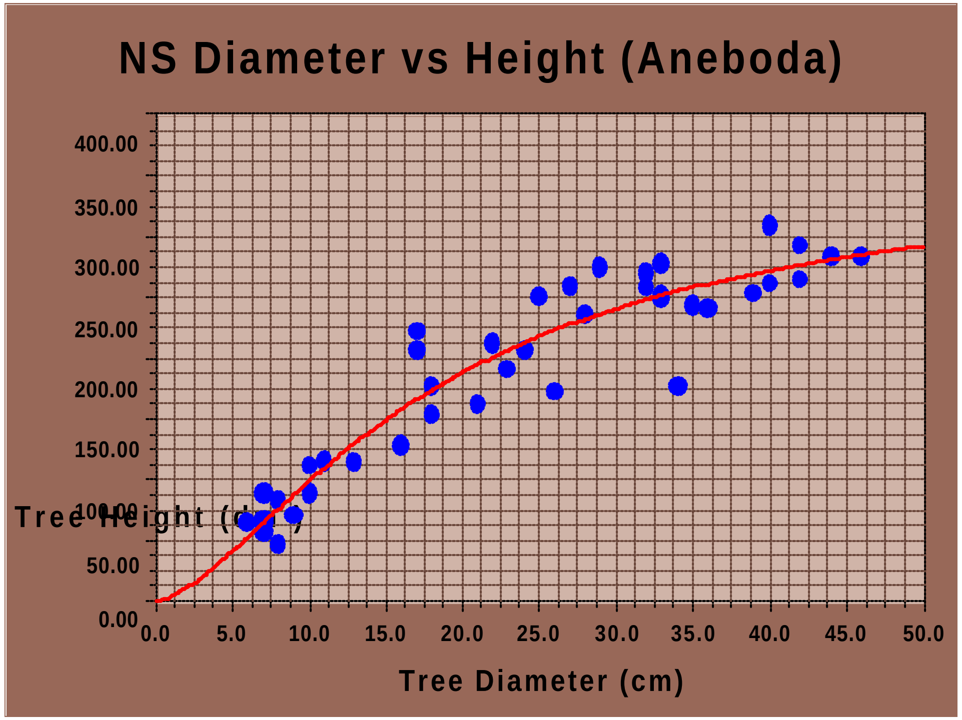
10 – Roots <5cm pg. 57[2]:
$\ln(\mathrm{DWroots}<5\mathrm{cm}) = 7{,}6283*(d/(d+12))-2{,}5706$

[1] = (Marklund 1987)
[2] = (Marklund 1988)

APPENDIX F – THE DIAMETER VS HEIGHT CONNECTION



This graph shows the general relationship between the tree diameter and height in southern Swedish Norway spruce trees.
MMF Model: y=(a*b+c*x^d)/(b+x^d)
Coefficient Data:
a=1,448901
b=43450,34
c=32,52502
d=2,026527
Standard Error: 2.7612951
Correlation Coefficient: 0.9366938
Comments:
The iteration count of 100 was exceeded.
The fit failed to converge to tolerance of 0.000001 (CHI2 at 7929.740883). No weighting used.
Data Points Used = 1044



This graph shows that the trees in the Aneboda forest have the same relationship between the diameter and height shown above.

MMF Model: y=(a*b+c*x^d)/(b+x^d)
Coefficient Data:

a =	0,610858
b =	90,11677
c =	352,9467
d =	1,54736

MMF Model: y=(a*b+c*x^d)/(b+x^d)
Standard Error: 25.6734177
Correlation Coefficient: 0.9581182
Comments:
The fit converged to a tolerance of 1e-006 in 10 iterations.
No weighting used.

Data Points Used
44