United States Department of Agriculture

Forest Service

Pacific Southwest Forest and Range Experiment Station

Research Paper PSW-149

Roadless Area-Intensive Management Tradeoffs on the Sierra National Forest, California

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ACKNOWLEDGMENTS

We thank K. Norman Johnson, Utah State University, for developing the mathematical programing model used in this study and for preparing the data and making the computer runs. We are also indebted to Klaus Barber, Pacific Southwest Region, Forest Service, U.S. Department of Agriculture, and John Kruse, Sierra National Forest, for compiling and preparing data. Without their firsthand knowledge of the Sierra National Forest, the study would not have been possible.

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Pacific Southwest Forest and Range Experiment Station
P.O. Box 245
Berkeley, California 94701

December 1979

IN BRIEF

Hrubes, Robert J., Kent P. Connaughton, and Robert W. Sassaman. 1979. **Roadless area-intensive management tradeoffs on the Sierra National Forest, California.** Res. Paper PSW-149, 11 p., Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Retrieval Terms: wilderness areas, roadless areas, allocations, timber management, timber supply, alternatives, Sierra National Forest, simulation, statistical methods.

Because of increasing debate over the use of National Forest lands, a proposal has been made to help resolve the conflict between wilderness allocation and timber management by reallocating roadbuilding funds in roadless areas to investments in more intensive timber management on roaded lands. Roadless areas thus precluded from planned future development would be logical candidates for wilderness designation; the associated loss in timber harvests would be compensated by anticipated yields resulting from investments in more intensive timber management. The research described herein tested this tradeoff hypothesis on the Sierra National Forest of northern California.

The harvest levels for the reallocation alternatives are based upon specific assumptions. Thus, the calculated harvest levels reported should not be considered as what could now be obtained from the Sierra National Forest, but rather what might be reached if the stated assumptions are satisfied.

Results of this research indicate that programed timber harvest levels cannot be maintained when roadless areas are withdrawn and funds are reallocated. Approximately one half of the loss in programed harvest can be made up. Additional investments in intensive timber management fail to make up the entire harvest loss, partly because of other restrictions imposed in the harvest scheduling process. The nondeclining, even-flow constraint as well as environmental considerations, realized through various harvesting constraints, serve to limit the efficacy of additional investment funds. However, actual (versus programed) harvest effects would not be as significant, since the recent selling level in the Sierra National Forest has been below the programed harvest level.

Consistent with the harvest effects on the Sierra National Forest, revenues to the Forest Service, county payments, present net worth of the timber harvest plan, and regional timber-based employment decline when the roadless areas are withdrawn from the timber management base.

Major nontimber and environmental tradeoffs are also anticipated if this plan were implemented. Fish, wildlife, and visual resources would benefit in roadless areas. Game species would benefit in roaded areas. Conversely, adverse effects on fish, visual resources, and developed and dispersed recreation potential would occur in the roaded areas; game species and road-related dispersed recreation would be adversely affected in the roadless areas.

