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AN APPLICATION OF DYNAMO SIMULATION MODEL FOR THE EXPERIMENTAL FOREST OF SEOUL NATIONAL UNIVERSITY

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I. Introduction

The planning process is an important part because it can guide or misguide a whole project. Upon the increasing need of useful planning skills, the needs of more skillful and effective planning models have increased. Because, as Chappelle noted, a model is a representation of a system and is used to explain the behavior of some aspects of the system. A model can be a essential tool to manipulate a real world system. Owing to the increasing demand for concentrated management, the Korean Forest Service needs to employ more useful models to plan and manage forest areas.

There are a variety of models and these models may be characterized in many ways. One way is by the different approach of the individual manager, namely, optimization models and simulation models. These models are basically different.

The optimization model provides an optimal solution on the basis of the management goals and constraints.

The most widely used mathematical optimization model is the linear programming (LP) model. The LP is a mathematical technique that allows decision makers to compare the ability of alternative management strategies to meet stated goals within available resource limitations (Iverson and Alston, 1986).

There are many forest-related models developed using LP framework, such as Timber Resource Allocation Method(Timber RAM, Navon 1975), Multiple Use-Sustained Yield Calculation

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Technique(MUSYC, Johnson and Jones 1979), and FORPLAN (Johnson, 1986). Timber RAM was designed to help in formulating "plans which are efficient with respect to stumpage harvested, costs, or revenues, and which are consistent with specific management policies and available resources" (Navon, 1971). MUSYC evolved to improve the multiple use orientation of Timber RAM, thus, it is basically similar to Timber RAM, but more sophisticated model. FORPLAN was developed to connect the gap between functional resources planning and integrate landuse planning, but its basic concepts are shared with Timber RAM and MUSYC.

Computerized LP models have become very popular in the forest area because they can recommend the best decision among numerous alternative decisions under the constraints and the management goals. These recommended decisions become very useful information in the human decision-making process. Under certain kinds of management goals, the manager can get an optimal solution from the LP model.

The negative aspect of LP model is that the manager sometimes has to spend a tremendous amount of time in developing constraints and variables.

The simulation model is basically different from the optimization model. The planner can get several alternative solutions on the basis of the management goals through the simulation model. That is, he can get many solutions depending on management goals and solutions.

The meaning of 'simulate' is to imitate or to feign. This means that 'simulate' is to imitate something. On the process of simulation, many models are usually involved. These models can be a physical, mental, mathematical or the mixture of these approaches. These models are useful because they mimic the important elements of what is being simulated.

The physical model is usually expensive, thus computerized simulation model are preferred nowadays. Since the computer has replace hand calculations in recent years, the mathematical model has been much cheaper and has reduced time. Because of these changes, mathematical simulation models are often preferred and widely used.

Nowadays, computer simulation is used in a wide range of applications in areas such as physical science, social science and economics. There are many different approaches to be employed by model builders for their models, but DYNAMO computer simulation models use a dynamic feedback systems approach.

A system may be defined as "an aggregation or assemblage of objects united by some form of regular interaction of interdependence" (Webster's dictionary, 1946). For example, a forest can be viewed as a system which provides water, air, wildlife habitat and other benefits for its inhabitants and to the society.

The systems approach is mainly concerned with connectedness and wholeness among modeled variables. For example, viewing a forest as a system, it might involve interaction between trees and wildlife, or geological condition and inhabitants, or climate condition and inhabitants or all of interactions. System science emerged as a serious field of study after the Second World War. Urban Dynamics (Forester, 1969) was developed using a computer simulation model which analyzed urban growth and decay. Meadows(1972) employed "THE WORLD 3" simulation model in his book 'The Limits to Growth' which analyzed possible relationships between population, pollution, natural resources, and economic growth.

In the late 1970's, Boyce(1977) applied computer simulations to forest systems. He developed several DYNAST models which is an acronym for Dynamically Analytic Silviculture Technique. Its basic core is an ecological model. The fundamental purpose of the model is to guide the management of the forest in question toward a steady-state structure that provides the best possible combination of benefits (Boyce, 1977). There are several DYNAST models such as DYNAST-MB(multiple benefits), DYNAST-TM(timber), DYNAST-OB(optimal benefits). DYNAST is written in the DYNAMO language and is based on systems dynamics concepts.

II. Model for Planning in Specific Area

1. The purpose

The purpose of this paper is to develop a forest planning model using the data of Experimental Forest of Seoul National University and employing a computer simulation package which is called "DYNAMO".

The management goal of this forest is assumed to achieve a steady state condition and a maximum sustainable yield. Because of the data availability and time constraints, this paper only treats how to achieve a steady state forest by the regulation of the forest area.

