# MULTIPLE-USE OF RENEWABLE RESOURCES IS ENHANCED WITH SYSTEM DYNAMICS METHODS

Stephen G. Boyce[1/]

*Abstract*.--A study of the multiple-use task produces a method for integrating quantitative and subjective information to enhance decision-making about the multiple use of renewable resources. Methods of resolving conflicts and applying system dynamics methods are given.

*Additional keywords*: Forest, management, silviculture, simulation, DYNAST

## INTRODUCTION

This paper describes a study of a complex system defined as the multiple-use task. System dynamics methods (Forrester 1961) are used to investigate the flows of information, energy and materials. The finding is a method for integrating quantitative and subjective information to enhance the multiple use of renewable resources.

The method uses a system dynamics model to structure, for all interested parties, a medium for explicit communication of mental models and scientifically derived relationships. Simulations project the responses of the renewable resource for alternative modes of silviculture. Administrators and other interested parties can inject into the simulations personal experiences and insights. Optimal strategy is derived by subjective decisions determined by insights, value judgments, experience and acumen of interested parties. The responsibilities of administrators are not usurped in mathematical expressions; mental models and scientifically derived relationships are communicated explicitly; people make the decisions.

Two important problems of the multiple-use task are identified. One problem is the complexity of predicting multiple benefits from silviculture. A second problem is the lack of communication channels structured to integrate subjective perceptions and quantitative information. Both problems are resolved by asking the question: "What biologically possible state of forest organization do we want?"

This question leads to the identification of a single goal toward which all cultural actions are directed. The process of choosing the goal is a systematic evaluation of alternatives.

Relatively simple charts display biologically possible combinations of benefits for each alternative state of forest organization. Figure 1 displays a combination of five benefits expected from transformation of a forest from the present state to a future state of organization (Boyce 1977, 1980). The common denominator for calculating each benefit is the state of

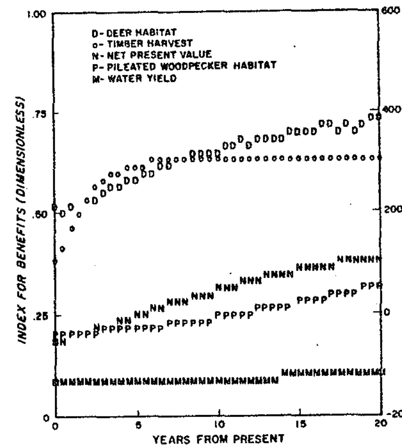


Figure 1.--Display of a combination of five benefits expected from transformations of a forest from the present state to a future state. Charts are enhanced from computer plots for printing.

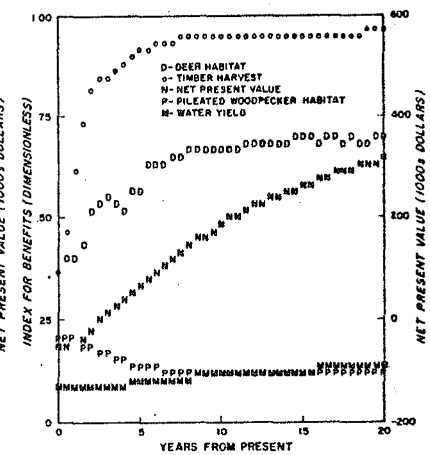


Figure 2.--Display of the same combination of benefits and for the same forest as for figure 1, but the forest is transformed to a different future state.

forest organization. Figure 2 is a display of the same combination of benefits expected from an alternative transformation of the same forest from the present state to a different future state. Other alternative transformations and other combinations of benefits are displayed by each interested party to explicitly communicate to others personal perceptions and scientific relationships.

The paper is organized to describe the multiple-use task, the method of solving the two problems and the application of system dynamics in directing the use of renewable resources.

