Chapter 7

Technologies for National Forest Planning

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The National Forest Management Act of 1976 (NFMA) does not explicitly require the use of any particular technologies in preparing and revising forest plans. However, NFMA establishes various resource quality standards, and specifies various considerations for the planning process. While a variety of techniques are available for organizing and analyzing information to meet these requirements, the Forest Service chose one particular computer model—FORPLAN--as the principal analytical tool for forest planning.

FORPLAN is a complex and expensive computer program. Some have blamed FORPLAN for a costly and time-consuming planning process, and have asserted that FORPLAN has increased the controversy over national forest management. Congress asked OTA to assess Forest Service planning partly to determine if FORPLAN has helped or hindered the process. This chapter briefly examines planning technologies that exist, reviews the development of FORPLAN, and discusses FORPLAN's strengths and weaknesses for supporting the forest planning process.

RELEVANT PLANNING DECISIONS

To assess the planning technologies, it is necessary to understand the decisions to be made in the planning process. As discussed earlier in this report, the purpose of national forest management is to accommodate uses and produce outputs while sustaining ecosystems. (See ch. 3.) Thus, technologies that can allocate (analyze spatially) and/or schedule (analyze temporally) could be useful in decision-making, while technologies that assess the effects of decisions on ecosystems and values could be useful in understanding the consequences of decisions.

Because of the concerns over clearcutting in the early 1970s, NFMA focused on protecting the forest environment during timber harvesting (123). (See ch. 4.) NFMA included two particular provisions that lend themselves well to computer analysis. The first, section 6(k), prohibits most timber harvesting from lands identified as not suited for timber production, "considering physical, economic, and other pertinent factors to the extent feasible, as determined by the Secretary." In essence, this provision requires a land allocation decision, based in part on an economic (temporal) analysis of timber production.

The second provision, section 13(a), generally limits timber sales (the allowable sale quantity, or ASQ) to a level that can be sustained in perpetuity; this requirement is commonly known as nondeclining even flow (NDEF). Assuring that the plans provide this perpetual, sustainable flow is a long-term scheduling problem, based in part on the land allocation decision under section 6(k).[1] The long timeframe for managing timber makes both the allocation and scheduling decisions well suited for analysis using computer technology.

These provisions of NFMA limit timber harvesting based on certain specified criteria. The Multiple-Use Sustained-Yield Act (MUSYA) and NFMA further require that timber harvesting be coordinated with other uses. Decisions coordinated to allocate and schedule the various uses and outputs are one means to minimize conflicts and to accommodate compatible activities. Again, computer models can be useful in analyzing the allocation and scheduling decisions for timber production as well as other uses and outputs.

The various legal requirements of MUSYA and NFMA imply a sequential analysis. Lands suitable for timber production are identified, the ASQ is determined, and finally timber management is coordinated with other uses and outputs. Notably, both sections 6(k) and 13(a) provide exceptions to their limitations on timber harvesting based on multiple-use considerations. Thus, arguably timberland suitability and ASQ are to be determined without limitations based on multiple-use coordination (293). However, Forest Service practices make these three analyses (timberland suitability, ASQ determina-

[1] Some observers have noted that current techniques and the cyclical Forest Service planning process could lead to declines in the ASQ in each subsequent plan for a national forest, contrary to the intent of nondefining even flow in NFMA (163). Such an occurrence can apparently be made insignificant with additional restrictions on the current models (134), and thus this difficulty is not considered in this Assessment. However, further analysis of this possibility by the agency maybe warranted.

tions, and multiple-use coordination) simultaneously. The regulations for implementing section 6(k) specifically include multiple-use benefits for determining the suitability of lands for producing timber. By including multiple-use benefits in determining timberland suitability, multiple-use considerations also have been included in determining the ASQ. Thus, the Forest Service has chosen to combine timberland suitability, ASQ determi nation, and multiple-use coordination in one large, allocation and scheduling problem.

TYPES OF PLANNING TECHNOLOGIES

Two types of computer modeling are useful for analyzing alternative plans. One approach—simulation—imitates the relevant system, and is used to examine how important measures change when the decisions or inputs change. The other--optimization--attempts to maximize or minimize important measures within the system's limits. Optimization models are often preferred for supporting decisionmaking, but may not be relevant if one cannot define all the variables that should be optimized. Furthermore, because optimization models (and the calculations they require) are often much more complex than simulations, they can be very expensive to use.

It is important to note that computer models are not perfect duplicates of the real world. Reality is generally too complex to replicate precisely. Thus, models necessarily simplify the real world. Nonetheless, the results of useful models must approximate the actual results of management actions. Models are tested (verified, in technical parlance) to determine if their results are sufficiently similar to reality to make the model useful. Computer model results, however, are still only estimates of what will happen. This, together with the human responsibility for decisions, is why computer models are used to support decisionmaking, rather than to make decisions.

Computer tools contribute to forest planning in two ways—by assisting in allocation and scheduling decisions and by assisting in estimating the consequences of decisions. Additional techniques can be used to supplement and coordinate the technologies that contribute to allocation and scheduling decisions and that estimate impacts.

Decision Support Technologies

Resource Scheduling Decisions

Resource scheduling decisions determine the levels of uses and outputs that will occur over time. Most scheduling tools used in business are optimization models, determining the 'best' (typically most profitable) timing for activities within the constraints of the systems. Common scheduling models include inventory models for reordering decisions, transportation models for the delivery of goods, and models for determining the optimum mix of outputs from a common input. These latter two models both use linear programming, a tool that achieves an objective function within the constraints of the system. For example, linear programming is used in determining the output mix in the refining of crude oil: the output of the model (the solution) identifies the most profitable mix of gasoline, kerosene, fuel oil, and other petroleum products, within the constraints of current prices for each product; the relationship among the products (producing more of one product reduces the amount of other products that can be produced); the costs to produce each product (which increase as the quantity produced from a barrel of crude oil increases); and the capacity of the refinery.