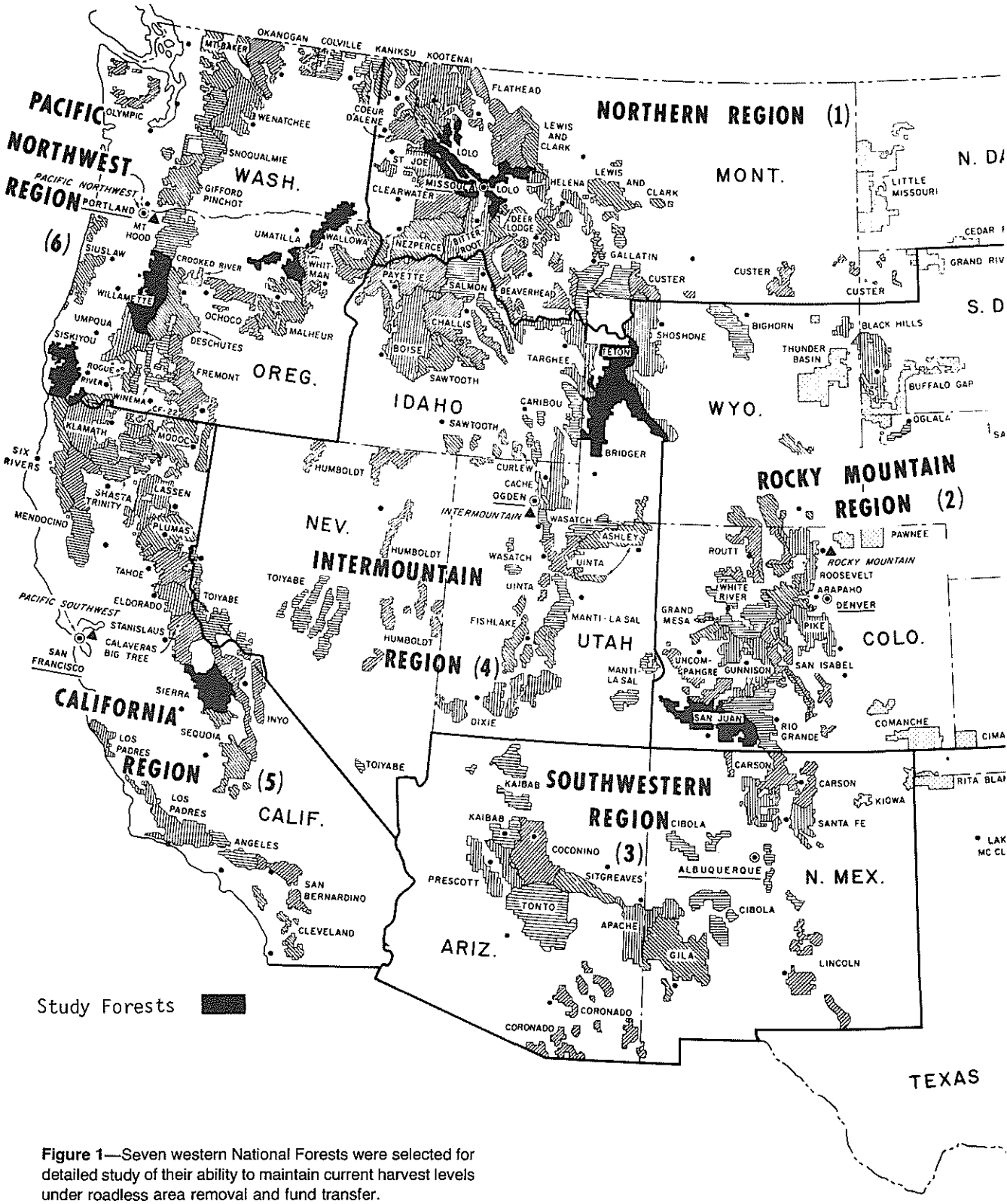

Figure 1—Seven western National Forests were selected for detailed study of their ability to maintain current harvest levels under roadless area removal and fund transfer.

Recent debate over the USDA Forest Service's Roadless Area Review and Evaluation (RARE II) and the resulting administration proposals for wilderness designation make obvious that no simple solution exists to the disposition of remaining roadless areas within the National Forest System. Heightened political sensitivity is due perhaps to the fear that significant costs will be incurred, regardless of the use allocation of these roadless areas, for either wilderness or commodity production. Because of these costs, wilderness use and commodity production on wildlands invariably are considered within the context of conflict.

A strategy to circumvent or at least to mitigate the severity of conflict would surely help to attain a politically acceptable land-use allocation of the remaining roadless areas. Such a strategy must aim at either lessening the allocation costs for resource development—cost in terms of destroying de facto wilderness—or offsetting the opportunity costs of wilderness allocation—resource flows foregone. The first option, reducing the wilderness costs of resource development, appears infeasible unless the term wilderness is drastically redefined. In the present context, the wilderness potential is essentially destroyed when land is developed for commodity production.

What, then, is the potential of the second option—offsetting opportunity costs of wilderness allocation? In 1977, Kutay[1] designed a strategy to negate the effects of wilderness allocation on timber harvest levels. He proposed that road construction funds that would have been used in the roadless areas be reallocated to intensive timber management funds for areas already roaded. The goal was to compensate for the loss of timber flows from roadless areas allocated to wilderness through intensified timber management on already roaded areas.

A study team comprised of USDA Forest Service economists and planning personnel was organized to test the feasibility and consequences of Kutay's proposal. The team selected seven western National Forests for detailed study, testing each for its ability to maintain current harvest levels under roadless area removal and fund transfer *(fig. 1)*. The test was made within the context of existing Forest Service policies and procedures; results were later published in a summary document (Fight and others 1978). This paper examines in more detail the procedures and results of that study as related to one of the seven test sites, the Sierra National Forest, in the Pacific Southwest Region.

THE TEST FOREST

Several criteria were used to select the test forest. First, timber data suitable for use in the timber harvest scheduling model used in the study had to be available. Second, a significant portion of its commercial forest land had to be in roadless area classification. Third, it was desirable that the road costs, land productivity, and multiple-use restrictions on the test forest be as representative of the regional average as possible. In the Pacific Southwest Region, the Sierra National Forest best met these criteria.

The Sierra National Forest lies on the west side of the Sierra Nevada, in California, between the crest and the foothills adjacent to the south side of Yosemite National Park. Mixed conifer is the major timber type. Other types include ponderosa pine, red fir, and subalpine types. Most of the productive forest land lies at elevations ranging from 4000 to 6000 feet. The Forest contains about 1.3 million acres of National Forest land, of which 28 percent was considered regulated commercial forest land for purposes of this study. The National Forest acreage in roadless areas for this study was about 352,000 acres, of which 14 percent was considered regulated commercial forest land. The average volume of chargeable harvest[2] for the past decade was about 20 million cubic feet per year.

