ALTERNATIVES ANALYSIS FOR MULTIPLE USE MANAGEMENT : A Case Study

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The multiple use doctrine is part of the guiding philosophy of the Forest Service, but its effective implementation is a difficult task. This paper presents an application of the multiple use principle using economic analysis to evaluate management alternatives on a mixed conifer watershed. Physical yields of sawtimber, pulpwood, water, and forage, and effects on wildlife habitat and esthetics are estimated for six alternatives reflecting a variety of management emphases. Where possible, yields and costs of the alternatives are valued in dollars. The analysis is presented in a form that facilitates explicit identification of tradeoffs, in dollars where possible, and provides an easy way of isolating, and in most cases quantifying, the most relevant tradeoffs.

Keywords: Multiple use management, mixed conifer watershed, economic analysis.

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ALTERNATIVES ANALYSIS FOR MULTIPLE USE MANAGEMENT: A Case Study

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Introduction

Population growth and economic development are continually changing the character of our society. One change obvious to the public land manager is the increasing interest in and demand for forest products. Demand is increasing for timber harvest, wilderness, and everything in between. While some uses are compatible, others are conflicting. The job of determining the best mix of forest products is becoming more complex and difficult.

Land managers rely increasingly upon ecologic, economic, and other analyses as input to their decisionmaking. These analyses help managers to more accurately reflect the best interests of the body politic. They "sharpen the efficiency" (Kelso 1964, p. 61) of the final—political—decision.

The most comprehensive type of analysis in land use planning is the alternatives analysis, which is a general comparison of management options. Considering options is nothing new; all decisions are a matter of choice. When individuals decide how to spend their time or money, for example, they necessarily consider alternative ways, although perhaps not in an organized fashion. The difference between individual allocation decisions and public ones is not in the basic approach, but rather in the method. Planners are not planning for themselves, but for the public. Planners are expected to remain impartial and consider the best interest of the general public. This is best done with a comprehensive analysis of alternatives.

Economic theory offers a framework for evaluating alternatives. Indeed, economics is defined as "the study of how men and society end up *choosing,* with or without the use of money, to employ scarce productive resources that could have alternative uses. . ." (Samuelson 1973, p. 3). Economics has a much broader scope than the popular notion equating economics with accounting or with dollars. The analysis of tradeoffs in decisionmaking, as presented in this paper, is one facet of this broader scope.

The purposes of this paper are to: (1) present a general outline for an alternatives analysis, (2) briefly describe how economic principles can be applied to help evaluate forest management alternatives, and (3) show how the analysis can be presented in a useful form for decisionmaking. Although data from South Thomas Creek watershed (Arizona) are used to help illustrate the procedure, no attempt is made to select the "best" management plan. The emphasis is on methods rather than results. Shortcomings of this type of analysis are also summarized.[2]

One problem with using a case study to illustrate a general technique is that every case is unique. Use of the technique for other areas requires adjustments to the new area's particular situation. South Thomas Creek is a small, heavily timbered area that receives little recreation use, and the analysis described herein reflects this situation. Extrapolation of the analysis procedures to a much larger area with heavy recreation use, for example, would require some changes. Nevertheless, the basic approach would remain unchanged.

Alternatives Analysis Procedure

The planning process can be described as having three basic stages. The first stage (stage 1) consists of assessing the management situation, defining basic management assumptions and constraints, and setting general goals and objectives for an area, including setting sideboards on the possible alternatives and specifying the schedule and explicit procedures to be employed, including data requirements. The second stage (stage 2), the topic of this paper, is the formulation and analysis of viable management alternatives, a procedure referred to herein as the alternatives analysis procedure. Decisionmaking is the final stage (stage 3). Interaction and overlap are essential between each stage. Public involvement is important, especially in stages 1 and 3.

The alternatives analysis procedure is separated into four iterative steps (fig. 1). The first step (step 1) consists of formulation of alternatives to be analyzed. Alternatives are formulated in light of overall direction given in stage 1 of the planning process.

Second (step 2), relevant impacts of the alternatives on the various resources are predicted

[2]*A forthcoming paper concerning central Arizona's Woods Canyon watershed will build upon the foundation presented here and present a more thorough analysis of alternatives with sensitivity analyses.*

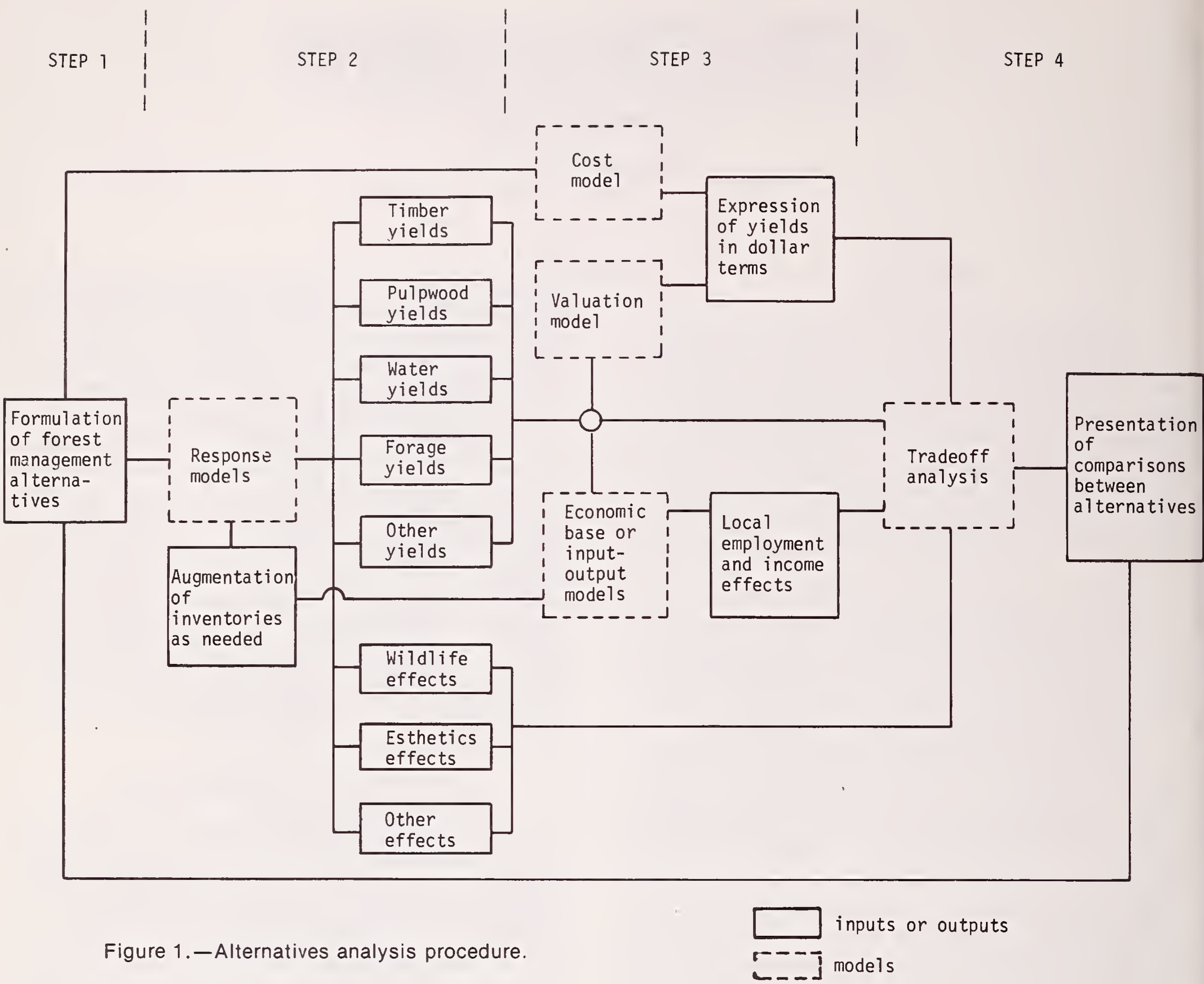


Figure 1.—Alternatives analysis procedure.

