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A CONTROL SYSTEMS APPROACH TO FOREST RESOURCE MANAGEMENT

by
Thomas Ray Mitchell

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Natural Resources)
in The University of Michigan
1975

Doctoral Committee:

Professor Allan Feldt, Chairman
Professor William Bentley
Professor John Carow
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CHAPTER 1

PUBLIC FOREST MANAGEMENT PROBLEMS OF OHIO

Introduction

The Ohio Division of Forests and Preserves is responsible for managing Ohio State Forests. The agency's mandate is complex. At strategic levels, it requires assessment of possible product mixes which could be produced from forest ecosystems in State ownership and selection of product mixes or ecosystem-states which are expected to further general objectives of the State and meet needs of Ohio citizens. At tactical levels, the mandate requires planning, design, and implementation of action programs to produce the product mix selected. These tasks require development of management systems for individual forests which provide: (1) standardized information for strategic decisions at higher organizational levels; and (2) bases for design and implementation of action programs at forest levels. This study involves design and evaluation of a resource management system based on control systems theory in context of Ohio State Forests.

The study is presented in four sections. In the first section, management problems faced by the Ohio Division of Forests and Preserves are described. From this, design criteria for forest level management systems are formulated. An evolutionary study of forest resource management and concepts is then used to identify: (1) present conceptual state of the art and science of forest resource

management; and (2) concepts presently available and useful for construction of a management system to meet design criteria.

The second section of this study reviews three models that could be used to structure forest resource management systems. A basic management system is designed using a cybernetic management model and a control systems process. Then this structure and process are combined in a control systems approach to forest resource management. Apparent advantages of such an approach also are discussed.

Applicability of this approach is investigated in the third section using a case study of the Blue Rock State Forest in Ohio.

In the final section, the usefulness of such an approach for management of forest resources are considered in general and results of this investigation are summarized.

The Problem Context

Interest in forest resource management in Ohio has a long and sporatic history. At one time, ninety-five percent of Ohio was forested. These forests were mature, hardwood forests with large trees. An early settler, Norris Birkbank, described some of these:

> Yesterday, June 18, 1817, I measured a walnut almost 7 feet in diameter, clean and straight as an arrow. The white oak is the glory of the upland forest. I measured a white oak by the roadside which at 4 feet from the ground was 6 feet in diameter, and at 75 feet it measured 9 feet around. Before we entered on the flat country were some hills (near Chillicothe) covered with the grandest white oak, I suppose, in America. They measured 14 or 15 feet in circumference, their straight stems rising without a branch to 75 or 80 feet -- thousands of them (Kingsley, 1970).

White settlement, encouraged at first by land gifts to soldiers of the revolution, expanded through Ohio. With construction of canals and locks to connect waterways, Ohio's unique situation with Lake Erie to the north and the Ohio River to the south made it an early trade center and accelerated its growth. As settlement increased, so did clearing of lands, even in the steep Hill Country in southeast Ohio.

As Ohio was settled and lands were cleared, interest in forest management grew within the State. This was punctuated by the American Forestry Congress of 1882 in Cincinnati, and led to formation of the Ohio Forestry Bureau in 1883 (Diller, 1962). Forestry courses were offered at the Ohio State University as early as 1881, and a Department of Forestry was founded at Ohio State in 1909 (Lampe, 1950). By 1915, State forests were being managed and forestry research was being done by the Department of Forestry at the Ohio Agricultural Experiment Station at Wooster, and the Department of Forestry at Ohio State was the second largest forestry school in the United States (Diller, 1962).

With the death of William R. Lazenby in 1916, interest in forest management in Ohio began to fall. By 1917, the Department of Forestry at Ohio State had been disbanded and efforts at the Agricultural Experiment Station began to emphasize research rather than management. This trend continued until the mid-thirties. At this time there was a short flurry of interest in rebuilding a forestry school, but this effort failed. Also in the thirties, the Federal Government acquired large tracks of land through rural relocation programs. Much of this land was planted in trees and turned over to

Ohio for management as State Forests in 1940. In 1949, the State Department of Natural Resources was established. Management responsibilities for State Forests were transfered at this time from the Agricultural Experiment Station to the Division of Forestry and Reclamation within the new Department.

Interest in forest management remained at a low level until the late sixties and early seventies. Starting in 1968, interest began to build. A Division of Forestry was founded in a new School of Natural Resources at the Ohio State University and was combined with the Department of Forestry at the Agricultural Experiment Station. Also, the Ohio Department of Natural Resources underwent organizational changes which included a new Division of Forests and Preserves. This agency was given the responsibility for management of State Forests. Since this reorganization, the Division has been working to develop planning processes and management systems for its 18 forests.

Presently, about 24 percent of Ohio is covered by commercial forests (Kingsley, 1970). This number is somewhat deceiving because commercial forest land is concentrated in the Hill Country. Many of these counties are more than 60 percent forested. Area and volume of Ohio's forests are increasing, especially in softwoods (Kingsley, 1970). The potential for timber production and management in Ohio is limited by the ownership pattern. Most commercial forest land, about 92 percent, is owned by farmers or other small owners. Forest industries own about 2 percent of Ohio's commercial forests; the U.S. Forest Service owns about 2 percent; and Ohio owns and manages about 4 percent of its commercial forest land. This 4 percent, or about 222,700 acres, is distributed among 18 State Forests. Management

of these forests is influenced by relatively small State ownership, and by pressures from over 12 million Ohioans for goods and services such as high quality forest environments; areas for camping, hiking, and hunting; and protection of watersheds as well as commercial timber. This is part of the context of the forest management problems of the Ohio Division of Forests and Preserves.

Another important part of the context is the institutional setting. As a division of the Ohio Department of Natural Resources (ODNR), the Division of Forests and Preserves' budget and priorities come from the Governor's office through the Director of ODNR. The Chief of the Division has a staff as outlined in figure 1.1. Legislation governing Division actions provides little guidance concerning goals or objectives for management. The Division has promulgated a set of objectives to partially fill this need:

Multiple Use

A. Production of timber primarily to furnish raw material and jobs for Ohio's forest industries.

B. Augmentation of recreation, including coordination with park plans, and recognition of aesthetic values.

C. Provide public hunting areas in cooperation with Division of Wildlife.

D. Provide demonstrations of good forestry practices.

E. Provide practical tests of forest research.

F. Provide for protection of watersheds.

G. Assist reforestation and fire protection programs (Gebhart, 1971).

These objectives are too vague for effective management and must be translated into strategic goals in terms amenable to measurements of

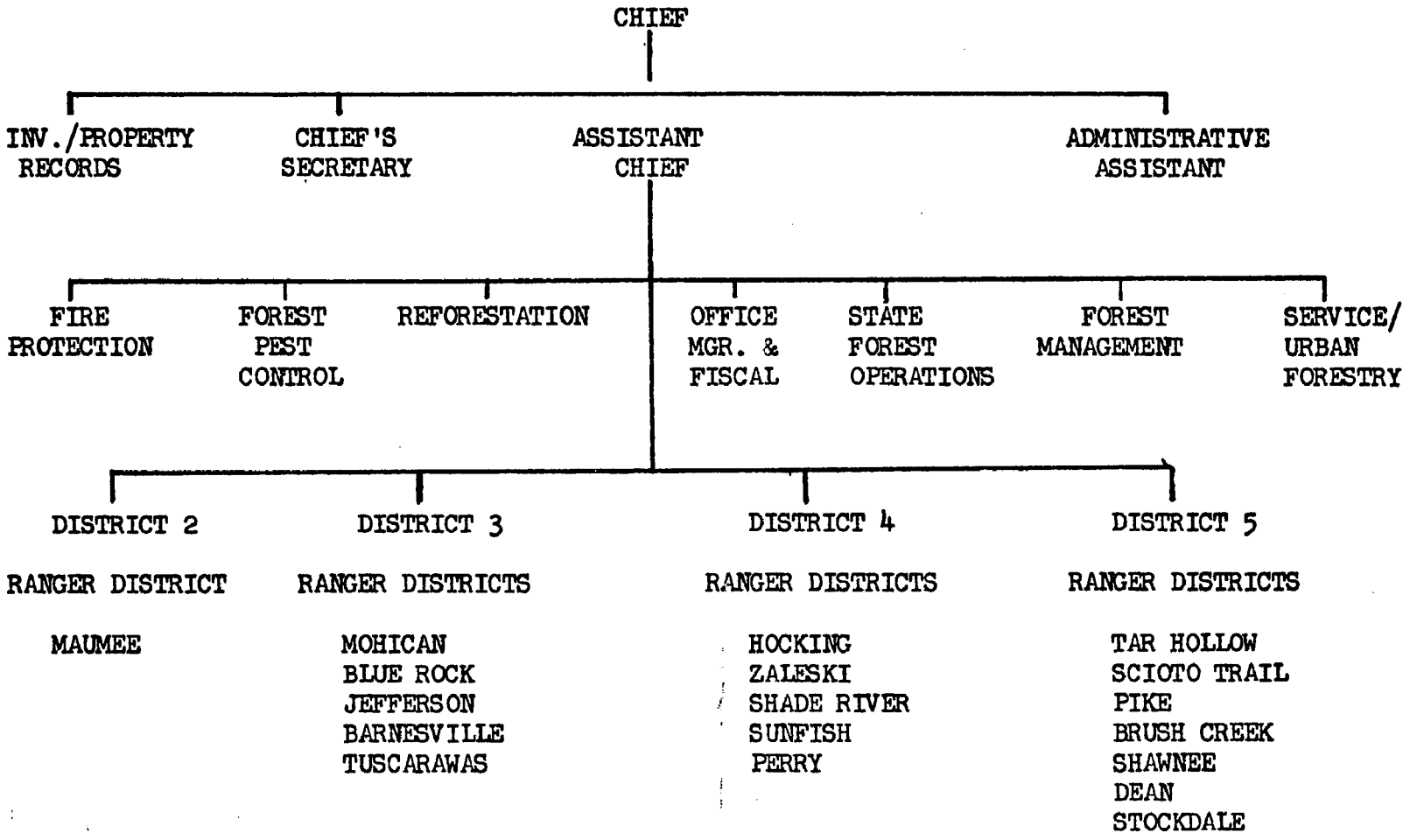

CHIEF
INV./PROPERTY RECORDS
CHIEF'S SECRETARY
ASSISTANT CHIEF
ADMINISTRATIVE ASSISTANT
FIRE PROTECTION
FOREST PEST CONTROL
REFORESTATION
OFFICE MGR. & FISCAL
STATE FOREST OPERATIONS
FOREST MANAGEMENT
SERVICE/ URBAN FORESTRY
DISTRICT 2
RANGER DISTRICT
MAUMEE
DISTRICT 3
RANGER DISTRICTS
MOHICAN
BLUE ROCK
JEFFERSON
BARNESVILLE
TUSCARAWAS
DISTRICT 4
RANGER DISTRICTS
HOCKING
ZALESKI
SHADE RIVER
SUNFISH
PERRY
DISTRICT 5
RANGER DISTRICTS
TAR HOLLOW
SCIOTO TRAIL
PIKE
BRUSH CREEK
SHAWNEE
DEAN
STOCKDALE

FIGURE 1.1

achievement. Translation requires assessment of needs in Ohio and determination of what contribution management of 18 State Forests can make in meeting these needs.

Achievement of strategic goals begins with the task of disaggregating state-wide goals into specific goals for individual forests. Local goal achievement processes include program design, planning, and implementation. In other words, the second level of this problem involves actual management of each State Forest and blending their individual outputs to meet State needs.

A management system for use at forest levels could facilitate solution of both levels of the Division's problems. Such a system would have six characteristics.

1. It should be capable of dealing with complexities associated with biological and socio-economic systems.

2. It should be capable of collecting, processing, and organizing data to provide information needed at various levels of planning and desision-making.

3. It should be capable of providing for coordinated operation of management functions and coordinating operations to keep daily actions relevant to long range objectives and goals.

4. It should be capable of learning through time. This is necessary because of a lack of perfect knowledge concerning involved systems.

5. It should provide mechanisms for analysis of problem situations and design of solutions.

6. It should be capable of adapting to changes in biological systems; changes of needs and values of the people of Ohio; and changes in organizational goals and objectives.

The specific merits of these characteristics are more obvious after: (1) a review of historic and current concepts of forest management; and (2) design of a more general conceptual framework.

A Historic Overview of Forest Resource Management Concepts

Over the last eighty years, forest management concepts developed in this country. A historic overview of forest resource management concepts provides insights and concepts which are helpful in designing a management system for Ohio State Forests.

Development of concepts designed to deal with forest management problems in this country began in 1876. There had been interest in forest management prior to this date, but publication of The Elements of Forestry, by Dr. Hough initiated a sustained interest in forest management (Dana, 1956). This beginning was born out of alarm over destructive exploitation of the country's timber resources and perceived potential of a timber famine.

Efforts by several individuals, such as Carl Schurz, Hough, Bernhard Fernow, and Gifford Pinchot, brought problems of rapidly depleting timber reserves to public attention over the 1876 to 1905 period. This interest, combined with reactions to frauds in land development, led to reservation of some timberlands from homestead entry in 1891. Management of these lands and others subsequently reserved was authorized by the Organic Act of 1897 (Dana, 1956). In 1905, all facets involved with management of federal forest reserves were incorporated into a single agency, the Forest Service, and the Reserves were renamed National Forests (Pinkett, 1970).

Forest management concepts during this period focused on two major objectives. The first, partially reflecting European training of early foresters, was sustained yield; "... the fundamental idea in forestry is that of perpetuation by wise use; that is, of making the forest yield the best service possible at the present in such a way

that its usefulness in the future will not be diminished, but rather increased" (Pinchot, 1905). This objective was a means to meet contemporary demands for timber and other forest products while making provision for future demands.

The second objective emphasized by early foresters was multiple-use. It was recognized that a forest simultaneously produces a number of products such as timber, water, forage, and wildlife. Also a broader view of forests based services such as wind-breaks, watershed protection, recreation, and erosion control emerged. Concerns for efficiency reinforced contentions that it would be wasteful if a forest was managed for only one use or product (Hays, 1959). Early foresters used this argument to fight single-use interests for development of public forests.

Public management was the vehicle chosen by early pioneers for spreading management and achieving sustained yield and multiple-use for two reasons. Public management of forests was consistent with European practices and, therefore, consistent with training of early foresters. A second reason was recognition that private forestry was not yet economically feasible in America:

> Forestry, after all, is as little matter of pleasure as mining or any other enterprise.... Forest growing is not an undertaking for a day, or even a decade; though from a well managed forest, near a good market, returns may be derived in a man's lifetime. A cultivated forest requires at least 70 or 80 years to be a profitable investment.... I write all this to persuade you that the time has not yet arrived when profit from forest-growing will induce private capital, at least in the East, to arrest the devastation of our timber lands. The protection, therefore, of this factor of national wealth must be, at present, mainly expected from a sound, protective legislation... (Fernow quoted in Rogers, 1951).

Concepts of forest management at this time seemed to reflect all of these issues, objectives, events, and national needs. This is illustrated in A Primer of Forestry - Part II, published as a U.S. Department of Agriculture document by Gifford Pinchot (1905). This publication was used as a text for teaching forest management (Pinkett, 1970). It can be viewed as a statement of contemporary forest resource management.

In his text, Pinchot emphasized biological and conservation aspects of forest resource management, and presents little discussion of Forestry as a business venture. He stressed four tasks of forest resource management: (1) provision of adequate regeneration after cutting; (2) protection of forests from harmful agents (especially fire, over-grazing, and thieves); (3) regulation of a forest in terms of age and/or size classes; and (4) regulation of a forest in terms of stocking in each stand. These four steps reflect problems faced by early forest management: (1) harvesting with little regard for regeneration; (2) stealing from public lands and over-grazing on private lands; (3) frequent occurrence of fires; and (4) little regulation for a sustained yield of timber products. Management and silvicultural practices developed by Pinchot to alleviate these problems were presented as mimics of natural phenomena.[1] In this way, he provides a biological basis and justification for forest resource management.

---

[1]He presents practices such as even-age management with clear-cutting; selection cutting; two storied seed forests; and shelterwood cutting as well as thinning as mimics of naturally occuring events in the life of a forest. In this way, he justifies forestry in terms compatible with contemporary conservation movements.

In his Primer, Pinchot presents a comprehensive view of forest resource management and guides for its implementation. Included are discussions of alternative methods for setting rotation ages, methods for determining allowable cuts, and a discussion of working plans, their content, and uses. Also included is a discussion of trees as components of forest ecosystems. This discussion is used to relate management of timber to such goals as protecting watersheds, and providing windbreaks.

Beyond discussions of the micro-aspects of Forestry, Pinchot provides some insight into macro-aspects. For this, he discussed development of forest management in Europe, and its potential role in the United States in developing the nation's natural resources:

> It was Gifford Pinchot who first brought to the American people's attention the importance of our forest resources and who began to direct and guide the thinking of some others, ..., towards the relationship between the maintenance of a strong economy and society in this country or in any country and the effective use of its soil and other natural resources (Secretary of Agriculture Brannan quoted in Pinkett, 1970).

Finally Pinchot discussed philosophy of management by distinguishing conservative lumbering from ordinary lumbering in three ways:

> First. The forest is treated as a working capital whose purpose is to produce successive crops.
>
> Second. With that purpose in view, a working plan is prepared and followed in harvesting the forest crop.
>
> Third. The work in the woods is carried on in such a way as to leave the standing trees and the young growth as nearly unharmed by the lumbering as possible (Pinchot, 1905).

Initial presentations of forest management concepts began, then, as a mixture of micro and macro aspects. Specific forest management

practices were presented, as were general discussions of forestry and its role in meeting varied demands placed on forest resources. Reactions to contemporary problems formed the core of forestry practices. Emphasis was placed on biological and societal justifications for management and not on micro-economic justifications. Thus early forest resource management reflected contemporary values, problems, and scientific thought in an attempt to develop the nation's forest resources efficiently.

By the middle 1920's, the context of forest resource management had changed. Forestry by then, seemed to have wide-spread acceptance as a profession. Many colleges and universities were offering professional programs in forestry and the ranks of the Society of American Foresters were growing. Legislation supporting early contentions that forests play an important role in watershed management had been passed. National Forests were purchased east of the Rocky Mountains, and management was spreading throughout the national forest system. Destructive logging continued; but there were hopes that forest resource management would begin on private lands:

> The profession of Forestry in America is entering a new phase. No longer is Forestry confined to public lands. The forest industries are turning to forest management as the only solution of their problem of future timber supplies (Dana, 1956).

Despite generally booming business in most sectors of the national economy, biological and social justification for forest management on private lands seemed hopeless. Forestry was viewed as non-economical by many lumbermen who wanted micro-economic justifications for management.

Forest Management by Recknagel, Bentley, and Guise, printed in 1926, provides insight into forest management concepts in this era. This text is presented in three parts: Mensuration; Forest Organization; and Forest Finance. From this list of topics, it seems that forest management concepts shifted from the "why" of Forestry to the "how." This reflects Forestry's acceptance as a profession and a need for trained foresters.

Comparisons between Pinchot's Primer and Forest Management by Recknagel, et. al., reflects shifts in pressures facing forest managers and changes in management concepts. Pinchot presented forests as resources to be managed for the good of all. He stressed relationships between trees and other components of forest ecosystems, and used studies of nature to develop forest management practices. Recknagel, et. al., relegated discussion of forests as biological phenomena to silvics and silviculture. They divorced management from understanding natural systems and portrayed forest management as a business. The purpose of forest management concepts changed from justifying management to emphasizing "how-to-do-it"; management objectives changed from "the greatest good for the greatest number in the long run" to production for private gain. Shifts from a mixture of macro and micro-concepts to almost entirely a micro focus reflects a shift from concern with government regulation to regulation by the market system and a hope that private forestry is economically feasible.

Each topic in Forest Management is discussed in great detail. In mensuration, for example, discussions of what to measure, what instruments to use, what units of measurements to use, and how to measure a forest are presented. Pinchot's simple statements concerning

regulation are expanded into an entire section, including in-depth discussions of calculating volume of growing stock, the normal forest as an ideal, determination of rotation, and determination and regulation of the annual cut.[1]

Recknagel, et. al., also present a number of topics in forest finance. This includes a discussion of basic micro-economic terms, use of interest and interest rates, soil rent, and property valuation and damage appraisal.[2] Basics of business finance are applied to forestry to portray timber management in terms acceptable and understandable to private industry.

Beyond this extensive discussion of forest finance, which was almost totally absent in Pinchot's Primer, Forest Management portrays other conceptual changes in forest resource management. Working plans are not seen as important, but implementation is stressed. The use of a control book to keep accurate records of forest surveys, boundaries, protection efforts, cutting records, planting records, recreation use of forest property, and money returns is presented. The control book incorporated many benefits of a working plan while avoiding some rigidities. Regulation plans were not included, which allowed

---

[1]Methods discussed for determining rotation age include technical, economic, and financial methods as well as a presentation of factors to consider when choosing a rotation age. In their presentation of determination of cut, the authors present an extensive discussion with examples of both area and volume methods including VonMantel's formula, Heyer's formula, a Swiss method, Hufnagl's method, and Chapman's "Horizontal Cut."

[2]This includes a discussion of determining the value of forest soil and of both even-age and all-age forests under annual, periodic, or irregular management plans. Also included are discussions of stumpage values, taxation, and timber insurance.

flexibility for management reactions to short-term price changes and other uncertainties. Consequently, a control book was more attractive to private owners contemplating forest management.

Excessive cutting and early effects of the depression drove timber prices down during the late twenties and early thirties dampening hopes for quality industrial forest management. Forest management in the public sector, though given legislative support at both federal and state levels, was meagerly funded (Dana, 1956). Management at state levels was generally limited to protection programs. Management of forest resources was viewed by many as a national problem by 1932, and it became part of a general conservation plank in Franklin D. Roosevelt's first presidential campaign.

Roosevelt's election and concern for conservation set the stage for many federal programs of the thirties and forties. These programs included programs intensifying forest management such as the Civilian Conservation Corps as well as programs designed to fight particular problems such as the Shelterbelt program. Also, programs such as rural relocation extended public ownership and reforestation of lands.