Natural resource scheduling is, in many ways, comparable to the oil refinery decisions. Forest lands have the ability to produce a variety of uses and outputs, with varying prices and values. The uses and outputs are related, sometimes complimentarily but also in ways that are competing or incompatible. The financial and environmental unit costs vary, in part, with the level of each use and output produced. And production is limited to levels that can be sustained in perpetuity. As described below, the Forest Service chose a linear programming approach —FORPLAN--for assisting in resource scheduling and other forest planning decisions. The requirement to assure sustainable timber production over long periods and the complex interrelationships among the various resources make linear programming quite useful in attempting to maximize resource uses and outputs within long-run, ecological limits.

Linear programming, however, has inherent limitations in supporting resource scheduling decisions. First, linear programming requires massive amounts of data to define the interrelationships among resources and the changes that result from management activities. Linear programming also is *deterministic—risk* and uncertainty cannot be included in the model, even though they are common in natural systems (65, 234). Finally, linear programming is *linear—all* relationships must be direct, continuous, and symmetrical (reversible).[2] Linearity is a problem because: 1) inputs on one site can affect the outputs and management costs of other sites—there are indirect effects of management (14, 146); 2) some inputs, such as facilities, cannot be adjusted in small increments--they are not continuous functions (14, 179); and 3) ecosystems may have thresholds-irreversible changes can result from management activities (65, 118).

Land and Resource Allocation Decisions

Land and resource allocation decisions determine how uses and outputs are combined (or separated) over space. Thus, technologies for supporting allocation decisions must be able to evaluate spatial relationships among resources. Linear programming has some capacity to account for spatial relationships (122), and including spatial details substantially increases the size, cost, and complexity of the model (1 18).

The Forest Service has traditionally examined and presented spatial relationships with maps, which are a part of every forest plan. However, the maps have generally been produced by hand, with an enormous investment of time and energy. Overlays can be used to combine different types of spatial information, but the process of creating and using overlays is cumbersome and expensive. Thus, despite its importance, spatial analysis for land and resource allocation decisions in forest planning has been limited by the shortcomings of FORPLAN and current mapping practices.

Geographic information systems (GIS) are basically computerized mapping systems that can store, manage, and analyze spatial information. GIS are not optimization systems, but are very useful for examining spatial questions. After the user defines the relevant spatial information to be combined, GIS can display locations of specified conditions (e.g., mature timber on moderate slopes) or of situations sensitive to certain management activities (e.g., highly erodible soils or critical habitat for an endangered species). The Forest Service has been testing a variety of GIS, and expects to have GIS available at each national forest eventually.

GIS also has limitations for use in forest planning. First, the systems require sizable investments in computers, plotters, and software. The General Accounting Office (255) recently concluded that the Forest Service has not adequately analyzed the alternatives to the estimated $ 1.2-billion investment, and to date, Congress has not funded GIS acquisition by the Forest Service. In addition, GIS require spatial information, and putting such information into the systems is generally an expensive and time-consuming manual process. However, the cost of putting spatial information into a GIS may not much exceed that of manual mapping currently used in forest planning.

Impact Assessment Technologies

Ecological and Environmental Impacts

Examining the likely ecological and environmental impacts of management decisions is an important part of forest planning. Resource simulation models are the principal technologies used for this purpose. Resource simulations quantify the relationships within natural systems, and attempt to estimate the likely results of management actions. Many simulations have been developed for single resources; the most common are timber growth-and-yield models, although the Forest Service has also developed sediment yield and wildlife habitat models. A few have attempted to simulate changes in forest and ecosystem structure over time (with and without various management activities), but these more comprehensive models are usually more expensive to build, test, and use or more simplified, and thus less precise in their predictive ability.

The Forest Service is considered to be a leader in developing resource simulation models (146). However, in contrast to scheduling and allocation models, which address common decisions, the diversity of resources and resource relationships typically leads to unique simulation models that address locally or regionally specific issues and problems. The diversity of national forest lands and resources has prevented the development of universal models. The existing models are often used in modifying the general FORPLAN model to address local issues,

[2] Linear programming does not actually require freed linear relationships. Curvilinear and other relationships can be approximated with multiple equations, if the relationships are direct, continuous, and symmetrical.

but this has not always been done well (234), and some important data and relationships are poorly known (72, 278).

Economic Impacts

Predicting the economic consequences of management decisions is another important part of forest planning. The economics of management is typically examined by comparing the benefits and costs of the proposed activities. Distinct models for such analyses exist, but in forest planning it is done with FORPLAN. FORPLAN's objective function (the goal) is to maximize present net value (PNV)---the value of uses and outputs minus the costs, with future values and costs discounted to the present. (See ch. 8 for a fuller discussion of strengths and weaknesses of economic analysis in forest planning.)

The traditional tool used for assessing local economic impacts is input-output analysis. An input-output model describes an economy in terms of its quantitative financial interactions among manufacturing, service, and other sectors. The Forest Service has developed a standardized input-output model with localized adaptations—IMPLAN—for estimating economic consequences on each national forest. IMPLAN is useful for appraising the total economic impacts of a forest plan, but is insufficient for evaluating impacts on communities (278). (See ch. 8 for a more thorough analysis of IMPLAN and its limitations.)