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[1]Kutay, Kurt. April 1977. Oregon economic impact assessment of proposed wilderness legislation. Unpublished. On file Pacific Northwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Portland, Oreg.

[2]Chargeable harvest is that portion of the annual harvest volume credited to the programed harvest. Examples of nonchargeable harvests are those harvests from the unregulated component.

GENERAL APPROACH

The general approach for testing the feasibility of the tradeoff strategy involved simulating timber harvest schedules under alternative land base and funding level assumptions. For each alternative, both programed harvest and potential yield for timber were calculated.[3] Timber harvest schedules were formulated with a linear programing model, Model II, developed by K. Norman Johnson.[4] As with actual harvest schedules developed in the Sierra National Forest planning process, Model II was programed to maximize the first decade harvest level subject to a nondeclining even-flow constraint. That is, harvests are allowed to rise over time, but not fall.

In terms of relevance to the hypothesis, an important phase of the harvest scheduling procedure is establishing additional programing constraints that reflect or are induced by environmental considerations. Land management planners have found that in the absence of these environmentally induced constraints, optimization models such as Model II tend to schedule concentrated harvests within a small geographic area over a relatively short time period. Obviously, such concentrated harvesting activity could result in unacceptably high environmental costs. Thus, planners have found it necessary to impose additional constraints in the scheduling process in order to limit the degree of spatial concentration of harvesting activities. For the Sierra National Forest scheduling runs, restrictions were imposed on the maximum allowable clearcut acres per decade, in the standard and marginal components separately. In addition, restrictions were imposed on the number of regeneration harvest acres by standard and marginal components.

Environmental considerations are also reflected implicitly in preparing input for the mathematical harvest scheduling model. The definition of management alternatives and working-group land-class condition-class combinations can implicitly reflect environmental considerations (see the user's manual referenced in footnote 4 for a discussion of these concepts). The management alternatives and class combinations, in part, form the structure of the mathematical representation of the "real world." As such, their definitions can influence the optimal schedule.

For comparison, a base alternative was developed, the intention of which was to simulate the actual timber harvest schedule for the test forest under current management directions. To directly address the feasibility of the tradeoff strategy, a reallocation alternative was constructed, entailing the removal of roadless areas from the timber management land base and transferring subsequent savings in road construction costs to investments in more intensive timber management. Additional alternatives were also constructed that involved roadless area removals without budget reallocation and 50 percent roadless area removal *(table 1)*.

ALTERNATIVES

Base Alternative

The base alternative incorporated current forest plans for timber management, road construction, multiple-use constraints, and funding levels. Under the base alternative, the existing roadless areas are programed for eventual road construction and timber harvesting. Forest engineers estimated that 196 miles of road construction would be required to carry out the base alternative in roadless areas. The base alternative included the standard, special, and marginal components of the regulated forest base amounting to 357,000 acres. Management of these acres consisted of stocking the nonstocked (cut-over) backlog, reforestation, stocking level control, thinning, and final harvests. The final harvest was programed under clearcut, shelterwood, and selection silvicultural systems, as appropriate, to meet silvicultural and multiple-use objectives of the forest.

The definition of intensive timber management activities is central to the study, since these activities directly determine the feasibility of the tradeoff strategy. A wide spectrum of management actions fall within the limits of intensive timber management—the

[3]Potential yield is a ceiling on the volume of timber that may be sold from a forest for the next 10 years. The programed harvest for a forest is the part of the potential yield that is scheduled for sale during a specific year.

[4]Johnson, K. Norman, and Daniel D. Jones. 1979. Timber Harvest Scheduling Model—User's Guide and Operations Manual. Unpublished. On file Forest Serv., U.S. Dep. Agric., Timber Management Staff, Fort Collins, Colo.

Table 1—*Summary of alternatives*

Alternative	Roadless areas available for timber management	Funds reallocated to more intensive timber management
1. Base	All	No
2. 50 percent out	Half	No
3. 50 percent out—reallocation	Half	Yes
4. 100 percent out	None	No
5. 100 percent out—reallocation	None	Yes

planting of genetically improved growing stock, irrigation, fertilization, repetitive artificial regeneration, and intensive stand grooming to name a few. While many management techniques are used to improve the quantity and quality of yields, quantifiable effects of most intensive management activities are not available because of the required observation time.

Long range mathematical modeling nevertheless requires quantified estimates. This study uses a conservative approach, assuming the net effect of intensive management on a stand to be a one-decade acceleration in the time required to attain a stocking level sufficient to allow commercial thinning. The intensive management activities used to bring about this acceleration are assumed to be the planting of genetically improved growing stock and a greater use of precommercial thinning and release. Intensive timber management practices such as fertilization and irrigation were not considered because quantifiable results of those practices would require even greater assumptions.