Pressure on Forestry during this period was bimodal in nature. First, Forestry was tied to wise use of resources and federal programs that strengthened multiple-use management as part of a second conservation movement. Second, efforts were made to strengthen private sector management of forest resources in a dual effort to spread management and revitalize the economy. Texts such as Management of American Forests by Matthews (1935) and C.C.C. Forestry by Kylie, Hieronymus, and Hall (1937) reflected changes in forest management

concepts because of these pressures.

Management of American Forests by Matthews presents a balanced discussion of management in biological and economic terms. In this way, management is presented in terms compatible with the public conservation movement and private management of forests. Biological considerations were reincorporated as an integral part of management along with business aspects of Forestry. It reflected contemporary conservation thinking in a discussion of how management can alter forest stands to produce desired products.[1] The maturing profession is reflected in a flexible approach to management and movement away from rigid rules-of-thumb and presentations of how-to-do-it.

Matthews stressed management in economic terms, and devoted over half of his book to economic considerations. He up-dates discussions of topics introduced in the twenties, and discusses economic implications of "destructive" logging versus sustained yield management.[2]

Government conservation efforts added new dimensions to Forestry. There was a surge in the number of people engaged in Forestry through programs such as the C.C.C.. Further, emphasis of

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[1]Matthews presents an up-date of timber management as presented by Recknagel, et. al., including discussions of information needs for management, methods for determining rotation age as well as volume and area methods for determining allowable cuts. Matthews adds discussions of various silvicultural methods and their advantages and disadvantages in management terms.

[2]Topics presented include financial problems of forest resource management; the nature of capital and income; valuation of land, growing stock, and stumpage; forest taxation, and insurance; and damage appraisal.

these programs intensified multiple-use of forest resources through construction of new recreation areas, range improvements, watershed protection devices, and wildlife improvements.[1] This intensification of management and large influx of man-power created a need for forestry training at a technical rather than professional level.

C.C.C. Forestry by Kylie, Hieronymus, and Hall (1937), was written for technicians. In 305 pages, it covers such diverse topics as: forest values; forest conservation; forest reproduction; timber management; forest utilization; mensuration; lumbering; wildlife management; range management; recreation; and a guide to becoming a professional forester. It emphasizes "how-to-do-it" with a brief discussion of biological reasons for management practices. It was written "... to serve as an aid to both instructional and learning phases of Civilian Conservation Corps education" (Kylie, et. al., 1937). Though at a lower level than Matthews' text, C.C.C. Forestry is a direct combination of Pinchot's A Primer of Forestry - Part II and Forest Management by Recknagel, et. al.. Forestry matured during the thirties as a profession as it adapted to American conditions and developed into a two-level entity of professionals and technicians.

From the late thirties to the early fifties, forest resource management went through drastic escalations in scope. This escalation began in 1938 when President Roosevelt called for federal agencies to assume leadership roles in management of forest resources (Dana, 1956).

---

[1]It was during this period that a forester, Aldo Leopold, published Game Management. This began wildlife management as a profession and one involved with Forestry.

A Joint Congressional Committee studied conditions of American Forests both public and private. A number of recommendations were made from this study including recommendations for more intensive multiple-use management of National Forests; recommendations to begin or strengthen cooperative fire, insect, and disease protection programs; recommendations for cooperative reforestation programs and formalization of sustained yield units; and recommendations for increased research in both forest management and wood utilization (Dana, 1956). Pressures imposed by the second world war intervened before action could be taken on these recommendations.

World War II put great demands on timber resources in this country. Wood was viewed as one of the most vital war materials (Dana, 1956). To meet timber demands, extensive cutting was done on virgin forests of the Northwest and Alaska. Reliance on these remote forests for timber needs dramatically illustrated the poor condition of American forests in the East. Reliance on virgin stands also was disturbing because of the amount of transportation resources required to haul wood from remote areas to manufacturing centers.

A number of actions were initiated because of pressures imposed by the war. Increased wood utilization research, expansion of tax laws to allow returns from timber to be considered capital gains, and the Sustained Yield Act of 1944 to assure stability of communities dependent on forest industries are examples of changes spawned during this period.

Pressures on forest resources were not eased following the war. Grazing pressures had increased because of demand for meat and hides during the war and demands remained high. Demand for timber increased

and timber prices soared as new housing starts rapidly increased. Demands for other forest resources, such as wildlife and recreation also began to increase with increases in income, leisure time, and use of automobiles.

Forest resource management began to expand in scope and intensity by the late forties in response to these pressures. Legislation expanding programs for forest protection passed Congress.[1] Also by the end of the forties, rising timber prices combined with improvements in wood utilization and changes in tax laws to provide an environment for expansion of forest management on private lands. Thus coming into the fifties, forest resource management faced an expanded and more intensive role in both public and private sectors.

American Forest Management by Davis (1954) was written in this context and represents conceptual responses to a new context for forest management. At first glance, Davis's text appears to be simply a revised edition of his former mentor's text: Management of American Forests (Matthews, 1935). Both texts are broken into two major sections: one dealing with biological aspects of management and the second with financial aspects. Many of the same topics are presented and both use case studies to illustrate management principles.[2] This

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[1]Examples include: Forest Pest Control Act of 1947 expanding cooperative fire, insect, and disease programs; and the Anderson - Mansfield Reforestation Act of 1949 accelerating reforestation and revegetation of National Forest lands for multiple-use management (USDA, 1974). These acts grew out of the recommendations of the Joint Congressional Committee of the late thirties.

[2]Both authors present discussions of resource factors such as: site and stocking; growth; the nature of a fully regulated forest; the use of yield tables; determination of cut; and regulation of even-age and all-age forests. Also there is commonality in discussions of financial issues including: valuation, use of interest, and appraising.

commonality in presentations seems reasonable given the dual pressures of both the thirties and fifties.

Beyond many similarities in the texts by Davis and Matthews, Davis made significant additions. He approached forest management in terms of integrating disciplines needed for multiple-use management in either public or private sector management. The list of disciplines Davis says "A well trained forest manager needs to have a general knowledge ... of most of them and training in as many as possible," include resource related disciplines such as silvics, silviculture, mensuration, pathology, wildlife, grazing, water, and recreation. Also included in this list are disciplines from social sciences and management theory including economics, law, finance, labor relations, sociology, political science, and organization and administration. Though Davis did little beyond listing these disciplines, he greatly expanded the scope of management as presented by Matthews.

Beyond discussions of discipline content, Davis introduced management philosophy. He begins this discussion by quoting Charles Broiliard, a French forester of the nineteenth century:

> Forest management is also varied according to the forest concerned .... Every forest offers a real and living individuality. It differs from every other forest by its situation, its aspects, and configuration; by its soil, by its component crops, and also by the character of the surrounding country.... it would be a great mistake to suppose that the management of forests adjoining each other or situated in the same region can be built upon the same framework or pattern. The forester labouring under so erroneous an impression would lack the very fundamental idea that should guide him, and instead of adapting himself to circumstances, would vainly endeavor to force circumstances to suit his silly imaginings.

Davis further states that "Beyond a definite and ingrained desire to

see that the area in his charge is efficiently and productively managed and that the basic soil resource is maintained, he a forester should avoid preconceived ideas or prejudices." Davis, thereby, emphasized flexibility in management and presented forest management in a form that can be adapted to either public multiple-use or commercial land management contexts.

Davis carries his emphasis of flexibility into his discussion of planning. Intellectual consideration of forest resource management neglected planning after an early emphasis. Davis begins a section on planning by presenting a historical discussion of working plans and why they were not included in texts such as Matthews. These reasons include: (1) lack of flexibility; (2) they were based on a theoretical ideal that had little relevance to real situations in America; and (3) they were based on having a "regulated" forest approaching normality over an adjustment period of up to 100 years and this seemed to ignore short run considerations. Planning, according to Davis, is a continuous process. As a management tool, planning aids coordination between: levels in an organization; the front office and the field; and between multiple-uses of forest resources. Planning can provide standardization of information so that data collected is in appropriate units or form to be used as information at various levels of the organization and different stages in management. Finally, planning and plans can add continuity to management by providing an organized framework for storing and interpreting information over repeated changes in personnel.

Davis also reintroduces macro-aspects of forest management. He discusses macro-aspects of forest management in terms similar to

early presentations of Pinchot in his Primer. Included is a discussion of multiple-use management and more importantly, a discussion of regional and national aspects of forest management.

Davis combines topics presented by Matthews dealing with the micro-context of forest management with discussions of related disciplines, multiple-use management, use of planning and macro-aspects of management. In this way, his text reflects an intellectual broadening of forest resource management in response to growth in scope during the forties and fifties. Forest management, as portrayed by Davis, provides conceptual tools for intensive management of timber and considerations for other traditional forest products on either public or private lands. It also is a philosophical basis for flexible multiple-use management on public lands.

Changes in pressures, technology, and values facing forest resource management did not remain static in the fifties and sixties. Single-use demands for exclusive use of National Forests grew throughout the fifties. This included pressure from clientel concerned with grazing, timber, irrigation and municipal water supplies, recreation, wilderness, and wildlife (Crafts, 1970). The Forest Service sponsored the Multiple-Use-Sustained-Yield Act of 1960 to provide a countervailing force to these specialized interests. Passage of this Act strengthened the multiple-use philosophy and practice of public forest management.

Subsequent to this reinforcement of federal policy, there were two other policy changes that affected the public forestry sector. The first was Program, Planning, and Budgeting Systems (PPBS). After successful application in the Defense Department, President Johnson

called upon all federal agencies to incorporate PPBS into management and planning (Gregory, 1972). The Forest Service and Bureau of Land Management were pioneer test agencies for implementation of this order. This, in effect, required federal forest managers to quantify management plans and programs in terms of economic benefits and costs.

Shortly after requiring quantification of programs in economic terms, the National Environmental Policy Act was passed which required quantification in ecological terms as well (Alston, 1972). Section 102 of this act states that:

> ... all agencies of the Federal Government shall ... identify and develop methods and procedures ... which will insure that presently unquantified environmental amenities and values may be given appropriate consideration in decision making along with economic and technical considerations ... (all agencies are to) study, develop and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources ... (and to) initiate and utilize ecological information in the planning and development of resource oriented projects ....

Thus in the seventies, the context of public forest resource management requires quantification of management plans in both economic and ecological terms.

Concurrent with these changes in context, forest management was also facing changes in tools and concepts available for use in management. Developments after World War II included improved timber survey techniques such as point sampling, 3-P sampling, and use of statistics to assure accuracy (e.g. Spurr, 1952; Grosenbaugh 1952, 1958, 1964). Beyond this, there were efforts to aid predictions of growth and yield using regression models (e.g. Clutter, 1963). Further, forest management and planning began using other analytical

techniques such as linear programming and inventory analysis (e.g. Navon, 1971; Walker, 1974). Other uses of computers in forest resource management include forest growth simulations (e.g. Botkin, Janak, and Wallis 1972; Dale, 1972). And other managerial and economic concepts entered forest resource management such as decision theory and a sophisticated use of marginal analysis (e.g. Duerr, Teeguarden, Guttenberg, and Christiansen, 1974; Gregory, 1972).

Texts dealing with aspects of forest resource management reflect incorporation of new tools and concepts in a changing management context. Forest Planning by Johnston, Grayson, and Bradley (1967) combines traditional forest management with advanced management technology. This text covers the same material presented in Davis (1954). It includes material associated with regulation, determination of the cut, and valuation. Also there are discussions of sites, and site classifications as well as presentations dealing with regular and irregular forest regulation. There are some additions, too. Forest Planning introduces a new set of tools and concepts including discussions of goal determination, planning theory, capital budgeting, and decision theory. Addition of these concepts is designed to strengthen tactical capabilities of forest management by providing tools for dealing with time factors associated with timber growing, as well as with risks and uncertainties surrounding management. By presenting these topics, the authors attempt to keep traditional forest management abreast of changes in general management theory.

A second response to forest resource management context changes is illustrated in Forest Economics by Gregory (1972). This text supplies tools and concepts needed by forest managers for dealing

with PPBS in public sector management as well as micro-economic concepts needed for management of commercial forests.[1] Gregory adapts micro-economic concepts to forest management including discussions of production functions, marginal analysis, pricing, and effects on management by such factors as property and capital gains taxes. Also presented is an interesting application of joint production concepts to multiple-use management.[2] Further, Gregory deals conceptually with management of forest resources other than timber including watershed management, recreation, and wildlife.

A third conceptual response to changes in context and management technology is illustrated in Forest Resource Management: Decision-Making Principles and Cases, a commissioned anthology edited by Duerr, Teeguarden, Guttenberg, and Christiansen (1974). This text deals with many specific analytical decision making tools and their application in management of forest resource. Because of emphasis on decision-making tools, biological foundations of management are discussed in a cursory manner in comparison to presentations in American Forest Management by Davis (1954) and Forest Planning by Johnston, et. al., (1967).[3]

Forest Resource Management adds new concepts to forest resource

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[1]This is the latest of texts on forest economics building on Butterick (1943), Worrell (1959), and Duerr (1960).

[2]This builds upon earlier work on multiple-use by Ciriacy-Wantrup (1938) and Gregory (1955).

[3]One might suspect a bias in Forest Resource Management simply because of the strong economics backgrounds of the editors and the authors they selected.

management. One additional set of concepts is associated with watershed, wildlife, recreation, and grazing management. This effort to abstract essential concepts from these fields and present them in a forest management text marks a departure from previous emphasis on timber. In line with these additions is an introduction of systems concepts to management. Though left undeveloped, the idea of a forest as a system in both a biological and socio-economic sense is introduced to provide a basis for integrated management of forest resources. Further, Forest Resource Management applies a set of optimization techniques that expands the set presented in Forest Planning.

Though groundwork is laid for integrated management, linkages between concepts appear to be missing in Forest Resource Management. Each chapter develops a different set of concepts with little to draw these concepts together. Biological aspects of forest management and a systems view of forests are presented, but integration of these concepts with economic decision making concepts is only hinted at. Further, though concepts for management of various resources are presented, there is no discussion of how these concepts can be linked in multiple-use management of forests. For these reasons, Forest Resource Management appears to be a text designed to provide how to do it procedures for solution of specific problems, not a text to provide in-depth development and/or integration of such procedures.

Historically, then, forest resource management has evolved in this country facing two partially conflicting pressures. The first is pressure to integrate management of forests into the general resource conservation movements of the early 1900's, the 1930's and the 1960's and 1970's. The second is to present forest management in terms

compatible with profits and investments in private sector timber management. Resulting from responses to these pressures, forest management is composed of two vaguely linked sets of concepts. One deals with biological and ecological aspects of Forestry and the second involves economically based problem solving techniques.

This duality in evolution of forest resource management appears to have limited management's capabilities by stifling development of an overall framework for management. Tools and concepts have been developed for specific problems such as regulation of a forest for maximum timber production or optimum allocation of management inputs for specific tasks; but little is available for integrating these tools. This leaves management with no basis for problem solution beyond simplified problems of biological or economic efficiency. In short, the conceptual basis of forest resource management is concerned with tactical questions and efficient solutions. Little is provided for dealing with strategic questions such as goal selection or even critical management policy questions such as current allowable cut arguements on western public forests. Further, few conceptual linkages are presented which would allow coordinated operation of concepts in solution of tactical problems or more importantly in context of multiple-use management.

Application to the Forestry Problems of Ohio

Management problems faced by the Ohio Division of Forests and Preserves (ODFP) are complex. As stated earlier, ODFP is responsible for managing Ohio State Forests. This mandate includes: (1) setting strategic goals and designing strategic programs in order to meet

demands placed on Ohio's public forests, and (2) design and implementation of programs to solve specific problems or develop specific resources. Both tasks involve gathering and processing vast amounts of information, analysing problem situations and designing and implementing action programs in a multiple-use context.

At the present time, management of Ohio's State Forests appears overwhelmed by this problem. General objectives for management exist, but these have not been translated in terms amenable to measures of achievement. Though presently striving to improve the amount of inventory data available for each forest, information necessary for problem perception and design and implementation of programs at both strategic and tactical levels has not been collected. Further, ranges of possible ends-means sets for each forest have not been explored or analyzed in terms of impacts on natural and socio-economic systems.

A management system designed for use at forest levels could facilitate solution of these problems . This would be accomplished by providing three system functions. First is an information system which can: (1) identify needed data; (2) organize and guide data collection; (3) process data into usable information; and (4) store information in a readily accessable manner. Second it would provide a framework for organizing and coordinating management tools and concepts needed for problem identification, analysis, and solution. Third it would provide a process for guiding management actions and programs. All three functions would have to be capable of operation at both strategic and tactical levels.

Present forest resource management concepts can aid solution

of specific problems, but do not offer a conceptual basis for design of a management system. As indicated by a historic overview of forest resource management, the present conceptual base for management is composed of a number of loosely related tools and concepts. Each is designed for solution of a specific problem. None provide guidance for solution of strategic problems nor for collection and presentation of information for integrated management of resources. Further, there is an almost total lack of linkages between biological and economic consideration or between resource specific management concepts. Hence, it would be virtually impossible to construct a management system which could accomplish the desired purposes using only concepts presently associated with forest resource management.

The problem, therefore, is to design a management system which is sophisticated in terms of overall integration of tools and techniques and provision of information. Sophisticated concepts already exist for solution of specific problems, thus the thrust of design will be in terms of management structure and process.

CHAPTER 2

DESIGN OF A FOREST MANAGEMENT SYSTEM

Introduction

Design of management systems for use at forest levels by the Ohio Division of Forests and Preserves involves four steps. First is choice of a structure which can: (1) identify management functions; (2) organize and coordinate management tools and concepts; and (3) facilitate heuristic and adaptive behavior. Second, the structure must be translated into terms compatible with management of forest resources. Third, tasks of each functional component should be described to specify its conceptual content and linkages to other components. Fourth, the structure must be combined with a process that is compatible with both structure and management realities of forest resources.

Three Models For Structuring Forest Resource Management

Three conceptual schools of thought provide models for structuring management. A "rational-comprehensive" model represents an analytical approach to management. "Successive-limited-comparisons" model presents a descriptive model for management designed to conform to management realities and avoid impracticalities of rational models. Finally, a systems approach to management is represented by a cybernetic model. These three models cover extremes in current thought and their investigation will provide needed insight for design of forest resource

management systems.

The first model is composed of four steps: (1) determination of goals or ends; (2) generation of a comprehensive set of alternatives; (3) analysis of alternatives in terms of their ability to achieve desired ends; and (4) decision making based on analysis of alternatives. Lindblom (1959) discusses this model as follows:

> (1a) Clarification of values or objectives distinct from and usually prerequisite to empirical analysis of alternative policies.
>
> (2a) Policy formulation is therefore approached through means-ends analysis: First the ends are isolated, then the means to achieve them are sought.
>
> (3a) The test of a 'good' policy is that it can be shown to be the most appropriate means to desired ends.
>
> (4a) Analysis is comprehensive: every important relevant factor is taken into account.
>
> (5a) Theory is often heavily relied upon.

This model is rational: it relies on an orderly approach to management and on 'rational' choice mechanisms. It is comprehensive: it requires generation of all important relevant factors. Though this model does not strictly require quantification, operationalized versions often require quantification of goals to facilitate measures of achievement. Also, quantified analysis of alternatives is required to measure which alternative best achieves defined goals.

Though a rational-comprehensive model provides guidance for design of forest resource management systems, it has a number of flaws which lead to rejection of it as a guide for design. The four steps of this model identify functions necessary for management; a function for goal specification; one each for generation and analysis of alter-

natives; and a function for decision making. These functions provide a framework for organizing and coordinating operation of some management tools and concepts. As presented, though, such operation focuses efforts on one problem at a time, working exhaustively until that problem is solved. This singularity in scope and inherent reliance on orderly, sequential operation precludes iterative processes essential for heuristic or adaptive behavior.[1]

Focus on exhaustive solution of single problems provokes other criticisms. One such criticism deals with requirements for comprehensive alternative generation; i.e. some feel it is beyond human capabilities to consider all relevant factors or to generate all possible alternatives (Lindblom, 1959). Also this model is criticized because of its attempt to separate ends and means. This criticism is based on a belief that each means produces a unique set of ends. One of these may be a desired end, but others associated with it may have little relevance in terms of a manager's stated goal set. For instance, assume provision of low-cost maintenance of all forest access roads as a desired end. One means would combine all needed work into a single project for large contractors, while a second combines work in a number of packages suitable for small contractors. Each means may provide the desired level of maintenance, as well as different effects on the local economy, especially if a large contractor from outside the local area wins the contract. In this way,

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[1]Heuristic behavior of management can be defined as behavior which learns about its operational context through successive attempts to design and implement programs. This property allows management to initiate operations based upon a limited amount of information and improve operations through time.

each means has a different set of effects; and some feel that decisions should be based on the total set of outputs of a means rather than on which means 'best' achieves a single end. These criticisms plus the inability of a rational-comprehensive model to facilitate learning or adaptation raises question concerning its usefulness as a guide for structuring management.

A second management model is successive-limited-comparisons. This model has three steps. First, as a triggering device, dissatisfaction with the status-quo is noted. Second, alternatives which vary marginally from the status-quo are investigated. Third the most acceptable alternative from this set is chosen for implementation. Lindblom (1959) discusses features of this model as follows:

(1b) Selection of value goals and empirical analysis of the needed action are not distinct from one another but are closely intertwined.

(2b) Since means and ends are not distinct, means-ends analysis is often inappropriate or limited.

(3b) The test of a 'good' policy is typically that various analysts find themselves directly agreeing on a policy (without their agreeing that this is the most appropriate means to an agreed objective).

(4b) Analysis is drastically limited: (i) Important possible outcomes are neglected. (ii) Important alternative potential policies are neglected. (iii) Important affected values are neglected.

(5b) A succession of comparisons greatly reduces or eliminates reliance on theory.

In other words, successive-limited-comparisons is an application of marginal analysis in context of satisficing; i.e. alternatives are compared in terms of their marginal differences from the status-quo in order to satisfy immediate pressures.