2. Assumptions

This model assumes that the area with a given age class is equally distributed throughout that age class. This assumption is very important because this model does not maintains individual stand area within that age class but maintains the area of each age class. Also, there are no conversions from forest area to other types of area. There are no intermediate treatments such as a thinning during the simulation period. After harvesting, a planting follows after on year.

3. Structure of the Model

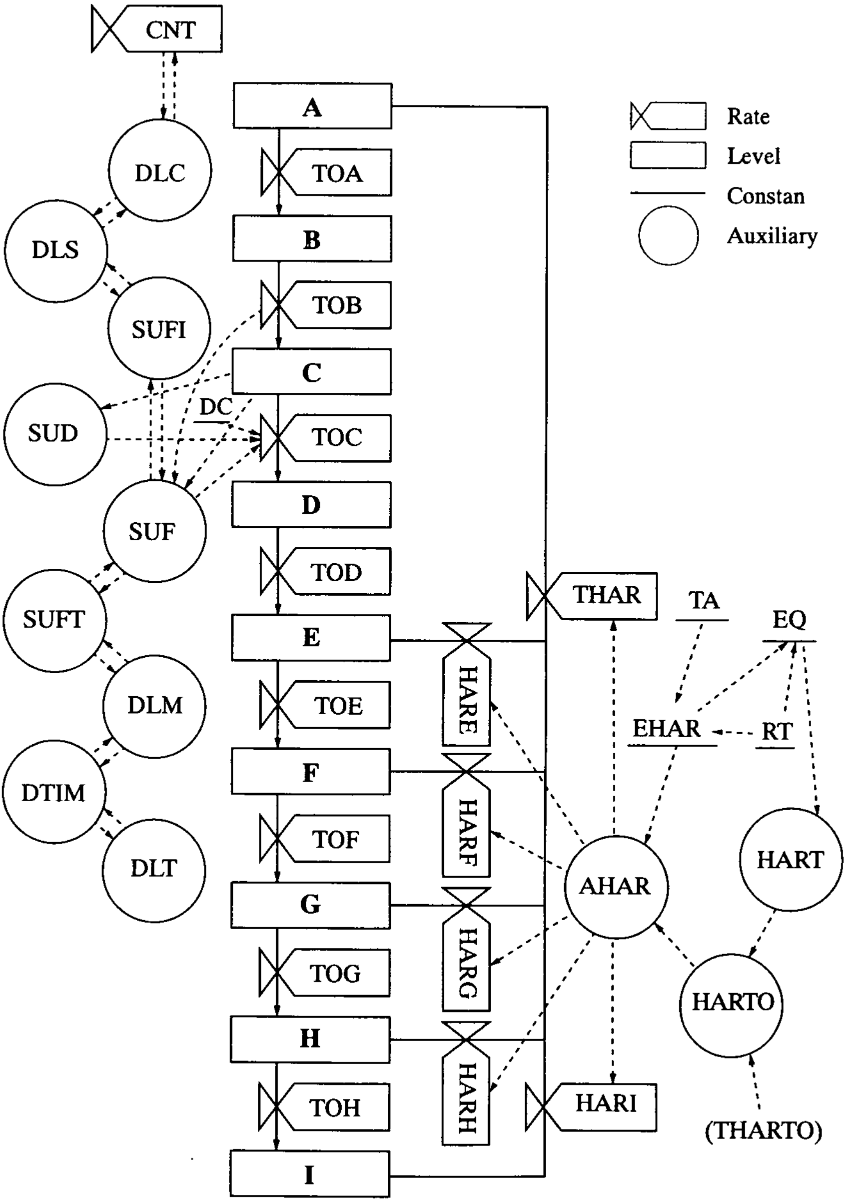
This flowchart shows how the model works (figure 1). The solid lines indicate the actual movement of a inventory and dotted lines indicate the movement of related information such as rotation age and total area. The main parts of the flowchart are succession and harvest section.

(1) Succession

The model has a set of negative feedback loops designed to achieve the goal of a steady state forest by converting the current distribution of forest state to the desired state of forest, and maintaining the achieved state of forest.

The succession model consists of L(level), R(rate), and A (auxiliary) functions. The level function indicates the amount of each age class area on each time period. So, A(0-9), B(10-19), C(20-29), D (30-39), ... and I(80+) are the area of each age class. The rate function indicates the amount of inversion from the younger age class and the amount of succession to the older age class. So, TOA is the diversion rate from A to B, while TOB is the diversion rate from B to C. The inversion and succession rate is a function of the inventory of age class and D(delay time).i.e., mostly represented by the area of each age class divided by the delay time of each age class. Also the auxiliary function is used to provide the information for the succession. For example, in case of the age class C, if area of age class

FIGURE 1. Flowchart of the Model.