using available data and response models pertinent to the study area. Resources fall into two groups for evaluation purposes. The first group includes those forest yields for which dollar values can be properly assigned. For Thomas Creek this group includes timber, pulpwood, water, and forage. Each of these outputs becomes an input in the production of some product sold in the market place. The other group consists of resources affected by the alternatives for which the effects are either not quantifiable or for which appropriate dollar values could not be assigned (such as wildlife habitat and esthetics).

The third step (step 3) involves expressing the costs and yields in dollar terms, where possible, and also determining the effect of the alternatives on the local economy. Economic base or input-output studies can often be used to estimate impacts on local employment and income. (Because of the small size of the study area in this case, however, alternative management directions are not expected to significantly influence local employment or income; hence these effects were ignored.)

The final step (step 4) is a comparison of the alternatives in terms of biophysical, dollar, local income and employment, and nonquantifiable effects. The effects must be presented in a form that facilitates comparison.

Study Area

South Thomas Creek, a 562-acre mixed conifer watershed on the Apache-Sitgreaves National Forest in eastern Arizona (fig. 2), is 8,800 feet above sea level, with average annual precipitation of 28 inches. Douglas-fir, white fir, and ponderosa pine are the most abundant species, but white pine, Engelmann spruce, blue spruce, corkbark fir, and quaking aspen are also found. Tree basal area averages 180 square feet per acre, and sawtimber volume averages 22,430 board feet per acre.

South Thomas Creek has never been logged. Much of the timber is mature or overmature, and there is considerable downed wood. Although Thomas Creek offers a ripe situation for harvesting timber, it also has other outputs. Annual runoff averages 160 acre-feet, much of which reaches final points of use in the Phoenix metropolitan area. The watershed provides habitat for wildlife and some forage for domestic livestock. Timber harvesting would affect these and other values.

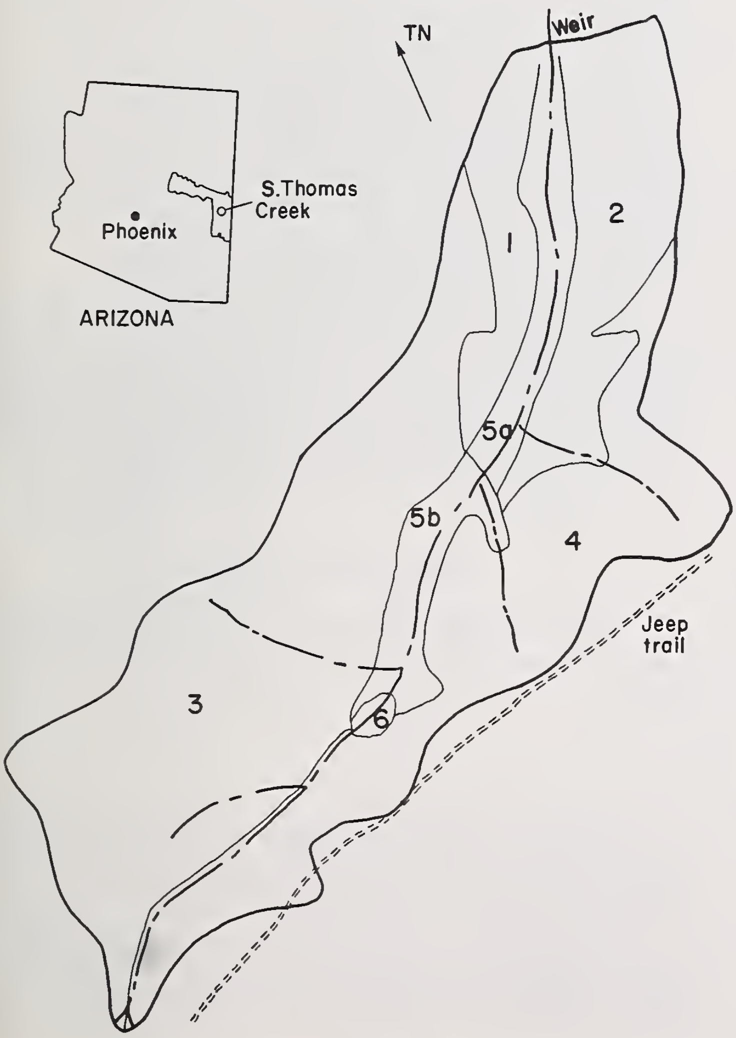


Figure 2.—South Thomas Creek watershed, located within the Apache-Sitgreaves National Forest, Arizona, as divided into seven units for evaluation.

Thomas Creek is not visible from any major road. It is reached by a little used access route, and receives little recreation use. There are many more accessible and heavily used sites in the general area.

For the purpose of this evaluation, Thomas Creek was divided into seven units (fig. 2) which correspond basically to land response units (USDA FS 1972). Most of units 1 and 2, at the north end of the watershed near the weir, are on slopes from 35 to 65 percent. Unit 5a is the relatively flat strip along the intermittent stream contiguous with units 1 and 2. These three units together comprise 25 percent of the watershed (table 1). If harvested, the majority of these units would require cable logging because of the steep slopes. Units 3 and 4, the bulk of the watershed, have slopes of less than 35 percent. Unit 5b is that portion of the waterway contiguous with units 3 and 4, and unit 6 is a small meadow. Units 3, 4, and 5b could be harvested in the traditional (tractor logging) manner.

Table 1.--Description of South Thomas Creek units

Units	Acres	Site index[1]	Description
1	36	90- 95	slopes>35%
2	77	85- 90	slopes>35%
3	233	85- 90	slopes<35%
4	159	85- 90	slopes<35%
5a	27	90-100	bottom
5b	28	90-100	bottom
6	2	--	meadow
	562		

[1]See Alexander 1967, Minor 1964.

Management Alternatives

Formulation of the alternatives to be evaluated is often the most important task of the analysis. No degree of diligence in evaluating alternatives can save an analysis if the best alternative is not in the running.

It is often desirable to initially formulate a wide range of alternatives for preliminary consideration, so as to help assure that the best alternative is bracketed somewhere in the range. By screening this group, a representative set of alternatives is then selected for intensive analysis. Although there are no definite rules for designing and screening alternatives, some direction is given from general management goals, objectives, and constraints as articulated in stage 1 of the planning process. Information on hand about resource values in the study area, as well as similar information for neighboring areas, also helps define the proper scope of the alternatives.