## THE MULTIPLE-USE TASK

Deliberate and carefully planned integration of various uses of renewable resources so as to interfere with each other as little as possible is the fundamental idea of multiple use (McArdle 1962). This idea has been conspicuous in writings (Marsh 1964) and in legislation (Cliff 1962) for at least 100 years. In the words of Giltmier (1980) "there is a deeply ingrained conservation ethic in the soul of the Republic, and a strong feeling that people can live in harmony with nature. This idea, ethic, and feeling of constituencies led the Congress to embed the multiple-use task in many pieces of legislation" (U.S. Senate 1979).

---

1/ Chief Forest Ecologist, USDA Forest Service, Southeastern Forest Experiment Station, and Adjunct Professor of Natural Resources, School of Forestry and Environmental Studies, Duke University, Durham, North Carolina.

The Multiple-Use Sustained Yield Act of 1960 (16 U.S.C. 528 (note)) includes the phrase:

"harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output."

Later legislation gave direction to the Secretary of Agriculture for "specific identification of program outputs, results anticipated, and benefits associated with investments in such a manner that the anticipated costs can be directly compared with the total related benefits..." (Forest and Rangeland Renewable Resources Planning Act of 1974 (16 U.S.C. 1601 (note)).

The task is not easy. Practical application to a specific forest seems to be limited by two problems, one in silviculture and the other in communications.

The silviculture problem is the lack of methods for "harmonious and coordinated" culture to yield a desired combination of benefits. This problem centers on the difficulty of integrating cultural actions from many disciplines to predict "results anticipated." Complexity is the issue.

The communications problem is the lack of channels structured to integrate subjective and quantitative information for decisions by interested parties. The phrase "interested parties" includes people with different perceptions of "the relative values of the various resources", people who represent profit and nonprofit institutions, and people employed to manage and culture renewable resources on public lands. The management decision centers on "relative values", "benefits associated with investments" and "anticipated costs...compared with the total related benefits." The subjective choice of a perceived optimum is the issue.

The control process uses silviculture to direct a forest toward the goals selected in the decision process. Decision and control are interdependent processes. Decision and control are, in practice, negative feedback loops linked by communication channels structured to integrate the processes (Beer 1966).

The structure of the management processes for multiple use or single use of a forest is diagramed (fig. 3). The decision and control loops are linked with a system dynamics model called DYNAST (Boyce 1977), that integrates quantitative and subjective information and continuously simulates transformations of the forest from the present state of organization through future states. For each stream of changes in the states of forest organization, plots (figs. 1,2), and tables if desired, project combinations of benefits in relation to a proposed mode of silviculture. These displays, the plots and tables, are the medium for explicit communication of information among the interested parties who are involved in the decision loop. Each plot is an integration of scientifically derived relationships and perceptions of mental models about responses of the forest to a mode of silviculture.