Though this method avoids some disadvantages of a rational-comprehensive model, it provides little guidance for design of forest resource management systems. It avoids some problems by allowing management to function when goals cannot not be specified, values quantified, or complete information gathered. Also, it attempts to recognize cognitive limitations of managers. But, before this method begins taking actions to change management direction or programs, a problem with the status-quo has to exist, rendering anticipation of problem situations impossible. Management in this case would always be in a crisis situation. Secondly, its process for generating and choosing alternatives relies little on creative processes, obviating needs for most forest resource management tools presently available. Because of this property, it provides a poor model for linking current management tools and concepts, and thereby provides a poor model for design of forest resource management systems.

A third model for structuring management comes from approaching management as a "self-controlled" system. Mouzelis (1968) provides an initial structure for this model using three functional components:

- the detector or censor who receives information concerning the state of the variable or goal to be controlled.
- the governor or selector who takes decisions about the steering of the system on the basis of the information received from the censor and on the basis of his preference ordering. (Often, as an extension of the governor's brain, an information processor which stores, classifies, and processes information is considered as a distinct component of the system.)
- the effector who executes the governor's decisions or orders.

A "self-controlled" or cybernetic model appears a more complete model of management. It contains three functions not found

in either rational-comprehensive or successive-limited-comparisons models: (1) a detector or sensor for data collection; (2) an information processor to convert data into usable information and store that information; and (3) an implementation function. Addition of these functions indicates that the other two models were not models of management, but rather processes for approaching tasks of a governor function. As such, a cybernetic model seems to provide a more suitable structure for organizing present forest resource management tools and concepts. Further, linkages between components of a cybernetic model provide a guide for coordinating operation of such tools and concepts.

The suitability of a cybernetic management model as a guide for design of forest resource management systems is enhanced by its tendencies for self-control. Self-control of this model is "achieved by the fact that information about the system's behavior is fed-back to the system, the latter readjusting its behavior in the light of new information received" (Mouzelis, 1968). A tendency for self-control in these terms provides a foundation for heuristic behavior; i.e. through feedback, initial assumptions and information are corrected and improved. Also, feedback can alert management to changing situations allowing adaptation of programs. Such capabilities for learning and adaptation are needed by forest resource management systems.

A tendency for self-control also frames management in terms similar to an engineering control system. Such similarity strengthens the appropriateness of this model for management of forest resources. Both an engineering control system and a cybernetic management model rely on feedback for self-correction. The purpose of such feedback is to enable engineering control systems to maintain stability and control

of parent systems as those systems interact with their environment to produce desired effects; e.g. aircraft control systems operate to maintain stability and control of aircraft as they take-off, fly at desired altitudes, speeds, and directions, and land. In the same manner, purposes of forest resource management systems can be stated as maintaining stability and control of forest ecosystems as they interact with their environment to produce desired goods and services. Thus it seems that structure and operation of a forest resource management system should be similar to those of an engineering control system.

From preceding discussions, it appears that a cybernetic model, when combined with processes of a control system, provides as adaquate basis for design of forest resource management systems.[1] Identification of components of a cybernetic model and their linkages can guide organization and coordination of management tools and concepts. Inherent tendencies for self control provide a basis for requisite learning and adaptation. And processes involved in maintaining control and stability frame such a model in terms compatible with purposes of forest resource management. The possible applicability of this combination of structure and process, or control systems approach, necessitates further investigation of its properties in context of managing forest resources.[2]

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[1]By some definitions, a cybernetic model and an engineering control system are identical. A distinction is made here to emphasize that both a structure and a process are necessary for management systems.

[2]Conventional usage of cybernetics implies a system which is fully automatic and closed to outside intervention, at least in terms of control properties. In this work, the term is broadened to include feedback systems containing people rendering judgements and decisions on the operation of the system based upon information flow. To the extent that the human component of such a system can learn from past decisions and can seek different information from the system over time, it might be most appropriately termed a heuristic control systems approach.

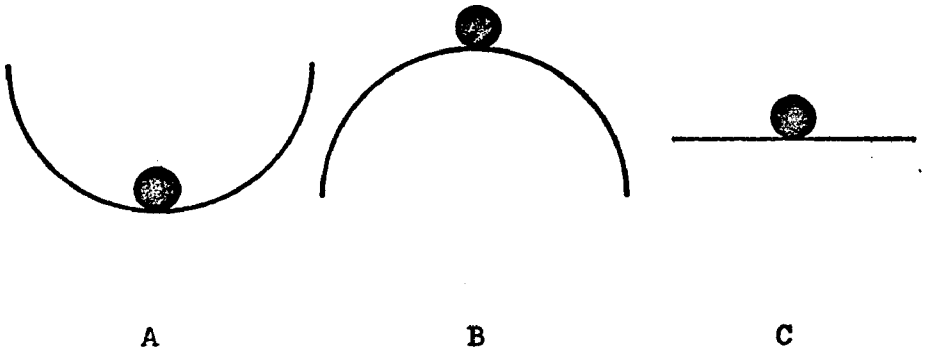
Properties of a Control Systems Approach

Investigation of properties of a control systems approach can begin by investigating concepts surrounding operation of an engineering control system. An engineering control system is composed of three functional components: (1) a sensor to monitor the environment and states of the system being controlled (i.e. parent system); (2) a control mechanism that reacts to maintain a desired state of the parent system; and a feedback mechanism to monitor actions and initiate signals to alter input signals or control functions to maintain stability of the parent system. Primary tasks of a control system are two-fold. First is maintenance of system stability at any equilibrium point within capabilities of its parent system. Secondly, it is expected to maintain control in non-equilibrium maneuvers needed to change from one equilibrium point to another (Etkin, 1959). Parallels in forestry are: (1) produce a sustained yield of products from a forest ecosystem and (2) maintain control of a forest ecosystem during adjustment periods for shifts from one product mix to another.

Accomplishment of these functions necessitated prior analysis of involved systems. Such analysis is needed to determine: (1) what a parent system is capable of; (2) interactions between a parent system and its operating environment; and (3) analysis of operations and interactions between subsystems within a parent system. Three examples will illustrate types and depth of analysis required for design and operation of a control system.

Concepts of stability, equilibrium, and tasks of a control mechanism are illustrated by three diagrams in figure 2.1. Each

figure shows a ball in an equilibrium state. Figure 2.1A illustrates a case of stable equilibrium. If a perturbation is introduced to this system, the ball would respond by rolling up a side of its bowl-shaped plane and eventually return to its original position. Figure 2.1B illustrates unstable equilibrium; and figure 2.1C illustrates neutral equilibrium. One task of a control system is to act as a bowl-shaped plane, returning and holding a system at an equilibrium state.



A B C

Figure 2.1

A control system should contain mechanisms for maintaining stability as well as for moving the controlled system from one equilibrium state to another. An example of a simple control system is one composed of a furnace-airconditioning system and a thermostat. A desired temperature, an equilibrium state, is set on the thermostat. The thermostat monitors room temperature. When a variation in temperature is detected either the furnace or the airconditioner is activated to return the air temperature to its desired level. Feedback provides a signal to terminate actions of the control mechanism when the desired temperature is achieved. Beyond maintaining room

temperature at a single level, this control system could change room temperature from one level to another within the range of the furnace and airconditioner based on: (1) analysis of a room's environmental factors, e.g. outside temperatures; (2) analysis of heating and cooling processes to determine a range of temperatures that could be maintained in this environment; and (3) analysis of room uses to predict a range of desired temperatures.

A question at this point is whether control systems theory can be directly applied to management of forest ecosystems. System analysis, program design, and operation of control systems are not as straight forward when dealing with biological systems. For example, consider control of mosquitos in an urban area. Assume total eradication of mosquito populations is impossible, and assume spraying an insecticide can reduce high population levels to or below a desirable level. Initially, a control system could consist of a monitor to measure mosquito population levels; a control mechanism to activate spraying programs; and a feedback mechanism to measure mosquito population levels after spraying. A model relating concentration and coverage of insecticide for various outbreak levels could be determined in a laboratory and would form a basis for design of spraying programs. As outbreaks are controlled, a mosquito-control manager could initiate further analysis to adjust spraying programs to prevailing environmental conditions.

Because this control system deals with biological systems further analysis is needed to maintain control and stability. Theoretically, each mosquito is genetically different and may be affected differently by an insecticide. Those mosquitos least affected

by the insecticide will have a selective advantage and will tend to have a greater representation in succeeding generations. Without analysis of this phenomena, spraying programs could become ineffective. But, through analysis based on feedback and redesign of spraying programs, a control systems approach could work to maintain control of mosquito populations.

This example illustrates a number of points concerning system analysis needed in development of control systems for biological systems and operation of such control systems. First, analysis can be incomplete and general initially. Second, models can be refined to fit a specific context through implementation and feedback, i.e. models are refined through learning about involved systems. Third, system analysis must continue beyond initial analysis to provide information necessary to keep control programs abreast of changes in relevant systems, i.e. control systems must adapt to changes in parent systems. This third point, while partially true for all systems, is particularly important when dealing with man-nature control systems.

Natural systems generally have natural control mechanisms associated with them. These can be classified as limiting factors for nutrients or energy; inter and intra-specific competition; or predator-prey, host-parasite relationships. Such relationships and interactions are dynamic; their specifics are changing through time. Each organism acts to exploit its environment as fully as possible to expand its representation in the next generation. In this way, selective pressures may change interactions between ecosystem components through time. Man, as part of natural systems, can and does affect the direction and

speed of selective change, as in the mosquito example. Management or development of resources to produce goods and services from natural systems such as forest ecosystems will have such effects. If viability of natural systems is important, i.e. if maintaining or enhancing productivity of ecosystems is important, thorough analysis of relevant natural systems is necessary to provide information for maintaining system stability throughout a range of possible ecosystem states. Further, dynamic characteristics of biological systems imply that ecosystem states are not static equilibrium points, but are dynamic. This calls for great care and depth of continued analysis for successful management.

Identification of Management Functions

A first step in applying a control systems approach to forest management is identification of management functions compatible with management of forest resources which can be structured as a control system. Bentley (1974) provides a listing of management functions that fit such criteria:

1. Perception - recognition that a problem exists, acceptance of this existence, and specification of the problem in systematic, solvable terms.

2. Planning and Decision - design, information generation, analysis, synthesis, evaluation, and choice.

3. Implementation - organization for action, operational budgeting, and actual field work.

4. Feedback - review of actual and projected results by implementation for control purposes, by planning and decision for factual knowledge, by perception for dynamics of values.

These four functions can be organized using components of a cybernetic or control systems model. Perception parallels a detector or sensor. Planning and decision, when combined with implementation, parallel control mechanisms. And feedback of a control system could be supplied by Bentley's feedback function. Development of a management system utilizing these functions requires specification of: (1) functional tasks of each component; (2) relevant tools and concepts to be stored in each component; and (3) information flows between each component.

Perception is the first component in a management system. In a control system, the detector monitors states of the parent system. In forest resource management, perception involves monitoring natural and socio-economic states of a forest. For example, perception would be responsible for alerting management to presence of fires; amount of snow accumulation; progress of land-use planning bills in Congress; local availability of labor, fuel, equipment, and materials; and current distribution of timber. For such tasks, perception requires concepts, tools, and techniques from such areas as mensuration, remote sensing, fire detection, stream monitoring, recreation user surveys, and concepts associated with monitoring social, legal, and political areas. Thus information will flow from outside a management system through perception. Perception will screen this information looking first for automatic signals, such as notification of a fire; and secondly for any other indication of problems. Problem statements will be transmitted from perception to planning.

Planning and decision can be viewed as the first half of a control mechanism. It is responsible for devising plans to maintain

stability and control of forest systems when producing a desired mix of goods and services or when altering production mixes. Required tasks include situation analysis, program design, program analysis, and decision making. Situation analysis is needed to identify: (1) ranges of possible product mixes; (2) conditions which must exist within a forest to produce each mix; and (3) desires and needs of the forest owner and his clientele. Program design is needed at strategic and tactical levels to devise and coordinate actions necessary to achieve and maintain desired forest states. Program analysis is necessary for assessing costs, effects, and impacts of alternative programs. And decision making chooses a course of action based on analysis of management situations and programs.

Concepts, tools, and techniques required by planning for these tasks include biological concepts such as: silvics, silviculture, regulation, and ecology of the local biome including floral and faunal interactions. Some knowledge of physical concepts such as hydrology, soils, and geology should be included. Also socio-economic concepts from sociology, organizational theory, political science, economics, and law will be needed for identifying and understanding conponents and interactions of social systems involved with management. Further, concepts from planning theory and techniques such as McHarg's overlays would facilitate program design (McHarg, 1971). Analysis of alternatives and decision making require tools such as capital budgeting, PPBS, decision theory, game theory, and operations research as well as some knowledge of computer programming.

Planning is linked to perception, implementation, feedback, and systems outside of management. Indications of problem situations

will flow from perception to planning. Information needed for analysis and solution of these situations will come from outside management into planning. Finished plans and associated data will be transmitted from planning to implementation. And feedback on such implementation will flow from feedback into planning. Beyond this, there will be requests for information sent from planning to perception as well as requests for clarification of programs coming from implementation.

Implementation is the second half of a control mechanism and is responsible for putting plans generated by planning into action. Concepts, tools, and techniques required by implementation include those needed to hire and maintain a crew, and legal concepts for contracting work, or acquiring equipment. Also required are concepts associated with road construction, construction of recreation areas, and logging as well as technical skills associated with management of other resources such as wildlife or forage. Information in the form of implementation plans will come from planning into implementation and relevant actions will flow from implementation into systems outside of management.

Monitoring those actions is the role of feedback. In engineering control systems, feedback is a measure of output signals to provide a basis for either changing input signals or altering control. In other words, feedback monitors program implementation to: (1) assure conformance with plans; (2) indicate problems with plans because of imperfect information; (3) alert management to changing situations; and (4) determine if the results of implementation are the ones expected and desired. For these tasks, information from planning

is needed to provide performance specifications for programs and for implementation. A second set of inputs will come from monitoring efforts. Outputs will be feedback to implementation, planning, and perception. Concepts needed for these tasks will include those needed by perception plus concepts needed to design monitoring schemes.

Schematically these functions and their interactions could be presented in the same form as an engineering control system.

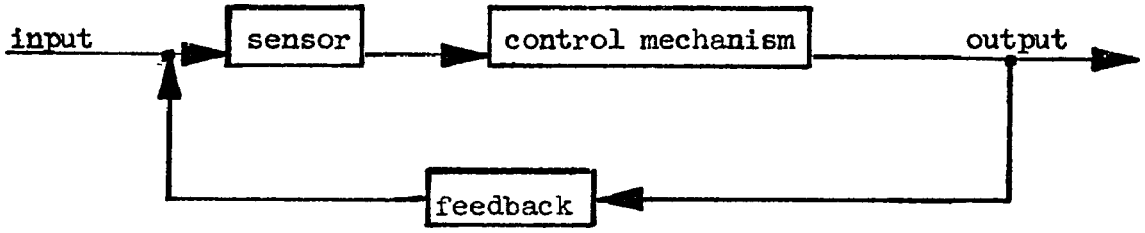


Figure 2.2

Direct substitution of management functions results in:

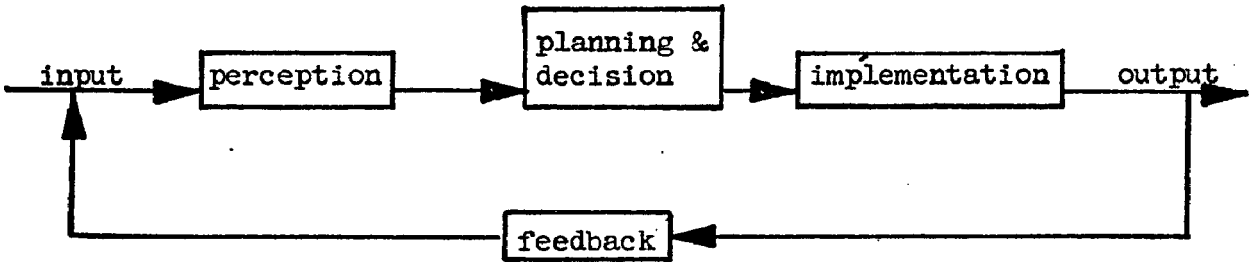


Figure 2.3

There is an additional component which could be added at this point. This is an information processing function. Purposes of this

component include gathering, processing, and storing information needed by the other components. This would include design of system models for use by perception to indicate potential problems; by planning for situation analysis, program design, and program analysis; and by feedback for predictions of future states based on initial results of implementation. Also included in this function is a listing of tools, concepts, and techniques to be used by other components of this management system. Adding this component results in the following schematic.

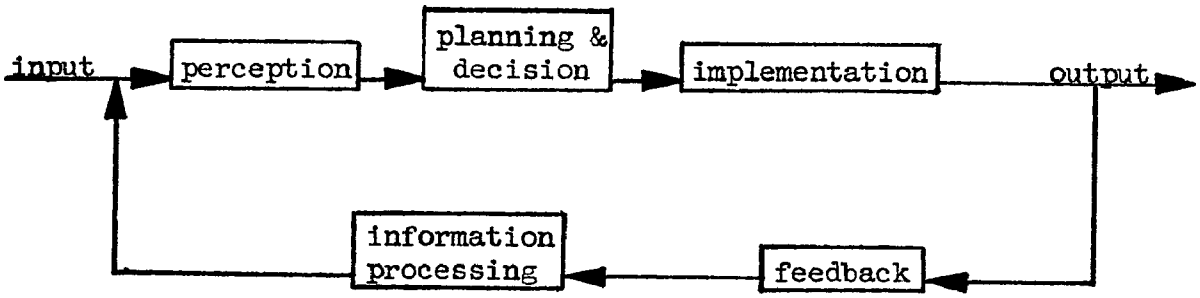


Figure 2.4

Advantages of a Control Systems Approach

From discussions in the last section, a control systems approach seems to provide an appropriate model for forest resource management. It, unlike other models, provides a process for management, a complete listing of functions and functional interactions needed by management, and a structure for organizing and coordinating operation of these functions. Further, this model yields a listing of functional

tasks identifying roles that tools, techniques, and concepts previously developed for forest resource management can play in management systems. Before it can be applied, however, capabilities of a control systems approach should be investigated in context of complexities and realities associated with management of forest resources as outlined in Chapter One.

Management of forest resource systems involves manipulation of forest ecosystems to produce goods and services.[1] Management in these terms consists of two task sets. The first set involves tasks associated with setting goals for long range direction; i.e. deciding what mix of goods and services to produce. The second set deals with design, choice, and implementation of time-joint sequences of tactical projects to produce desired goods and services. Conventional management concepts are inadaquate for accomplishing either set of tasks, except in extremely limited cases. A control systems approach provides a structure and a process capable of guiding management toward accomplishment of both tasks.

Often objectives for management of forest resources involve multiple-use concerns; statements such as "the greatest good for the greatest number in the long run"; improvement of corporate images; or some other general statement of direction for which measures of achievement are difficult. This poses problems for forest resource

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[1]An additional objective commonly assumed in forest resource management is protection of forests and their productive capabilities. In public sector management, protection objectives stem from basic normative constraints based on concepts of sustained yield and multiple-use. In private sector management, financial stability and long-term growth considerations often provide justification for including protection of ecosystem stability and productivity as associated goals.

managers who must translate such objectives into achievable goals for strategic and tactical planning. Conventional management processes provide some guidance. But, they are normally concerned with biological efficiency, economic efficiency, or both; none of which directly deals with non-monetary value systems inherent in objectives for multiple-use or improvement of corporate images. If timber is a component crop of resource management, for instance, managers often rely on biological efficiency models such as a normal forest as a strategic goal; i.e. if a normal forest is achieved, then a maximum sustained flow of timber is assured. Modification of this model for economic efficiency in terms such as maximization of present-net-worth is common. But, modification in terms of multiple-use is a difficult task and one for which few, if any, concepts exist.

Techniques and methodologies presently available for design and choice of projects are also inadequate. Management techniques developed through evolutionary processes were developed to counter specific problems. As such, each technique provides mechanisms for design of single-use tactical projects. Except when attempting to manage for maximum timber production, such techniques provide few mechanisms for design of time-joint sequences of projects. This severely hampers medium and long range planning. Beyond this inability, their single-use orientation ignores forest production realities. Pioneers of American Forestry expoused a multiple-use philosophy recognizing that forests simultaneously produce a wide variety of goods and services (Pinkett, 1970). The joint-production characteristic of forests is not addressed by most techniques or methodologies available for design of projects, forcing forest resource managers into a

dominant-use strategy when dealing with multiple-use objectives (Hall, 1963). This hampers design of projects which recognize interactions between forest resource production functions. It appears that, based upon currently available concepts, forest resource managers do not have tools for choosing strategic goals which are consistent with general management objectives; nor do they have capabilities for designing or coordinating time-joint sequences of tactical projects for forest resource systems which recognize a forest's joint production capabilities.

Tendencies of present forest management concepts to emphasize tactical problem solving also has a detrimental effect on analysis and design capabilities. Situation analysis and design of goals and programs relies on data and resulting information. Procedures for collecting and processing data presently available emphasize data needs for design of tactical projects. Procedures for data collection for timber management, for example, focus on inventory data needed to draw comparisons between actual forests and a normal forest. In this way, data other than inventory data is completely ignored, differences between ecosystems are blurred, and the scope of possible analysis is drastically limited. Missing is information concerning operations of forest systems; i.e. information concerning interactions between system components and interactions between forests and their environments. Without such information, predictions of total production of goods and services are impossible as are estimates of a forest's impact on associated socio-economic systems. Thus, both complete analysis of management situations and design of realistic goals and projects to meet those goals are impossible using present

forest resource management concepts.

A control systems approach provides a structure and a process for management with capabilities for overcoming limitations of present forest resource management concepts. Information deficiencies can be remedied through use of system analysis and model construction. As discussed earlier, forest resource management requires collection, processing, presentation, and storage of a great deal of information. Information concerning a resource system's immediate response to management activities is needed for design and choice of tactical projects; time-linked response data for each resource system is needed for design and choice of single-use project sequences; and selection of strategic goals and design of multiple-use projects requires information concerning interactions between resource systems. Systems analysis and associated model construction inherent in a control systems approach provides a vehicle for collecting, processing, storing, and presenting this information.