No-Reallocation Alternative

The no-reallocation alternative consisted simply of removing all roadless areas from the timber harvest land base without compensatory additions to the budget on the remaining land area. The alternative measures the timber supply effects of simply allocating all roadless areas within the forest to wilderness or any other exclusionary classification. The difference in 10-year harvests between the no-reallocation alternative and the base alternative serves as a reasonable measure of the harvest consequences of noncompensatory wilderness allocation.

Reallocation Alternative

Comparing the reallocation alternative and base alternative harvest schedules determines the extent to which the tradeoff strategy can offset the timber opportunity cost of wilderness allocation. The reallocation alternative differs from the alternative in only one area: the budget for intensive timber management in the reallocation alternative was increased by the amount of money that would have been spent roading the roadless areas on a decade-by-decade basis. The increased budget results in the availability of genetically improved growing stocks, as discussed above.

The amount of money available was determined by estimating costs for road construction, reconstruction, and maintenance necessary to fully develop the roadless areas. The amount to be reallocated was equal to the costs avoided by not developing roadless areas, less any increased roading costs incurred in the currently accessible areas as a result of not developing the roadless areas. No increased costs were projected.

The cost saving consisted of two components: 1) purchaser credits generated from timber sale receipts in the roadless areas and 2) appropriated funds. If roadless areas are not developed, purchaser credits are not generated; therefore, this saving then is not available money. This fact does not influence the study results, but it does mean that reallocation alternatives could be implemented only if Congress appropriated additional money for intensive management.

Partial Allocation Alternatives

Timber harvest schedules were also designated for a withdrawal of 50 percent of the roadless areas. To the extent that a wilderness allocation of all roadless areas in a National Forest may not be politically feasible, the partial allocation alternatives should be of interest to forest planners. The partial allocation alternatives also support the observation that no linear relationship exists between the size of roadless area withdrawal and the magnitude of timber harvest loss.

Selecting half of the roadless area for removal was based on:

- Quality of the area for wilderness
- Public concern for the area as wilderness
- Congressional and administrative interest
- Manageability
- Direct costs and opportunity costs of permanent roadless designation

The intention was to identify that half of the roadless area in the forest that would be the most likely candidate for wilderness allocation, in the judgment of Forest Service planners.

RESULTS

Effects on Timber Harvest

The harvest levels for the reallocation alternatives reported *(fig. 2)* are based partly on two specific assumptions. Therefore, the harvest levels should not be considered as what could now be obtained from the Sierra National Forest, but rather what might be reached if these two assumptions are satisfied.

One assumption is that funds saved by not roading certain areas would be spent on planting genetically improved growing stock. At present—and possibly for the next decade or more—planting such stock is not a viable widescale practice in California. Another assumption is that there would be "100 percent efficiency" in terms of actual harvest levels being equal to calculated programed harvest levels for both the standard and marginal components; that is, the calculated programed harvest levels will actually be attained. Although 100-percent efficiency may be a desirable goal in the long run, actual efficiency levels, according to the Sierra National Forest, have been 89 percent for the standard component and 30 percent for the marginal component. The *appendix* illustrates the estimated harvest levels based on the actual efficiency levels and the absence of the two specific assumptions.

We emphasize that the results reported *(fig. 2)* are not obtainable under current conditions. But by removing the two specific assumptions from the analysis—especially the second one—there would no longer be any tradeoff strategy to be examined.

Two major conclusions on harvest impact are apparent, nevertheless, from the alternative levels *(fig. 2)*. First, it is not possible to maintain the programed harvest on the Sierra National Forest if roadless areas are withdrawn and funds are reallocated. Only about one half of the loss can be made up through more intensified management. Second, the recent selling level of the Sierra National Forest has been considerably below the programed harvest level. As such, the results of this study indicate that it may be possible to maintain the recent selling level under a strategy of roadless area withdrawal and fund reallocation.

However, an important warning about the general conclusions bears mentioning. The inability to make up the loss resulting from roadless area withdrawal may be a valid conclusion only within the context of the constraints presently imposed on the Sierra National Forest timber harvest scheduling process. The most important constraints are nondeclining, even-flow, environmentally induced restrictions and available intensive management silvicultural practices.

The Model II scheduling runs reveal that several of the environmentally induced maximum clearcut and regeneration harvest restrictions were indeed binding; that is, these restrictions did limit the harvest level, explaining in part the inability to maintain the "pre-roadless area removal" programed harvest level through the allocation of more investment funds. The nondeclining yield constraint was also binding. The effect of a narrowly defined spectrum of available intensive management opportunities cannot be deduced from the Model II runs.