Supplemental Technologies

Database Management Systems

Computerized databases are often used to store and manipulate inventory information for the national forests. Computerized databases are essentially sophisticated filing systems, with the ability to store, sort, and rearrange massive amounts of data. Information sorting is the only analytical capability of databases, and thus databases are not really analytical tools. However, relational databases can store inventory information with site relationships, and therefore, can provide data for other allocation and scheduling models and for impact assessment tools.

In addition, one computerized database can be linked to other databases. If uniform structures and definitions are used for inventories, individual databases can be aggregated, creating a "corporate database' —i.e., nationwide access to local data on national forest lands and resources. This would certainly assist the agency in the RPA planning process. However, the Washington Office has not yet decided on the nature and structure of such a corporate database. Many forests are delaying the initiation of forest plan revisions until they receive some direction on database structures and definitions (146, 166).

Knowledge-Based Systems

Knowledge-based systems (KBS), also known as expert or rule-based systems, are relatively new in natural resources management. Expert systems can be optimization models, depending on the rules incorporated into the system, but the goal for such systems is to replace traditional computer logic with a more humanlike reasoning process (146). Currently, KBS are usually based on ''if-then' rules, such as "if tree age exceeds the specified rotation age, then the stand can be scheduled for harvest' or ''if a stream of the specified minimum width, depth, and flow lacks spawning gravel, then the stream can be scheduled for fish habitat improvement." However, because of our limited understanding of the rules and limits of natural systems, KBS are used primarily for relatively simple, repetitive decisions.

KBS can also be interactive, such that systems ask the users a series of questions with subsequent questions depending on previous answers. In this capacity, KBS can assist decision support and impact assessment technologies by assuring that appropriate models and information are used. The Forest Service is developing a KBS to assist in assuring that project planning complies with NFMA and NEPA. However, KBS could be expanded to a broader role in coordinating information and analysis in forest planning.

Integrated Systems

Integrated systems combine various technologies with systematic, automated linkages. Computerized databases can be linked with GIS for allocation decisions; with resource simulations for estimating ecological and environmental impacts; and/or with a linear programming model for scheduling decisions. Simulations and GIS can also be linked with linear programmingg. The Forest Service is developing an integrated system—INFORMS---coordinated through the Rocky Mountain Forest and Range Experiment Station in Fort Collins, Colorado. Parts of the system have been used in various locations, but the integrated system has not yet been implemented (146). Another integrated system—TEAMS—has been developed at Northern Arizona University in Flagstaff, Arizona (54). TEAMS is used in teaching, and has been applied successfully on the Coconino National Forest and on other lands (146).

As with all planning technologies, integrated systems have their limitations. First and foremost, the shortcomings of the component technologies must be recognized. Computer models cannot give perfect answers, because the models necessarily simplify reality, and results are less precise than they appear (13, 14). Not only modelers and analysts, but more importantly, managers and the public, must be aware of the limits of the technologies (60). Furthermore, the technologies and linkages must be understandable so that the public (and agency employees not involved in planning) can recognize what is being evaluated, what the decision criteria and other critical standards are, and how the results will be used. However, given these cautions, integrated systems and the technologies that they integrate can be very useful in land and resource management planning for the national forests.

FORPLAN AND FOREST PLANNING

Historically, forestry has focused on sustaining the production of timber and other forest products over long periods of time. The European tradition was to manage forests to achieve a ‘‘fully-regulated condition, ’ with stable annual timber harvests and approximately equal forest areas in various stages from seedlings to “mature’ stands. Forestry education in America followed this tradition (63), but European forest regulation could not be adopted easily for the unmanaged U.S. forests (122). Various methods were developed to regulate harvest rates for old-growth timber, and to convert such stands to more productive conditions. These methods were essentially designed to determine the ***allowable cut—the*** volume of timber that could be harvested annually while forest productivity was maintained.

Relatively simple approaches to determining allowable cuts were used until at least the 1950s (122). However, two changes complicated the determination of allowable cuts. The first was the increasing importance of the national forests for timber and recreation, which led to the enactment of the Multiple-Use Sustained-Yield Act of 1960, as described in ch. 3. The second was the recognition in the early 1960s that timber harvests from private lands, at least in Washington and Oregon, could not be sustained at their historic levels. These concerns and the development of computer models led to more sophisticated approaches for determining the allowable cut from the national forests.

The Development and Selection of FORPLAN

Prior to 1973, the Forest Service had as many as 48 different types of functional plans for the national forests (212). In the initial response to NEPA, the Forest Service chose to develop integrated unit plans for areas within the national forests. RPA echoed this direction by requiring “land and resource management plans for units of the National Forest System,” prepared under an interdisciplinary approach. NFMA then provided substantial direction on what to consider in developing plans.

Two linear programming approaches were developed initially to assist in integrated, multiple-use management planning for the national forests. One approach, the Resource Capability System (RCS), focused on site-specific responses to management alternatives. RCS analysis was generally organized by watersheds, and the model provided timestreams for resource yields, site-specific area control, and a balanced treatment of all resources (i.e., all resource outputs were included in the objective function) (125). However, RCS was not widely accepted because of its emphasis on watershed concerns (122) and because of its inadequacies for timber harvest scheduling and control (125).