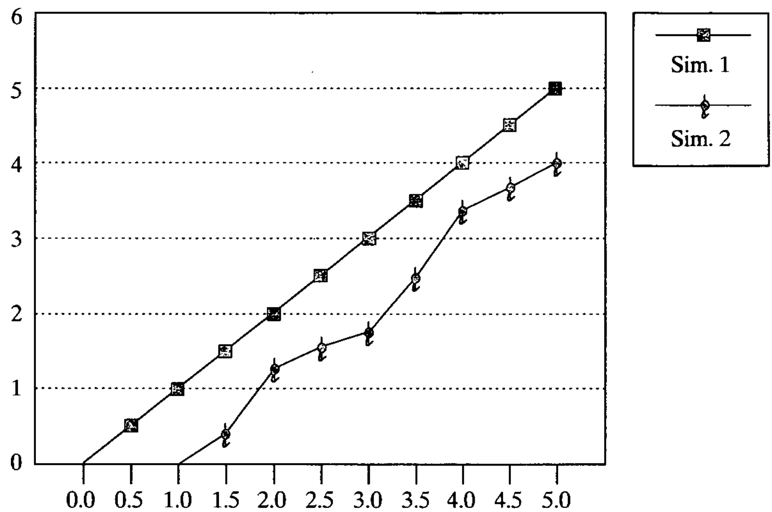


C is zero, go to SUDC, but if not, go to SUFC. At the SUFC, if transfer from younger age class (in this case B) is zero i.e., TOB is zero, takes SUFIC. If not, SUFC takes SUFTC. DLCC, DLSC and CNYC are designed to count the number of years which has zero of TOB. These numbers of years will affect the amount of succession area from this age class. For example, if there is 200 ha in age class C and there is no inversion from age class B, i.e., TOB is zero for 10 years, the 200 ha should be gone after 10 years to the age class of D. So, the TOC are not 200/10 (TOC represent by C/DC) every year, but 200/10 at first year, 180/(10-1) at second year, 160/(10-2) at third year, and 20/(10-9) at tenth year. 1,2,3 ..., and 9 represent the count of years which no inversion from age class B occurs. If TOB is not zero, SUFC takes SUFTC rather than SUFIC. After going to SUFTC, if there is no area in age class C, the DLT, DTIM, and DLM count the years when there is no area in age class C. For instance, the age class B has 200 ha but age class C is empty. After one year, 20 ha move to age class C from age class B. After two years, another 20 ha move in age class C but 2 out of 20 ha from age class C move out to age class D. So it does not make any sense because age class C has to wait for 10 years during which the empty age class C succeeds to age class D. So DLT, DTIM and DLM count the years when there is zero area in this age class and modify the amount of succession.

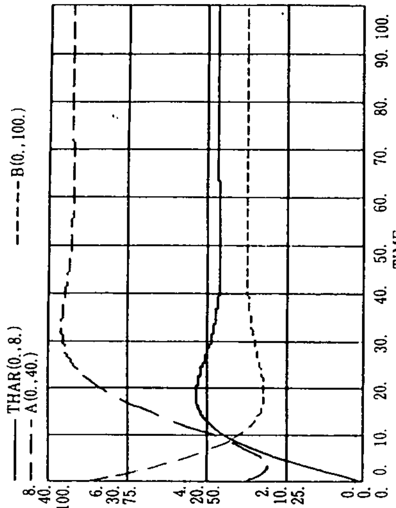
(2) Harvest

The harvest schedule is a core factor of achieving a steady state forest. The algorithm of the model regulates the harvest schedule on the basis of the forest conditions and the management regimes. The EHAR (expected harvest) is calculated by TA(total area) divided by RT (rotation age). The EQ(equilibrium) is derived from the EHAR and RT and it indicates the amount of expected harvest within the time difference between the rotation age and the youngest age of the old growth forest. For example, if EHAR is 20 ha, and RT is 40 years while the youngest age of the old growth forest is 30, the most desirable old growth area is 20*(40-30)=200 ha because we can harvest 20 ha which is the same as EHAR every year until the youngest age of the old growth reach the rotation age. The HART (harvestable ratio) is from the proportional ratio of the old growth area and the EQ. The desirable value of HART is 1.0 because it means the area of old growth is the same as what ought to be. The HART is decided by the THARTO. The value of THARTO is provided by the manager. The figure 2 shows the relation between HART and THARTO.