Systems analysis involves three steps: (1) identification of system boundaries; (2) identification of flows across those boundaries; and (3) identification of subsystems and their interactions. Collection of this data and structuring it as in system models provides information necessary for management. Analysis of a timber system, for example, would identify system components such as associated vegetation and tree species and their interactions in terms of micro-climate modifications and inter and intra-specific competition. Such analysis also provides a basis for identifying flows of energy, nutrients, water, and other physical products or micro-climate modifications into and out-of a resource system. When structured

appropriately, as in descriptive or predictive models, this information is a basis for design of such actions as thinning, pruning, or harvesting; of for projects to relax limiting factors through such actions as fertilization, irrigation, or elimination of competition or harmful agents. In this way, analysis and model construction of each resource system of a forest has the potential for providing information needed to design time-joint, single-use projects. Additional information can be gained as analysis and models of individual resource systems are combined.

Beyond identification of subsystems and their interactions needed for design of single-use projects, analysis of resource systems includes collection of information concerning flows across system boundaries. Identification of such flows provides a basis for combining system models. For instance, a possible set of flows out of a timber system could include pounds of browse and mast produced by that system. Available food in terms of browse and mast, in turn, could be an input of a wildlife model. These two system models could be partially linked through this flow of materials. In this manner, specification of separate system inputs and outputs provides a mechanism for linking the resource systems of a forest. Combining all resource systems of a forest through their interactions provides a basis for analyzing and understanding total operations of a forest. This in turn provides a mechanism for studying multiple-use production possibilities and actions needed to produce each possibility. Schematically, a production information system with linkages to planning and decision-making processes could be represented as in figure 2.5.

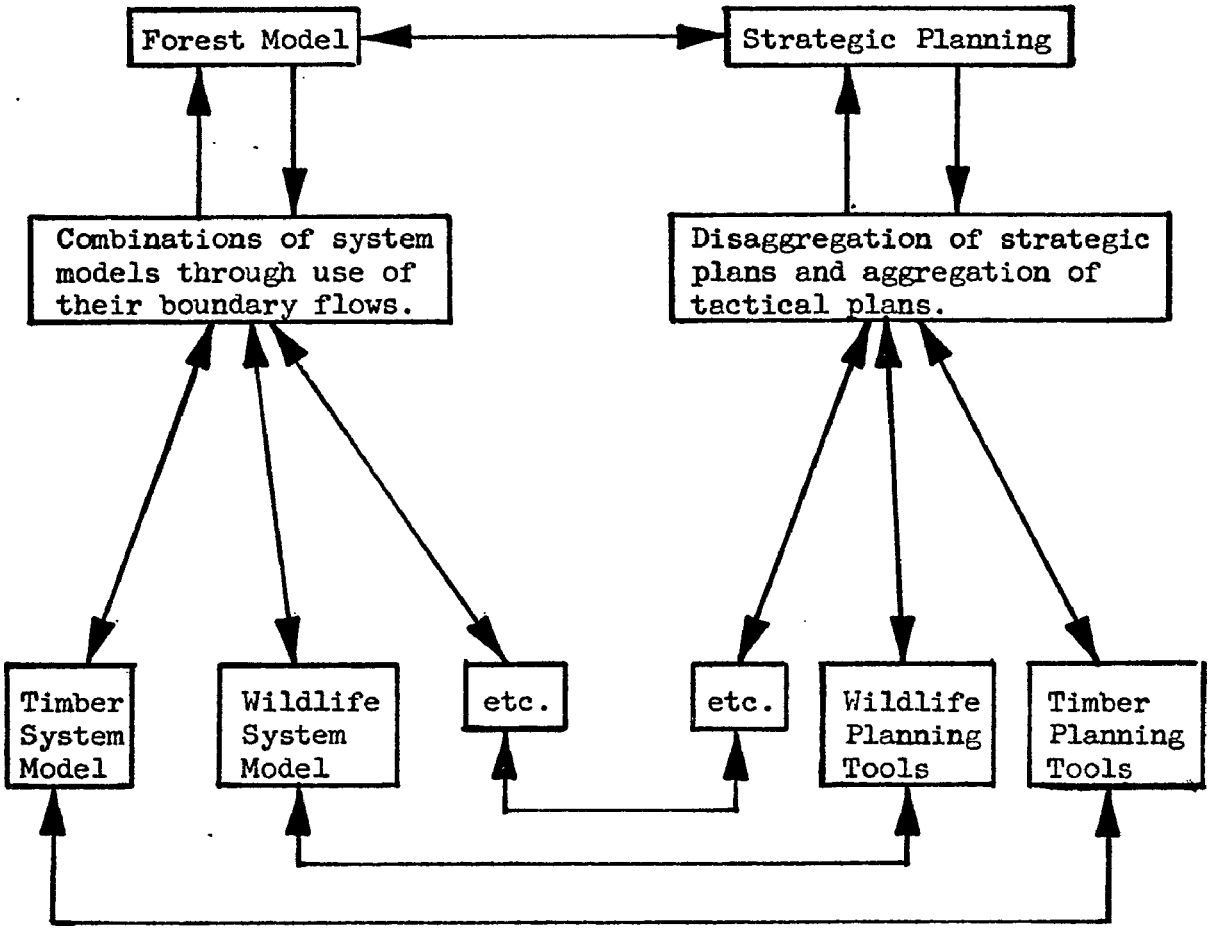


Figure 2.5

With this information structure in mind, attention can be turned to advantages of a control systems approach in terms of selecting and invoking appropriate planning and decision-making methodologies. The process for management of a control systems approach focuses on providing control and stability of managed systems. This is done through monitoring a managed system and interpreting monitored information using system models in search of present or potential problems. Presence of at least problem potential invokes planning. Planning, through specification of problems, identifies the level

of management affected, and resource areas involved. Based on this identification, planning begins a search through catalogued design and decision methodologies for relevant problem-solving techniques. Planning would then use these in conjunction with available information and system models for design and choice of appropriate management projects. Once a solution is chosen, it is sent to implementation. Here again, management can rely on a cybernetic structure to have all available implementation tools catalogued so that choice of an appropriate tool can be made. During and after implementation, progress of a project is monitored by feedback providing an update on accuracy of information, system models, planning techniques, decision-making processes, and implementation tools. Such feedback is facilitated by tracing through the catalogued procedures and information as organized in management. Thus, appropriate planning, decision-making, and implementation tools can be invoked for solution of management problems and they can enter the information system at appropriate points to acquire needed information. If present tools or techniques are inadequate for tasks at hand, specification of this problem by planning provides criteria for design of new solution methodologies. Such methodologies would be automatically catalogued and then tested using feedback. If needed information is not available, designated solution methodologies will indicate what information is needed and system models will provide a structure for processing, and storing this data. Again feedback will ascertain accuracy of such information and involved predictions. This procedure, based on the structure and process of a control systems approach, has potential for freeing managers from reliance on established management practices through iterative operation

of designing, cataloging, invoking and testing solution methodologies as they are needed. A schematic illustrating this expanded concept is presented in figure 2.6

A control systems approach is a process and structure for management. It does not solve all problems of management, but it does provide mechanisms for searching for solutions. Through its structure and requirements for information, presently available management concepts and data can be organized in a problem solving framework. Through its iterative processes of design, choice, implementation, and feedback, inadequacies in available concepts and data can be identified and more importantly, coordinated efforts to remove such inadequacies can be initiated. This process relies strongly on a central information system, which, through feedback, constantly tests accuracy and completeness of information and management procedures. It is this self-correcting tendency which allows a control systems approach to improve present information, i.e. learn; and which allows it to adapt to changing situations. An example of how such an approach can be applied in an information poor management context follows in the next chapter.

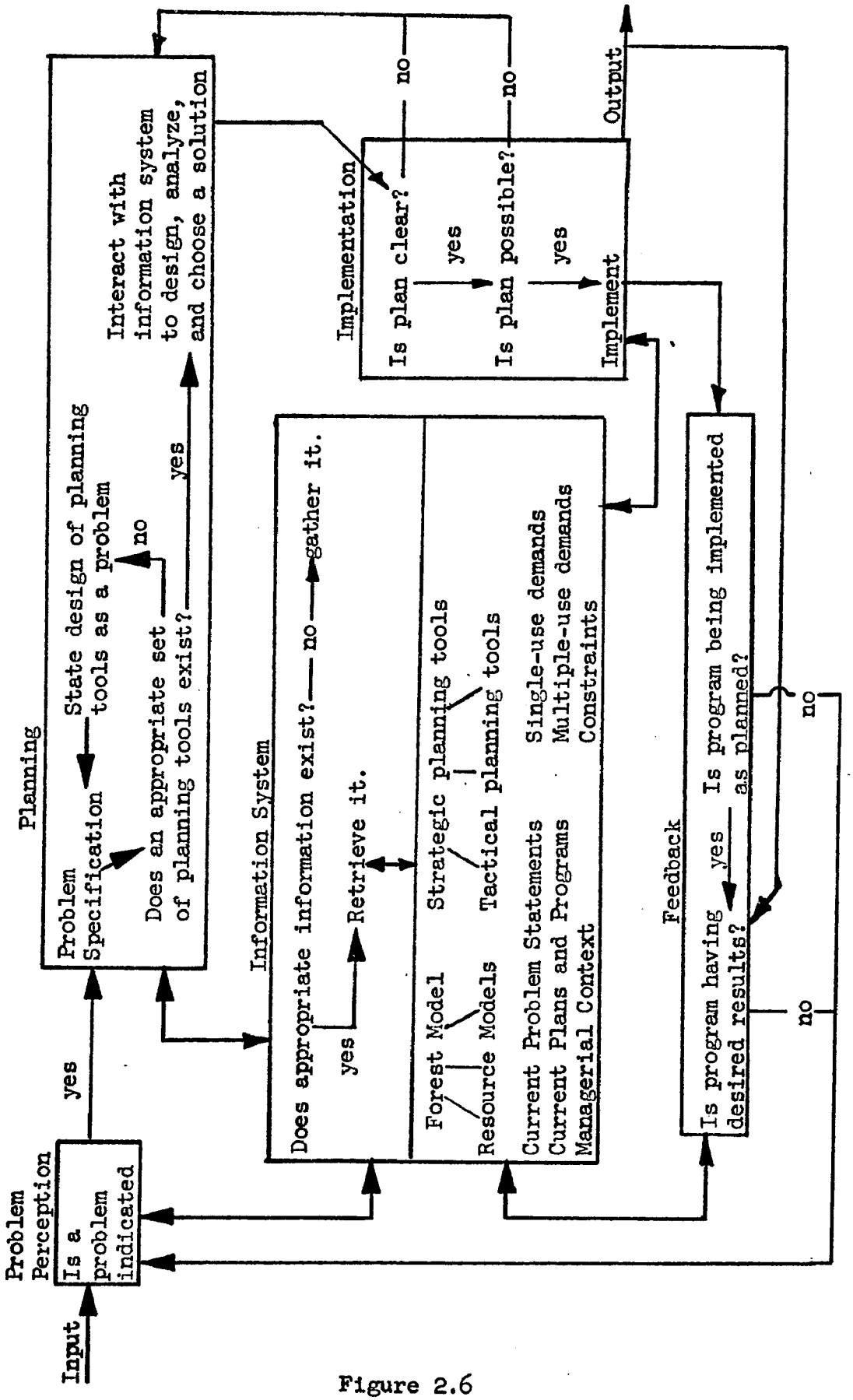

Input
Problem Perception
Is a problem indicated
yes
Planning
Problem Specification
State design of planning tools as a problem
Does an appropriate set of planning tools exist?
no
yes
Interact with information system to design, analyze, and choose a solution
Information System
Does appropriate information exist?
no
gather it.
yes
Retrieve it.
Forest Model
Resource Models
Strategic planning tools
Tactical planning tools
Current Problem Statements
Current Plans and Programs
Managerial Context
Single-use demands
Multiple-use demands
Constraints
Implementation
Is plan clear?
no
yes
Is plan possible?
no
yes
Output
Implement
Feedback
Is program having desired results?
yes
Is program being implemented as planned?
no
no

Figure 2.6

CHAPTER 3

BLUE ROCK STATE FOREST
A CASE STUDY

Introduction

Application of a control systems approach in context of managing Blue Rock State Forest serves a number of purposes. First, it clarifies how a control systems approach operates and highlights its advantages over traditional management systems. Second, it illustrates how such a system can be applied in situations where there are gaps in available information; facilitating design and implementation of programs while directing efforts to gather additional data as needed. Finally it provides a forum for comparing this approach with other contemporary model-based systems such as RAM or ECHO.

To accomplish these purposes, this case study follows the process of a control systems approach and emphasizes accomplishment of some specific tasks. First a "perception" of the management context of Blue Rock State Forest is presented. Based on this perception, planning processes are illustrated through specification and solution of two management problems: (1) identification of strategic goals, and (2) design of tactical projects. Next roles of implementation and feedback are discussed, primarily in terms of improving planning processes and associated information.

Management Context of Blue Rock State Forest

The management context of Blue Rock State Forest is complex due,

in part, to its prior uses and location. Blue Rock State Forest lies in southeastern Ohio. It is ten miles southeast of Zanesville, approximately sixty miles east of Columbus, where the Ohio "Hill Country" begins on the western fringe of Appalachia. The forest lies just east of the Muskingum River and forms the headwaters of Manns Fork, Salt Creek (see figure 3.1). Topography of the forest is typical of Ohio Hill Country with narrow valleys ringed by rocky ridges that stretch to over a thousand feet in elevation, four hundred feet above the valley floors. It is about six miles long, north to south, and varies in width from over two miles wide in the ridges in the south to less than half a mile at the bottoms where Kent Run joins Manns Fork. Even with this, Blue Rock encompasses only 4573 acres.

History of the Blue Rock area is long. The Muskingum River played an important role as a transportation route for Indians and white settlers. Zanesville, named after an Ohio pioneer of this area, became an important trade center. It was here that goods, transported up the Muskingum River from the Ohio River, were traded for produce floated down from the north on the Muskingum, or from the west on the Licking River.

As settlement expanded through this area, lands were cleared for farms. Soils of Blue Rock include a number of silt and silt-clay loams with Muskingum Silt Loam predominating. These soils are agriculturally poor. Thus many of the farmers in this rugged area were eligible for federal relocation programs of the thirties. This transfered ownership of much of the land now in Blue Rock to the Federal government. In 1940, these lands were leased to the State and later ownership of them was turned over to Ohio. In 1949, a portion

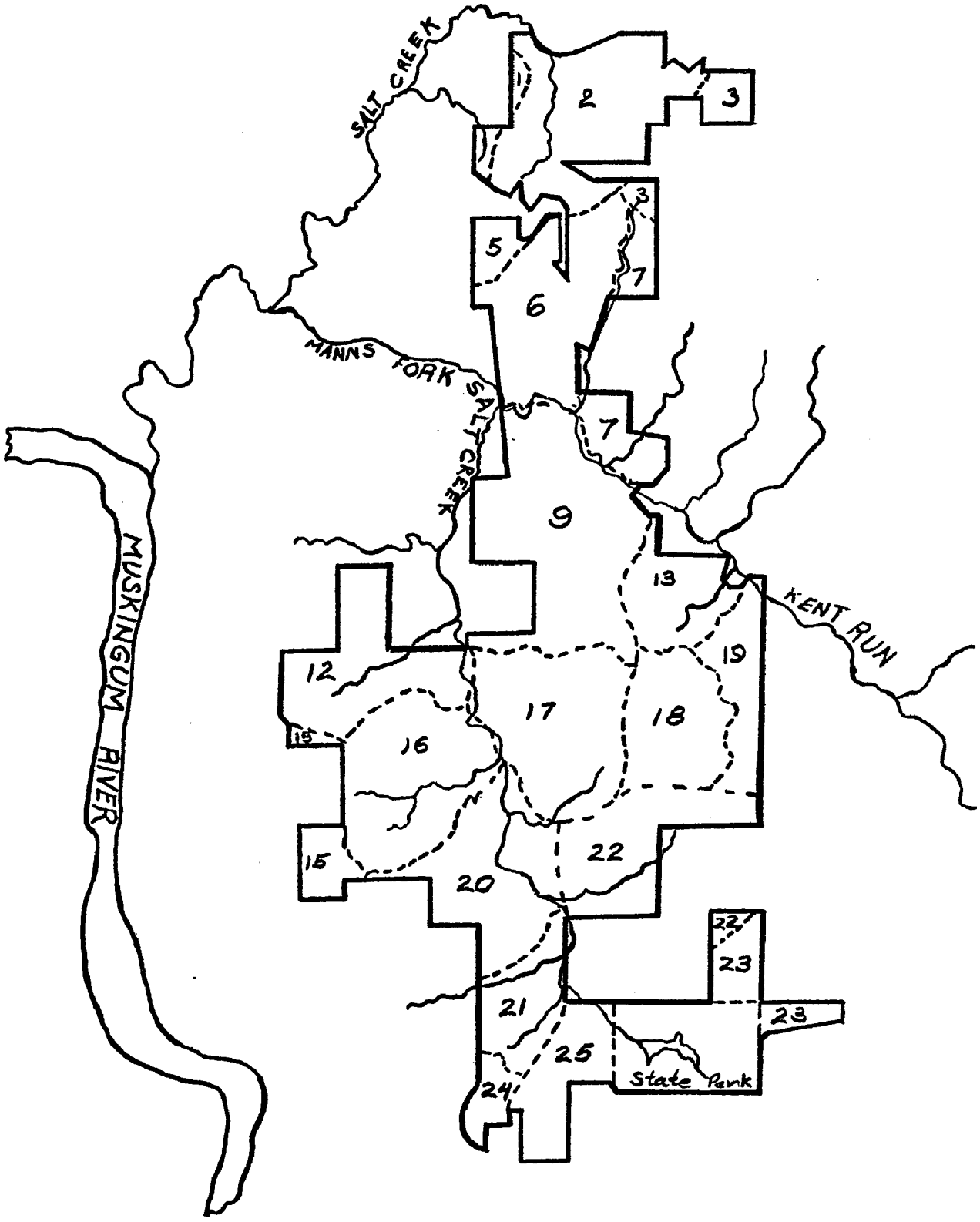


Figure 3.1
BLUE ROCK STATE FOREST

of the State Forest was designated as a State Park and administration of this portion was turned over to the Division of Parks. Other surrounding lands were purchased by the State for the forest until 1962.

Because of this varied history of use and ownership "... the forest cover on the Blue Rock Forest, while generally of a beech-maple type, is extremely heterogeneous in regard to cover type, stocking density, etc" (Branam, 1966). The last complete cover survey of Blue Rock Forest was done in 1966. It indicated that over the previous ten years approximately 1,000,000 board feet of timber had been harvested and that future harvests should be between 100 and 175 thousand board feet per year from hardwoods with an additional 1,000 tons of chipwood per year (Branam, 1966). For this survey, the forest was divided into compartments. Reports on each compartment include a compartment map and a short narrative description. Summaries from this survey are included in table 3.1.

Large sized trees (large and small sawtimber) occur most frequently on steep slopes and narrow ridge tops. Plantations (which is the State's designation for all pine stands) are frequently found along broad, relatively flat ridge tops and valleys. An explanation for this distribution is that early plantation, done primarily through conservation programs, were planted on former open agricultural land. This accounts for occurrence of plantations on flat or gently sloping areas. Further, occurrence of pioneer species on relatively flat areas represent former farm lands that were not planted, i.e. they are old fields going through natural succession. This leaves lands that were not suitable for farming, i.e. the steeper slopes, enough time to be occupied by larger trees of climax species. Species in plantations

Table 3.1
ACREAGE SUMMARY FOR BLUE ROCK FOREST *

COMPT. NO.	LARGE SAWTIM.	SMALL SAWTIM.	POLES	SAPS	PIONEER	PLANTATIONS	OTHER
1	0	2	0	0	22	0	1
2	0	78	73	42	191	63	17
3	18	0	0	0	13	28	3
5	0	19	0	0	6	16	2
6	88	19	0	0	36	153	11
7	0	45	0	0	25	107	4
9	115	85	19	0	223	110	16
12	94	0	0	0	79	53	10
13	42	53	0	0	70	28	4
15	0	55	22	9	0	0	8
16	194	41	0	0	42	107	12
17	0	121	11	7	46	135	26
18	97	15	0	0	21	56	17
19	60	11	0	0	14	61	9
20	214	25	0	0	17	91	30
21	61	0	6	4	55	80	4
22	59	10	4	7	94	154	23
23	21	0	2	0	14	71	14
24	0	0	0	0	35	4	16
25	62	0	0	0	32	72	12
TOTAL	1125	579	137	69	1035	1389	239

GRAND TOTAL 4,573 acres

* Branam, 1966.

are dominated by white and red pine, though there are short leaf pine plantations and one or two plantations of a mix of white pine and yellow poplar. Species in pioneer areas include sassafras, ash, alder, soft maple, yellow poplar, locust, and aspen. Other species found in the forest include oaks, hickory, beech, elm, walnut, and hard maple. Generally areas in sawtimber were 60 to 70 percent stocked and had volumes of 3,000 to 7,000 board feet per acre with the majority of stands at the lower end. While the cover survey does not present figures for plantations, researchers report that they seem to be near full stocking.

Another feature of Blue Rock that stems from its past ownership and uses is its roading. The forest is well roaded with virtually every area of the forest accessible. Though there are no trails exclusively designed as hiking trails, there are six miles of bridle trails. Use of motor vehicles on these or fire lanes is prohibited.

Wildlife improvements of Blue Rock include practices associated with old field management including plantings and maintenance of established grass-legume meadows or native grasses and forbs. Also ten water holes, occupying 2.5 acres and 24 meadows, occupying 24 acres have been established (Cannon, 1974). Information on wildlife other than game species is limited. In 1959, two beaver were introduced to Culter Lake in Blue Rock State Park. They remained for several years and successfully reared young. Recently, though, they moved out of the lake area presumably because of a lack of food (Cannon, 1974). Since this move, the Forest Ranger has reported sightings of beaver down stream of the lake along Manns Fork.