The other approach was the development of a long-term timber harvest scheduling model, intended to assure the biological sustainability and multiple-use compatibility of harvest levels over an entire national forest (122). The frost such model was the Timber Resource Allocation Model (Timber RAM), developed in 1971. However, concerns about a timber bias and increasing interest in site-specific environmental effects led to the development of a more sophisticated timber harvest scheduling model, the Multiple Use-Sustained Yield Calculator (MUSYC). However, MUSYC was considered to be just a more sophisticated timber harvest scheduling model, rather than an integrated resource management model (122). Finally, FORPLAN was developed in the late 1970s to overcome some of these limitations. FORPLAN followed the basic approach established in Timber RAM and MUSYC, but was modified to incorporate some of the advantages of RCS, such as timestreams for yields, improved area control, and an objective function that included all resource outputs (122).

In 1979, as planning was beginning under the new NFMA regulations, the Forest Service became concerned that confusion in management direction and excessive cost might result from having various, competing computer models to assist forest planning. On December 3, 1979, Associate Chief Douglas Leisz sent a letter to regional foresters and staff directors designating FORPLAN as the primary analysis tool to be used in forest planning (125). FORPLAN was chosen because it addressed two key issues in forest planning: cost efficiency, and an allowable timber sale quantity (the NFMA term for allowable cut) within constraints (123). With FORPLAN, the Forest Service felt it would have a consistent, unified approach to forest planning (122).

FORPLAN has evolved substantially over the past 12 years (125). As a result, there are two distinct versions of FORPLAN, and more than 10 releases (upgrades) of each version (64). Thus, more than 20 different FORPLAN models have been used in forest planning. Furthermore, each national forest structures the FORPLAN inputs to analyze relevant problems for that forest (173). In essence, each national forest has used a unique FORPLAN model in developing its forest plan, and will probably use a different FORPLAN model when it revises its forest plan.

What Is FORPLAN?

As noted earlier, FORPLAN is basically a linear programming model. It has three distinct parts. The first organizes the required information into the structure necessary for linear programming; technically, this is called the “matrix generator, ’ because linear programming uses matrix algebra. The second part is the calculator-the linear program itself. The Forest Service uses commercial linear programming software for this. The third part of FORPLAN presents the solution in a variety of formats, to assist in understanding and using the results; this part is called the “report writer, ’ because it produces various displays of the results.

Linear programming is a technique for finding the best possible combination of outputs within specified limits. Thus, linear programming essentially has three components: 1) the objective function (the goal to be maximized or minimized), 2) the constraints (the specified limits), and 3) the production functions (the relationships between the constraints and the objective function).

The Forest Service has directed that economic criteria will be used for the objective function in FORPLAN. This function is intended to include all national forest uses and outputs, using market prices or some other relevant value for unpriced outputs. (See ch. 8 for more information on valuation techniques.) Future values and costs are discounted to the present for comparing alternative investments. (Again, see ch. 8.) The objective is then to maximize the present net value of outputs by emphasizing production of the most “profitable” outputs (those with the largest difference between the price/value and the cost of production). For example, if recreation is valued at $10 per unit and timber is priced at $8 per unit, and if the costs to produce additional units is $6 for each, FORPLAN will emphasize recreation, within the specified constraints. FORPLAN will not necessarily choose only recreation, or even more recreation than timber; the selection depends on how recreation and timber outputs are related to the constraints.

A large number and wide variety of constraints are used in FORPLAN (122). Some constraints are absolutes—total forest area, productive capacity, minimum requirements or production targets, budgets, etc. FORPLAN also includes “flow constraints,’ principally to assure sustained production of timber and other outputs over long periods; as described above, one flow constraint--nondeclining even flow of timber-is specified in NFMA. A third category is relational constraints, which allow the user to specify relationships among management activities and outputs; for example, road construction into a specific area could be required before timber harvesting is allowed there.

Production relationships connect the constraints to the objectives. In FORPLAN, these relationships are generally defined by analysis areas and management prescriptions (specific patterns of related activities). Each prescription in each area includes costs and output yields, to relate possible activities to the objective function, and is aggregated for each of the relevant constraints. The prescriptions applied to analysis areas are called "decision variables," and FORPLAN selects among possible combinations to maximize the objective function while meeting all of the constraints.

FORPLAN's Strengths

FORPLAN has been used because it performs certain tasks very well and because it helps organize planning around certain issues. The strengths of FORPLAN have been described as: its analytical capacity, its focus on important issues, its common language for analysts, and its protection of agency discretion.

Analytical Capacity

One reason the Forest Service accepted linear programming and FORPLAN is that it can be used to consider thousands of possibilities (combinations of prescriptions and analysis areas). Linear programming is used because the number of decision variables to consider is beyond the capacity of the human mind (122). For example, in determining whether to manage an area for timber production, *one* must consider the productivity of the land for timber, the economics of timber management, the continued flow of timber over 100 years or more, and the relationships between timber management and water flows (quality and quantity), recreation use, big game habitat, endangered species protection, and other outputs and ecosystem requirements. In addition, such an analysis must be conducted for *each* area that *might* include timber production as part of the area's management. FORPLAN is a tool that, with the appropriate constraints, can perform such a complicated analytical task.

Focus on Important Issues

Most of the important **values of the national forests are related to trees and the manipulation of tree vegetation—wilderness, ancient forests, timber production, recreation development, visual quality, water flows, and the like (64). Concerns particularly focus on timber management—how much timber to harvest and from which lands.**

> To **foresters ..., the important issues in forest planning relate to active manipulation of the forest, and** such planning should focus on what timber harvest levels can be sustained over time, given the objectives and constraints from all forest uses (123).

FORPLAN focuses on these issues. FORPLAN is structured to examine land allocations to various management prescriptions, many of which include timber production. FORPLAN relates timber management activities to the other uses and values of the national forests. And, FORPLAN results are organized to provide information on land allocations especially with regard to timber production, and on timber and other output levels. Thus, FORPLAN is useful in addressing important national forest management issues.