Perhaps the most valuable qualities in selecting alternatives are imagination and flexibility. McKean (1958, p. 52) writes of a common lack of these qualities in a simple consumer decision: "After exhaustively comparing several camping outfits, and finally buying one, we realize that we should have considered rental in order to find out, first of all, if camp life lived up to our expectations." While consideration of alternatives is natural in human decisions, viable alternatives are often overlooked.

Stage 1 of the planning process established two possible management directions in Thomas Creek: to maintain the virgin timber stand, or to institute a more intensive management scheme. Under the first direction, designated as Alternative VN (for virgin), the water, forage, recreation, wildlife, and esthetic resources would continue to produce much the same as they do now. Only timber harvesting would be precluded, at least temporarily; all future options are maintained.

The other direction should include as wide a range of choice as is consistent with existing management direction (goals, objectives, and constraints). At Thomas Creek, managers could emphasize one or more of the following: timber or pulpwood harvest, water runoff, forage production, quality of wildlife habitat, or esthetics. Because the dense timber stand completely dominates the landscape on Thomas Creek, any intensive management scheme would necessarily involve some timber removal. Furthermore, because Thomas Creek has an exceptionally high potential for producing timber relative to most other Arizona sites, alternatives that provide for some near-future timber yields should be selected for intensive analysis.

The question that intensive management alternatives should deal with can be broken into three parts: (1) what resource or combination of resources should be featured, (2) should harvesting be limited to the portion that can be tractor-logged, and (3) what should be the degree of slash cleanup? This paper deals with the first two parts. Inclusion of slash cleanup alternatives here would unduly lengthen the paper. The methodology and procedures explained are equally applicable to evaluation of slash cleanup alternatives.

Rather than letting one analyst design all the alternatives, we asked several persons of different disciplines to propose alternatives that, while including some timber harvests, favored their particular interest. This approach netted six alternatives, two timber-oriented (alternatives TM and TM'), two water-oriented (alternatives WT and WT'), and two wildlife-oriented (alternatives WL and WL').

The timber harvesting alternatives project a 20-year cutting cycle over a 120-year planning horizon. Because of the possibility of windthrow, the following rule of thumb was followed: a stand cannot be thinned by more than 30 percent of its basal area the first harvest, and not by more than 35 percent the second harvest (Jones 1974, p. 28). The alternatives also include the following measures: preclearing of the road installed for the harvest, fuelbreaks around the perimeter of the watershed, removal of slash above the high-water mark along the intermittent stream, and piling and burning of slash left at the landings.

In alternative TM (fig. 3), trees are harvested by tractors using a group selection silviculture method. In alternative WT[3] (fig. 3), about 40 percent of units 3, 4, and 5b is maintained in grass or small trees. The openings are designed to increase water yield by reducing evapotranspiration and trapping snow, but should also favorably affect forage for livestock and habitat for deer and elk. In alternative WL[4] (fig. 3), "wildlife leave areas" are designated to benefit various wildlife species, and cleared patches are designed to create "edge." Alternatives TM', WT', and WL' are cable-logging extensions of TM, WT, WL, respectively. With each pair the treatment on 5b is extended to 5a, and that on units 3 and 4 to units 1 and 2.

This paper is limited to a representative set of alternatives for ease of presentation. Tractor logging portions of units 1, 2, and 5a, varying degrees of thinning and cleaning of the stand, different intervals of entry, and use of fertilizers are only four possibilities not considered.

Physical Responses

Effects of the alternatives on forest resources are estimated with the aid of response models (see fig. 1).

[3] *Thompson, J. R. A water-oriented timber harvest for South Thomas Creek. (Unpublished manuscript, 1974, on file at Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.)*

[4] *Adams, John K. Proposed wildlife prescription—Thomas Creek watershed. (Unpublished manuscript, 1974, on file at Apache-Sitgreaves National Forest, Springerville, Ariz.)*

Year	ALTERNATIVE TM: TIMBER-ORIENTED GROUP SELECTION CUT. Units 1, 2, and 5a receive no treatment. Units 3, 4, and 5b are treated as follows:	ALTERNATIVE WT: WATER-ORIENTED TIMBER HARVEST. Units 1, 2, and 5a receive no treatment. Unit 5b is clearcut and maintained clear. Units 3 and 4 are treated as follows:			ALTERNATIVE WL: WILDLIFE-ORIENTED TIMBER HARVEST. Units 1, 2, 5a, and 5b receive no treatment. Ten percent of units 3 and 4 is left untreated in "wildlife leave areas." (These areas may or may not be the same from one entry to the next.) The remaining 90 percent of units 3 and 4 are treated as follows:					
		1/3	1/3	1/3	1/6	1/6	1/6	1/6	1/6	1/6
0	Group selection cut: 30% reduction in basal area	Clearcut in patches 5-12 acres; plant	Group selection cut: 30% reduction in basal area		Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Group selection cut: 30% reduction in basal area				
20	Group selection cut: reduce basal area to 100 sq ft by harvesting saw logs and pulpwood, but do not reduce basal area by more than 35%; precommercial thinning if necessary		Group selection cut: reduce basal area to 100 sq ft by harvesting saw logs and pulpwood, but do not reduce basal area by more than 35%; precommercial thinning if necessary			Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Group selection cut: reduce basal area to 100 sq ft by harvesting saw logs and pulpwood, but do not reduce basal area by more than 35%; precommercial thinning if necessary			
40		Precommercial thinning	Repeat above treatment				Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Repeat above treatment		
60	Repeat above treatment		Clearcut in patches 5-12 acres; plant	Repeat above treatment	Precommercial and commercial thinning			Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Repeat above treatment	
80	Repeat above treatment	Commercial thinning		Repeat above treatment	Commercial thinning	Thin			Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Repeat above treatment
100	Repeat above treatment	Commercial thinning	Precommercial thinning	Repeat above treatment	Intermediate cut to 100 sq ft of basal area	Thin	Thin			Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant
120	Repeat above treatment	Commercial thinning		Clearcut in patches 5-12 acres; plant	Clearcut in patches 2-10 acres; leave 15 sq ft advanced repro; plant	Intermediate cut	Thin	Thin		

Figure 3.—Three alternatives selected for management and analysis of South Thomas Creek watershed, Arizona.

Sawtimber and Pulpwood

Alternative timber yields for South Thomas Creek were estimated with a simulation model (MXCNFR) developed by Larson.[5] MXCNFR simulates growth, mortality, and reproduction for mixed conifer stands subject to user-imposed harvest or thinning activities. The model is interactive; it allows the user to examine the timber stand at specified time intervals and tailor each cut, within the dictates of alternative prescription, to the stand condition at the "time" of the cut.

The further timber growth and yield are projected into the future, the more the possibility of error increases. Specific board feet or other estimates of future timber harvests must therefore be examined with caution. More important for choosing among alternatives than the specific quantity predicted for each alternative, however, are the relative differences among the quantities for each alternative. Predictions of the effects of all alternatives are subject to the same errors, so by using relative differences most of the errors get subtracted out, and the problem of inaccurately estimating future yields is mitigated. If the model were exaggerating future yields, for example, yields of all alternatives would be exaggerated, and the relative position of the alternatives in terms of future yields would not be greatly affected.