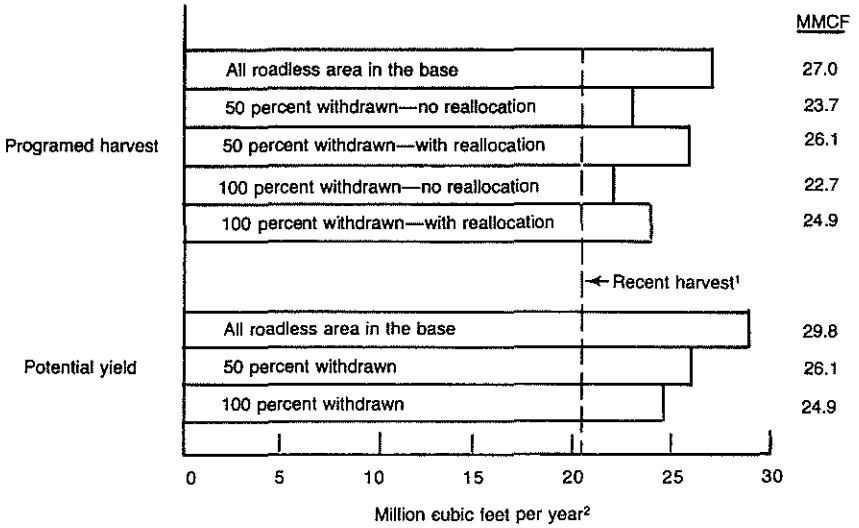

Figure 2—Alternative harvest levels, Sierra National Forest

[1] The recent harvest is less than the base programed harvest primarily because of inadequate financing of the timber sale program.

[2] Harvests can be converted to board feet, local scale, by using the board-foot/cubic-foot ratio 6:3.

Effects on Financial Indices and Employment

The purpose of the financial analysis is to determine the effect of some broad roadless-area allocation alternatives on gross revenues, road costs, silvicultural costs, net revenues, in-lieu-of-tax payments to counties, present net worth, and employment. The county payments and employment results are valuable indicators of the effect of the Sierra National Forest harvest changes on local economies. The present net worth calculations are important components of a national efficiency analysis. Finally, the revenue and cost results are useful indicators of the effect of the alternatives on Forest Service budgets and receipts to the Treasury.

We have no financial results for individual roadless areas. We know, however, that within the broad roadless area aggregates analyzed in this study, individual roadless areas vary tremendously in timber inventory, commercial forest land, productivity, and financial values.

Silvicultural and timber sale preparation and administration costs were supplied by Sierra National Forest personnel *(table 2)*. The higher level of intensive management made possible by reallocation is shown by the increased costs of precommercial thinning, release, and reforestation for the reallocation alternatives. The costs in *table 2* do not include charges for general administration or overhead costs of program administration.

Table 2—*Silvicultural and timber sale preparation and administration costs for the Sierra National Forest*[1]

Cost category and working group	Dollars per acre	
	Base alternative	Reallocation alternative
Precommercial thinning, all timber types	63.50	[2]76.80
Release, all timber types	25.90	[3]31.08
Timber sale preparation and administration, all timber types	[4]27.20	[4]27.20
Reforestation, mixed conifer	135.80	162.96
Reforestation, ponderosa pine	194.00	232.80
Reforestation, red fir	164.30	197.16
Reforestation, subalpine fir	135.80	135.80

[1]Costs include contract preparation, contract costs, materials and labor and contract administration. Costs do not include general administration and program management charges.

[2]Cost for subalpine fir working group reallocation alternatives is $63.50 per acre.

[3]Cost for subalpine fir working group reallocation alternatives is $25.90 per acre.

[4]Dollars per MBF.

Road construction and road cost data were also provided by Sierra National Forest personnel:

Total miles to be constructed in roadless areas	196 miles
Total construction costs	$21,400,000
Cost per mile	$109,000
Construction, by decade	
First	60 percent
Second	25 percent
Third	10 percent
Fourth	5 percent
Roadless miles per section in roadless areas	
Regulated CFL acres	2.5 miles/section
Total National Forest acres	0.4 mile/section
Reconstruction cost per mile	$25,000
Reconstruction cycle	60 years
Maintenance costs per mile per year	$450

The road construction mileage and costs would be necessary to support the base programed harvest. Reconstruction and maintenance costs were also included in the financial calculations.

Two assumptions about future costs were used in the analysis. First, future real costs for all cost items would remain constant at the levels specified by the Sierra National Forest. Second, costs for labor intensive practices (reforestation, precommercial thinning, and timber sale preparation, and administration) would increase to the year 2020 at the same rate as real per capita income in California (U.S. Water Resources Council 1974). Other cost items were assumed constant. After 2020, costs for labor intensive practices are assumed constant at their 2020 levels.

Stumpage prices for each working group in the standard component are shown in *table 3*. Prices for the marginal component were estimated to be $35 per one thousand board feet lower than the prices for the corresponding working group in the standard component. Quality differences and logging and hauling cost differences account for the lower prices on the marginal component. All stumpage prices are high bid, or the price which one would observe if the road system were in place.