Game species on Blue Rock include ruffed grouse, white-tailed

deer, rabbits, and gray squirrels. Surveys indicate moderate to low populations of grouse. Deer numbers have increased to 7 to 9 deer per section within Blue Rock Township (Cannon, 1974). From measures of hunter success it seems that squirrel populations are increasing while rabbit populations are declining. This seems to be due to advancement of forest succession beyond optimum rabbit habitat (Cannon, 1974).

According to the Ranger, outside of hunting, recreation use of Blue Rock Forest is low. Occasionally there are large group gatherings for horse-back riding. Other than this, recreation appears limited to sporatic use by those camping in the State Park. Facilities in the State Park include 65 class B campsites, a beach and picnic area on Cutler Lake, and a concession stand. From informal surveys by the Ranger and people from the Division of Parks, it seems that the park is rarely used to capacity even on popular weekends such as the fourth of July. Reasons for this include lack of publicity and crowding of campsites on a small ridge. Also the surrounding area offers many developed recreation areas along lakes and rivers, and in other State and National Forests to divert potential users. Thus, even though Blue Rock sits in a very popular area for recreation, it is not under great recreation pressures.

The socio-economic environment of Blue Rock Forest is similar to other parts of Appalachia. In Zanesville, for example, umemployment for 1969 was 6.2 percent which was high compared to other cities in Ohio. Also the number of people with income less than the poverty level was 15.2 percent which is very high relative to other cities of 10,000 or more people. Farming in much of the surrounding area is typically marginal. Many farmers hold non-farm jobs to supplement their income. Generally, local socio-economic conditions are ones of high unemployment

and poverty or near poverty conditions.

The five man forest work crew on Blue Rock are all farmers who work to supplement their incomes. They have been working on Blue Rock for an average of twenty years. These workers, as well as the Ranger, shop in Zanesville. For professional services such as visits to doctors and dentists, they go to Philo most of the time.

The lowest level, organizationally, for Blue Rock is its five man forest crew. Above them are a Ranger and his assistant. The Assistant Ranger deals primarily with fire protection programs for the forest and neighboring counties; while the Ranger supervises implementation of timber management plans and timber stand improvement operations on the forest. Above the Ranger is the District Forester who is in charge of operations on five State Forests. On his staff is a management forester responsible for developing timber surveys and timber management plans for all five forests in this district. The District Forester interacts directly with the Chief and his staff.

Timber management planning is initiated by the management forester working closely with a Forest Ranger. As planning procedes, the District Forester is involved if for nothing more than approving a tentative plan. About the same time, the Chief's forest management assistant becomes involved. He normally allows the district management forester and Forest Ranger do tentative planning and then becomes involved in developing a final plan. Once a plan is finalized, it is sent to the District Forester for his review and approval and then to the Columbus offices and the Chief. The Chief reserves the right of final approval for all timber management work in hardwoods, including timber stand improvements. However, in the past, he has delegated

decision making authority for work in pine plantations to Forest Rangers and management foresters.[1]

Budget requests and allocation of budgets follow similar hierarchical channels. An operating budget is initiated for each State Forest through efforts and inputs of the Forest Ranger, District Forester, and the Columbus office. A composite budget for all of the forests and other operations of the Division is sent to the Chief for review and approval. An approved budget is sent to the Director of ODNR, whose staff combines it with similar requests from other Divisions. This budget is sent to the Governor's Office of Management and Budget where it is combined with budgets for all State agencies and is revised according to existing priorities and projected availability of funds. Though the Office of Management and Budget is attempting to initiate some form of program evaluation, none is used in budgeting at this time. After a budget receives approval of the Governor, it is presented to the State Legislature. Money allocated by a budget law of the State flows down to a forest following the same channels as its budget request. All receipts from forest operations go into the State's general fund.

Legally, besides providing protection for State Forests and promulgating rules for this purpose, the Chief of ODFP may "... take such measures as are necessary to bring about a profitable growth of timber ..." on State lands (Section .04, Chapter 1503, Ohio Revised Code). Also the Chief is directed by law to cooperate with the Ohio

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[1]This dicotomy in decision making seems to be caused by the political sensitivity of timber work in hardwoods. This is especially true in regard to such issues as clear-cutting, aesthetics, and habitat for game species of wildlife.

Agricultural Experiment Station, all State operated Universities and the Department of Agriculture. Beyond this, he is given the power to enter into agreements for acquisition of lands from the federal government, and, with the approval of the Director of ODNR, he may purchase or accept lands suitable for forestry purposes. Further, the Chief is given the power to enter into cooperative agreements with the Secretary of Agriculture of the United States for protection "... of forested watersheds of navigable streams in this state" (Section .27, Chapter 1503, Ohio Revised Code). Thus present laws provide minimum direction for management of forests.

This, then, is the management context of Blue Rock State Forest. Organizationally it is part of a system of State Forests for which a multiple-use set of objectives has been promulgated. Legally, few sanctions are provided governing powers and responsibilities beyond some broad and general statements. Financially it relies on administrative priorities and legislative generosity for funding. Geographically it is situated in Ohio Hill Country with high narrow ridges and agriculturally poor soils. Further it is part of Appalachia with surrounding poverty and high unemployment. Finally it sits in a recreationally attractive area, but seems to have little recreation use. It is in this context that management of its resources must be accomplished.

Specification of Strategic Goals

An initial task for management of Blue Rock State Forest is translation of organizational objectives into strategic goals which can be achieved within its context. Such translation assures, in part,

conformance of management with wishes of the people of Ohio as expressed by the executive branch of government. Also, specification of goals provides a target for planning activities as well as criteria for selecting, coordinating and directing daily activities. For these reasons, early specification of goals is an essential task of management.

Strategic goals can be specified in a number of ways. One method states goals in terms of a desired level of production such as a desired volume of timber, number of campsites, or wildlife population levels. A second method involves placing economic values on outputs and choosing goals in terms of economic indicators, such as present net worth or internal rate of return. And a third method, particularly common to timber management, states goals in terms of achieving and maintaining a specified forest configuration such as a normal forest. When generalized, this last method appears to provide a mechanism for translating multiple-use objectives of the Ohio Division of Forests and Preserves into specific and quantifiable goals.

A normal forest model specifies an ecosystem state by identifying a desired age distribution, spacial arrangement, and performance specifications for the overstory of a forest: (1) an even distribution of age and size classes on equally productive sites; (2) full stocking in each stand; and (3) a normal increment for the forest as a whole (Osmaston, 1968). By means of this specification, a normal forest model is in a form which is amenable to measures of achievement, i.e. one can measure how close an actual forest is to being arranged as a normal forest. In this way such a goal provides a guide for planning and implementation processes. Further, achievement and maintenance of

this configuration will result in sustained production of timber at maximum levels. Therefore, selection of a normal forest configuration as a goal successfully translates an objective of maximum sustained timber production into a goal suitable for management.

Following this example, a general process for translating objectives into goals can be formulated. Such a process involves specifying and choosing as a goal a forest configuration which is physically and technically possible, and which appears to satisfy objectives in terms of outputs, physical appearance, or both. This process would begin by identifying a range of forest configurations (ecosystem states) which could be achieved by the end of a planning period. Second, descriptions of each configuration would be combined with predictions of its outputs to form a basis for evaluation in terms of organizational objectives. Based on such evaluations, one of these ecosystem states would be chosen as a goal for management; i.e. as a target for program design and implementation.

This process for translating objectives into specific goals is well suited to forest resource management, particularly in multiple-use contexts. Objectives for mangement often include both quantifiable and non-quantifiable statements or values; e.g. maximize present-net-worth while maintaining a good corporate image; or produce timber for Ohio's industries, wildlife for hunting, and aesthetics for recreation. Combining descriptions of alternative forest configurations with predictions of their physical outputs facilitates comprehensive analysis of goals in quantitative and qualitative terms. Predictions of physical outputs provide data for quantified analysis of alternatives; e.g. economic values of alternatives can be calculated through economic

valuation of each alternative's outputs. Similarly, data for quantitative analysis in terms of total physical output or environmental quality is provided by such predictions of total outputs. Such a list, when combined with a description of an alternative's configuration, provides a basis for assessing aesthetic values and other non-quantifiable values such as social or political acceptability. This combination of quantitative and qualitative analysis provides a mechanism for incorporating a variety of value systems in analysis of alternatives and, based on such analysis, it is a mechanism for translating vague objectives into specific goals suitable for managerial problem solving processes.

Application of this process to Blue Rock State Forest involves three steps. First is identification of forest resource system outputs which are relevant to organizational objectives. Second is construction of a device capable of predicting levels of those outputs for alternative forest configurations. And third is construction of a device for specifying alternative forest configurations in terms compatible with the above predictive device.

System Outputs

Organizational objectives indicate three classifications of system outputs which can be used in analysis of alternative configuration of Blue Rock State Forest:

1. Timber - An objective of the Ohio Division of Forests and Preserves is to produce timber for Ohio's industries. Presently such industries are using hardwoods for pulp, sawlogs and veneer. Further there is a strong possibility that a market for pine will be opening.[1] Thus, analysis of

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[1]From personal discussions with Extension Forester Robert Touse.

alternatives should include considerations of production levels of both hardwoods and pines.

2. Wildlife - The wildlife consideration is indicated by an organizational objective of providing hunting in cooperation with the Division of Wildlife. Based on the management philosophy and recommendations of the Ohio Division of Wildlife, game species of Blue Rock include deer, squirrel, and grouse (Cannon, 1974). Thus population levels of these three species should be included in analysis of alternative forest configurations.

3. Recreation - The objective of providing areas for recreation to augment recreation on State Parks requires analysis of alternative forest configurations in terms of the amount of land available for recreation. This should include estimates of the amount of land managed under an uneven-age management plan suitable for recreation, as well as areas reserved from timber management for recreation. Also included should be suitable lands reserved for other considerations such as difficulty in logging or preservation of old growth for improvement of wildlife habitat.

Predictions of output levels of timber, wildlife, and recreation, then, provides a basis for quantitative analysis of alternative ecosystem states based on these objectives.

A Predictive Model

SOSAF (Simulation of Ohio State Forests) is a computer program written to predict one year output levels of timber, deer, grouse, and squirrels as well as acreage available for recreation. It is a deterministic model which does not simulate growth and development of a forest ecosystem through time. Rather, it is designed to operate using data files representing possible future forest configurations and provide predictions of single year outputs of such configurations.

A number of suppositions were made in construction of this program. First, the forest was divided into forty acre plots for ease of data handling. Each forty acre plot was assumed homogeneous in terms of soil, cover type, and topography. Further, it was assumed

that the dominant vegetative cover type (i.e. the overstory) has a determining effect on other biological activity within a forty acre area. In other words, the type, age, and density of an area's overstory is a determining factor in natural selection of understory vegetation, provision of wildlife habitat, and suitability of an area for recreational use. Finally the model presumes that wildlife populations expand to fill all available habitat; i.e. that population levels of deer, squirrel, and grouse are directly related to amounts of habitat available. Six subroutines were written as part of SOSAF to predict output levels of timber, wildlife, and recreation based on these suppositions.

Timber. The first of these subroutines, titled Timber, is designed to predict volume growth of hardwoods and pine. The algorithms for predicting growth in this subroutine were developed for mixed hardwoods and red pine in SNAFOR (Countryman, 1973). These algorithms were chosen for SOSAF for a number of reasons. First, the algorithm for predicting growth for mixed hardwoods was based on volume and yield tables for Upland Oak (Countryman, 1973; Schnur, 1937). Since Upland Oak is the predominant cover type in southeast Ohio and these tables are used for predicting growth and yield of such forests, selection of this algorithm appeared reasonable. Secondly, no other model for predicting growth throughout the necessary age span exists for hardwoods in Ohio.[1] Thus this represents the best information currently available. Selection of the red pine algorithm was based

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[1]Martin Dale (1974) of the U.S. Forest Service has developed a regression model for predicting growth and yield of Upland Oak forests, but this model is only accurate for stands 20 to 110 years in age.

on similar reasoning. Except for a few scattered patches of Virginia pine, there are no native pine stands in Ohio. Experience with management of pine plantations is limited and little data on growth or yield of pine in Ohio presently exists. Thus the algorithm chosen seems to be an appropriate approximation for its designated use.

Information concerning forest stands needed by these models includes data on stand age, basal area, and site index. None of this information is available for Blue Rock. For this reason, such information was approximated in the following manner. From the cover survey, a stand was classified as either pine or hardwoods. Further, based on occular estimates of size and percent stocking of hardwoods recorded in the cover survey, age and basal area of each stand were estimated through use of Schnur's volume tables (Schnur, 1937). It was estimated that pine stands were fully stocked based on discussions with Blue Rock's Forest Ranger. Estimates of plantation ages were based on the same discussions and planting records. Site data for both hardwoods and pine were based on a soils map and topographical map of Blue Rock in conjunction with soil-site studies.[1] Site indexes were approximated by first determining the predominant soil type of a forty acre plot from soils maps. This was then combined with topographical data to classify a site in terms compatible with soil-site studies. Based on such estimates, site indexes ranged from 47 to 90 for hardwoods and 52 to 90 for pine. Data for Blue Rock estimated in this way was then stored in a computer file in forms compatible with

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[1] For hardwoods, site indexes were based on soil-site studies of Carmean (1964). Pine site indexes were based on current research by Dr. James Brown of the Ohio Agricultural Research and Development Center in Wooster as reported through personal communications in 1975.

operation of the timber subroutine.

Operation of the timber subroutine is straight forward. First the land-use code of a cell is checked to determine its ownership; cover type; whether or not it is reserved from timber management; and if it is being managed under an even-age or uneven-age regulation plan. If it is being managed for timber, the program reads the appropriate age, basal area, species, and soil-topographical classification. Volume is then calculated using the following equation:

$$V = \text{scale } (V.F.)*(B.A.)*(T.H.)*(S.I./50)$$

where:

V = volume in cubic feet per cell
scale = the number of acres per cell
V.F. = volume factor based on a site index of 50 (V.F. = .4085 for pine and .3879 for hardwoods)
B.A. = basal area
T.H. = tree height
S.I = site index

One year is then added to a stand's age which automatically updates tree height of the stand. Growth of basal area is accomplished through addition of average basal area growth increment determined through tabular data classified by age and species. Updated tree height and basal area are then used to calculate a new volume using the same equation. Volume growth is then the difference between the two calculated volumes.

In calculation of basal area and basal area growth under even-age management, it is assumed that the stand is fully stocked. For stands being managed under an uneven-age management plan, calculation of growth is modified to take effects of understocking into consideration. In such cases the following equation is used:

$$A.G. = GFS*((\tfrac{1}{2}(BAa + BAf))/BAf)$$

where

A.G. = actual stand growth
GFS = volume growth of fully stocked stands using the previous equations
BAa = actual basal area
BAf = basal area of fully stocked stands

This equation takes understocking into consideration based on the assumption that an understocked stand will grow at a rate greater than fully stocked stands, but that its total volume growth will be less than a fully stocked stand.[1] Volume growth for each cell is then summed and printed as an output for each species.

Wildlife. After timber volume growth is calculated, four subroutines are called upon to calculate population levels of deer, squirrel, and grouse. Three of these subroutines are similar in terms of basic logic. As stated earlier, it was assumed that wildlife population levels are a function of the cover type within an animal's home range. With this assumption in mind, three subroutines (Deer, Squirrel, and Grouse) assign a basic population level to each cell based on the species and age of its cover type. For squirrel and deer, this base figure is based primarily on the amount of mast produced by different ages of hardwoods (U. S. Forest Service, 1971)[2] For grouse, a base figure was assigned based on population averages presented in

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[1]This is a common assumption in Forestry. See the discussion of Gehrhardt's formula in Davis (1954) for rationale behind this assumption.

[2]Initial estimates were modified based on technical expertise of Dr. T. W. Townsend, a wildlife researcher at The Ohio State University through personal communications in 1975.

Wildlife Management Handbook for different cover types and ages (U. S. Forest Service, 1971). Base figures set in this manner for grouse and squirrel were modified in terms of a forest-wide diversity index calculated in subroutine Divers. Base figures for deer were modified in a slightly different manner.

Home range for squirrel and grouse are normally less than forty acres in Ohio Hill Country. Deer, on the other hand, range over 100 to 150 acres.[1] For this reason modifying base deer numbers using a general diversity index was rejected. Instead, an initial population level for each cell is modified to take into consideration the type and age of cover on its eight adjoining cells. Increases in initial values were calculated in the following situations:

1. If a neighboring cell is of a different species, additions are made to respond to differences in food available and to edge effects.

2. If a neighboring cell is of the same species and has an age difference of greater than twenty years compared with the target cell, additions are made to reflect differences in food available.

3. If a neighboring cell is less than ten years old, additions are made to reflect additional browse available.

Initial values for all three species of wildlife are also modified to reflect effects of soil fertility (site productivity). And deer numbers are modified to reflect additions to browse if a stand is less than fully stocked (this is done within limits for gains in browse can be offset by reductions in the amount of mast produced). Each subroutine for wildlife, then, assigns a value for available habitat for each cell based on its cover type; this is modified to take site

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[1]Based on deer research in Ohio by Dr. T. W. Townsend as reported in personal communications in 1975.

productivity into consideration; for deer, neighboring cells are surveyed and initial values are modified to take edge effects into consideration; and for squirrel and grouse, a fourth subroutine, Divers, is called upon to calculate a general diversity index for the forest to modify initial population levels.

Recreation. After wildlife populations are calculated, the Create subroutine is called upon to calculate the number of acres available for recreation. This subroutine checks for cells which have a reserved land-use-code or a land-use-code indicating that the cell is being managed under an uneven-age regulation plan. The number of such cells is totalled and multiplied by the number of acres in each cell.

The final action of SOSAF is printing its predictions. Timber growth for hardwoods and pine is expressed in cubic foot volumes; wildlife in population numbers for each species; and areas available for recreation in acres. Before any such predictions can be made for model validation or predictions of outputs of alternative forest configurations, data files representing current and possible configurations of Blue Rock State Forest must be constructed.

LABDAT - Land-use, Age, and Basal Area Data Program

SOSAF was designed to operate using a 26 by 10 matrix of data representing Blue Rock State Forest and surrounding lands. Each cell in that matrix represents a forty acre plot of land. Each entry in these base data files is seven digits in length for each plot and

is composed of three numbers: (1) a land-use-code providing information concerning a cell's ownership, its cover type, whether or not it is reserved from timber management, and if it is being managed under an even-age or uneven-age management system; (2) the age of its timber; (3) the basal area of its timber. Information from the 1966 Cover Survey was used to construct a data file in these terms to represent the current configuration of Blue Rock State Forest.

Construction of this data file serves two purposes. First, it provides a database for initial calibration of models in SOSAF. Second, it provides a base for generating alternative future forest configurations.

Generating data files to represent alternative future forest configurations involves a number of steps. The first step is to select a time horizon for strategic planning, e.g. twenty years. Second, each cell of the base matrix must be updated to depict a forest which has grown over the total planning period; e.g. a cell representing a stand which is presently 85 years old would be revised in terms of age and basal area to represent a stand 105 years old for a strategic planning period of twenty years. Once all cells have been revised in this way, the updated database would be altered to reflect proposed management practices; e.g. harvesting an 85 year old stand fifteen years into the planning period would call for changing its entry from a 105 year old stand to one representing a five year old stand. The resulting database would represent what the forest could look like in twenty years given a specified strategy and assuming no incidence of disasters. In short, this process for generating future forest configurations is a generalization of conventional stand table methods for projecting growth modified to create datafiles

compatible with SOSAF.[1]

Updating datafiles by hand following this procedure would be a tedious task. LABDAT is a computer program written to aid such updating. The first action LABDAT takes is to ask a number of questions: (1) Which file do you want to use as base data? (2) On which file should the new database be stored? (3) What is the time frame for strategic planning? and (4) Do you want a printout of the base data file? After receiving responses to these questions, LABDAT: (1) prints a base-map if requested; (2) updates this data to depict growth over the time-horizon for planning; and (3) offers a number of options. The first option is to printout the new database. Second, LABDAT provides an option for automatically searching for and identifying all cells of specified land-use-codes and age ranges. And finally, it provides an option to alter specific cells.

These options aid design and construction of a database representing a new forest configuration. A printout of the updated database delineates a future forest configuration if no management practices were implemented. Identification of cells by age class and species upon request aids design by identifying cells that would be altered through management. For instance, identifying hardwood cells with ages greater than 100 would identify cells that could be considered for harvesting during that planning period based on a rotation age of 100. Finally, the option to alter specific cells in the database allows a manager to construct a similitude of a future forest configuration based on a proposed strategy. Once these options have been

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[1]See Davis (1954) for a discussion of stand table projection.

exercised, LABDAT transfers this database to the specified file and asks if a printout of this file is desired. Thus by using LABDAT, a forest resource manager can construct alternative forest configurations in a form amenable to analysis using SOSAF.

Following this procedure, LABDAT was used to construct seven alternative forest configurations. These seven were chosen to represent a full range of managerial alternatives for Blue Rock State Forest in terms of single and multiple-use; and extensive and intensive management. Further, the time horizon for each alternative was set at twenty years. Finally, it was assumed that no disasters such as a fire or extensive insect or disease attacts would occur within this planning period.

The first alternative represents a "preservationist" strategy. In this case, management's strategy is to protect the forest and to limit cutting to salvage cuts. This allows the forest to progress "naturally" and is not too far from depicting management of Blue Rock over the last ten years.

The second alternative is a status-quo timber alternative. This strategy presupposes a rotation age of 100 years for hardwoods and 60 years for pine. Final harvests are done approximately every year to bring the forest toward full even-age regulation. The distribution of pines and hardwoods remains the same, and little is done for wildlife beyond harvesting timber to create openings. No areas are set aside for recreation.