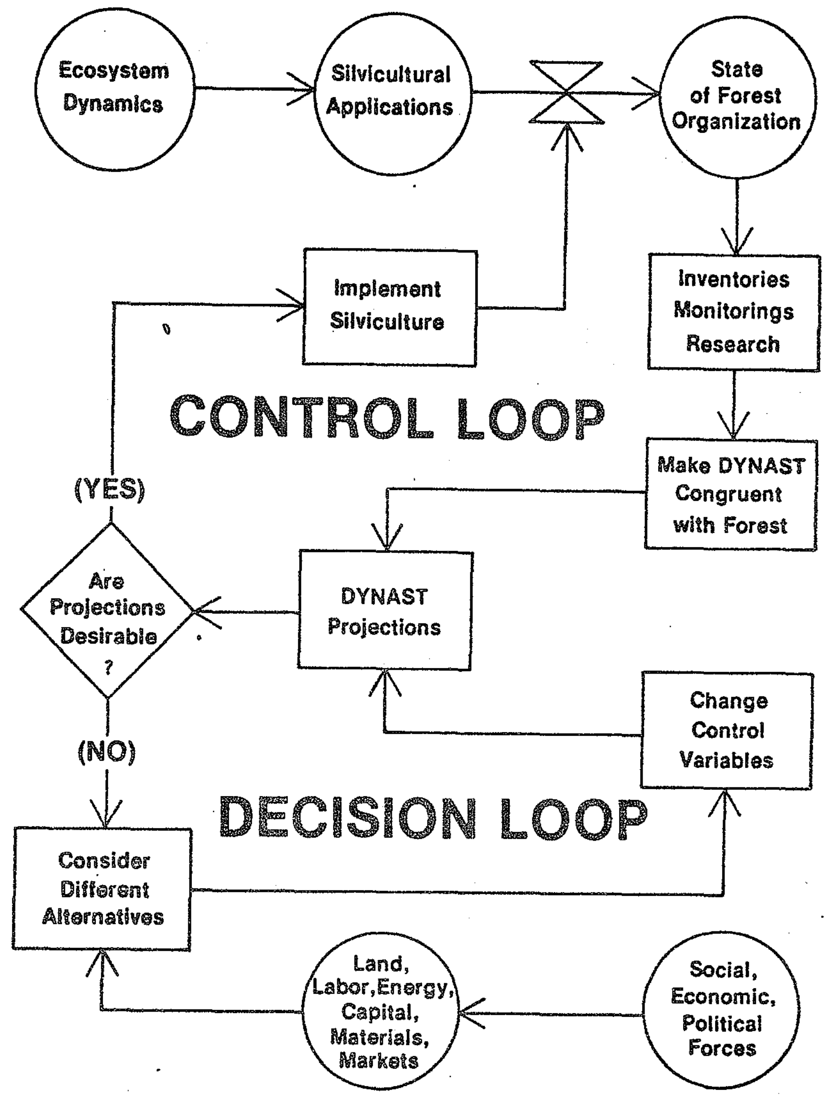


Figure 3. Structure of the decision and control system for integrating biological and managerial information.

The decision and control loops depend on solutions of the silviculture and communication problems.

## THE SILVICULTURE PROBLEM

The silviculture problem is a lack of methods for "harmonious and coordinated culture" to yield a desired combination of benefits. The primary difficulty in harmonizing multiple benefits from silviculture is the complexity created by many variables changing simultaneously. A new direction for forest management provides a solution to this difficulty (Boyce 1978).

The typical question forest managers attempt to answer is how much timber, water, wildlife, recreation, and wilderness experience should be made available to users. An answer is difficult if not impossible to derive because of the complexity of projecting more than three or four benefits with an equal number of management actions. This question increases complexity by forcing managers and decision-makers to rank large numbers of both commodity and noncommodity benefits in order of their relative worth to society. Answers to this question require the projection of complex matrices of outputs to an equal number of cultural actions.

The new direction is to ask a different question: "What biologically possible state of forest organization do we want?" The answer is a single goal for silviculture. This goal, the state of forest organization, is determined by the choice of a projected, biologically possible combination of benefits (figs. 1,2).

States of forest organization are operationally defined by the proportional distribution of stands by age, area and type classes. Since forests are constantly transforming from state to state, the goal for silviculture is a certain dynamic distribution of stands by stand condition classes. This single goal is achieved by controlling rates of timber harvest, sizes of openings formed, and conversions of forest types. In-place decisions and actions may enhance the control process (Boyce 1977). All silviculture is directed toward this goal.

Benefits available at any moment are determined by the state of forest organization at that moment. Benefits available now and into the future are determined by the transformation of the forest from the present to some future state. Since these transformations can be directed by silviculture, future states of forest organization can be projected and the combinations of benefits can be predicted.

The simulations and predictions in relation to silviculture can be made in many ways. The calculations and displays described here are made with the computer model DYNAST (Boyce 1977, 1980) which is written for the DYNAMO compiler (Pugh 1976). Alternatives are to use simulation compilers or languages such as FORTRAN, SIMSCRIPT II.5, General Purpose Simulation System (GPSS) and Continuous System Modeling Program (CSMP).