FORPLAN, or a similar model, is also probably a necessary tool for forest planning. As noted earlier, NFMA limits the allowable timber sale quantity to a level that can be sustained in perpetuity-i. e., nondeclining even flow. A computerized model is undoubtedly necessary to analyze long-term timber harvest schedules, and thus to determine if the nondeclining even flow constraint is met. For several decades now, the simple formulas for determining the allowable cut, generally based on current growth and on harvesting the remaining old-growth timber, have been inadequate, and will probably remain inadequate for assuring sustainable timber production from Federal lands.

Common Language for Analysts

One of the problems in interdisciplinary efforts is that the various disciplines and specialties use different terms and measures for their particular concerns and problems. The direction to use FORPLAN required foresters, hydrologists, biologists, archaeologists, landscape architects, and others to deal with one model to address all the issues and concerns (64, 278). Thus, each of these specialists had to learn how to translate their particular concerns and problems into a common format. The requirement forced the specialists to work together, and to communicate among themselves. The use of a common model compelled interdisciplinary teams to be truly interdisciplinary-to combine their specialties for assessing management alternatives.

Some have suggested that FORPLAN, and quantitative analysis generally, has protected against "professional omnipotence. " In this view, computer models and analyses:

> .,. prevent professional groups within the Forest Service, especially foresters, from imposing their objectives for management of the forest on the rest of society (123).

Others note that the Forest Service may have simply replaced professional wisdom with computer analysis for explaining the decisions (64), and that decisions based on computer analysis may be no more acceptable to the public than those based on professional expertise were in the late 1960s and early 1970s. Nonetheless, FORPLAN has shifted power within the agency from the traditional resource staffs toward the analysts and planners of the interdisciplinary teams (64).

Protection of Agency Discretion

Some observers have asserted that FORPLAN has become a shield to thwart the efforts of interest groups to shift national forest management in various directions. The complexity of the issues analyzed and the multitude of constraints limit the ability of analysts outside the Forest Service to understand the process well enough to know where and how to modify the analysis to get the desired results. According to the model's principal author, K. Norman Johnson, FORPLAN:

> . . . is a formidable roadblock to gaining leverage to push the national forests in any direction other than the one they wish to go. The complexity and subtleties of its options, the comprehensiveness of its view, the incredibly ambitious task given to it by the national forests, and the tremendous variance in its use from forest to forest makes it difficult to understand . . .
>
> Thus FORPLAN is very effective at preserving local agency discretion. It represents a formidable way for the national forests to insulate themselves from their critics (123).

The difficulties in understanding FORPLAN is a weakness of the model, as will be discussed below. Furthermore, some have hypothesized that FORPLAN has shifted criticism and control from local interests to national interests, giving greater power to such centralized critics as the Office of Management and Budget, the National Forest Products Association, and The Wilderness Society (23). Thus, FORPLAN may not provide as much protection for local discretion as some have suggested.

FORPLAN's Weaknesses

As many observers have noted, FORPLAN has numerous weaknesses. Some are inherent in linear programming; as discussed earlier, linear programming cannot include risk and uncertainty, and assumes continuous, direct, and reversible relationships among variables. The FORPLAN model has numerous unique shortcomings, such as massive data requirements, use of economic criteria for the objective function and the importance of constraints, lack of spatial details, and the 'black box' nature of the model. Additional problems exist with the system for supporting and using FORPLAN, such as documentation problems, inadequate verification, the loss of expertise, and the poor understanding of how results can be used in decisionmaking.

The FORPLAN Model

Data Requirements—Linear programming requires massive amounts of data, and in terms of size and complexity, FORPLAN has extended the frontiers of linear programming (14). As noted above, FORPLAN requires analysts to develop costs and output yields in order to relate activities to the objective function, and relevant measures to relate activities to absolute, flow, and relational constraints. For each management prescription (such as clearcutting with site preparation for natural regeneration) and each analysis area (areas with similar resource conditions and responses to the prescriptions), the user must identify the expected schedule, over 100 years or more, for at least: 1) the implementation costs; 2) the quantitative yields for all relevant outputs (timber harvests, water flows, animal populations, recreation uses, etc.); and 3) the relationship to the various constraints (endangered species habitat protection, soil erosion limits, nondeclining even flow of timber, maintaining biological diversity etc.). Thus, FORPLAN clearly requires enormous amounts of information, which undoubtedly exceed the limits of knowledge.

Many critics have noted that data are inadequate to meet FORPLAN's needs. Timber inventories are often out-of-date (64). Yield information for other resources is rare, and ''Assessments [of nontimber resources] are subject to large measurement errors' (72). In its recent internal critique, the Forest Service noted the lack of data on water, old-growth timber, range condition, and threatened and endangered species, and the lack of tools for addressing cultural resources, biological diversity, erosion and sedimentation, cumulative impacts on water quality, visual quality, and wildlife habitat capability (278). The lack of data could lead the various resource specialists to coordinate their needs, but 'the agency still has not developed an effective strategy to develop and manage data systems" (64).

One particular data problem could cause serious legal difficulties for the Forest Service. NFMA requires assurance that clearcutting is used only where it is the optimal cutting system. However, "FORPLAN has an inherent bias for even-age timber management' systems, such as clearcutting (64), and comparable yield data for uneven-age timber management do not exist (278). "Research and practice has largely ignored . . . uneven-aged management systems' (64). This problem has not been widely recognized.