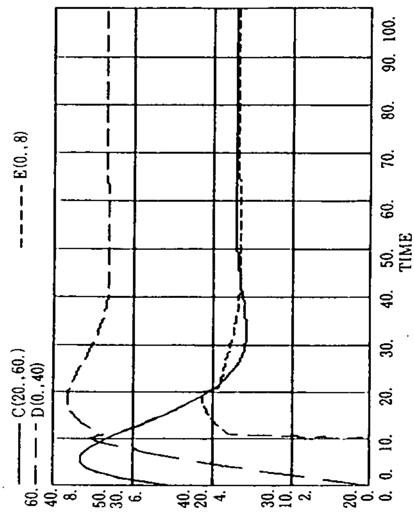
FIGURE 2. The Relation between HART and THARTO



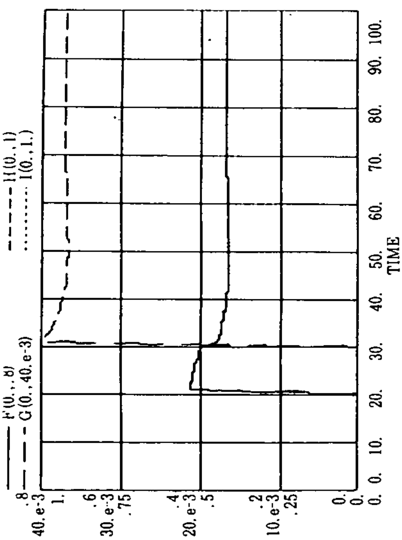
The value of THARTO is the most important factor to affect the amount of harvest volume. The simulation 1(45 degree line) indicates the amount of harvest volume is the same as the amount of the expected harvest volume because the THARTO is the same as the HART. Under the 45 degree line(simulation 2) indicates the amount of harvest volume is less than the amount of the expected harvest volume. The decision of THARTO is based on the manager's management strategies. The decision maker chooses the THARTO expecting the optimal forest type under the management goals and constraints. For example, if the management goal is the maximal harvest, the decision maker chooses the 45 degree line of the THARTO. If the management goals is to achieve the maximum population of a certain wildlife species such as woodpecker which survives in the old forest, he can choose the lower than 45 degree of THARTO to allocate more area to the older age forest.



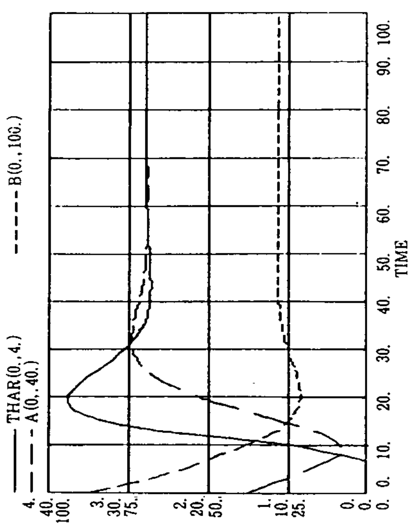
Graph 1. Korean Pine. Simulation 1



Graph 2. Korean Pine. Simulation 1



Graph 3. Korean Pine. Simulation 1



Graph 4. Korean Pine. Simulation 2

4. Study Area

Table 1 shows the statistics figures of the Experimental Forest of Seoul National University. The Experimental Forest of Seoul National University is occupied by the three major species and other minor species. Its geological and climactic conditions are close to the average conditions of whole Korean peninsula. Its management goals are also close to those of other forest on Korea, i.e., getting a steady state forest.

This model used the figures of table 1 under the assumption that other management practices except final harvests will not be implemented. This model used the figure of THARTO (0.0/0.5/1.0/1.5 /2.0/2.5/3.0/3.5/4.0/4.5/5.0) because the management goal of this forest is getting the maximum sustained yield.

TABLE 1. The Area Information of Each Species and Each Age Class of the Experimental Forest of Seoul National University