An important consideration is to focus on the simulations and the predictions rather than on the computing. It is important that information carried in all the quantitative and subjective relationships be explicit to the parties involved in the decision loop. Joint functions must be clear to all persons in the different forestry disciplines and to the administrators who must implement the silvicultural application (fig. 3). Another important consideration is that the calculations be structured to harmonize silviculture.

The DYNAST calculations are structured to relate indices and values for benefits to transformations in the states of forest organization. This structure keeps the computation of indices and values for benefits independent of each other, yet linked to the common denominator. Resource specialists, such as professional people trained in economics or in producing timber, water, game habitats, and recreation opportunities, translate information from their disciplines without preconceptions of interactions, preferences, and trade-offs among benefits. Translations, called benefit algorithms, are attached to the DYNAST model. The interrelationships among the benefits are revealed by the plots (figs. 1,2) and the tables. The calculations are not based on ranking the benefits relative to their worth to society. No benefit in the simulation is constrained by another and no interaction coefficients are required.

The scientifically derived relationships for each disciplinary area are made explicit in diagrams that document the model (Boyce 1977). These translations, explicitly displayed, are available for scrutiny by scientists, resource managers, decision-makers and other interested parties. The validity of these relationships is determined from information derived from research, monitoring, inventories, and the experience of specialists.

Any quantifiable relationship between a benefit and a state of forest organization can be translated into an explicit algorithm. Benefit algorithms, being adjuncts to the core model, can be connected to and disconnected from the core model in any number and combination at will. Hundreds of benefits--likely all operationally defined ones--can be examined with the core model.

The choice of an optimal strategy is made in the decision loop (fig. 3) by interested parties who are evaluating displays of biologically possible combinations of benefits (figs. 1,2). The choice identifies for silvicultural applications a single goal, which is the answer to the question posed by the new direction. The silvicultural applications (figs. 1,2) are "harmonized and coordinated" to achieve this single goal.

## THE COMMUNICATION PROBLEM

The problem is perceived to be a lack of communication channels structured to integrate subjective perception and quantitative information. Quantitatively derived optimal strategies have low credibility for decision-makers who are unaware of the relationships that produced them. Analysts, trained in manipulating definable criteria and measurable variables, are reluctant to incorporate into quantitative models the ill-defined forces of political, economic and social attitudes. One solution is to integrate these two kinds of information.

Another consideration is indicated by Beer (1966) who describes decisions as the fixing of a belief. Beliefs, according to Beer, derive from biological necessity more than from intellectual processes. The result is decisions subjectively made for surviving rather than an objective choice of a mathematically identified optimal strategy.

Apparently, a solution is to structure communication channels to integrate quantitative and subjective information perceived by the parties or their institutions to be in their self-interest. The communication channels are to be structured to accept subjective perceptions, such as preferred rates of timber harvest, integrate this information with quantitative data, and display the results as expected combinations of benefits (figs. 1,2). This structure incorporates the experiences of satisfaction or displeasure embodied in each party's mental model. This structure changes the question from "What benefits do I want?" to "What benefits will I have then?" The latter question, when answered with care, can be the more useful guide in difficult decisions. In particular, mental models of hedonic experience are used to select the alternative perceived to represent self-interest (Tversky and Kahneman 1981).

The evaluation of alternative management strategies for multiple-use of renewable resources includes many quantitative methods. Specific mathematical techniques include but are not limited to linear, nonlinear, goal, dynamic, and multi-objective programing techniques. These techniques are developed with the intent of providing decision-makers and resource managers with ways to identify an optimal strategy. Many practitioners of the quantitative methods expect to have the optimal routines accepted and used by forest managers, directors of forest-based industries, leaders of special interest groups, and administrators of public lands (Tobin and others 1980).