The lack of necessary data typically leads analysts and specialists to extrapolate existing data and to make various judgments and assumptions, as needed (64). "In most cases, modeling coefficients [the internal data] were based on anecdotal or 'best-guess' information rather than scientific quantification" (13). This is not all bad, especially when it leads to cooperative, interdisciplinary discussion and learning (64). However, in at least some cases, the resource specialists have become resource advocates, and subordinated the common good of the planning team to the needs of their disciplines (13). At this point, it is unclear whether FORPLAN has contributed to integrated resource management, as some have suggested (278), or has simply created "the illusion of interdisciplinary integration of all multiple uses' (13).

Objectives and Constraints-As noted earlier, the goal of the FORPLAN model is to maximize the present net value of national forest uses and outputs. While some have argued that this was clearly the intent of Congress (246), others are not convinced:

> It is more difficult to find justification for this economic approach in NFMA than the focus on timber management. . . A much stronger focus is the assurance of protection of the forest environment during all actions (123).

The economic objective function has added to the difficulties with data in building and using FORPLAN, because all resource uses and outputs must be measured in dollars, even though only timber has a true market price (64). (See ch. 8 for a discussion of valuation techniques for unpriced resources.)

All goals for national forest management are included in FORPLAN through constraints on the model. Insufficient constraints can lead to unrealistic estimates of uses and outputs (and thus to infeasible targets), but excessive constraints can cause capabilities to be underestimated and lead to significant opportunity costs (50).

The most limiting constraints in FORPLAN have been the flow constraints, especially nondeclining even flow for timber (278). Timber harvests are regulated by total timber growth, which is determined by the area allocated to timber management and by investments in timber growing. However, in forests with substantial timber inventories (i.e., with old-growth timber), nondeclining even flow limits timber harvests largely by the amount of land allocated to timber harvesting. In many western national forests with substantial old-growth timber, timber harvest flow constraints have often been "used as surrogates for restrictions on harvest for economic, social, political, or environmental reasons" (122). Easing the rigid nondeclining even flow constraints could substantially increase all of the uses and outputs, without compromising long-term timber productivity (278). However, to the extent that timber flow constraints have been used as surrogates for other values, easing this requirement for FORPLAN analyses may be politically infeasible.

The choice of tools and data is not objective, because the selection carries implicit values and emphases (50, 51). FORPLAN maximizes the value of ***uses and outputs.*** Nonuse values, such as visual quality and soil productivity (or having undisturbed ecosystems or providing a natural resource legacy), can only be included as constraints to maximizing uses and outputs. The value implicitly associated with a constraint can be determined, but this is a costly and time-consuming process that has not been done extensively in forest planning (64). As constraints, nonuse values must be fully achieved at the specified levels, but FORPLAN grants no additional benefits for exceeding the specified levels. Thus, FORPLAN can examine tradeoffs among uses and outputs, but cannot readily examine tradeoffs between outputs and protection. This approach has been described as reactive--preserving current conditions and mitigating damages-rather than as proactive—managing ecosystem functions (234). Therefore, FORPLAN may not provide the balance among accommodating uses, producing outputs, and sustaining ecosystems as is intended in the laws guiding national forest management.

Spatial Limitations--FORPLAN's **capability to accommodate spatial relationships is limited. Initially, analysis areas were simply areas with similar conditions and responses to management activities--areas with comparable soils, similar timber stands, identical costs, etc. The areas did not need to be contiguous; in fact, version 1 of FORPLAN did not allow the analyst to specify whether the areas were contiguous (122). In version 2, spatial relations among analysis areas could be specified (65). However, including spatial details substantially increases the size of the model (and hence the cost to use it), and only a few spatial configurations can be analyzedinFORPLAN(118).**

Spatial relationships are very important in land and resource management:

> **In terms of outputs** such as water, wildlife and fish, and aesthetics, it is probably more important how a management action (for example, a timber harvest) is spatially laid out than how many acres are involved (1 18).

Furthermore, limited spatial details lead FORPLAN (and all other optimization models) to overestimate the feasible outputs (54, 72). This happens because implementation requires local adjustments and site-specific tradeoffs that cannot be included in FORPLAN (146). Unless additional spatial analysis is conducted, the use of FORPLAN to establish output targets in the forest plan can lead to planned targets that exceed the feasible productive capacity of the forest.

The "Black Box" Nature—FORPLAN is a very large and complex computer model; its complexity increases with the number of land areas, outputs, practices, and years being analyzed (51). In some respects, FORPLAN has gotten so complex that even professional users fail to understand model results.

> It is possible to build a model that is so complicated that even the analyst no longer understands why certain outputs are identified as optimal . . .
>
> The level of sophistication, and the concurrent ability to hide assumptions and manipulate data, have risen to the point that even trained users are not always aware of the ties that bind (122).

Furthermore, the data and constraints in FORPLAN can be, and at times probably have been manipulated to produce specific preferred results (13).

> Some interest groups believe that the data, the models, or the analysis is, or has been, intentionally or unintentionally distorted, twisted, or slanted to rationalize certain conclusions. Even worse, if these suspicions are occasionally true and discovered, then the entire analytical system, the analysts, and the planning process risks rejection. I think some of this has happened (64).

The sheer size **and** complexity of FORPLAN, or of any other computer model, lead to a distrust of the model (64, 234).

> The 'black box' nature of FORPLAN allows for data errors and hidden assumptions to go undetected (14).

The frequent modifications to FORPLAN and the resulting variety of FORPLAN models have added to the confusion (173, 179). Finally, FORPLAN has not been widely available for public examination and testing (123); however, the recent development of a FORPLAN model that can be used on a personal computer will alter this condition (64). All in all, FORPLAN has probably contributed to Forest Service difficulties in communicating with the public.