The main problem in simulating timber yields results from the practical necessity, when dealing with large areas, of averaging stand conditions (stand tables) over relatively homogeneous areas. This relegates any conclusions from the analysis to average stand conditions, and leaves decisions regarding small stands or clumps of trees to more intensive investigations.

Input to MXCNFR consists of initial stand tables, estimated adjustments to the mortality function, and the desired timber cuts and thinnings. The stand tables chosen to represent Thomas Creek are averages of inventoried plots.[6] Output from the model consists of estimates (by species) of board feet, cords, and square feet of basal area per acre harvested, as well as periodic estimates of basal area in standing trees in the precommercial, pulpwood, and sawtimber size classes.

[5] *Larson, Frederic R. MXCNFR: A simulation model for the mixed conifer type of Arizona. (Unpublished manuscript, 35 p., 1974, on file at Rocky Mt. For. and Range Exp. Stn., Flagstaff, Ariz.)*

[6] *Embry, Robert S., and Gerald J. Gottfried. Overstory and multi-product inventory of the Thomas Creek watersheds (Unpublished manuscript, 1969, on file at Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz.)*

Water Runoff

Estimates of the effects of alternative harvests on runoff were based on research by Rich and Thompson (1974). They found that selection cuts in mixed conifer forests similar to alternative TM did not significantly increase runoff. However, openings in the forest greater than three times the height of the surrounding trees, similar to those of the water- and wildlife-oriented alternatives, were effective in increasing runoff. Alternative WT', for example, is expected to increase average annual runoff by 1.65 inches (above the past average of 3.25 inches) over the entire watershed following the initial cut (Rich and Thompson 1974, p. 6). The openings are expected to retain their effectiveness in increasing runoff (predominantly from snowmelt) on Thomas Creek until the trees in the opening reach half the height of the surrounding trees. From that point on, the runoff increase declines. All runoff increases are assumed to augment existing flows and thereby be wholly transported with the normal flow to points of use downstream.

Forage

Forage production and utilization for each unit were estimated from basal area, slope, aspect, and soil data.[7] Very little utilization is expected on units 1 and 2 because of steep slopes. With existing fence and water facilities, units 5a and 5b should receive high utilization (60 percent) and units 3 and 4 a good deal less (20 to 30 percent). Only alternatives WT and WL and their extensions (WT' and WL'), because of the clearings created, are expected to increase forage production significantly.

Pounds of utilizable forage were converted into animal-unit months (AUMs). Physical yields for the four basic alternatives on an average annual basis are listed in table 2.

Table 2.--Average annual physical yields, South Thomas Creek

Outputs	Alternatives			
	VN	TM	WT	WL
Sawtimber (1,000 bd ft)	--	143	124	124
Pulpwood (cords)	--	164	121	160
Water runoff (acre-ft)	152	152	195	171
Forage utilization (AUMs)	12	23	101	36

[7]*Based on communication with Miles P. Hanrahan, Range Staff Officer, Apache-Sitgreaves National Forest, Springerville, Ariz., 1974.*

Wildlife Habitat

Wildlife habitat for 23 species or groups (of similar species) of mammals and birds was ranked by a team of wildlife biologists.[8] Based on the alternative prescriptions and the timber simulations, the team was able to arrive at a consensus about habitat effects for each species or group on a scale of 1 (poor) to 5 (good) for each 20-year period over the 120-year planning horizon. A rating of zero was used when habitat was considered eliminated for a species or group. The team assumed that neighboring areas would be treated similarly to Thomas Creek (that surrounding areas would not remain as refuges of virgin timber if Thomas Creek were treated). Averaging over time, one rating was then assigned to each species or group. In most cases, the average reflected an equilibrium which was anticipated after the first or second harvest.

Esthetics

Daniel and Boster (1976) and Arthur (1975) have added to our understanding of people's relative esthetic preference for forested landscapes. Although their work compared various cutting practices in ponderosa pine which are not enough like the Thomas Creek alternatives to allow direct comparisons, some insights into the public's relative esthetic preference for the Thomas Creek alternatives can be garnered. The amount and distribution of slash on the ground appears to be the best single predictor of esthetic preference. Because the Thomas Creek harvest alternatives provide for little slash cleanup, the harvested area will rate poorly esthetically compared with the virgin stand (alternative VN). Also, in the absence of considerable slash cleanup, especially in highly visible areas such as along roads, there is little basis esthetically for distinguishing between the harvest alternatives. If all slash were cleaned up, however, the harvested stands would probably be liked somewhat better than the existing stand. (The virgin mixed conifer stands contain considerable slash from natural sources.)

Dollar Valuation

The physical yields take on an extra dimension when expressed in dollar terms. First, the relative dollar value of an additional (marginal)

[8]*The team consisted of David R. Patton and Robert Vahle of the Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz., John K. Adams and James K. McKibben of the Apache-Sitgreaves National Forest, Springerville, Ariz., and Virgil E. Scott of the U.S. Fish and Wildlife Service, Tempe, Ariz.*

unit of each cardinally quantified output (in this case, timber, water, and forage) is determined. This procedure not only weights the outputs according to society's preferences, but also puts quantified outputs on a common scale for comparison. Next, the discounted gross return for each alternative is calculated using the marginal (dollar) values. Then the discounted costs are subtracted to give the net return for each alternative.

Where markets are truly competitive, resource valuation is a simple matter of observing market prices. Because quantified forest outputs are not always sold in competitive markets, the prices paid for these resources do not always reflect their true value to society relative to all other goods. In the case of Thomas Creek, most products produced from these forest outputs—lumber, feed grains and forage, and livestock—are, however, sold in relatively competitive markets (hydroelectric power is an exception). For this reason, the forest output values were derived from the selling prices of the final products. The variable costs—those which vary directly with the quantity being produced—were subtracted from the product selling price to yield the maximum the producer could pay for the resource and stay in business in the short run (O'Connell 1972). This is the marginal revenue product of the output.

While this ability-to-pay method does provide relative estimates of forest output values, two things must be remembered. First, the marginal values apply only to small changes in the total annual outputs from the overall area (the working circle). The average value of the total annual yields from the entire working circle must take fixed as well as variable costs into account. Second, the noncompetitive resource markets may influence the mode of production as well as the quantity and price of the final products, even if the final products are sold in relatively competitive markets.

Stumpage

To keep short-term price fluctuations from biasing long-range valuations, sawtimber stumpage values for Thomas Creek were derived from a 5-year (1970–74) inflation-adjusted average selling price for lumber. Variable costs of harvesting and processing the logs (1974 costs) were subtracted from the average lumber selling price, yielding values similar to traditional Forest Service stumpage values less fixed costs and profit (see O'Connell 1972). The derived sawtimber stumpage values average $76 per thousand board feet (MBF log scale) for the spruce-fir species, $130 for the pine species, and $56 for quaking aspen. Although pulpwood yields were also quantified, an appropriate value for pulpwood is not available at this time.