The third alternative is similar to the second with one difference. Rather than leaving the relative proportions of pine and hardwoods constant, liquidation of pine stands is initiated. In this alternative,

four cells of pine are harvested in each five year period and are replanted in hardwoods. (Hardwoods are also harvested in line with a general regulation plan.) Under this plan, the forest would be totally in hardwoods and approaching full even-age regulation within forty years. This alternative represents present trends in planning as expressed by the Forest Ranger of Blue Rock.

The fourth alternative, again, is similar to the second. In this case, though, cutting and planting are done to shift toward a fifty/fifty distribution of pine and hardwoods. Since pine appears to produce more fiber than hardwoods on many sites of Blue Rock, this could be classified as an option to increase total timber production.

Guidelines proposed by the Ohio Division of Wildlife form the basis for the fifth alternative. These guidelines called for a reduction of pine areas to less than five percent of the total area and the following distribution of hardwoods (Cannon, 1974):

10%	Reserved (ages greater than 100 years)
42%	40 to 80 years old
32%	10 to 39 years old
16%	less than 10 years old

To accomplish this distribution, eleven cells of the 120 cells representing Blue Rock were reserved from timber management. Cells to be reserved were chosen based on their topography and age; i.e. areas with steep slopes (making lumbering difficult) and mature or near mature age classes were reserved. Further, the plan would retain six cells (5% of the total area) in pine on a thirty year rotation. This leaves 99 cells to be managed for hardwood timber. The age distribution presented by the Division of Wildlife for the total area, if followed,

conforms fairly well to a fully regulated forest on an 80 year rotation for these 99 cells with one discrepancy. This age distribution calls for eighteen cells in the one to nine year old age class while only twelve cells would be in this age class if the forest was fully regulated. This is not a serious discrepancy, though. A reason for retaining sixteen percent of the total area in the youngest age class is to provide open areas where browse would be produced. Under this alternative, three pine cells would be in an age class where there would be some browse produced, increasing the number of cells available for browse production to fifteen. This is only three cells less than that recommended. In this way, the fifth alternative depicts a forest configuration that would result after twenty years of working toward the distribution of cover-type and ages recommended for wildlife management.

The sixth alternative is basically the same as the fifth, In the sixth, though, fourteen cells are taken out of even-age management and are managed under an uneven-age management plan. This has a number of implications. Cutting on these cells would be done in terms of individual or small group selection; and management would tend to be more intense leading to increased cleaning and thinning. The combination of these factors can: (1) provide more edge for wildlife; (2) provide more browse for wildlife under resulting partial canopies; and (3) provide management which would not adversely effect aesthetics and thus open areas for recreation. The fourteen cells were selected to connect cells previously reserved from timber management; providing an area potentially useful for a system of hiking trails.

The final alternative is an expansion of the sixth representing very intensive multiple-use management. In this alternative, an

additional 30 cells are placed in uneven-age timber management. Thus, while providing for management and production of timber and wildlife, this alternative provides areas for linking almost all parts of the forest in a network of hiking trails.

These, then, are the seven alternatives to be considered as strategic goals. Each represents twenty years of progress toward eventual full regulation of Blue Rock State Forest. Further, they provide a full range of management strategies for initial consideration in selection of strategic goals.

Calibration of SOSAF

Calibration of SOSAF was accomplished in two steps. First, parameters were checked for accuracy of predictions using data representing the current configuration of Blue Rock. Then, using the seven alternative future states, parameters were modified to exhibit realistic trends in population shifts due to strategy differences. Results of SOSAF based on data representing the current configuration of Blue Rock is shown in Table 3.2.

Table 3.2
Predictions of Current Forest Configuration
Outputs Using SOSAF

Growth of hardwoods	183,174.62 cu.ft.	(52.64 cu.ft./acre/year)
Growth of pines	139,692.38 cu.ft.	(105.8 cu.ft./acre/year)
Deer	70.	(9.3 deer/section)
Squirrel	562.	(1 for every 6.5 acres of hardwoods)
Grouse	64.	(1 for every 54 acres of hardwoods)

The estimate of hardwood growth of 52.64 cubic feet per acre per year appears within acceptable limits. In an inventory of the

timber resources of Ohio Hill Country, DeBald and McCay (1969) state:

> Over three-fifths of the Hill Country timberland is capable of producing more than 50 cubic feet per acre per year, and almost one fourth could produce more than 85 cubic feet per acre per year (potential expressed in terms of mean annual growth at culmination of increment in fully stocked stands).

Since most hardwood stands of Blue Rock are not fully stocked and some of the sites are less than average in productivity in terms of Ohio Hill Country, the 52.64 cubic feet per acre per year estimate appears reasonable and no further calibration of this model is indicated at this time.

As stated earlier, little data is available concerning growth of pine in Ohio. Though there is some data on Ohio pine stands, there does not seem to be any which can provide estimates of average volume growth for calibration of this model. Hence, much reliance must be placed on calibration of this model in SNAFOR (Countryman, 1973). Also, based on experience with pine in Ohio, William Cowen, an extension Forester, estimated pine growth at between 1 and 1.5 cords per year in Ohio. The estimate of 105.8 cubic feet per acre per year translates into 1.18 cords using a conversion factor of 90 cubic feet per cord. Thus, based on earlier calibration of this model in SNAFOR and estimates of a forester familiar with Ohio conditions, this model appears acceptable and no further calibration is indicated.

Wildlife surveys of the Blue Rock area report seven to nine deer per section (Cannon, 1974). This estimate was considered conservative by Dr. T. W. Townsend based on research he has done on deer in Ohio. Further, expected deer population levels for the southeastern United States range from an average of 36 deer per section in Oak-

Hickory forest types to 5 deer per section in White Pine - Hemlock types (U. S. Forest Service, 1971). Based on this data, the 9.3 deer per section estimated by SOSAF is within expected limits; is marginally above present estimates for this area; and may be a bit conservative based on recent research findings. No further calibration of this model is indicated by these observations.

There are no current population figures for squirrels in the Blue Rock area. Estimates of squirrel population levels in upland hardwoods range from one squirrel per 10 to 15 acres in stands ten to thirty years old to one squirrel per 1 to 5 acres in mature stands.[1] Also the Forest Service proposes one squirrel per two acres as a wildlife management objective in the southeastern United States (U. S. Forest Service, 1971). Since Blue Rock is not currently being managed intensively for squirrels and considering current age distributions of hardwoods are slightly skewed toward younger stands, the estimate of one squirrel per 6.8 acres again is reasonable and does not indicate a need for further calibration of this model.

Estimates for grouse population levels range from one grouse per 10 to 15 acres in young stands (less than 10 years old) mixed with older stands, to one grouse per 50+ acres in mature hardwood stands.[2] Reported measurements in Michigan estimated one grouse per 128 acres in unmanaged areas to one per 5 acres in areas managed for grouse (U.S. Forest Service, 1971). Thus, given the

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[1]Based on personal discussions with Dr. T. W. Townsend, a wildlife researcher at The Ohio State University.

[2]Based on personal discussions with Dr. T. W. Townsend, a wildlife researcher at The Ohio State University.

age distribution of timber and present conditions of Blue Rock, an estimate of one grouse per 54 acres of hardwoods is within expected limits and is reasonable requiring no further calibration of this model at this time.

From analysis of estimates of timber growth and wildlife population levels for the current forest configuration of Blue Rock, models used in SOSAF appear acceptable. This, however, is only a single data point on which to judge accuracy and reasonableness of predictions. Further evidence of acceptability can be acquired by observing shifts in these estimates with changes in forest configurations. Table 3.3 presents estimated outputs for the seven alternative forest configurations using SOSAF as a predictive device (i.e. this is sample output of SOSAF using data files representing the seven alternative forest configurations discussed earlier). All values fall within acceptable limits and shifts in estimates seem reasonable. Changes in values for alternatives one and two provide an illustrative example.

Alternative one entailed protecting the forest from harmful agents while allowing it to progress naturally. In comparison with output predictions of the current configuration, the following changes are observed:

Hardwood Production	down 35%
Pine Production	up 11%
Deer	down 7%
Squirrels	up 28%
Grouse	down 100%

These shifts seem reasonable. As the age of hardwoods shifted toward mature and over-mature age-classes one would expect a decrease in net growth. The age distribution of pines, on the other hand, went from a

Table 3.3
Sample Output Predictions of
SOSAF for Seven Forest Configurations

Alternative / Output	1	2	3	4	5	6	7
Oak (cu. ft.)	119164	161263	197992	141712	189717	181678	171853
Pine (cu. ft.)	154868	116470	81256	150235	98616	98616	98616
Deer	65	72	70	76	79	81	86
Squirrel	720	605	621	538	780	793	815
Grouse	0	50	71	39	94	95	98
Recreation (acres)	0	0	0	0	440	1000	2200

fairly even distribution of ages between 10 and 40 years old to a distribution of ages between 30 and 60 years old; placing many of these stands in their peak growing ages. The growth of stands in both hardwoods and pines eliminated openings and would cause browse production to drop and mast production to increase. These trends explain the increase in squirrels which are heavily dependent on mast and decrease in deer which require both mast and browse. Grouse require openings and young stands mixed with mature stands (U. S. Forest Service, 1971). Allowing stands to close-up eliminated openings and destroyed grouse habitat in the forest.

One would expect the following results if a moderate amount of cutting were done in both hardwoods and pine. First, as over-mature hardwoods are harvested and brought into younger age classes, one would expect an increase in net growth. In contrast, cutting pine from high growth age classes and planting cut areas with young classes where growth is not as high would reduce total net growth. Through cutting operations, openings in the forest would be created. This would increase the amount of browse available and thus have a positive effect on deer populations. Also creating openings provides habitat for grouse. Squirrels, however, would suffer as hardwoods are harvested from mast productive age classes and brought into age classes at which little or no mast is produced. The second alternative involves some cutting in both hardwoods and pine. Changes shown on the next page are comparisons between the first alternative and the second alternative. These results are as expected.

Based on this discussion, two conclusions can be drawn: (1)

Hardwood Production	up	35%
Pine Production	down	25%
Deer	up	10%
Squirrels	down	16%
Grouse	up	50 grouse from a population level of zero

predictions of timber growth and wildlife population levels are reasonable in terms of absolute numbers; and (2) shifts in predictions resulting from changes in proposed forest configurations can be easily explained based upon known interactions within forest ecosystems. Thus, for initial comparisons of alternative future configurations of Blue Rock State Forest, no further calibration or development of SOSAF is indicated at this time.

Analysis and Selection of Strategic Goals

The purpose of developing SOSAF and LABDAT was to facilitate design and analysis of alternative strategic goals for management of Blue Rock State Forest. LABDAT was used to construct seven data files representing alternative forest configurations which could serve as strategic goals. SOSAF was then used to predict component outputs of each configuration. A listing of these outputs as predicted by SOSAF is shown in table 3.3.

Based on this data, a number of procedures could be used to select an alternative as a strategic goal. Such procedures include: (1) placing economic values on each output set and selecting an alternative in terms of maximum economic benefit, maximum present-net-worth, or maximum benefit-cost ratio; (2) choosing an alternative in terms of maximum physical outputs; (3) selecting a desired level for each output and choosing the alternative which achieves this level or achieves it

at least cost; or (4) selecting an acceptable level for some of the component outputs (e.g. wildlife) and choosing the alternative that maximizes either physical or economic output of the other components while providing the specified level of the exempted component. Each of these methods should lead to selection of an alternative, but it is unclear which method would be best in choosing an alternative which meets organizational objectives.

In Forest Use and Resource Management Plan - Blue Rock State Forest, organizational objectives for management are presented (State of Ohio, Department of Natural Resources, 1975). These objectives are:

> The recreational objectives at Blue Rock State Forest are: to provide quality backcountry recreation opportunities commensurate with the resource base; and to provide esthetic surroundings for the public activities and programs of the forest area.
>
> The wildlife management objectives of Blue Rock State Forest are: to develop and maintain an abundant and diverse wildlife resource representative of the central hardwood forest types best adapted to the varied sites that occur on the forest through the application of sound silvicultural practices and, to a lesser extent, through the use of specialized wildlife habitat practices; and to provide quality wildlife-related recreational experiences on the forest consistent with wildlife resource needs through limited recreational use, principally determined through access and regulation.
>
> The objectives for timber management at Blue Rock State Forest are: to provide and sustain a resource base for the continuous harvest of quality wood products and demonstration of management practices; to provide habitat for the greatest diversity of wildlife species that the forest is capable of supporting consistent with the previous objective; to provide and enhance the forest environment for backcountry recreation and activities.

Based on these objectives, it appears that, to be acceptable, a strategic goal must provide for deliberate management for timber, wildlife, and recreation. If this is true, the first four alternative

forest configurations must be rejected. While they produce some wildlife and possibly a potential for recreation, such production is incidental in deliberate timber management. Further, they seem to be technically less efficient than the last three alternatives in terms of total production of goods and services; i.e. for little or no losses in timber production, significant increases in wildlife and recreation can result from switching from one of the first four alternatives. In fact, the last three alternatives are surpassed by only one alternative in terms of production of hardwoods and even this is not a serious long term drawback.

Strategic objectives for management of Blue Rock stress production of wildlife representive of the central hardwood types. Also there is an apparent policy within the Division of Forests and Preserves favoring liquidation of pine. These last three alternatives, when achieved, would confine pine to five percent of the area of Blue Rock, providing ninety-five percent of the area for production of hardwoods and wildlife associated with hardwood forest types. This strengthens selection of these three alternatives as consistant with organizational objectives. With some interpretation of organizational objectives, the acceptable set of alternatives can be narrowed even further.

One objective for timber management of Blue Rock State Forest is demonstration of management practices. Also objectives promulgated by the Division of Forests and Preserves for all State Forests include providing for demonstrations of good forestry practices and providing tests of forestry research. Recent research in upland hardwood types have indicated that these forest types can be managed economically

under all-age management plans entailing either single tree or small group selection methods (Nelson, 1973; McCauley, 1972). Further, preliminary economic analysis of all-age management for hardwoods in Ohio done by Brenner (unpublished) indicates superiority of all-age management for small woodlots. Thus managing some timberlands under an all-age management plan would: (1) provide tests of forestry research; and (2) provide demonstration of a forestry practice of potential benefit in Ohio. Based on this interpretation of objectives, only alternatives six and seven are acceptable in that they: (1) provide for more areas in hardwoods than all but one other alternative; (2) provide deliberate management for timber, wildlife, and recreation; (3) are superior to all other alternatives in terms of the amount of wildlife produced and areas available for recreation; and (4) provide for demonstrations and tests of all-age and even-age management of hardwoods.

Choice between alternatives, at this point, is no longer based on which alternative meets organizational objectives because both of the remaining alternatives appear consistent with those objectives. Further analysis and final selection, then, must be based on which of these acceptable alternatives is "best". Such decision-making may not be within the delegated powers of the Forest Ranger or even the District Forester. Rather it could be a decision for the Columbus office. Possible analysis criteria could include: the cost of each project; potential impacts of each program on local and regional environmental, economic, and social systems; or the social or political acceptability of each alternative. Information necessary for analysis in these terms can be supplied by Blue Rock's forest resource manager

by providing: (1) a list of component outputs of each alternative; (2) a description of each forest configuration; and (3) a discussion of actions needed to achieve each configuration within twenty years. Further, as this information system is developed beyond basic levels, information can be provided concerning ecosystem stability and effects on associated socio-economic systems. In this way, through use of a control systems approach, the forest resource manager can identify acceptable forest configurations and provide information necessary for selection of one of these as a strategic goal without having to force economic values on all outputs or attempt to figure out how many cubic feet of timber a deer is worth. This is true because decisions are no longer made strictly in terms of outputs, but in terms of the total forest configuration and its relationship to environmental and social systems. In other words, use of a control systems approach provides a structure, process, and information system needed to translate vague multiple-use objectives into clear and quantifiable goals even when dealing with complex natural systems and rapidly shifting demands and values in associated social systems.

Tactical Planning and Improvement of Information

Planning activities for forest resource management encompass a wide span both spacially and temporally. At one extreme is design, analysis, and selection of strategic goals; i.e. long range goals for the entire forest. At the other extreme is design, analysis and selection of tactical plans; i.e. short range projects of limited scope. Just as the structure and process of a control systems approach facilitated selection of strategic goals as discussed earlier,

such an approach can aid design, analysis, and selection of tactical plans. Further, through sequential operation from strategic to tactical levels, information is refined for improved successive iterations of all levels of planning. An example involving timber management planning for Blue Rock State Forest illustrates these points.

One focus for tactical planning in management of Blue Rock State Forest is development of even-age regulation plans for upland hardwoods. In each of the acceptable strategic goals discussed in the last section, portions of Blue Rock were designated as areas to be managed for hardwood timber under an even-age management plan. Achievement of this goal is predicated on designing a plan to: (1) regulate these areas in terms of age classes for sustained production; and (2) regulate each stand to provide growing space for each tree while assuring full site utilization. By providing access to and coordination of information concerning growth and response of upland hardwoods, a control systems approach can aid design and analysis of appropriate tactical plans.

Information needed for design of even-age regulation programs includes information on volume growth throughout the life span of hardwoods to select a rotation age. Also information concerning response of forest stands to thinning is needed to specify: (1) at what ages stands should be thinned; (2) which method should be used for each thinning (e.g. high, low, or mechanical); and (3) what percentage of the stand should be removed in each thinning. Models of timber growth in SOSAF, while adequate for one year predictions for the

forest as a whole, are inadequate for providing the above information. Thus, a control systems approach would call for a search for models capable of providing this information and if there were none, this approach would guide data collection and model design to develop suitable models.

After some searching, a set of regression equations were discovered "...that will provide ... growth and yield estimates up to 30 years after initial thinning for any desired combination of age, site, basal area, and average stand diameter..." for upland hardwoods (Dale, 1972). These equations are valid for stands 20 to 110 years old. Though this restricts their usefulness, they are a basis for constructing models capable of providing information necessary for design and analysis of regulation plans.

SMOAKS (Simulation of Oak Stands) is a model based on the above equations which provides a basis for design and analysis of regulation plans (Lieser, 1974). This program provides estimates of timber volumes produced and economic indicators (benefit-cost ratios, present-net-worth, and internal-rates-of-return) resulting from manager specified regulation plans for a single stand of upland hardwoods. Specifications needed to begin operation of this model include: (1) initial stand age; (2) number of trees per acre; (3) basal area; (4) site index; and (5) an interest rate for economic evaluation. If these values are not specified, default values are supplied by the program. Also a strategy in terms of scheduling thinnings and final harvest must be entered. Thinning options available at times for thinning are high or low thinnings to remove any specified percentage of the basal area at that age. Results presented to the manager include: (1) a tabulation of timber

growth throughout the life of the plan; (2) volumes of timber removed in thinnings and final harvests; and (3) economic indicators of the plan's success using the specified interest rate and assuming that timber prices remain constant through time and over a range of volumes produced. This information provides a basis for comparing alternative rotation lengths and thinning strategies in terms of total volume of timber produced and economic indicators. In this way, information necessary for design and analysis of alternative regulation plans is provided. In other words, through search for and incorporation of appropriate models of timber growth as dictated by a control systems approach, information necessary for tactical planning was generated, processed, and stored as part of a managerial information system. Incorporation of these models and subsequent design, analysis, and selection of tactical plans have other implications in management systems based on a control systems approach.

Choice of strategic goals was based, in part, on predictions of total ecosystem outputs. Such predictions were made using SOSAF based on some fairly general models in an information poor context. Strategic and then tactical planning requires an increasingly refined set of models for more precise predictions. As models, such as SMOAKS, are developed and applied in planning, three consequences are produced. First, to develop these refined models and then apply them to Blue Rock, additional data is needed. Guidance on what data should be collected and how it should be processed are indicated by information needs of tactical planning and models upon which such planning is based. Second, as models of individual resource systems are developed (e.g. SMOAKS) there will be pressure brought about by information needs for strategic planning to combine these models into total forest models. This process will result in gathering more data on

resource systems and how they are linked. Following this trend, base data will be improved and an improved (i.e. more precise and accurate) version of SOSAF can be developed. Finally, then, based on improved resource data and refined predictive tools, alternative strategic goals can be reinvestigated in terms of their total outputs.

Beyond changes in perception of the relative attractiveness of alternative goals based on improved information, this process can have an impact on design of new strategic goals. For instance, rotation lengths used to design the seven original strategic goals were approximations based on current practices and plans of the Division of Forests and Preserves. Through operation of SMOAKS or other models, these rotation ages could be discarded as inappropriate and replaced by rotation ages which are perceived as more desirable in terms of organizational objectives. Supplanting the original rotation ages calls for redesign of strategic goals to reflect acceptance of a new set of rotation ages. Thus goals and subsequent programs can be altered to reflect improved information even if there is a substantial time lag between development of models such as SMOAKS and a rewriting of SOSAF to reflect this improved understanding and information.

These two tendencies to alter the direction and content of program planning based on process imposed improvement of information is a primary strength of a control systems approach. A second strength comes from constant testing of management's understanding of its context and of the forest ecosystem as represented by predictive models through feedback on implemented programs. These two properties of a control systems approach allow a manager to develop simple forest models, such as SOSAF, design and choose a direction for management,

and begin designing strategic and tactical plans even in an information poor context. Then, planning processes of program design and analysis guide data collection and model construction necessary for learning about involved systems and improving managerial programs. Resulting models and their predictions are then tested using feedback on implemented programs. In this way, a control systems approach for management provides a structure for coordinating managerial activities and a process which guides learning and adaptation. Comparisons with conventional forest management concepts and other model-based management systems will further illustrate strengths of this approach.