Reality often differs from expectations. Mathematically derived strategies, which are intended to be aids for decision and control, are often ignored, tolerated, or discounted by administrators and other decision-makers. Eilon (1980) describes how potential benefits from operations research and management science are constrained by keeping mathematical analyses well away from the board room, the subcommittee hearings, and the managers' staff meetings. There is little evidence for the scientists' argument that dispassionate analysis of data is removing management decisions from the subjective arena of political, economic, and social attitudes (Amara 1981).

A concern of administrators is indicated by recent comments of an Acting Deputy Assistant Secretary of Agriculture (Thornton 1980) concerning the planning for multiple use of the National Forests: "My only real fear is that we will succumb to the siren songs of the data gatherers and analysts who are entranced themselves by the power and potential of the computers. ...Well thought-out and carefully directed planning can be the heart and strength of the Forest Service of tomorrow...planning that relies on computer analysts and data flows more than it does on hard thinking by people...can be the nemesis of the Forest Service."

One can mathematically model the decision and control loops (fig. 3) and quantitatively derive optimal strategies. These exercises have value for decision and control when decision-makers can manipulate the outcome by incorporating personal insights, experience, subjective values, and acumen.

The primary value of the DYNAST simulation (figs. 1,2) is to communicate explicitly integrations of subjective and quantitative information. These integrations have value when framed to answer the questions: What benefits will I have then?, What will be the "relative values of the various resources"? What are the "benefits associated with investment?", What "anticipated costs can be directly compared with the total related benefits"?

The new direction provides a way to answer these questions. The answers can be displayed in plots (figs. 1,2) and in tables, if desired. Decision-makers and other interested parties can manipulate the outcome by inserting into the calculations personal perceptions such as rates of timber harvest and changes in interest rates. Each party can use the displays to communicate personal perceptions to other parties. This communication is achieved without quantification of all the subjective elements in the mental models. A consensus by the interested parties is a subjective choice of the most favorable conditions for a given situation.

Avoided are the difficult and complex problems associated with the typical question: How much timber, water, wilderness experience, wildlife habitat, and recreation opportunity should be made available to users? With the new direction there is no need to rank benefits in order of their relative worth to society; no need to justify monetary values for noncommodity benefits; no need to project complex matrices of resource outputs to cultural actions and monetary costs; and no need to incorporate into quantitative models an assumed monetary equilibrium for supply and demand.

The communication problem is solved by structuring the system dynamics model, DYNAST, to serve as a medium for explicit communication of mental models and scientifically derived relationships. The projection of combinations of benefits for biologically possible modes of silviculture encourages the interested parties to focus on selecting the alternative that best represents hedonic experiences. The result is not the majority vote but the subjective choice of a perceived optimum.

## THE USE OF SYSTEM DYNAMICS

The system dynamics method (Forrester 1961) is a way of studying the behavior of complex systems. This method depends on the concept that behavior of systems is principally caused by structure—how the component parts are connected. These connections direct the flows of information, energy, and materials through feedback loops to integrate the behavior of elements in the system. Orientation of this study of the multiple-use task toward a flow structure resulted in the decision mechanisms crossing forestry disciplines without conflict and led to a new direction for forest management. The use of system dynamics is summarized in the following paragraphs.

Multiple use of forests is enhanced by changing the question from "How much of this and that do we want to produce?" to "What biologically possible state of forest organization do we want?" This new direction, identified by the second question, resolves the conflicts created by the inconsistent preferences forced on interested parties by the first question. The new question encourages the interested parties to focus on predictive consideration for a single goal. This goal, being the common denominator for combinations of benefits, is related to perceptions of self-interest. For the difficult decisions inherent in the multiple use of forest, we can now develop useful guides (figs. 1,2).