Water Runoff

Runoff increases from Thomas Creek can be valued at three locations: (1) in streams leaving the watershed, (2) at hydroelectric dams downstream, and (3) at final points of use in the Salt River Valley. Any value to society of the *addi-*

tional water for fish, wildlife, and livestock uses along existing streams leaving the watershed is of questionable significance. Measurement was not attempted.

Runoff passes through four dams (Roosevelt, Horse Mesa, Mormon Flat, and Stewart Mountain) as it travels down the Salt River. The output value was derived from the most costly alternative power source which the added hydroelectric power replaces. Updated from Brown et al. (1974), the runoff increases are valued at $2.85 per acre-foot (1974 prices).

The primary users of any additional water in the Salt River Valley are in the agricultural sector—there is some unmet demand for the water to irrigate relatively low-valued feed grain and forage croplands. All water demands for producing higher-valued products are already met. Furthermore, Kelso et al. (1974) estimate that most higher valued demands will continue to be met, and that some acreage will continue to produce feed grains and forage crops, through at least the year 2015. This is expected to happen even though urban growth is projected to cause a major decline in agricultural acreage in the Salt River Valley by that time. Updating Kelso et al. (1974) to 1974 prices, the derived value for additional surface flow to the valley is $12.00 per acre-foot. That is, farmers could not, on an average, pay more than $12.00 for an extra acre-foot of water and break even in the short run. This value ($12.00) plus the hydroelectric power value ($2.85) puts the water value at $14.85 per marginal acre-foot.

Forage

The forage value is derived from the price of cattle. Rather than attempt to deal with the widely fluctuating prices of the past 2 years, a 1972 derived value of $6.50 per AUM was used (Brown et al. 1974). The $6.50 value is just 12 percent greater than the average western range private lease rate of $5.82 per AUM for 1974 (USDA ERS 1975).

These dollar values for the three primary outputs were applied to the change in the physical yields associated with moving from alternative VN (the past management situation) to some other alternative. It was assumed that the relative position of prices would not change over time. The stream of dollar yields over the 120-year planning horizon was reduced to one present value[9] by discounting at 7.0 percent, as recently recommended by the U.S. Water Resources Council (1973). Discounting is an accepted procedure for expressing society's time preference, and brings into account the opportunity cost of capital. Simply stated, discounting future yields expresses the assumption that a given return (whether in physical or monetary form) is worth more if received now as opposed to some future date.

Annuities[10] put present values on an average annual basis (table 3), providing another way to express discounted time flows. Theoretically, receiving the present value today is no more or less desirable than receiving a corresponding annuity each year for a specified time period.

Timber harvests account for 91 percent of gross returns for all harvest alternatives considered for Thomas Creek. Water and forage account for 8 and 1 percent, respectively. Variable costs for the following activities, which are not physically necessary for producing these outputs, were subtracted from gross returns: fuelbreaks, clearing the streambottom, clearing the landings, preclearing the roads, precommercial thinning, and planting. Subtracting these costs yields relative estimates of net return for each harvest alternative (table 3).

Table 3.--Annuity of marginal[1] yields and costs (dollars), South Thomas Creek (discount rate is 7.0 percent)

Outputs	Alternatives		
	TM	WT	WL
Stumpage	$25,776	$42,471	$31,307
Water		861	302
Range	61	695	155
Gross return	25,837	44,027	31,764
Cost	817	2,492	2,582
Net return	25,020	41,535	29,182

[1]Only the changes from alternative VN (the marginal yields and costs) are valued, using the derived marginal values given in the text.

[9]*Present value (PV) =* $\sum_{t=1}^{120} [Y_t/(1+i)^t]$, *where* Y_t *is the annual cost or benefit, i is the discount rate, and t is time in years.*

[10]*Annuity =* $PV[i(1+i)^t/((1+i)^t - 1)]$.

Tradeoff Analysis

How is all this information used? Quite simply, it allows the decisionmaker to better understand differences in the consequences of viable alternatives. Comparing alternatives in terms of the predicted major differences in their effects helps the decisionmaker to focus his attention on the key issues. Such differences among alternatives can be expressed as tradeoffs, which represent opportunity costs (whether expressed in dollars or not). An opportunity cost, or benefit foregone, is the amount of one output given up to attain a given amount of another output. For example, by choosing a high timber yield alternative over a lower one, an opportunity cost in terms of foregone wildlife habitat may be incurred.

The task for the analyst at this point (fig. 1, step 4) is to present the comparisons in a meaningful way. The comparisons should facilitate formulation of scenarios that, if implemented, would resolve the decisionmaker's chief concerns. Summary tables such as tables 4 and 5 are helpful. Physical and dollar effects are presented in these tables as totals or changes from the totals. In addition, the wildlife habitat ratings are summarized for the tables.

Table 4.--Average annual effects of timber harvest change from alternative VN for South Thomas Creek

Outputs	VN	Change from alternative VN		
		TM	WT	WL
MARKET				
Sawtimber (1,000 bd ft)	--	+143	+124	+124
Pulpwood (cords)	--	+164	+121	+160
Water runoff (acre-ft)	152	--	+43	+19
Forage utilization (AUMs)	12	+11	+89	+24
Economic effects (dollars)[1]				
Gross return[2]		+25,840	+44,030	+31,760
Costs		+820	+2,490	+2,580
Net return		+25,020	+41,540	+29,180
NON-MARKET				
Wildlife habitat (Index 1 to 5)				
Class 1	1.6	+1.5	+1.8	+2.1
Class 2	1.4	+0.5	+0.2	+1.6
Class 3	4.2	-1.5	-2.2	-0.5
Class 4	2.6	+0.9	+0.2	+1.4

[1]Presented as an annuity; discount rate is 7 percent.
[2]Includes returns from sawtimber, water runoff, and forage utilization.

Summarizing the wildlife habitat analysis presents a particular problem because of the large number of species that are affected by forest management practices. Although detailed information on each species or group should always be available to decisionmakers, summaries often facilitate decisionmaking. There is no generally accepted technique for summarizing data such as wildlife ratings, and numerous methods could be devised. For this analysis, the wildlife species and groups have been combined into four classes based on habitat requirements (table 6). Class 1 includes those species for which habitat rates low (an average of 1.6 on the 5-point scale for the species and groups in the class) with the virgin situation (alternative VN), and for which habitat improves with all treatment alternatives. Class 2 contains species which have low habitat ratings with VN (1.4), and for which habitat quality does not generally improve with the treatment alternatives. Habitat for wildlife species in class 3 rates high with VN (4.2), and rates relatively lower for all treatment alternatives. These species generally prefer a mature, dense forest. Class 4 includes those species for which alternative VN provides medium quality habitat (2.6), and for which habitat either remains the same or improves with the treatment alternatives.