Unit : ha

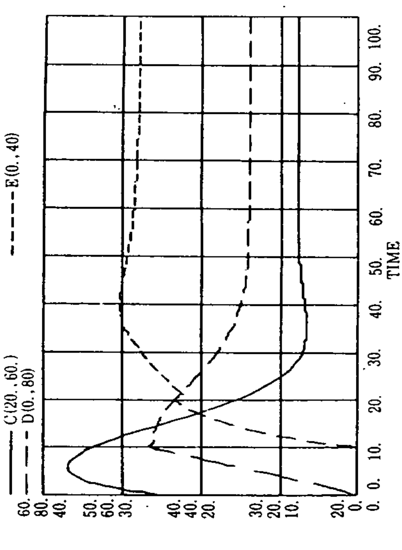
Species Age Class	Korean Pine	Oak	Larch	Other	total
A(0- 9)	15.10	48.11	0.00	2.10	65.31
B(10-19)	88.14	278.24	91.68	22.54	480.60
C(20-29)	45.25	90.83	28.48	65.05	229.61
D(30-39)	0.00	0.00	0.00	0.00	0.00
E(40-49)	0.00	0.00	0.00	0.00	0.00
F(50-59)	0.00	0.00	0.00	0.00	0.00
G(60-69)	0.00	0.00	0.00	0.00	0.00
H(70-79)	0.00	0.00	0.00	0.00	0.00
I (80-89)	0.00	0.00	0.00	0.00	0.00
Total	148.49	417.18	120.16	89.69	775.52

Source : Seoul National Universty

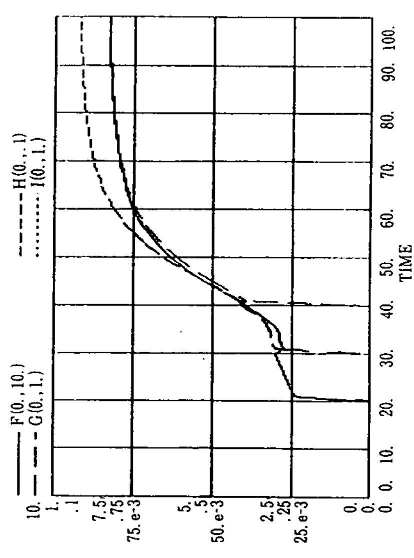
5. Sensitivity Analysis

The core of the sensitivity analysis is to analyze the state of forest in the future by the changing of the value of THARTO and the relation between the shape of each age class curve and the THARTO figure under the condition that the other variables are assumed to be fixed. Two different figures are assigned to the THARTO (simulation 1 and simulation 2) and the results are shown on the several graphs. Graphs 1, 2, and 3 are the results from the simulation 1 and the graphs 4, 5, and 6 are from the simulation 2. As shown in the graphs, the time of reaching a steady state of inventory in each age class by the simulation 1 is comparatively shorter than that of the simulation 2.

The older age class have more significant difference of the time between the simulation 2 and simulation 1. For example, in case of age class G, the curves for simulation 1 reach a steady state after 31 years but the curves for simulation 2 reach a steady state after 90 years. This trend was also found by the more changes of the figure of the THARTO while the figure of the THARTO indicates the amount of the harvest. Also, the sensitivity analysis proved that we could get a steady state forest at a certain time regardless of the value of the THARTO. But, the value of THARTO decides the time of getting a steady state forest and the shape of the each age class forest in the future.



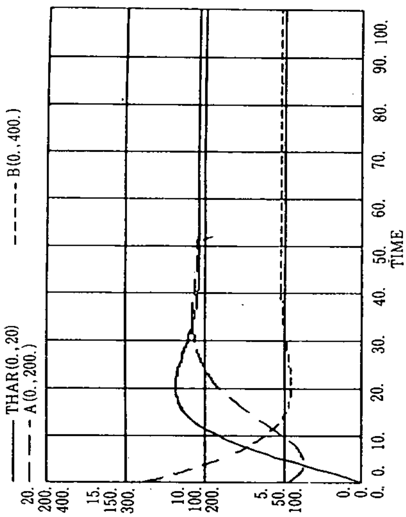
Graph 5. Korean Pine. Simulation 2



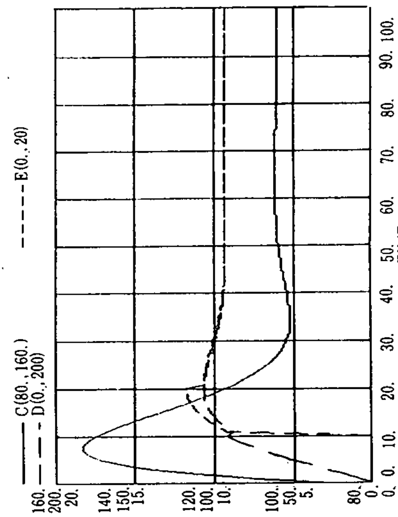
Graph 6. Korean Pine. Simulation 2

6. Results

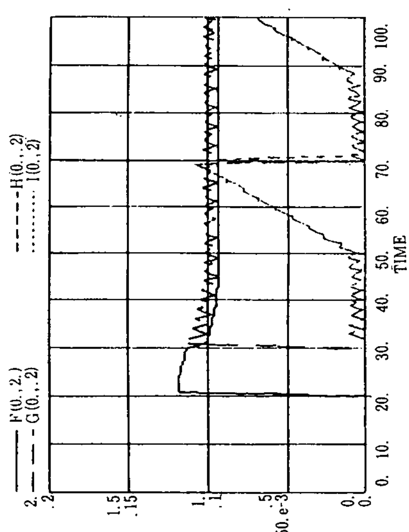
Graphs(7-15) showed that each age class of each species reached a steadv state forest at a certain time. Also, the sensitivity analysis