The guides, which are displays of combinations of benefits, aid the parties who make the decisions. The displays are integrations of quantitative and subjective information constrained only by biologically possible outcomes. Experience, insights, value judgments, and acumen are used by the decision-makers to manipulate the core model. The control variables, which are rates of timber harvest, size of openings formed, interest rates and conversions of forest types, are specifications derived in the mental models of the decision-makers. These perceptions derive from information flows that originate from social, economic, special-interest, and governmental activities. Most of these sources of information influence opinions and attitudes toward forestry from outside. These perceptions of self interest and hedonic outcomes for individuals and institutions are more important to the decision-maker than any "forestry opportunities" presented by a professional forester, wildlife biologist, forest economist, systems analyst, or other resource specialist.

The multiple use of forests is enhanced because the optimums are subjective perceptions of the most favorable combinations of benefits for a given situation. The obligations and responsibilities of administrators and other interested persons are used in the analytic and decision process. Relationships are displayed explicitly. People make the decisions.

The approach described here is easily modified to direct the use of all renewable resources. The core model can be adapted to simulate the transformations of grasslands, coral reefs, lakes and other biological systems. The structure for decision and control for all renewable resources is essentially that illustrated for forestry.

The techniques described here are simple compared to most kinds of mathematical programing procedures. The system dynamics methods can be used directly by line and operating managers to guide their units' decisions and control procedures and to communicate with groups both in and out of the user's organization (Fey 1980). The dynamic analytic silviculture technique is one example of a use by staff specialists and line managers.

## LITERATURE CITED

Amara, R. 1981. Management in the 1980s. Tech. Rev. 83(50):77-82.

Beer, Stafford. 1966. Decision and control; the meaning of operational research and management cybernetics. 556 p. N. Y.: John Wiley and Sons.

Boyce, S. G. 1977. Management of eastern hardwood forests for multiple benefits (DYNAST-MB). USDA For. Serv. Res. Pap. SE-168. 116 p. Southeast. For. Exp. Stn., Asheville, N. C.

Boyce, S. G. 1978. Theory for new directions in forest management. USDA For. Serv. Res. Pap. SE-193. 19 p. Southeast. For. Exp. Stn., Asheville, N. C.




Boyce, S. G. 1980. Management of forests for optimal benefits (DYNAST-OB). USDA For. Serv. Res. Pap. SE-204. 92 p. Southeast. For. Exp. Stn., Asheville, N. C.

Cliff, E. P. 1962. Multiple-use management on the National Forests of the United States. Proc. 5th World For. Congr. Seattle, Wash. 1:173-181.

Eilon, S. 1980. The role of management science. J. Oper. Res. Soc. 31:17-28.

Fey, Willard. 1980. The philosophy of the system dynamics method. *In* Proc. IEEE 1980 Int. Conf. on Cybernetics and Society. N. Y.: Inst. Electr. and Electron. Eng., Inc.

Forrester, Jay W. 1961. Industrial dynamics. 464 p. Cambridge, Mass.: MIT Press.

Giltmier, J. W. 1980. Panel response--Congress. *In* Proc. Natl. Private Non-Industrial For. Conf. p. 106-107. USDA For. Serv. Gen. Tech. Rep. WO-22.

McArdle, R. E. 1962. Keynote address. Proc. 5th World For. Congr. Seattle, Wash. 1:143-145.

Marsh, G. P. 1964. Man and nature. 259 p. Cambridge, Mass.: Harvard Univ. Press.

Pugh, Alexander, L. III. 1976. DYNAMO user's manual, including DYNAMO III/F, DYNAMO III, Gaming DYNAMO. 5th ed. 131 p. Cambridge, Mass.: MIT Press.

Thornton, P. L. 1980. Overall role of the Forest Service planning process and how this process is seen by Congress and special interest groups. USDA Forest Service Management Seminar, Oct. 28, 1980. The Friday Newsletter No. 47, Nov. 21, 1980. 3 p.

Tobin, N. R., Rapley, K. and Teather, W. 1980. The changing role of operations research. J. Oper. Res. Soc. 31:279-288.

Tversky, Amos, and Kahneman, D. 1981. The framing of decisions and the psychology of choice. Science 211:453-458.