Table 5.--Average annual effects of timber harvest change from alternative TM for South Thomas Creek

Outputs	TM	Change from alternative TM	
		WT	WL
MARKET			
Sawtimber (1,000 bd ft)	143	-19	-19
Pulpwood (cords)	164	-43	-4
Water runoff (acre-ft)	152	+43	+19
Forage utilization (AUMs)	23	+78	+13
Economic effects (dollars)[1]			
Gross return[2]		+18,190	+5,930
Costs		+1,670	+1,760
Net return		+16,520	+4,170
NON-MARKET			
Wildlife habitat (Index 1 to 5)			
Class 1	3.1	+0.3	+0.6
Class 2	1.9	-0.3	+1.1
Class 3	2.7	-0.7	+1.0
Class 4	3.5	-0.7	+0.5

[1]Presented as an annuity; discount rate is 7 percent.
[2]Includes returns from sawtimber, water runoff, and forage utilization.

Table 6.--Wildlife classes for Thomas Creek[1]

Class 1	Class 2	Class 3	Class 4
Mule deer	Red-tailed hawk	Black bear	Blue grouse
Rocky Mountain elk	Band-tailed pigeon	Red squirrel	Goshawk
Merriam's wild turkey	Flickers	Hermit thrush	Owls
Juncos	Vireos	Kinglets	Woodpeckers
Wrens	Swallows	Chickadees	Flycatchers
		Warblers	
		Creepers	
		Nuthatches	

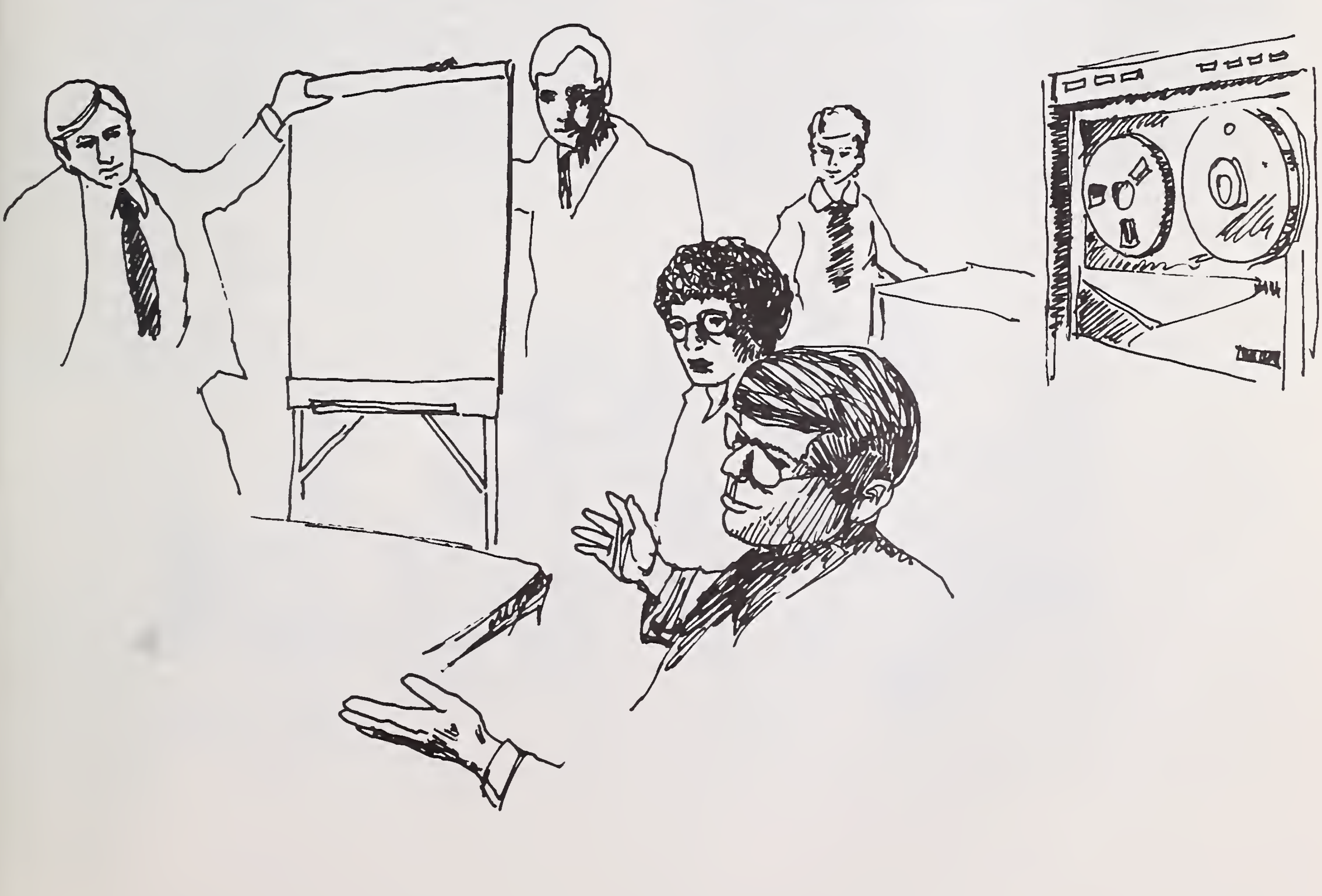
[1]This grouping is particularly adapted to Thomas Creek, and may not apply to other areas.

The manager may ask, "What are the consequences of maintaining the original stand and maximizing future management options by adopting alternative VN?" From table 4, he learns that net returns of at least $25,000 annually are foregone when compared with alternatives TM, WT, or WL. Lack of a sawtimber harvest of between 124 and 143 MBF, on an average annual basis, accounts for most of this loss. Water runoff is not expected to increase drastically with any treatment considered (the maximum was a 28 percent increase with alternative WT). A complete clearcut would increase water yield more, of course, but is not considered to be a viable option. Forage production increases markedly with more intensive management—AUMs increase from 92 (alternative TM) to 742 (alternative WT) percent—but the increase accounts for little more than 1 percent of the total outputs valued (see table 3). Habitat for about two-thirds of the species and groups rated improves with more intensive management (see table 4). The wildlife of class 3 generally prefer a virgin stand over any type of management (the pigmy nuthatch is one exception; its habitat improves over the virgin condition with wildlife-oriented alternative WL).

Another important comparison is between alternative TM and alternative WT or WL (see table 5). Alternative TM incurs lower costs for activities other than timber harvesting, and yields less net benefit than WT and WL. It yields somewhat more sawtimber and pulpwood, somewhat less water, and considerably less forage. The larger net return of alternatives WT and WL over TM is not, however, due principally to larger water and forage yields. Rather, WT and WL gain their relative advantages because more timber is cut sooner (note that the value of an average MBF of stumpage from Thomas Creek is six times that of an acre-foot of water and 14 times that of an AUM). Society's time preference, when expressed in the 7 percent discount rate, heavily weights current production over future production.

The manager may ask, "Assuming we opt for some harvest alternative, what are the consequences of emphasizing water runoff rather than timber?" Water-oriented alternative WT yields a net annuity over $16,000 greater than alternative TM at a 13 percent loss in sawtimber and a 26 percent loss in pulpwood, but with a gain of 28 percent in water runoff and 340 percent in AUMs on an average annual basis (from table 5). However, the 6- to 12-acre openings over one-third of the area in alternative WT are detrimental to wildlife habitat for the majority of species relative to alternative TM (three of the four classes show a less desirable habitat).