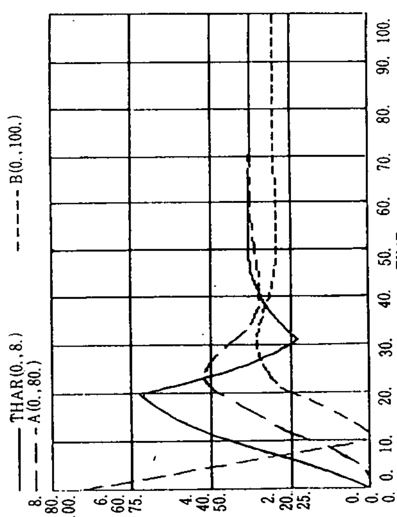
Graph 7. Oak



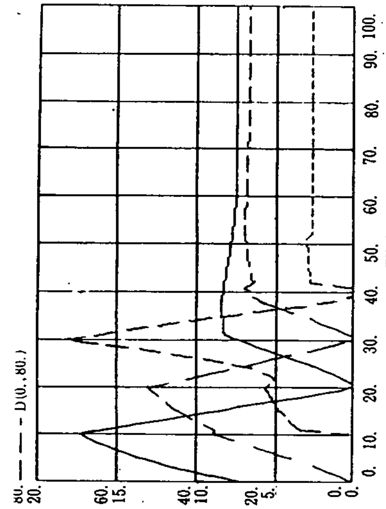
Graph 8. Oak



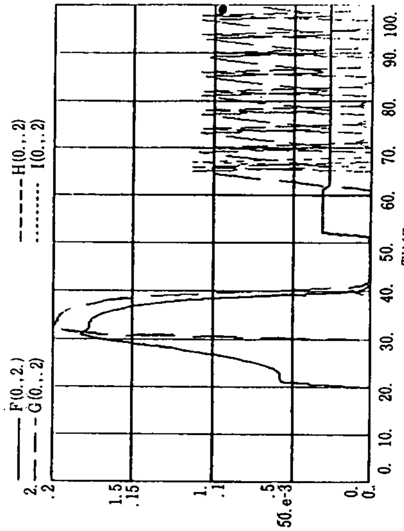
Graph 9. Oak



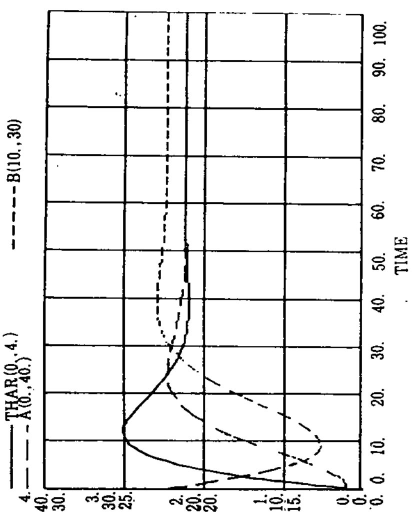
Graph 10. Larch



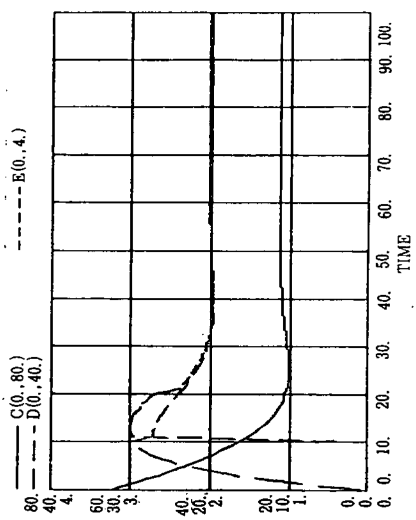
Graph 11. Larch



Graph 12. Larch

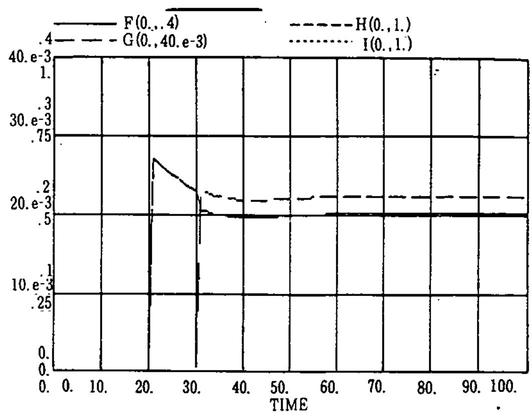


Graph 13. The Rest



Graph 14. The Rest

showed that this model predicted the time of achieving a steady state forest. By those results, this model was proved to predict the future projection of forest.