U. S. Senate Committee on Agriculture, Nutrition and Forestry. 1979. Compilation of the Forest and Rangeland Renewable Resources Act of 1974, 96th Congress, first session. 1508 p. Washington, D. C.:U.S. Gov. Print. Off.

# Appendix (DYNAST Documentation)

ACCESS TO MODEL:

Name of Model: Dynamic Analytic Silviculture Technique (DYNAST)

Name and current address of the senior technical person responsible for the model's construction: Stephen G. Boyce, School of Forestry Duke University, Durham, N.C. 27706

Who funded the model development? USDA - Forest Service

In what language is the program written? DYNAMO

On what computer system is the model currently implemented? Any System with a DYNAMO compiler

What is the maximum memory required to store and execute the program? Core model less than 100K; Auxillary algorithms can increase memory to 200K or more.

What is the length of time required for one typical run of the model? 40 Sec. including ~~[illegible]~~ 10 reruns and 5 auxillary algorithms.

Is there a detailed user's manual for the model? Yes, and for modifications See attached list of publications.

PURPOSE OF THE MODEL:

For what individual or institution was the model designed? Silviculturists (foresters) in public, private and industrial positions

What were the basic variables included in the model? The Core model Simulates transformations of forests from State to State over time. Transformations are directed by silviculture, control variables in the model. Auxillary algorithms Calculate flows of benefits which may include Cash flows, timber, water, wildlife, recreation, biological diversity, etc.

Over what time period is the model supposed to provide useful information on real world behavior? Time period is a control variable that may be set for one to many decades.

Was the model intended to serve as the basis of:

an academic exercise designed to test the implications of a set of assumptions or to see if a specific theory would explain historical behavior — Yes, in the initial development - See appendix citations 71, 78.

communication with others about the nature and implications of an important set of interactions — Yes, see appendix Citations 74, 77, 89.

projecting the general behavioral tendencies of the real system — See appendix citations 71, 72, 73, 81, 87, 88

predicting the value of some system element(s) at some future point in time — See appendix citations 71-74, 77, 78, 81, 87-89.

MODEL SPECIFICATION AND THEORETICAL JUSTIFICATION:

Provide two diagrams illustrating the extreme behavior modes exhibited by the major model elements:

Diagrams of a range of behavior modes are published in the Appendix citations which are available from:
Director, Southeastern Forest Experiment Station
P.O. Box 2570,
Asheville, N.C. 28802

If they are not included in the body of the paper indicate where the reader may find: See Appendix Citations

a model boundary diagram that indicates the important endogenous, exogenous and excluded variables — 71, 73, 77, 87

a causal influence diagram, a flow diagram, the computer program and definitions of the program elements — See Appendix Citations 71, 78

Is the model composed of: Some parts may include any or all of these depending upon the auxillary algorithms that are used.

simultaneous equations ____

difference or differential equations ____

procedural instructions ____

Is the model deterministic ____ or stochastic ____

continuous ✓ or discrete ____

4. DATA ACQUISITION

What were the primary sources for the data and theories incorporated in the model?

Data Basic Silviculture Concepts (200 years) recent forest inventory data (10 to 30 years) Data from experimental plots mostly since 1920.

Theory from biology, thermodynamics, economics and management - See Appendix Citation 78

What percent of the coefficients of the model were obtained from:

measurements of physical systems — 90% (timber, water, wildlife algorithms)

inference from social survey data — 10% (recreation, esthetic, visual appeal algorithms) See citation 89

econometric analyses — 10% plus, depends on modification of algorithm

expert judgment — 10%

the analyst's intuition — 10%

What was the general quality of the data? Good for physical and biological relations, good for most economic variables, subjective for recreation and esthetic variables.

5. PARAMETER ESTIMATION

If they are not given in the publication, where may the reader obtain detailed information on the data transformations, statistical techniques, data acquisition procedures, and results of the tests of fit and significance used in building and analyzing the model? See Appendix Citations 71-74, 77, 78, 81, 88, 89.