Table 3—*High bid stumpage prices for 1977, by working group and land class, Sierra National Forest*

Working group	Land class	
	Standard	Marginal
	Dollars	
Mixed conifer	99.81	64.81
Ponderosa pine	121.49	86.49
Red fir	36.11	1.11
Subalpine	15.87	—

Three assumptions were made about future stumpage prices: 1) prices would remain constant at the current level reported for the Sierra National Forest; 2) prices would follow trends projected by an early version of the Timber Assessment Softwood Market Model,[5] assuming that Forest Service harvest levels in the Pacific Southwest Region would not be affected by roadless area withdrawals; and 3) prices would follow trends projected by the Timber Assessment Softwood Market Model, assuming that Forest Service harvest levels in the Pacific Southwest Region would be affected by roadless area withdrawals in the same proportion as the harvest change for each alternative on the Sierra National Forest. Prices for the latter two projections increased at an average annual compound growth rate of 2.1 percent to the year 2020, and were constant thereafter.

Effects on employment were estimated with an input-output model recently developed for the Sierra National Forest and the immediately surrounding area.[6] For this 12-sector model, industry gross output figures were established through direct survey. Interindustry transaction figures were based on national breakdowns and available survey information.

Harvest level changes were assumed to translate directly and fully into changes in sectoral sales to final demand. Private sector harvest levels were assumed not to be influenced by Sierra National Forest harvests. Employment effects can be interpreted as deviations from the direct, indirect, and induced employment levels associated with the base programed harvest. But since the recent selling level has been less than the programed harvest, these employment deviations represent, in part, losses in employment potential and not actual job losses.

Increases in dispersed, nonmotorized, recreation-related employment were not considered in the analysis. It was considered unlikely that the establishment of additional wilderness areas in the Sierra National Forest would have significant impact on that type of employment. Also, no attempt was made to estimate the employment effects of changes in payments to counties.

Revenues, county payments, and employment decline as the roadless areas are withdrawn *(table 4)*.

Table 4—*Four-decade average financial effects and employment effects of withdrawing roadless areas and reallocating funds to intensive management, Sierra National Forest*[1]

Item	Base programed harvest	Change from base when	
		50 percent roadless withdrawn	100 percent roadless withdrawn
Harvest (MMCF/yr)	27.0	−0.9	−2.1
Gross revenue ($1,000,000/yr)	34.2	−1.2	−1.9
Cost of roads ($1,000,000/yr)	—[2]	−0.3	−0.7
Cost of cultural treatments ($1,000,000/yr)	—[2]	−0.1	+0.2
Cost of selling timber ($1,000,000/yr)	—[2]	−0.1	−0.1
Net revenue (Item 2−Items 3, 4, and 5) ($1,000,000/yr)	—[2]	−0.7	−1.4
Payments to counties ($1,000,000/yr)	8.5	−0.3	−0.5
Present net worth for 10 decades at 5 percent ($1,000,000)	—[2]	−0.7	−13.2
Present net worth for 10 decades at 10 percent ($1,000,000)	—[2]	+3.0	0.0
First decade's average annual total employment (person-years)	2,438	−81	−203

[1]Trends in real costs and real stumpage prices with no harvest changes due to roadless area withdrawals on other Region 5 National Forests were used. Because the recent harvest on the Sierra National Forest is less than the programed harvest with all of the roadless area withdrawn, all reductions in revenues and employment represent losses in opportunities for increases rather than reductions from actual recent levels.

[2]Not available.

[5]Adams, Darius M., and Richard W. Haynes. 1978. A preliminary description of the 1980 Timber Assessment Softwood Market Model. Unpublished report. On file Pacific Northwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Portland, Oreg.

[6]Canavan, James J. 1978. Input-output analysis for land management planning. Unpublished report. On file Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Cultural treatment costs, which are higher on a per-acre basis for the reallocation alternatives, increase as all of the roadless areas are withdrawn and decrease if only one half of the roadless areas are withdrawn. Present net worth (PNW) is sensitive to the interest rate. PNW declines if all or one half of the roadless areas are withdrawn and calculations are made with a 5 percent interest rate. PNW increases when one half of the roadless areas are withdrawn and is unchanged when all of the roadless areas are withdrawn and calculations are made with a 10 percent interest rate. The results shown in *table 4* pertain to the assumptions of increasing costs and increasing prices, with prices on the Sierra National Forest assumed to be unaffected by roadless area withdrawals elsewhere in Pacific Southwest Region.

When other cost and price assumptions are used, the results are similar to those reported above, with the exception of present net worth and net revenue. Present net worth increases for both reallocation alternatives and both interest rates when the results are calculated with constant costs and constant revenues *(table 5)*. Increases in net revenue and large increases in present net worth (with both interest rates) are realized when calculations are made with increasing costs and increasing prices that reflect the price effects of proportional harvest changes on other National Forests in the Pacific Southwest Region *(table 6)*.