Graph 15. The Lest

III. Conclusion

Most of forest in Korea are still very young and not ready to be used as timber resources. But, some of forest will be harvestable and useful to the society in the very near future. By changing of forest practice plans from planting alone to the more complex management, models which can project the future and help plan management will be needed. Although this model is fairly short and simple, it can fulfill the need of the Korean society by increasing its complexity and accuracy. Thus, the most important reason to develop this model is not to develop the most accurate and useful tool but to create a milestone for the establishment of modeling skills for Korean foresters.

IV. Discussion

1. Applicablilty to Other Area

This model is highly applicable to many forest planning efforts dealing with the succession, harvest and regulations for achieving a steady state forest. It is also useful for analyzing forest policies and management by

FIGURE 3. Stand Structure as Simulated by Original Succession Algorithms in DYNAST-OB.

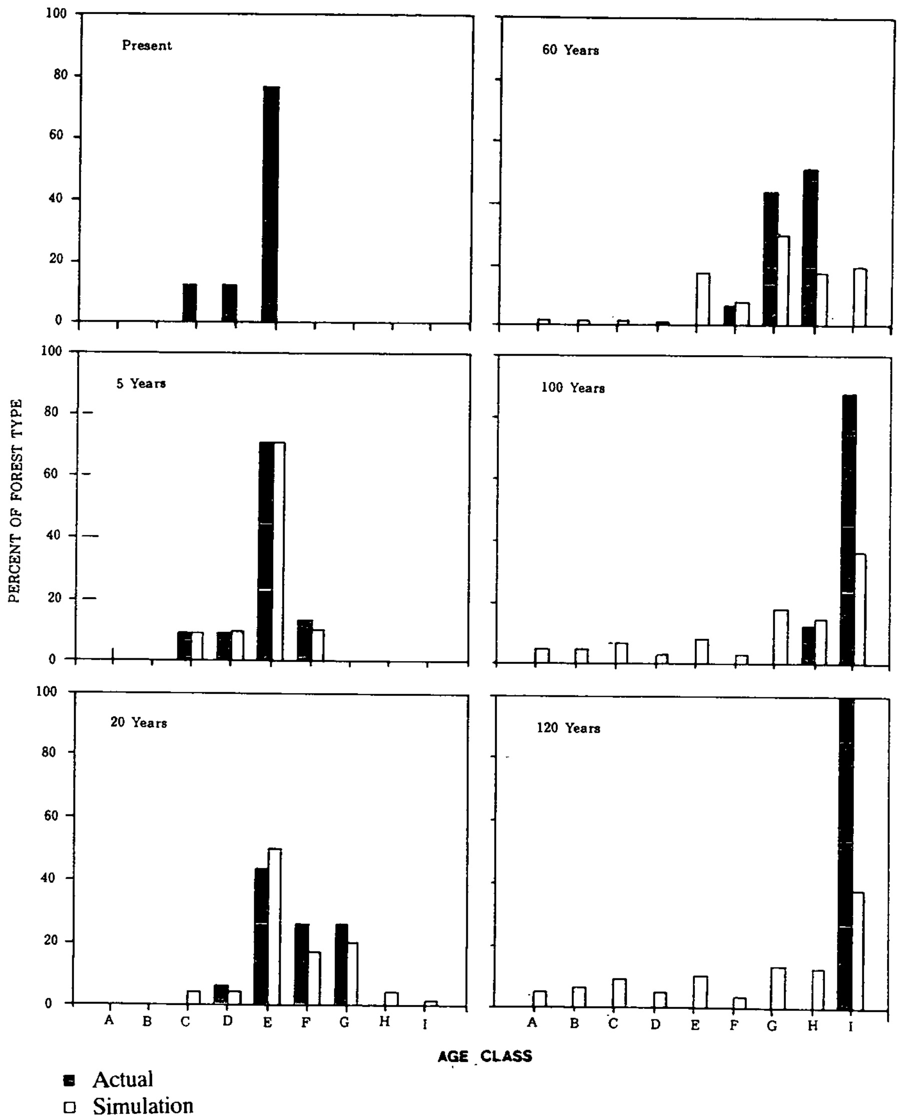
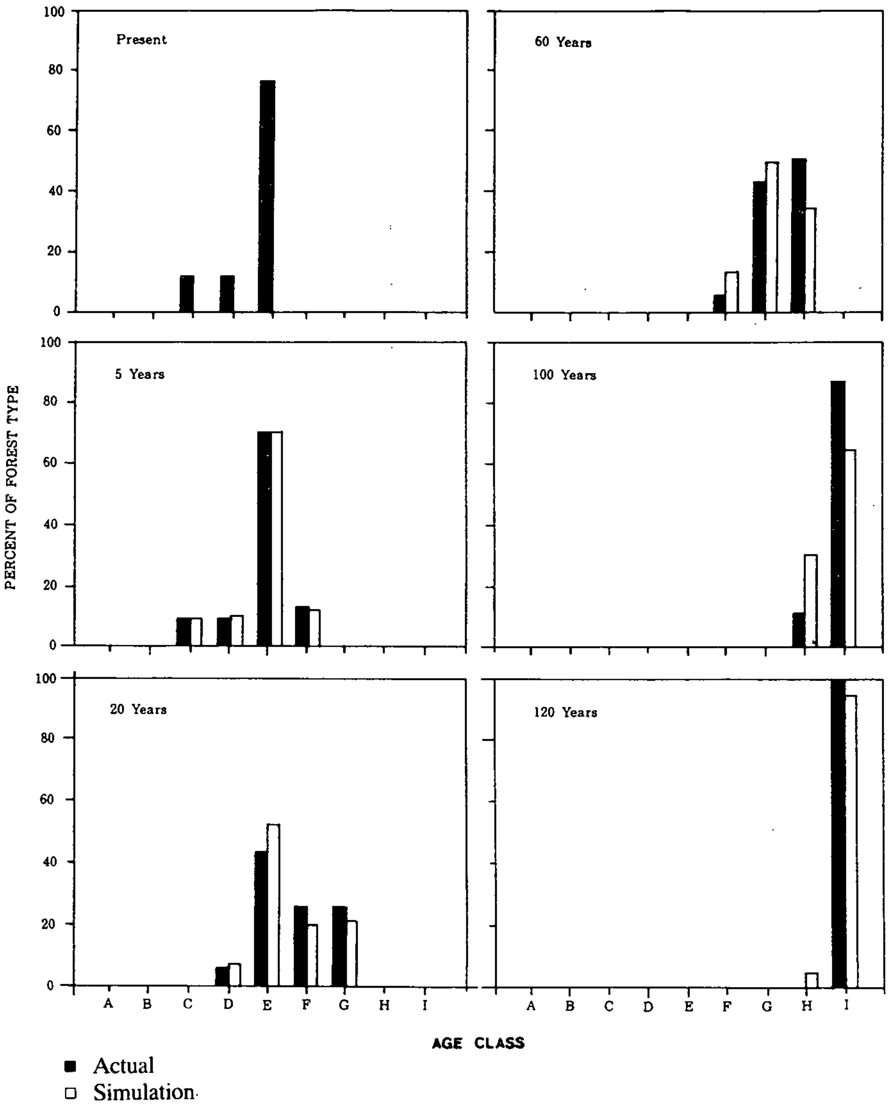


FIGURE 4. Stand Structure as Simulated by the Revised Succession Algorithms in Sweeney's Refined Model.



prediction the future projection of forest. Furthermore, it is applicable to other resources which can be linked to the forests systematic structure.

2. Shortcomings

By assuming that the inventory is equally distributed within am age class, the original DYNAST model couldn't calculate the inventory of each age class correctly in some cases such as a extremely biased distribution of the inventory between each age class.

To enhance the accuracy of counting the inventory, Sweeney refined the original DYNAST model in 1984. He inserted a timesensitive function and a time counter algorithm to the succession model and developed a new model which can count the inventory of each age class very close to the actual inventory. Figure 3 and figure 4 show the differences of the simulation results between DYNAST and the Sweeney's revised model. This model revised and refined Sweeney's model and Boyce's model. Therefore, this model can count the area more accurately than the original DYNAST and nearly as same as Sweeney's model because Sweeney's thought of the time-sensitive function and time counter algorithm was adapted.

However, the usefulness of a model depends on the mixture of its complexity and its simplicity. Also, the success of model depends on the proper combination of its accuracy and convenience. For this reason, although this model cannot count the inventory of each age class as close as the real world, its convenience will cover up its shortcoming because the cost and time of handling is very little.

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