Management System Comparisons

A justification for developing a control systems approach for forest resource management was predicated on the assertion that conventional forest management concepts were inadequate for dealing with management situations like that of Blue Rock State Forest. Lacking were concepts that could: (1) identify, analyze, and choose strategic goals amenable to measures of achievement while compatible with organizational multiple-use objectives; (2) specify and coordinate operation of managerial functions from strategic to tactical levels; (3) provide for an understanding of and information about complex natural systems associated with management of forest resources; and (4) provide for heuristic and adaptive behavior. As illustrated in the last two sections, a control systems approach does provide a structure, process, and information system which can accomplish these four tasks. Further, it provides for integration and application of conventional tools, techniques, and concepts as they

are needed. In this way, this approach utilizes the best concepts presently available while avoiding use of these concepts when they are inappropriate. A control systems approach, therefore, is not a set of concepts developed to supplant conventional managerial concepts. Rather, it is an approach that builds upon these concepts to expand management capabilities for dealing with the full range of problems and complexities associated with management of forest ecosystems. Two contemporary model-based systems for management bear discussion at this point.

A Resource Allocation Method (RAM) "...is designed to provide an analytical framework for drawing long range forest management plans and for evaluating wildland multiple-use management policies" (Navon, 1971). Timber RAM, a subset of RAM, provides an example of how RAM operates. Based on a linear programming algorithm, Timber RAM calculates cutting schedules to meet such goals as "... maximize revenues, maximize stumpage volume harvested, or minimize expenditures ..." subject to constraints on desired periodic levels of revenues, expenditures, or volume of stumpage harvested (Navon, 1971). Using Timber RAM as a planning tool, a forest resource manager can test a number of plans consisting of objectives and constraints stated in both economic and physical flow terms; first to see if those combinations of objectives and constraints can be met by a given forest and secondly, to produce a listing of economic indicators and physical outputs for ranking of alternative plans. As such, Timber RAM goes further than SMOAKS in that it automatically calculates cutting schedules which optimize a constrained objective set. Hence it is a sophisticated and powerful planning tool. But, it presupposes an understanding of the

forest ecosystem being managed as well as defined sets of constrained objective sets. Thus, though it can aid analysis of strategic goals and generates tactical project sequences, it does not provide information necessary for understanding natural systems being managed. As such, it is really a tactical planning and evaluation tool and not a management system capable of strategic planning and heuristic behavior. The same appears true of ECHO.

An Economic Harvest Optimization Model (ECHO), like Timber RAM, is a sophisticated set of computer programs designed to calculate cutting schedules to optimize present economic value of timber management plans (Walker, 1974). Though they produce extremely different answers based on divergent assumptions and algorithms, there is a similarity in terms of their use in a total management system. Again, ECHO requires some prior understanding of the forest ecosystem being managed, a complete survey of this forest and some direction as to a set of appropriate objectives. Thus, it too can be a powerful planning tool, combining and analyzing many factors involved with both physical and economic growth of timber. But, like Timber RAM, it is not a management system capable of gathering and processing information needed for developing an understanding of a forest ecosystem, improving that understanding through time, or analyzing management situations based on that understanding in order to identify appropriate strategic goals. In short, these models are complex optimization models capable of greatly facilitating tactical planning, but are of marginal use in setting strategic goals or as total management systems.

The nature of a control systems approach should be clear by now. It is not a tool for management in the same sense as Timber RAM, ECHO, capital budgeting, or ecosystem analysis. Rather, it is a structure for organizing such tools and a process for operating them. Its purpose is to maintain stability of forest ecosystems while: (1) producing a desired mix of goods and services; or (2) shifting from one mix to another. It relies on gathering data, making predictions, designing and implementing programs, and monitoring results to improve understanding, predictions, and plans. It provides for heuristic behavior in a systems context and thus provides potential for understanding present problems and anticipating potential problems. When implemented, it forces forest resource managers to examine management objectives, formulate achievable goals based on those objectives, and forge programs to achieve those goals. As such, it allows managers to integrate the vast variety of tools, techniques, and concepts available to solve problems and design new tools when they are needed. Finally, it provides a means for examining a variety of value sets in setting goals and decision-making in a multiple-use framework.

CHAPTER 4

SUMMARY AND CONCLUSION

A forest can be viewed as "... an assemblage of populations of plants, animals, bacteria, and fungi that live in an environment and interact with one another, forming together a distinctive living system with its own composition, structure, environmental relations, development, and functions" (Wittaker, 1970). As a system or community, a forest could be expected to exhibit the same properties as other natural communities; i.e. "... in the absence of outside disturbance most communities either remain in a steady state for long periods or pass through an orderly progression of successional stages culminating in a steady state" (Pielou, 1969). By studying forest ecosystems, their internal relationships (subsystem interactions), and their development, foresters developed practices to manipulate production and harvest desired products. This was first accomplished by practices which mimicked nature to remove production which would have been lost through natural mortality; e.g. thinning out trees which would die through competition or harvesting mature trees which would have died of natural causes. A second class of practices are based on altering relationships within a forest ecosystem to relax factors limiting production of desired products; e.g. removing "weed" species to ease competition pressures; fertilization; protecting forests from natural harmful agents; and maintaining a forest in a successional stage which is perceived as more productive in terms of desired

products. Intensification of managerial practices, particularly the second kind of practice, can and does effect stability and future productivity of forest ecosystems. Maintenance of stability or desired productivity is, at least, an implicit goal of management. If it were not, then any actions taken comprise nothing more than destructive exploitation and cannot be considered as management.[1] Thus, one function of management is to attempt an understanding of ecosystems being managed in order to maintain stability while producing desired goods and services.

A question at this point for management is which possible set of goods and services is desired for production. This question is particularly bothersome in public sector management. Such management often is performed under vague sets of multiple-use objectives. Conventional wisdom dictates valuing all goods and services in economic terms and choosing the mix which maximizes an economic objective (O'Connel and Boster, 1974). Some products indicated as desirable within multiple-use objectives, though, do not have widely accepted mechanisms for such valuation. This means managers of public forest resources often face a variety of value sets regarding possible goods and services. In order, then, to make a decision as to which set of goods and services should be produced, forest resource managers must provide for consideration of a number of value systems, some of which may be shifting rapidly (Hendee, Clark, and Stankey, 1974).

Management of Ohio State Forests must deal with these issues as well as design, analyze, select, and implement programs to produce

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[1]For a discussion of this point, see Pinchot's discussion of conservative lumbering and destructive lumbering (Pinchot, 1905).

desired goods and services. As discussed in Chapter 1, management systems for Ohio State Forests cannot deal effectively with this complexity if they are based soley upon presently available forest management tools, techniques, and concepts. This is true for a number of reasons.

First, present conceptual forest management is comprised of a loosely connected set of tools and concepts.. Each was developed for a specific problem and often is presented as though it is totally unrelated to other management concepts. The number and complexity of these concepts has increased, especially since World War II. This combination of factors presents a confused set of concepts for a manager with little available to aid him in sorting out these concepts and applying them in a coordinated manner.

Second, because of their specific problem orientation, most forest management concepts are aimed at tactical problem solving. Few, if any, are available for dealing with strategic questions, such as choosing a desired product mix for management of public forests. In multiple-use contexts this can lead to either an unacceptable direction for management based on dominant-use or, perhaps even worse, no long term direction for management at all (Hall, 1963).

Third, because current concepts are single-use oriented, they are almost totally unemcumbered by multiple-use considerations. A consequence of this is that such concepts are narrow in scope and tend to ignore the system or community context of forest ecosystems. Thus they hinder or prohibit the understanding of forest ecosystems necessary for maintaining stability or future productivity.

A control systems approach was developed in this study to remedy these weaknesses and provide a model for designing management systems for Ohio State Forests. After a review of three alternatives, a cybernetic management model was selected as a guide for structuring management. When the basic components of such a model were linked with functional descriptions presented by Bentley (1974), a structure suitable for organizing forest resource management was developed. This structure identified functions of management and linked these functions in an operable manner. Resulting from this combination was a structure for: (1) organizing present managerial tools, techniques, and concepts; and (2) coordinating their operation.

While developing this structure, similarities between it and an engineering control system were noted. (This was not surprising when one considers that they were both developed from the same set of concepts.) The significant outcome of this similarity is the discovery of a process for guiding operation of a cybernetic management system. An engineering control system is designed to maintain stability of a managed system at one of a number of equilibrium states or through maneuvers from one equilibrium state to another. This ability is partially based on analysis of the managed system including identification of subsystems, their interactions, and the interactions between this system and its environment. Also, it is based on use of feedback in iterative operations to constantly monitor and correct operation of the managed system. Adding these process concepts to a cybernetic structure for forest resource management had a significant impact.

Framing management of forest resources in terms of a control system directs management toward consideration of the forest as a

system and the task of management as maintaining stability while producing desired goods and services. As such, it forces management to design and implement programs based on an understanding of the forest as a community of interacting organisms or subsystems. Further, this orientation, when combined with use of feedback, provides a framework for learning about manipulated systems and identifies an expanded role for information processing. In this way, the understanding of ecosystems so necessary for successful management is provided.

Through a combination of process and structure, management systems based on a control systems approach have capabilities for dealing with strategic problems and coordinating strategic and tactical levels of management. One of the most difficult problems facing management is the selection of strategic goals appropriate to management processes and multiple-use objectives. As outlined in Chapter 3, the systems orientation of the information system of this approach provides a means for solving this problem. By providing predictions of component outputs of various forest configurations, such a system presents goals based on the best technical knowledge available in a form amenable to a number of kinds of analysis. Alternative value systems can be applied to rank alternative forest configurations; and data is presented so that goals can be ranked using techniques such as benefit-cost analysis or goal programing.[1] In this way, reliance on single-dimensional analysis of goals is eliminated; allowing for broader and more realistic decision-making.

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[1]For a discussion of goal-programing in forest resource management see Edgar (1974).

As presented in Chapter 3, this approach to management can also facilitate tactical planning. Here, it was discovered, that a control systems approach would guide search for information and planning tools appropriate to each problem. If sufficient information or adequate planning tools were not available, such an approach would guide gathering and processing of needed data and design of new tools rather than trying to force solutions using tools or information presently available. The heuristic and adaptive behavior of this approach was also illustrated in this section through discussions of how information and techniques generated at tactical levels could be incorporated into management to alter planning process and information at strategic levels.

Finally this approach to management of forest resources was compared to other model-based approaches. Here again it was discovered that even sophisticated, computer based tools such as Timber RAM and ECHO were designed as specific problem solving tools. As such, they do not provide a model for designing management systems, but rather are powerful tools to be applied by management systems. This indicates the true nature of a control systems approach. It is not a tool for management, but rather a guide for design of management systems. It can not solve problems in the same way as tools like Timber RAM, but it provides a structure for organizing the many sophisticated problem solving concepts presently available to forest resource managers. It provides a process with a systems orientation that focuses on maintaining stability through heuristic and adaptive behavior based on systems analysis, problem perception, and feedback. It is a holistic approach capable of directing operation at both

strategic and tactical levels. And, if it is implemented, it forces managers to specify, quantify, and justify their operations, problem solving processes, and decisions in terms of the forest ecosystem being managed and organizational objectives under which such management is taking place.

As developed up to this point, models in SOSAF used to illustrate this approach only begin to provide the type of information and level of detail and precision necessary for full development of an effective management system. Far more research and more accurate data are required to improve SOSAF in terms of its overall database, models used, and its level of precision before it can be varified and accepted as accurate in a scientific sense. Further, additional information and models are needed to provide a requisite understanding of entire management situations facing the Ohio Division of Forests and Preserves. Nonetheless, the immediate management context of Ohio State Forests is such that the data provided in this study and projections this crude set of models makes is of value in aiding understanding and long range planning of these forests.

Next stages in use and development of this approach should be centered around its implementation in context of managing Ohio State Forests. Attempts to implement this approach will have a number of consequences. First, in terms of SOSAF, it will stimulate gathering field data needed for operation of its predictive models; e.g. site-indexes, overstory age, species composition, basal area, and percent stocking. Actual use of SOSAF in planning will open its models to review, critique, and refinement by experts in timber and wildlife management. And feedback inherent in a control systems approach will

provide data for testing the accuracy of SOSAF predictions. These efforts will lead to further research and refinement of models used in SOSAF, eventually resulting in verification of them in a scientific sense. Implementation of a control systems approach will necessitate initiation of other research as well.

Beyond attempts to improve and verify predictive models used in SOSAF, three other areas of research will be needed to complete a managerial information system required by this approach. First, as discussed in Chapter 3, there is research needed to provide information and predictive models for solution of tactical level problems such as designing even-age and all-age timber management plans or developing areas for wildlife or recreation. Second, concerns for maintaining stability and productivity of managed forest ecosystems in context of multiple-use demands dictates a need for research into interactions between ecosystem components to increase understanding and level of analysis of these ecosystems. And finally, to provide data for evaluating alternative strategic goals and programs, research is needed to identify how management of a State Forest can and does effect socio-economic systems through employment of men and materials and production of goods and services.

Concurrent with research to provide an accurate and comprehensive information system, there is a need to investigate, document, and recommend changes in this approach as it is implemented. Questions concerning the kind of training forest resource managers will need to implement this approach, organizational structures and decision paths needed, and procedures for actual implementation must be addressed and answered. Theoretical flows of information and channels of

communication must be tested in practice. And finally, operation of such a management system through time must be documented to see if it really is capable of the adaptive and heuristic behavior that seems so necessary for successful management of forest ecosystems.

In conclusion, then, this study proposes an approach to forest resource management which appears capable of dealing with both strategic and tactical level problems in context of complex ecological and socio-economic systems. It illustrates this approach using a set of preliminary models for management of Blue Rock State Forest. And finally, it provides a theoretical basis for application and verification of a heuristic systems approach and systems models in management of forest ecosystems.

APPENDIX

SOSAF - Simulation of Ohio State Forests 110

LABDAT - Land-use, Age, and Basal Area Data Program 118

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C     THIS PROGRAM PREDICTS THE VOLUME OF TIMBER, HEAD OF DEER
C     AND SQUIRREL AND GROUSE POPULATIONS FOR ALTERNATIVE ECOSYSTEM
C     STATES. BASE DATA FOR THE FOREST AREA CORRESPONDS WITH THAT
C     COLLECTED BY THE OHIO STATE DIVISION OF FORESTS AND PRESERVES
C     FOR BLUE ROCK STATE FOREST. THIS PROGRAM WAS WRITTEN AS PART
C     OF UNSPONSORED RESEARCH IN THE DEPARTMENT-DIVISION OF FORESTRY
C     AT OHIO STATE UNIVERSITY AS BOTH A RESEARCH AND TEACHING TOOL
C     BY TOM MITCHELL WITH PROGRAMMING ASSISTANCE FROM NICK MARTIN.
      INTEGER UNITN
      CALL INPUT
      CALL CHECK
    1 WRITE(6,9)
    9 FORMAT(' ENTER DATABASE FILE NUMBER OR ZERO TO STOP')
      READ(5,*)UNITN
      IF(UNITN.EQ.0)STOP
      CALL INPUTL(UNITN)
      CALL CHECKL
      CALL TIMBER(OTIMV,PTIMV)
      CALL DEER(DERNUM)
      CALL DIVERS(DIVIN)
      CALL GROUSE(GROSN,DIVIN)
      CALL SQUIR(SQRLN,DIVIN)
      CALL CREATE(RECLAN)
      WRITE(6,3)OTIMV
    3 FORMAT(5X,' OAK HARVEST VOLUME=',1X,F10.2,' CUBIC FEET')
      WRITE(6,4)PTIMV
    4 FORMAT(5X,' PINE HARVEST VOLUME=',1X,F10.2,' CUBIC FEET')
      WRITE(6,5)DERNUM
    5 FORMAT(5X,' DEER POPULATION=',1X,F8.0,' HEAD')
      WRITE(6,6)SQRLN
    6 FORMAT(5X,' SQUIRREL POPULATION=',1X,F8.0)
      WRITE(6,7)GROSN
    7 FORMAT(5X,' GROUSE POPULATION=',1X,F8.0)
      WRITE(6,8)RECLAN
    8 FORMAT(5X,' LANDS AVAILABLE FOR RECREATION= ',F10.1,' ACRES')
      GO TO 1
      END
      SUBROUTINE INPUT
C     IMPLICIT INTEGER*2(A,Z)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10)
     1,TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
C  FORMAT FOR UNIT 7 (DATASET TGF)
C    7 FORMAT(2F4.1,2I2,I4)
C  FORMAT FOR UNIT 8 (DATASET MSOILT)
    8 FORMAT(10I2)
      DO 10 I=1,100
   10 READ(7,7)((TREHT(I,J),J=1,2),(IBAG(I,J),J=1,2),IFLSTK(I))
    7 FORMAT(2F4.1,2I2,I4)
      WRITE(6,2501)TREHT(50,1),TREHT(50,2)
 2501 FORMAT(1X,2F4.1)
      DO 20 I=1,26
   20 READ(8,8)(MSOILT(I,J),J=1,10)
      RETURN
      END
      SUBROUTINE INPUTL(UNITN)
      INTEGER UNITN
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10)
     1,TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
C FORMAT FOR UNIT(UNITN) WHICH MAY BE 1,2,3,4 OR>= 9
C
      DO 10 I=1,26
```

```
    1 FORMAT(10(I1,2I3))
   10 READ(UNITN,1)((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10)
      RETURN
      END
      SUBROUTINE CHECK
C     IMPLICIT INTEGER*2(A,Z)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10)
     1,TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
C
C  ERROR MESSAGE FO4 MSOILT
C
    1 FORMAT(' VALUE OF MSOILT(',I2,' ,',I2,' ) IS',1X,I6)
C
C  ERROR MESSAGE FOR TREHT
C
    2 FORMAT(' VALUE OF TREHT(',I2,' ,',I2,' ) IS ',I6)
C ERROR MESSAGE FOR IBAG
C
    3 FORMAT(' VALUE OF IBAG(',I3,' ,',I3,' ) IS ',I6)
C
C  ERROR MESSAGE FOR IFLSTK
C
    4 FORMAT(' VALUE OF IFLSTK(',I3,' ,',I3,' ) IS ',I6)
      DO 10 I=1,26
      DO 10 J=1,10
C
C  VALID RANGE FOR MSOILT IS 1 TO 11
C
   10 IF((MSOILT(I,J).LT.0).OR.(MSOILT(I,J).GT.11)) WRITE(6,1)I,J,
     1MSOILT(I,J)
C
C VALID RANGE FOR TREHT IS 0 150
C
      DO 20 I=1,100
      DO 20 J=1,2
   20 IF((TREHT(I,J).LT.0).OR.(TREHT(I,J).GT.150)) WRITE(6,2)I,J,
     *TREHT(I,J)
C
C VALID RANGE FOR IBAG IS 0 TO 50
C
      DO 30 I=1,100
      DO 30 J=1,2
   30 IF((IBAG(I,J).LT.0).OR.(IBAG(I,J).GT.50)) WRITE(6,3)I,J,
     *IBAG(I,J)
C
C  VALID RANGE FOR IFLSTK IS 0 TO 200
C
      DO 40 I=1,100
   40 IF((IFLSTK(I).LT.0).OR.(IFLSTK(I).GT.200)) WRITE(6,4)I,J,
     *IFLSTK(I)
      RETURN
      END
      SUBROUTINE CHECKL
C     IMPLICIT INTEGER*2(A,Z)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10)
     1,TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
C
C  ALL VLAUES FOR EACH CELL WILL BE CHECKED TOGETHER
C
C  ERROR MESSAGE FOR LUC, AGE, IBAR
C
```

```
    1 FORMAT(' LUC(',I2,' ,',I2,' ) = ',I8)
    2 FORMAT(' IAGE(',I2,' ,',I2,' ) = ',I8)
    3 FORMAT(' IBAR(',I2,' ,',I2,' ) = ',I8)
C
      DO 10 I=1,26
      DO 10 J=1,10
C
C  VALID RANGE FOR LUC IS 1 TO 26
C
      IF((LUC(I,J).LT.1).OR.(LUC(I,J).GT.6)) WRITE(6,1)I,J,LUC(I,J)
C
C  VALID RANGE FOR AGE IS 0 TO 200
C
      IF((IAGE(I,J).LT.0).OR.(IAGE(I,J).GT.200)) WRITE(6,1)I,J,
     *IAGE(I,J)
C
C  VALID RANGE FOR IBAR IS 0 TO 200
C
      IF((IBAR(I,J).LT.0).OR.(IBAR(I,J).GT.200)) WRITE(6,3)I,J,IBAR(I,J)
   10 CONTINUE
      RETURN
      END
      SUBROUTINE TIMBER(OTIMV,PTIMV)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
     1TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
C
C  INITIALIZE VARIABLES
C
      OVOLRC=0.0
      OVOLC=0.0
      PVOLRC=0.0
      PVOLC=0.0
C
      DO 100 I=1,26
      DO 99 J=1,10
C
C  CHECK FOR FOREST OWNERSHIP
C
      IF(LUC(I,J).LT.3) GO TO 99
C
C  SEPARATE PINE AND OAK
C
      IF((LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.5)) GO TO 15
      GO TO 25
C
C  CALCULATE VOLUME GROWTH FOR OAK LT. 20
C
   15 KSPEC=2
      KSOIL=MSOILT(I,J)
      STINDX=SITE(KSOIL,KSPEC)
      KAGE=IAGE(I,J)
      IF(KAGE.GT.100) KAGE=100
      BAR=IBAR(I,J)
      VOLOLD=SCALE*(.3879*(BAR*(TREHT(KAGE,KSPEC)*(STINDX/50.))))
C
C  GROW 1 YEAR
C
      KAGE=KAGE+1
      IF(KAGE.GT.100) KAGE=100
      BAG=IBAG(KAGE,KSPEC)
      BARN=IBAR(I,J)
      GBAR=BARN+(BAG*(STINDX/50))
```