Or, the decisionmaker may ask, "What are the consequences of emphasizing wildlife?" Net returns for wildlife-oriented alternative WL are



considerably lower than for alternative WT, but still higher than alternative TM. Comparing alternative WL with TM, we find that, largely because of earlier heavy saw-log harvests, alternative WL yields a net annuity over $4,000 greater than alternative TM. Predicted average annual yields of sawtimber and pulpwood are 13 and 2 percent less, respectively, while yields of water and AUMs would be, respectively, 13 and 57 percent greater. Finally, wildlife habitat with alternative WL is superior to alternative TM for all classes (see table 5) and nearly all species.

Examining the above questions quickly pinpoints a major tradeoff between greater long-term timber production on the one hand and a larger net return plus improved wildlife habitat on the other hand. In the absence of specific goals for future timber production which exceed the timber output capacity of alternative WL, alternative WL is clearly superior.

Comparing alternative WL with WT we learn that WL produces more pulpwood and less water and forage than WT over the long run. Although average annual timber yields are similar, 80 percent of the difference in net return between these alternatives arises because alternative WT calls for heavier initial saw-log harvests than alternative WL. The most relevant tradeoff in this comparison is between net return and wildlife. Wildlife habitat with alternative WL is superior to that of alternative WT for all species, and far superior for many species. Is superiority in wildlife habitat worth a 30 percent loss in annuity of $12,350 ($16,520−$4,170, table 5)?

The question of how to compare wildlife habitat with net present value of market outputs is, by necessity, left to the decisionmaker. This analysis makes obvious that between alternatives TM and WL, for example, a long-run decrease in timber yield of 13 percent should be compared with a 17 percent increase in net present worth plus significant improvement in wildlife habitat.

Another important question in the Thomas Creek case is whether or not to harvest the steeper slopes. Per-acre costs of harvesting units 1, 2, and 5a are much higher than for the rest of the watershed. By extending alternative TM, WT, or WL to include the steeper slopes (by moving to alternative TM', WT', or WL') net returns are increased, based on a 5-year average ability-to-pay value for sawtimber (table 7). Actual stumpage values as appraised by the Forest Service, however, may drop to zero or below for skyline logging if lumber selling prices are below average. Feasibility of skyline logging in areas like Thomas Creek is thus precariously tied to lumber prices.

If skyline logging is feasible for Thomas Creek, wildlife habitat becomes an important decision variable. Harvesting the final 25 percent of the watershed may adversely affect wildlife habitat for several species (table 7). Only under alternative WL', where units 5a and 5b are not harvested and numerous special features are included for wildlife, would habitat be maintained or improved for a majority of the species rated if the steeper slopes are also harvested.

Evaluation of the seven alternatives presented here suggests additional alternatives. What would happen to average yields, for example, if alternative WL were altered to include harvest in unit 5b? Would the increase in average annual timber yield and net return more than compensate for the small deterioration in wildlife habitat? Or, what would happen if managers were to allocate alternative TM to units 3 and 5b and alternative WL to unit 4? These and many other questions

Table 7.--Average annual effects of timber harvest alternatives for South Thomas Creek (change with harvest of steeper slopes)

Outputs	TM	Change from TM TM'	WT	Change from WT WT'	WL	Change from WL WL'
MARKET						
Sawtimber (1,000 bd ft)	143	+48	124	+38	124	+35
Pulpwood (cords)	164	+57	121	+37	160	+47
Water runoff (acre-ft)	152	--	195	+19	171	+5
Forage utilization (AUMs)	23	+0.3	101	+35	36	--
Economic effects (dollars)[1]						
Gross return[2]		+8,010		+14,470		+8,720
Costs		+6,290		+9,060		+6,540
Net return		+1,720		+5,410		+2,180
NON-MARKET						
Wildlife habitat (Index 1 to 5)						
Class 1	3.1	+0.3	3.4	+0.2	3.7	+0.2
Class 2	1.9	[3]-0.7	1.6	[3]-0.3	3.0	+0.2
Class 3	2.7	[4]-0.6	2.0	[5]-0.4	3.7	-0.4
Class 4	3.5	-0.9	2.8	-0.4	4.0	+0.2

[1]Presented as an annuity.
[2]Includes returns from sawtimber, water runoff, and forage utilization.
[3]Includes a 0 rating for swallows, indicating that habitat has been eliminated.
[4]Includes a 0 rating for creepers.
[5]Includes a 0 rating for creepers and the pygmy nuthatch.

are easily handled when alternatives have been thoroughly evaluated. The initial analysis presented here is the basis for designing and evaluating these new alternatives. By iteration each sequential evaluation provides new insights for subsequently added alternatives that often prove to be the best of all.

Qualifications

Major qualifications to the above analysis involve problems of space (evaluation scale), time (future projections), and risk.

Evaluation Scale

This example of an alternatives analysis focused on a single watershed—one small part of an entire National Forest or working circle. This geographically narrow perspective allowed detailed data collection and indepth analysis. The effects of the alternatives on various resources were quantified with a greater degree of accuracy than is generally possible when looking at large areas. Yet, management decisions on Thomas Creek will affect decisions on other areas, and vice versa. Any management decisions for Thomas Creek should consider the effect on adjacent areas and reflect general forest management direction.

Ideally, all other areas in the working circle would be analyzed similarly, and the analyses could then be combined, in light of political, environmental, and other constraints, to arrive at an overall plan. Actual management decisions would not be made until all areas were examined and all relationships considered. Practically, however, this is both too cumbersome and time consuming. Decisions must be made today. While the forest manager must have the overall picture in mind, he is usually forced to make specific decisions about individual areas without knowledge of all forestwide relationships.

Putting Thomas Creek in the perspective of the entire Forest brings in constraints which were not considered in the above evaluation. Some examples of common constraints are to: (1) meet some specified average board-foot harvest, (2) keep costs below a specified maximum, (3) maintain a certain quality of wildlife habitat, or (4) increase water runoff by a given percentage. Such constraints could easily be included in an alternatives analysis by using a technique such as linear programing. The data described here for the alternatives analysis are the same as those needed for linear programing.

Future Projections

Three important time-related assumptions in the above economic analysis deserve elaboration. First, the assumption was made that a 7 percent discount rate expresses society's time preference regarding forest management. This assumption is questionable. Time preferences vary among individuals, and there surely never will be complete agreement on the most appropriate discount rate. Because present values for long planning horizons are highly responsive to changes in the discount rate, the usefulness of an economic analysis is enhanced when the results are expressed in terms of a range of discount rates. The sensitivity of the analysis to the discount rate would then be apparent to the decisionmaker.

Second, it was assumed that the derived marginal values could be applied to increases in yields of forest outputs from base yields throughout the planning horizon. This is not necessarily true, however, because physical plants (for example, machinery) change, and fixed costs become variable over time. At some point in time the fixed-variable cost relationships of producing saw logs, feed grains, or cattle may change, and the derived marginal values applied to yield increases should reflect the changed cost relationship. Unfortunately, it is very difficult to predict when, or how, such changes will occur.