6. MODEL PERFORMANCE AND TESTING

Over what period was the model's behavior compared with historical data? Minimum of 10 year inventory periods; a few data sets of 40, 50, 80 years.

What other tests were employed to gauge the confidence deserved by the model? Monitoring of results by resource specialists such as wildlife biologists, timber specialists, economists.

Where may the reader obtain a detailed discussion of the prediction errors and the dynamic properties of the model? See Appendix Citations.

7. APPLICATIONS

What other reports are based upon the model? In-house reports in Fish and Wildlife Service, U.S. Forest Service, Resources for the Future

Name any analysts outside the parent group that have implemented the model on another computer system. Fish and Wildlife Service, Ft. Collins Colo.; Several Universities for instruction; U.S. Forest Service Regions 8, 5, 6 + 2.

List any reports or publications that may have resulted from an evaluation of the model by an outside source. Proc. Nat. Wildlife Conf. 45(?).

Has any decision maker responded to the recommendations derived from the model? Yes. Both public and private forest managers

Will there be any further modifications or documentation of the model? Variations(?)

Where may information on these be obtained? Director, Southeastern Forest Exp. Station, P.O. Box 2570, Asheville, N.C. 28802



# Documentation Citations


(71) Boyce, S. G.
1977. Management of eastern hardwood forests for multiple benefits (DYNAST-MB). U.S. Dep. Agric. For. Ser., Res. Pap. SE-168. 116 p. Southeast. For Exp. Stn., Asheville, N.C.

(72) Boyce, S. G.
1978. Multiple benefits from forests: a solution to a most puzzling problem. In Growth models for long term forecasting of timber yields. Joran Fries, Harold E. Burkhart, and Timothy A. Max, eds, Proc. IUFRO Res. Organ., Div. 4, Subj. Group 1. Va. Polytech. Inst and State Univ. Publ. FWS-1-78, p. 40-52.

(73) Boyce, S. G.
1978. Management of forest for timber and related benefits (DYNAST-TM). U.S. Dep. Agric. For. Serv., Res. Pap. SE-184, 140 p. Southeast. For. Exp. Stn., Asheville, N.C.

(74) Biesterfeldt, R. C., and S. G. Boyce
1978. Systematic approach to multiple-use management. J. For. 76(6):342-345.

(77) Boyce, S. G., and N. D. Cost
1978. Forest diversity--new concepts and applications. U.S. Dep. Agric. For. Serv., Res. Pap. SE-194, 36p. Southeastern For. Exp. Stn., Asheville, N.C.

(78) Boyce, S. G.
1978. Theory for new directions in forest management. U.S. Dep. Agric. For. Serv., Res. Pap. SE-193, 19 p. Southeastern For. Exp. Stn., Asheville, N.C.

(81) Boyce, S. G.
1979. Ecosystem Dynamics for Multiple-Use Management p. 34-47. In Multiple-Use Management of Forest Resources. ED. by D. D. Hook and B. A. Dunn, Published by Clemson University Clemson, S.C.

(87) Boyce, S. G.
1980. Management of Forest for optimal benefits (DYNAST-OB) U.S. Dep. Agric. For. Serv., Res. Pap. SE-204, 92 p. Southeast. For. Exp. Stn., Asheville, N.C.

(88) Boyce, S. G.
1980. Predicting Multiple Benefits from Silviculture, P. 46-50 Proc. IUFRO/MAB Conference: Research on multiple-use of forest resources, Flagstaff, AZ, May 18-23, 1980. USDA-For. Ser. Gen. Tech. Report WO-25.

(89) Boyce, S. G.
~~(In Press)~~ 1981 Translation of Biological Information into Management Plans. Proceed. IUFRO Symposium on Forest Management Planning, Aug 18-20, 1980, Va. Polytech. and State Univ., Blacksburg, VA Pub. FWS-1-81.