```
C
C  CALCULATE NEW VOLUME
C
      VOLNEW=SCALE*(.3879*(GBAR*(TREHT(KAGE,KSPEC)*(STINDX/50.))))
C
C  CALCULATE VOLUME GROWTH
C
      VOLGRO=VOLNEW-VOLOLD
C
C  CHECK FOR RESERVES AND BRANCH FOR TOTALS
C
      IF(LUC(I,J).EQ.3) GO TO 50
      GO TO 51
C
C  CALCULATE VOLUME GROWTH FOR PINE
C
   25 KSOIL=MSOILT(I,J)
      KSPEC=1
      STINDX=SITE(KSOIL,KSPEC)
      KAGE=IAGE(I,J)
      BAR=IBAR(I,J)
      IF(KAGE.GT.100) KAGE=100
      VOLD=SCALE*.42*(.4085*(BAR*(TREHT(KAGE,KSPEC)*(STINDX/50.))))
C
C  GROW ONE YEAR
C
      KAGE=KAGE+1
      IF(KAGE.GT.100) KAGE=100
      BAG=IBAG(KAGE,KSPEC)
      BARN=IBAR(I,J)
      GBAR=BARN+(BAG*(STINDX/50.))
C
C  CALCULATE NEW VOLUME
C
      VNEW=SCALE*.42*(.4085*(GBAR*(TREHT(KAGE,KSPEC)*(STINDX/50.))))
C
C  CALCULATE VOLUME GROWTH
      VGROW=VNEW-VOLD
C
C  CHECK FOR RESERVES
C
      IF(LUC(I,J).EQ.4) GO TO 43
      GO TO 43
   40 OVOLRC=OVOLRC+GROAK
      GO TO 99
   50 FLSTOK=IFLSTK(KAGE)
      BAR=IBAR(I,J)
      BFAC=(BAR+FLSTOK)/2.
      OVOLRC=OVOLRC+(VOLGRO*(BFAC/FLSTOK))
      GO TO 99
   41 OVOLC=OVOLC+GROAK
      GO TO 99
   51 OVOLC=OVOLC+VOLGRO
      GO TO 99
   42 PVOLRC=PVOLRC+VGROW
      GO TO 99
   43 PVOLC=PVOLC+VGROW
   99 CONTINUE
  100 CONTINUE
      OTIMV=OVOLC+(OVOLRC)
      PTIMV=PVOLC+(PVOLRC)
      RETURN
```

```
      END
      SUBROUTINE DEER(DERNUM)
      REAL DERE
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10)
     1,TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
      COMMON /DEAR/OPEFCT,AGEDG,BROWDG,OLDEDG,PINEDG
      DERNUM=0.
      DEARNM=0.
      DO 100 I=1,26
      DO 99 J=1,10
      KSOIL=MSOILT(I,J)
C
C  CHECK LUC FOR OAK AND FOREST OWNERSHIP
C
      IF((LUC(I,J).EQ.2).OR.(LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.5)) GO TO 10
      GO TO 99
C
C  INITIALIZE DEER VALUES FOR EACH CELL
C
   10 IF(IAGE(I,J).LT.5) DERE=0.1
      IF((IAGE(I,J).GE.5).AND.(IAGE(I,J).LE.15)) DERE=.15
      IF((IAGE(I,J).GT.15).AND.(IAGE(I,J).LT.25)) DERE=0.08
      IF((IAGE(I,J).GE.25).AND.(IAGE(I,J).LE.40)) DERE=.2
      IF((IAGE(I,J).GT.40).AND.(IAGE(I,J).LE.50)) DERE=.3
      IF((IAGE(I,J).GT.50).AND.(IAGE(I,J).LE.70)) DERE=.6
      IF(IAGE(I,J).GT.70) DERE=.15
C
C  CALCULATE STAND DENSITY
C
      KAGE=IAGE(I,J)
      IF(KAGE.GT.100) KAGE=100
      BAR=IBAR(I,J)
      FLSTK=IFLSTK(KAGE)
      OPFAC=BAR/FLSTK
      IF((OPFAC.GE..6).AND.(OPFAC.LE..8)) GO TO 11
      OPEFT=1.0
      GO TO 12
   11 OPEFT=OPEFCT
   12 KSPEC=2
      DER=(DERE*OPEFT)*(SITE(KSOIL,KSPEC)/50.)
C
C  CALCULATE DIVERSITY EFFECTS
C
      ILUC=LUC(I,J)
      DERFAC=0.
      I1=I-1
      I2=I+1
      J1=J-1
      J2=J+1
      IF(I.EQ.1) I1=1
      IF(I.EQ.26) I2=26
      IF(J.EQ.1) J1=1
      IF(J.EQ.10) J2=10
      DO 50 M=I1,I2
      DO 49 N=J1,J2
      IF(LUC(M,N).EQ.1) GO TO 49
C  CHECK FOR PINE STANDS
C
C
C  CHECK FOR BASE CELL
C
      IF((ILUC.EQ.LUC(M,N)).AND.(KAGE.EQ.IAGE(M,N))) GO TO 49
```

```
      IF((LUC(M,N).EQ.4).OR.(LUC(M,N).EQ.6)) GO TO 22
C
C  CHECK FOR RESERVED AREAS
C
      IF(LUC(M,N).EQ.2) GO TO 17
C
C  CHECK FOR OPENINGS
C
      AGE1=IAGE(M,N)
      IF(AGE1.LE.10) GO TO 15
C
C  CHECK FOR AGE DIFFERENCES
C
      AGEDIF=KAGE-AGE1
      IF(AGEDIF.GE.20) GO TO 14
      GO TO 49
   14 DERFAC=DERFAC+.1
      GO TO 49
   15 DERFAC=DERFAC+.9
      GO TO 49
   17 DERFAC=DERFAC+.3
      GO TO 49
   22 PAGE=IAGE(M,N)
      IF(PAGE.GT.10) GO TO 25
      GO TO 15
   25 DERFAC=DERFAC+.9
   49 CONTINUE
   50 CONTINUE
      DEARNM=DEARNM+(DER*(1.+DERFAC))
C     NDEER=DER+.2
C     DERNUM=DERNUM+NDEER
   99 CONTINUE
  100 CONTINUE
      NDEER=DEARNM+.2
      DERNUM=NDEER
      RETURN
      END
      SUBROUTINE SQUIR(SQURLN,DIVIN)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
     1TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
      COMMON /SQRCOM/OGSQRL,BROQRL,DSQRL,OSQRL
      SQRNUM=0.
      DO 100 I=1,26
      DO 99 J=1,10
C
C  CHECK FOR OLD GROWTH
C
      IF(LUC(I,J).EQ.2) GO TO 20
C
C  CHECK FOR HARDWOODS
C
      IF((LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.5)) GO TO 40
      GO TO 99
   20 NSQRL=OGSQRL
      GO TO 60
   40 IF(IAGE(I,J).LE.10) NSQRL=BROQRL
      IF((IAGE(I,J).GT.10).AND.(IAGE(I,J).LT.30)) NSQRL=DSQRL
      IF(IAGE(I,J).GE.30) NSQRL=OSQRL
   60 SQRNUM=SQRNUM+NSQRL
   99 CONTINUE
  100 CONTINUE
      SQRPOP=SQRNUM*DIVIN
```

```
      ISOPOP=SORPOP+.2
      SOURLN=ISOPOP
      RETURN
      END
      SUBROUTINE GROUSE(GROSN,DIVIN)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
     1TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
      COMMON /GROCOM/OLGRS,BROGRS,DGRS,OGRS
      GRSNUM=0.
      DO 100 I=1,26
      DO 99 J=1,10
C
C  CHECK FOR OLD GROWTH
C
      IF(LUC(I,J).EQ.2) GO TO 20
C
C  CHECK FOR HARDWOODS
C
      IF((LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.5)) GO TO 40
      GO TO 99
   20 NGRS=OLGRS
      GO TO 60
   40 IF(IAGE(I,J).LE.10) NGRS=BROGRS
      IF((IAGE(I,J).GT.10).AND.(IAGE(I,J).LT.30)) NGRS=DGRS
      IF(IAGE(I,J).GE.30) NGRS=OGRS
   60 GRSNUM=GRSNUM+NGRS
   99 CONTINUE
  100 CONTINUE
      GROSP=GRSNUM*DIVIN
      NGROSP=GROSP+.2
      GROSN=NGROSP
      RETURN
      END
      SUBROUTINE DIVERS(DIVIN)
      COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
     1TREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
      SINDX=0
      CELNUM=0
      DO 100 I=1,26
      DO 99 J=1,10
C
C  CHECK FOR FOREST OWNERSHIP
C
      IF(LUC(I,J).EQ.1) GO TO 99
C
C  COUNT FOREST OWNED CELLS
C
      CELNUM=CELNUM+1
      I1=I-1
      I2=I+1
      IF(I.EQ.1) I1=1
      IF(I.EQ.26) I2=26
      ADIND1=0
      ADIND2=0
      ADIND3=0
      IF(LUC(I,J).EQ.2) GO TO 35
      IF((LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.5)) GO TO 20
      IF((LUC(I1,J).EQ.3).OR.(LUC(I1,J).EQ.5).OR.(LUC(I1,J).EQ.2)) ADIND
     *1=1
      IF((LUC(I2,J).EQ.3).OR.(LUC(I2,J).EQ.5).OR.(LUC(I2,J).EQ.2)) ADIND
     *2=1
      GO TO 40
```

```
 35 IF(LUC(I,J).EQ.LUC(I1,J)) GO TO 40
    ADIND1=1
    IF(LUC(I,J).EQ.LUC(I2,J)) GO TO 40
    ADIND2=1
    GO TO 40
 20 IF((LUC(I1,J).EQ.2).OR.(LUC(I1,J).EQ.4).OR.(LUC(I1,J).EQ.6)) ADIND
   *1=1
    IF((LUC(I1,J).EQ.2).OR.(LUC(I2,J).EQ.4).OR.(LUC(I2,J).EQ.6)) ADIND
   *2=1
 40 IF(LUC(I1,J).EQ.LUC(I2,J)) GO TO 41
    ADIND3=1
 41 SINDX=SINDX+ADIND1+ADIND2+ADIND3
 99 CONTINUE
100 CONTINUE
    DINDX=SINDX/CELNUM
    DIVIN=1+((DINDX-1)/4)
    RETURN
    END
    SUBROUTINE CREATE(RECLAN)
    COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
   1IREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
    ECLAN=0.
    DO 50 I=1,26
    DO 49 J=1,10
    IF((LUC(I,J).EQ.2).OR.(LUC(I,J).EQ.3).OR.(LUC(I,J).EQ.4)) GO T
   10 10
    GO TO 49
 10 ECLAN=ECLAN+1.
 49 CONTINUE
 50 CONTINUE
    RECLAN=ECLAN*SCALE
    RETURN
    END
    BLOCK DATA
    COMMON /SAFCOM/MSOILT(26,10),IAGE(26,10),LUC(26,10),IBAR(26,10),
   1IREHT(100,2),IBAG(100,2),IFLSTK(100),SITE(10,2),SCALE
    COMMON /DEAR/OPEFCT,AGEDG,BROEDG,OLDEDG,PINEDG
    COMMON /SQRCOM/OGSQRL,BROQRL,DSQRL,OSQRL
    COMMON /GROCOM/OLGRS,BROGRS,DGRS,OGRS
    DATA SCALE/40./,OPEFCT/1.2/,AGEDG/1.1/,BROEDG/1.25/,
   1OLDEDG/1.2/,PINEDG/1.1/,OGSQRL/20.0/,BROQRL/0.0/,DSQRL/3.8/,
   2OSQRL/8.0/,OLGRS/0.0/,BROGRS/4.0/,DGRS/2.0/,OGRS/0.5/
    DATA SITE/90.,88.,84.,75.,70.,83.,75.,70.,68.,52.,
   190.,85.,78.,69.,59.,69.,66.,58.,50.,47./
    END
```

```
C  THIS PROGRAM READS BASE DATA ON LAND-USE,AGE, AND BASAL
C  AREA FROM A DESIGNATED FILE.IT THEN ALLOWS THE OPERATOR
C  TO CONSTRUCT A NEW DATA SET THROUGH ALTERING SPECIFIED
C  CELLS AND READING THIS INTO A NEW FILE. DATA FILES
C  GENERATED BY THIS PROGRAM ARE FOR USE WITH SOSAF
C  (SIMULATION OF OHIO STATE FORESTS). THIS PROGRAM WAS
C  WRITTEN BY TOM MITCHELL AS PART OF UNFUNDED RESEARCH FOR
C  RESEARCH AND TEACHING PURPOSES.
C
C
      DIMENSION LUC(26,10),IAGE(26,10),IFLSTK(100),IBAR(26,10)
      INTEGER BASNUM,NEWON,L,AG,BA,AGEDIF,ADIF,ANS,NO,YES
      DATA YES,NO/'Y   ','N   '/
      DO 75 I=1,100
   75 READ(7,76)IFLSTK(I)
   76 FORMAT(12X,I4)
  700 WRITE(6,1)
      READ(5,*)BASNUM
    1 FORMAT(' WHICH FILE DO YOU WANT TO USE AS BASE DATA?')
      WRITE(6,3)
      READ(5,*)NEWON
    3 FORMAT(' WHICH UNIT DO YOU WANT TO WRITE ON?')
      WRITE(6,5)
      READ(5,*)AGEDIF
    5 FORMAT(' WHAT IS THE TIME HORIZON FOR STRATEGIC PLANNING?')
      DO 10 I=1,26
   10 READ(BASNUM,11)((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10)
   11 FORMAT(10(I1,I3,I3))
      WRITE(6,20)
      READ(5,21)ANS
   20 FORMAT(' DO YOU WANT A BASE MAP PRINT-OUT ?')
   21 FORMAT(A1)
C
C CHECK ANSWER AND BRANCH FOR PRINT-OUT.
C
      IF(ANS.EQ.YES) GO TO 24
      GO TO 280
   24 WRITE(6,1010)(J,J=1,10)
 1010 FORMAT(8X,10(I2,9X))
      DO 25 I=1,26
   25 WRITE(6,26)(I,((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10))
   26 FORMAT(1X,I2,3X,10(I1,I3,I3,4X))
  280 WRITE(6,4000)
 4000 FORMAT(' DO YOU WANT TO BY-PASS AUTOMATIC UP-DATE OF AGE ?')
      READ(5,4001)ANS
 4001 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 1001
      DO 1001 I=1,26
      DO 1000 J=1,10
      IF(LUC(I,J).EQ.1) GO TO 1000
 1025 IAGE(I,J)=IAGE(I,J)+AGEDIF
      NAGE=IAGE(I,J)
      IF(NAGE.GT.100) NAGE=100
      IBAR(I,J)=IFLSTK(NAGE)
 1000 CONTINUE
 1001 CONTINUE
      WRITE(6,1002)
 1002 FORMAT(' DO YOU WANT A PRINTOUT OF THE NEW BASE MAP?')
      READ(5,1003)ANS
 1003 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 1004
```

```
      GO TO 29
 1004 WRITE(6,1020)(J,J=1,10)
 1020 FORMAT(8X,10(I2,9X))
      DO 1005 I=1,26
 1005 WRITE(6,1006)(I,((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10))
 1006 FORMAT(1X,I2,3X,10(I1,I3,I3,4X))
   29 WRITE(6,2000)
 2000 FORMAT(' ARE YOU LOOKING FOR A SPECIFIC AGE CLASS ?')
      READ(5,2001)ANS
 2001 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 2002
      GO TO 290
 2002 WRITE(6,2003)
 2003 FORMAT(' ENTER LAND-USE CODE FOR SEARCH.')
      READ(5,*)NLUC
      WRITE(6,2010)
 2010 FORMAT(' ENTER MINIMUM AGE IN AGE CLASS.')
      READ(5,*)IAGMIN
      WRITE(6,2011)
 2011 FORMAT(' ENTER MAXIMUM AGE IN AGE CLASS.')
      READ(5,*)IAGMAX
      DO 2020 I=1,26
      DO 2019 J=1,10
      IF(LUC(I,J).EQ.NLUC) GO TO 2030
      GO TO 2019
 2030 IF((IAGE(I,J).GE.IAGMIN).AND.(IAGE(I,J).LE.IAGMAX)) GO TO 2040
      GO TO 2019
 2040 WRITE(6,2050)I,J,IAGE(I,J)
 2050 FORMAT(1X,I2,3X,I2,4X,I3)
 2019 CONTINUE
 2020 CONTINUE
      GO TO 29
  290 WRITE(6,30)
      READ(5,32)ANS
   30 FORMAT(' DO YOU WANT TO BE PROMPTED THROUGH A ROW AND COLUMN RANGE
     1 ?')
   32 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 500
  101 WRITE(6,130)
  102 READ(5,*)I,J
  130 FORMAT(' ENTER COORDINATES FOR CHANGE OR ZEROES TO STOP!')
      IF(I.EQ.0) GO TO 800
      IF((I.LT.0).OR.(I.GT.26)) GO TO 132
      IF((J.LT.0).OR.(J.GT.10)) GO TO 132
      GO TO 35
  132 WRITE(6,33)
   33 FORMAT(' THAT IS AN INVALID COORDINATE! REENTER!!')
      GO TO 102
   35 WRITE(6,40)
   36 READ(5,*)L
   40 FORMAT(' ENTER NEW LAND-USE CODE.')
      IF((L.LT.0).OR.(L.GT.6)) GO TO 42
      GO TO 48
   42 WRITE(6,43)
   43 FORMAT(' THAT IS AN INVALID ENTRY! REENTER!!')
      GO TO 36
   48 LUC(I,J)=L
   50 WRITE(6,53)
   51 READ(5,*)AG
   53 FORMAT(' ENTER NEW AGE.')
      IF((AG.LT.0).OR.(AG.GT.500)) GO TO 57
      IF((AG.LT.0).OR.(AG.GT.AGEDIF)) GO TO 57
```

```
      GO TO 60
   57 WRITE(6,58)
   58 FORMAT(' THAT IS AN INVALID AGE! REENTER!!')
      GO TO 51
   60 IAGE(I,J)=AG
      WRITE(6,63)AG,IFLSTK(AG)
   63 FORMAT(' BASAL AREA FOR A STAND',I3,' YEARS OLD IS',
     1I3)
   61 WRITE(6,64)
   62 READ(5,*)BA
   64 FORMAT(' ENTER NEW BASAL AREA.')
      IF((BA.LT.0).OR.(BA.GT.200)) GO TO 67
      GO TO 69
   67 WRITE(6,68)
   68 FORMAT(' THAT IS AN INVALID BASAL AREA! REENTER!!')
      GO TO 62
   69 IBAR(I,J)=BA
      GO TO 101
  500 WRITE(6,501)
  501 FORMAT(' ENTER ROW RANGE FOR CHANGES OR ZEROES TO STOP.')
  502 READ(5,*)I1,I2
      IF(I1.EQ.0) GO TO 800
      IF((I1.LT.0).OR.(I1.GT.26).OR.(I1.GT.I2)) GO TO 508
      IF((I2.LT.0).OR.(I2.GT.26)) GO TO 508
      GO TO 510
  508 WRITE(6,509)
  509 FORMAT(' THAT IS AN INVALID RANGE. REENTER!!')
      GO TO 502
  510 WRITE(6,511)
  511 FORMAT(' ENTER COLUMN RANGE FOR CHANGES.')
  512 READ(5,*)J1,J2
      IF((J1.LE.0).OR.(J1.GT.10)) GO TO 515
      IF((J2.LE.0).OR.(J2.GT.10)) GO TO 515
      GO TO 517
  515 WRITE(6,516)
  516 FORMAT(' THAT IS AN INVALID RANGE! REENTER!!')
      GO TO 512
  517 DO 600 I=I1,I2
      DO 599 J=J1,J2
  520 WRITE(6,521)LUC(I,J)
  521 FORMAT(' PRESENT LUC= ',I1)
      WRITE(6,522)
  522 FORMAT(' ENTER NEW LAND USE CODE.')
  523 READ(5,*)L
      IF((L.LT.0).OR.(L.GT.6)) GO TO 525
      GO TO 527
  525 WRITE(6,526)
  526 FORMAT(' THAT IS AN INVALID ENTRY! REENTER!!')
      GO TO 523
  527 LUC(I,J)=L
  530 WRITE(6,531)IAGE(I,J)
  531 FORMAT(' PRESENT AGE IS ',I3)
      WRITE(6,532)
  532 FORMAT(' ENTER NEW AGE.')
  533 READ(5,*)AG
      IF((AG.LT.0).OR.(AG.GT.AGEDIF)) GO TO 535
      GO TO 537
  535 WRITE(6,536)
  536 FORMAT(' THAT IS AN INVALID ENTRY. REENTER!!')
      GO TO 533
  537 ADIF=AG-IAGE(I,J)
      IF(ADIF.GT.AGEDIF) GO TO 535
```

```
      IAGE(I,J)=AG
  540 WRITE(6,541)IBAR(I,J)
  541 FORMAT(' PRESENT BASAL AREA IS ',I3)
      WRITE(6,550)IAGE(I,J),IFLSTK(AG)
  550 FORMAT(' AT ',I3,'YEARS OLD, FULL STOCKING= ',I3)
      WRITE(6,542)
  542 FORMAT(' ENTER NEW BASAL AREA.')
  543 READ(5,*)BA
      IF((BA.GE.0).AND.(BA.LE.200)) GO TO 547
      WRITE(6,545)
  545 FORMAT(' THAT IS AN INVALID ENTRY! TRY AGAIN!')
      GO TO 543
  547 IBAR(I,J)=BA
  599 CONTINUE
  600 CONTINUE
  601 GO TO 500
  800 DO 810 I=1,26
      WRITE(NEWON,802)((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10)
  802 FORMAT(10(I1,I3,I3))
  809 CONTINUE
  810 CONTINUE
      REWIND BASNUM
      REWIND NEWON
      WRITE(6,3000)
 3000 FORMAT(' DO YOU WANT A PRINT-OUT OF THE ALTERED NEW DATA BASE ?')
      READ(5,3001)ANS
 3001 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 3002
      GO TO 3300
 3002 WRITE(6,3010)(J,J=1,10)
 3010 FORMAT(8X,10(I2,9X))
      DO 5020 I=1,26
 5020 WRITE(6,2021)(I,((LUC(I,J),IAGE(I,J),IBAR(I,J)),J=1,10))
 2021 FORMAT(1X,I2,3X,10(I1,I3,I3,4X))
 3300 WRITE(6,815)
      READ(5,816)ANS
  815 FORMAT(' DO YOU WANT TO SET-UP ANOTHER DATA SET?')
  816 FORMAT(A1)
      IF(ANS.EQ.YES) GO TO 700
      STOP
      END
```

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