The FORPLAN Planning System

Documentation-The lack of model documentation has posed problems for FORPLAN. Documentation is needed to inform the public about FORPLAN, and to assure that its use is consistent, not arbitrary and capricious (51). However, "formal documentation [of the FORPLAN model] has always lagged well behind [the system's] development' (125). Although FORPLAN has been used since 1980, the final user's guide was not available until May 1986 (125), and scientific publications describing the system were sparse for the first several years (123). Thus, it has been difficult for agency analysts and outsiders to examine and review the technical structure of the model.

A **related problem is the lack of documentation of how FORPLAN has been used and on the underlying assumptions, yield data, etc. The forests have maintained "unclear and incomplete records such that new analysts could neither duplicate nor understand what had been done previously" (278). This lack of documentation could lead to successful legal challenges on the grounds that the analysis was arbitrary and capricious.**

Verification--Verification of the various assumptions, yield tables, and other inputs to FORPLAN has generally been inadequate (179). Unverified systems have undoubtedly been used because of the need for immediate answers in the ongoing forest planning process (146). Inadequate initial verification is not a fatal flaw, if forest plan implementation is monitored in a manner which allows the assumptions, yields, and other FORPLAN inputs to be examined; plan monitoring was intended, in part, to verify FORPLAN and its data (146). However, to date, monitoring has been inadequate for this task. (See ch. 6.)

Agency Expertise-In response to the direction to use FORPLAN, the Forest Service developed a pool of talented analysts and modelers (64, 146), and seems to have provided adequate training for using the system (278). However, retaining this expertise has proven to be more difficult. Mixing these experts with the traditional specialists within the Forest Service has led to "culture shock" and has created some hostility toward the analysts (64, 146). Furthermore, delays, poor data, and other planning difficulties led to disillusionment and "burnout" among analysts (64, 146). Apparently fruitless efforts also have contributed to low morale (50). Finally, the analysts often felt locked into their jobs; there has been no career ladder for talented individuals to move up in the organization (278). That the Forest Service still has the personnel to use and develop FORPLAN and other models is a tribute to the agency's tenacity and commitment, but additional steps may be necessary to assure that these people are retained.

Relationship to Decisionmaking—A major problem has been comprehending how FORPLAN analyses can be used in decisionmaking. The lack of ''clear understanding of the relationship between analysis and decision making" has led to many invalid and useless analyses (14). Analysts are typically separated (physically and by education and experience) from the decisionmakers (123), and managers often have not understood the limits of FORPLAN (64)--' 'people took FORPLAN and its results as gospel' (278). Unless they are familiar with computers, people commonly do not recognize that models "are dumb [and] do exactly what they are told' (64).

FORPLAN can be useful in assisting Forest Service decisionmaking, if its limitations are understood.

> FORPLAN's usefulness [is] as an aid to understanding the nature of forest planning problems [not as optimal answers]. . . Its major purpose is to provide insight into the behavior of multiple resources and their interactions, which in turn can be used to guide the development of effective plans and decisions, The model is more appropriately used to prevent wrong decisions than for making "right" decisions (13).

Virtually all analysts recognize that models are most useful for examining possibilities, and that using FORPLAN to obtain answers can waste money and inhibit development of a publicly acceptable forest plan. "The phrases 'FORPLAN says' and 'our model says' need to be purged permanently' from conversations with the public (64). Analysis is intended to help managers ''understand the forest, its potentials, limitations, and constituencies, and to use this knowledge to find a balanced, acceptable course of action" (64). Thus, FORPLAN is simply a tool, to be used with other tools in preparing implementable forest plans.

SUMMARY AND CONCLUSIONS

NFMA **does** not prescribe the use of any particular technology in forest planning, but various computer technologies can be very useful for analyzing alternatives and assuring requirements are met. The Forest Service designated FORPLAN as the primary analytical tool for forest planning, but the many shortcomings of the model and controversies over forest planning have led some to question whether FORPLAN may be part of the problem, rather than part of the solution.

Decisions and Tools

As discussed earlier, the purpose of national forest management is to accommodate uses, produce outputs, and sustain ecosystems. (See ch. 3.) In forest planning, important decisions about the scheduling (over time) and allocation (over space) of uses and outputs can be examined using various computer models. Linear programming is often used for scheduling decisions in business, and such an approach is useful in forest planning for examining the sustainability of uses and outputs over long periods. Linear programming also has some capacity for analyzing allocation decisions, but other technologies--notably geographic information systems —are better adapted for such analyses; however, GIS are expensive to acquire and use.

Analysis of the ecological and economic impacts of forest management is also important for planning. Resource simulation models are useful for examining environmental and ecological implications, and can be used to provide input for scheduling and allocation models, but more development is needed to provide sufficient analysis for forest planning. (See ch. 6.) Economic impacts can be evaluated by examining the benefits and costs of activities over time and by estimating the effect of management alternatives on local employment and income; the benefit/cost analysis is included within the structure of FORPLAN, and the Forest Service generally uses an input-output model--IMPLAN--to estimate local economic effects. (See ch. 8.)

Additional technologies can be used to supplement the decision support models (for scheduling and allocation analyses) and the impact assessment models (for ecological and economic analyses). Database management systems can be used to maintain and coordinate inventory and other data used by the various analytical models. A "corporate' database (i.e., national access to consistently measured, collected, and stored data) would be useful, but the Forest Service has not yet set standards for such a database. Knowledge-based systems (also known as expert systems) are useful for rule-based decisions, but the state-of-the-knowledge on forest and rangeland systems is too primitive to develop more than simple decision rules. However, knowledge-based systems can also be interactive (i.e., questions for users, with the answer determining the subsequent question), which opens numerous possibilities for forest planning. Finally, integrated systems provide for automated linkages among other technologies, and thus can be very useful for coordinating analyses; however, integrated systems are still being developed.