Table 5—*Four-decade average financial effects and employment effects of withdrawing roadless areas and reallocating funds to intensive management, Sierra National Forest*[1]

Item	Base programed harvest	Change from base when 50 percent roadless withdrawn	Change from base when 100 percent roadless withdrawn
Harvest (MMCF/yr)	27.0	−0.9	−2.1
Gross revenue ($1,000,000/yr)	15.0	−0.4	−0.8
Cost of roads ($1,000,000/yr)	—[2]	−0.3	−0.7
Cost of cultural treatments ($1,000,000/yr)	—[2]	0.0	−0.1
Cost of selling timber ($1,000,000/yr)	—[2]	0.0	−0.1
Net revenue (Item 2−Items 3, 4, and 5) ($1,000,000/yr)	—[2]	−0.1	−0.2
Payments to counties ($1,000,000/yr)	3.7	−0.1	−0.2
Present net worth for 10 decades at 5 percent ($1,000,000)	—[2]	+5.8	+4.1
Present net worth for 10 decades at 10 percent ($1,000,000)	—[2]	+2.9	+0.2

[1]Constant real prices and constant real costs were used.
[2]Not available.

Table 6—*Four-decade average financial effects and employment effects of withdrawing roadless areas and reallocating funds to intensive management, Sierra National Forest*[1]

Item	Base programed harvest	Change from base when 50 percent roadless withdrawn	Change from base when 100 percent roadless withdrawn
Harvest (MMCF/yr)	27.0	−0.9	−2.1
Gross revenue ($1,000,000/yr)	34.2	−0.4	0.0
Cost of roads ($1,000,000/yr)	—[2]	−0.3	−0.7
Cost of cultural treatments ($1,000,000/yr)	—[2]	−0.1	+0.2
Cost of selling timber ($1,000,000/yr)	—[2]	0.0	−0.1
Net revenue (Items 2, 3, 4, and 5) ($1,000,000/yr)	—[2]	+0.1	+0.5
Payments to counties ($1,000,000/yr)	8.5	−0.1	0.0
Present net worth for 10 decades at 5 percent ($1,000,000)	—[2]	+13.6	+20.1
Present net worth for 10 decades at 10 percent ($1,000,000)	—[2]	+9.3	+14.5

[1]Trends in real costs and real prices with proportional harvest changes on other Region 5 National Forests were used.
[2]Not available.

Several factors explain the behavior of present net worth and net revenue. First, there is considerable decade-to-decade variation in gross revenue within and between alternatives which is not due to price increases over time or total harvest changes. Even though the harvest level for each alternative is constant for 10 decades, there is a different mix of working groups, each with its own price, which contributes to the decadal harvests. For example, the first decade harvests for the reallocation alternatives are more heavily concentrated than the base alternative in the high value mixed conifer working group.

The result is that the first decade gross revenues for the reallocation alternatives are higher than the base gross revenue, even though the opposite is true for most ensuing decades. Since present net worth calculations, particularly those with the 10 percent interest rate, weigh first-decade revenues and costs most heavily, present net worth behaves differently than four-decade-average net revenue. Second, the road cost savings of reallocation alternatives are concentrated in the early decades, particularly the first. Present net worth calculations are influenced most significantly by these cost savings because they occur close to the present. Finally, when proportional harvest changes on other National Forests are considered, the price increases due to contraction of harvest elsewhere in the Region are sufficient to curtail drastically the declines in four-decade-average gross revenue. The higher prices even lead to large increases in present net worth. Note that these changes in present net worth are dominated by assumed changes in the rest of the Pacific Southwest Region and are not indicative of land allocation alternatives on the Sierra National Forest alone.

The financial results do not include a complete accounting of all benefits and costs of harvest alternatives. For example, nontimber benefits, such as increased opportunities for wilderness recreation, and nontimber opportunity costs, such as decreased opportunities for developed and roadside recreation, are not included in the financial analysis because defensible estimates of their monetary values are not presently available. Changes in direct management costs of producing nontimber benefits and differences in forest protection costs are also not accounted for. Therefore, financial results must be interpreted with care and considerable attention must be directed to a subjective valuation of the nontimber consequences before one can draw firm conclusions about the economic desirability of a particular alternative.

The financial analysis quantifies the major changes in timber program benefits and costs. The results are useful measures of the impacts of alternatives on local community employment, payments to counties, receipts to the Federal Treasury, and Forest Service timber management budgets under alternative assumptions about the future course of prices and costs. The results are a necessary component of an efficiency analysis; though, as the above discussion suggests, firm conclusions about the efficiency implications of alternatives requires concurrent scrutiny of nontimber consequences.

Effects on Nontimber Benefits

Many kinds of tradeoffs are related to the withdrawal of roadless areas from the timber base and reallocation of road funds to intensified timber management on the remaining areas. To demonstrate this point, our analysis dealt with a comparison of the alternative Roadless Area Out—Reallocation (of road construction funds) with the base alternative.

Impacts were estimated with the threshold of concern (TOC) concept (Sassaman 1977) for five decades into the future for each nontimber benefit criterion. Major, minor, and neutral impacts were recognized according to their timing (decades one, two through four, and five+), nature (adverse or beneficial), and, in the case of major adverse impacts, the costs of mitigation.