It was also assumed that the *relative* position of the resource values would not change in the future. This is less than certain. Changes in technology, resource availability, and consumer demand all affect resource values. Among commodity resources, experience suggests that timber values will gain relative to forage and water values (O'Connell 1972). It would have been as realistic to assume some specified change in the relative position of the value of timber to management costs and to the value of water and forage. Such a change was recently incorporated into a Forest Service Environmental Impact Statement on roadless and undeveloped areas (USDA FS 1973). Experience also suggests that the value of noncommodity (amenity) resources will increase relative to that of commodity resources (see Krutilla 1967). Because of the difficulty of choosing the appropriate change in the relative position of resource values, a sensitivity analysis showing how the evaluation results are affected by changes in values is often useful.

These significant time-related economic concerns bring into question the validity of long planning horizons. While the 120-year horizon was used here in order to show results for a full timber rotation period, 120 years is far too long for accurate economic projections. The problems of inaccurate projections are, however, notably mitigated by discounting. A 7 percent discount rate, as used here (see tables 3, 4, 5, and 7), weights costs and returns received now twice as heavily as those received 10 years from now, and four times as heavily as those received 20 years from now. Thus, even though costs and benefits were calculated for the 120-year horizon, only activities and events in the earlier years have significant bearing on the dollar results (present values or annuities) presented.

Summarizing physical response projections is a different situation. When yields and impacts are presented on an average annual basis (see tables 2, 4, 5, and 7), equal weight is given to all years in the planning horizon, even though 120-year projections are certainly less valid than, say, 20-year projections. Perhaps the best way to deal with the planning horizon question in this case is to present results for shorter horizons (such as 20 to 40 years) as well as for a longer, rotation-length horizon.

Risk

One final concern in planning is that of risk. Differences in risk between alternatives should be considered. The two main categories of risk relevant to the Thomas Creek analysis are fire and timber reproduction.

All harvest alternatives would increase risk of wildfire somewhat over alternative VN unless the extra fuel created were cleaned up. There is also the risk with alternative VN, however, that wildfire will destroy much of the timber before some future decision is made to harvest the mature timber. In this case, the advantage of alternative VN in "keeping options open" would certainly be nullified.

Alternatives WT and WL and their extensions created openings which are planted to assure regeneration. While there is little doubt that mixed conifer species will eventually reinhabit these openings, there is some risk in assuming that regeneration will proceed as promptly as planned.

Conclusions

A framework for analyzing alternatives in forest management has been presented, using South Thomas Creek as an example. Because of the nature of Thomas Creek, feasible alternatives were limited in scope. The basic approach to the problem of analyzing complex land management alternatives, however, should be similar for other areas.

Explicit evaluation of alternatives has distinct advantages over past methods. First of all, examining alternatives in terms of changes from the existing situation provides a sound mechanism for progressively moving from the status quo. Second, the effort at quantification forces one to be more specific and helps keep value judgments in the realm of the decisionmakers. Also, quite often quantification helps identify a preferable alternative that would otherwise have been overlooked. Third, the consideration of resource values weights the valued resources in terms of society's preferences, a considerable improvement over merely comparing physical quantities. Finally, this framework yields a rather concise presentation of how the alternatives compare, helping the decisionmaker to focus on the salient issues.

Decisionmaking of all kinds is a matter of tradeoffs. What an alternatives analysis provides is an explicit identification of the tradeoffs, in dollars where defendable, and an easy way of isolating and hopefully quantifying the most relevant. In general, decisions based on such analyses are much less likely to be misunderstood or opposed than decisions based on less rigorous analysis and less objective criteria.

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The multiple use doctrine is part of the guiding philosophy of the Forest Service, but its effective implementation is a difficult task. This paper presents an application of the multiple use principle using economic analysis to evaluate management alternatives on a mixed conifer watershed. Physical yields of sawtimber, pulpwood, water, and forage, and effects on wildlife habitat and esthetics are estimated for six alternatives reflecting a variety of management emphases. Where possible, yields and costs of the alternatives are valued in dollars. The analysis is presented in a form that facilitates explicit identification of tradeoffs, in dollars where possible, and provides an easy way of isolating, and in most cases quantifying, the most relevant tradeoffs.

Keywords: Multiple use management, mixed conifer watershed, economic analysis.

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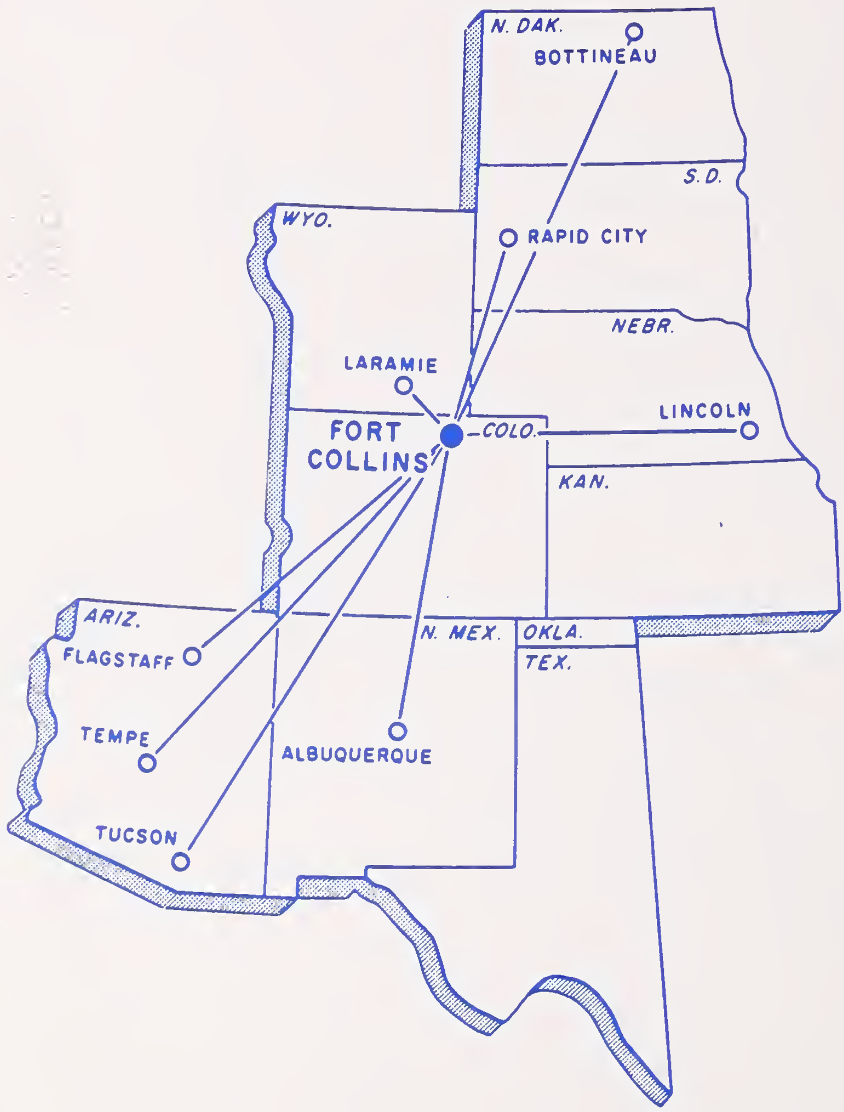
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