FORPLAN

Early in this century, following the European forestry tradition, simple formulas were developed to determine allowable timber harvest levels for the unmanaged American forests with their large stocks of old-growth timber. These formulas no longer sufficed by the late 1950s, and computer models were developed to assess the long-term sustainability of timber harvest levels. FORPLAN was an outgrowth of these models, and also incorporated various aspects of a land allocation model developed for watershed analyses. FORPLAN is basically a linear programming model that maximizes the present value of resource uses and outputs (minus costs) within the specified constraints. FORPLAN includes absolute constraints (e.g., acres, productive capacity, and targets or management requirements), flow constraints (for assuring sustainable production levels), and relational constraints (to specify relations among variables).

In December 1979, the Forest Service designated FORPLAN as the principal analytical tool for forest planning. The agency believed that consistency in analytical approach was necessary, and FORPLAN was chosen because it was available and addressed some of the key questions in forest planning: the allowable timber sale level under a policy of long-term sustainability, and the lands available for timber harvesting. This capacity of FORPLAN is one of its strengths for forest planning. Another strength is FORPLAN's enormous analytical capacity; it can consider hundreds of thousands of possible combinations of management prescriptions (combinations of management activities) and analysis areas. FORPLAN also has required foresters, biologists, archaeologists, landscape architects, and other specialists to translate their knowledge into a common format, thus forcing them to learn a common 'language' and encouraging real interdisciplinary efforts. Finally, some have asserted that FORPLAN's complexity has served as a barrier to criticism, and thus has preserved local agency discretion for forest management.

FORPLAN also has many weaknesses. Inherent in linear programming is the inability to include risk and uncertainty and the assumption that inputs and outputs are direct, continuous, and reversible (i.e., that prescriptions and analysis areas are independent of other prescriptions and areas, that inputs and outputs can be adjusted in minute quantities, and that there are no thresholds for ecological changes). Furthermore, FORPLAN requires data on costs, outputs, and the relationship to constraints for each prescription and analysis area. Such data requirements substantially exceed the knowledge base for many resources, including timber if uneven-aged management is to be considered (as is required by NFMA).

The structure of FORPLAN carries important implications for forest planning. The goal is to maximize the value of uses and outputs, but many uses and outputs are difficult to value because they lack market prices to indicate their worth. More importantly, nonuse values--e. g., protecting watersheds, preserving endangered species, improving aesthetics, and other values of having viable ecosystems—are included only as constraints on the uses and outputs. This structure implies that sustaining ecosystems is a constraint on production, and not a goal for managing the national forests.

FORPLAN has some capacity to analyze spatial considerations, but adding spatial data substantially increases the size, complexity, and cost of the model, FORPLAN is so large that sometimes even the users do not understand why certain results occur; it is also possible to manipulate the system and to hide assumptions. Furthermore, the documentation of the system and of the assumptions and data used has been inadequate, preventing others from examining the FORPLAN analyses. Parts of the system have not been tested (verified), although sufficient monitoring of implementation could provide the testing needed. (See ch. 6 for more on monitoring.)

The Forest Service has done a remarkable job of acquiring the analytical capacity to use FORPLAN. However, the difficulties in forest planning and the lack of promotional potential is causing low morale among analysts. The lack of clear understanding of how analyses would be used in decisionmaking has added to the dilemma. Managers have sometimes used analytical results without understanding the limits of the analysis. At other times, managers have ignored the results because they did not trust the system or the analysts. Better communication between analysts and management and with the public is needed if FORPLAN is to be useful in forest planning.

Options for the Future

FORPLAN will undoubtedly continue to evolve and be used in forest planning. The agency has sunk a lot of money into developing the system and in finding and training the people to use it (23). FORPLAN can provide useful information (13, 226), and it or a similar model is probably necessary to analyze the sustainability of timber harvest levels over long time periods. Furthermore, there are few real alternatives to FORPLAN (179). Thus, FORPLAN will continue to be used.

Although the use of FORPLAN in forest planning could be improved, it cannot do all of the analysis required for forest planning.

> No approach will produce a perfect model of the real world, because all models are abstractions which necessarily are simplifications of reality (14).

Thus, FORPLAN should be linked to other systems. The Forest Service is already using many resource simulations for input to FORPLAN, but additional development and more integrated use of simulation models are needed (146, 234). A GIS is probably essential to assure the spatial integrity of planning alternatives, and a corporate database would provide a consistent structure for the data needed in the various analytical systems.

A more hierarchical planning structure could also contribute to the use of FORPLAN in forest planning (72, 179). Some ecological modeling must occur at large scales, other at much smaller scales (172). Furthermore, FORPLAN has been devised to try to answer all forest planning questions at one time (14). The regulation requiring a timber sale schedule in the forest plan has particularly contributed to the complexity of FORPLAN (179, 234). FORPLAN could be substantially simplified, to the point where users and outsiders could understand the analysis, if more analysis was done before FORPLAN was used (234) and if additional planning and tools were developed for forest plan implementation (54, 146).

Finally, better communication about the results and limitations of the FORPLAN analyses is essential. A simpler FORPLAN model under a hierarchical planning structure would help (14), but closer connections between analysts and managers are also necessary (61, 123), FORPLAN is a useful tool for examining productive capacity and tradeoffs among activities (13). These analyses should contribute to public participation, rather than limit or prevent.