Major impacts were identified as those exceeding the TOC, which is defined as the amount of impact that would generate one or more of the following effects: (1) create a public expression of concern or interest, (2) change long-term traditional use patterns, (3) require funds substantially in excess of usual planning budget levels to lower impacts to an acceptable level. Though undesirable, major adverse impacts are considered acceptable (within limits) under current interpretation of multiple-use objectives.

Impact estimates were obtained from resource specialists representing various disciplines. Schedules for road construction, intermediate and regeneration harvests, and management activities were provided. Specialists evaluated differences in these data between the base alternative and the reallocation alternative in terms of nontimber benefits and ecosystem criteria. Data for roadless areas and roaded areas were evaluated separately.

Since 1972, all RARE I and II roadless areas—except those included in a completed land use plan—have been closed to timber harvesting, even though they are part of the commercial forest land base. Road construction and timber harvesting have been concen-

trated outside the roadless areas. As a result, adverse environmental impacts are beginning to develop and are in danger of exceeding acceptable levels on many National Forests. Both beneficial and adverse impacts are expected when transferring from the present condition to the base programed harvest; however, our concern is limited to changes expected between the base programed harvest and the reallocation alternative.

Environmental Evaluation Criteria

To identify the physical/environmental impacts of the reallocation alternative vis-a-vis the base alternative, the associated timber harvest schedules were evaluated with regard to the following criteria:

- Water quality: Slope failure associated with timber harvests and roadbuilding activities (road sites, design, construction methods, and maintenance levels) are critical factors affecting quality of managed forest watersheds. Sediment introduced to forest streams largely determines the effect on water quality.
- Water quantity and timing of flow: Effects related to peak flow are more important than total water quality in areas with abundant water. Water quantity would be a significant concern on forest land adjacent to semiarid areas.
- Soil stability: Road construction, timber harvest operations, steepness of terrain, and soil characteristics all affect soil stability. Major problems may result from erosion and mass soil movement, threatening life and property.
- Soil productivity: Soil compaction, affected by frequency of timber harvest and type of machinery used, can be minimized by careful selection of harvesting systems. Similarly, proper handling of forest residues decreases nutrient loss.
- Forage production: On western National Forests, domestic forage production is usually associated with forested ranges utilized during the summer grazing season. Accessibility of the terrain to domestic livestock and the proximity of existing grazing allotments determine the amount of forage grazed.
- Resident cold water fish populations: Water quality and sport fishing pressure directly affect fish populations and associated habitats.
- Wildlife populations: Road construction and timber harvests alter the numbers, size, age, arrangement, and species composition of timber stands, thereby affecting wildlife habitats and associated wildlife populations.
- Opportunities for developed recreation: Developed recreation usually involves a relatively high density form of recreation centered around a developed site, such as a campground or boat launch. Frequently, the developed facilities (whether primitive or elaborate) are located at or near natural land features, such as lakes, streams, waterfalls, or scenic vistas that provide an attractive setting.
- Opportunities for road-related dispersed recreation: Opportunities for dispersed recreation related to roads include scattered activities usually not associated with developed areas, such as camping in a camper or trailer at a trail head, undeveloped stream, or lake site.
- Opportunities for dispersed off-road recreation: Opportunities for this type of recreation include backpacking, horseback riding, and certain types of off-road vehicles, and involve a more primitive form of camping not normally associated with developed or road-related dispersed recreation.
- Visual resources: An inverse relationship generally exists between visual resources (opportunities for viewing natural-appearing forest landscapes from a distance) and the total acreage disturbed at any time. Short term, adverse timber harvest affects may be minimized by proper shaping of the harvest unit to the natural characteristics of the land.
- Air quality: Burning slash produces air pollutants that directly affect air quality on a short-term, seasonal basis. Smoke management plans to overcome this problem include increased utilization and conversion of overmature forests to younger, less defective stands, thus reducing the need for burning slash.
- Mineral and energy development opportunities: Efficient development of mineral and energy resources are directly related to road accessibility.

Findings on Environmental Impacts

If the reallocation alternative were adopted in place of the base alternative on the Sierra National Forest, timber harvests would continue to be concentrated in roaded areas. Roadbuilding or road-related timber harvests would not occur in roadless areas. Given this assumption, there are anticipated to be seven major adverse and four major beneficial nontimber or environmental effects *(table 7)*. Five effects would involve roadless areas; six would involve roaded areas. Another 15 minor and 4 neutral effects are anticipated.

Major benefits involve fish and wildlife populations and visual resources. Fish and wildlife benefit by preserving their habitats in roadless areas. Visual resources benefit when landscapes remain undisturbed in the roadless areas.

The major adverse effects involve fish, wildlife, recreation, and visual resources. Fish habitats would be degraded in roaded areas. Conversely, an adverse impact on wildlife game species is expected in the roadless areas from opportunities forgone to increase browse in the roadless areas when they remain unroaded.

All three recreation criteria listed have major adverse impacts associated with them *(table 7)*. Those affecting developed recreation relate to the roaded areas. Those affecting dispersed recreation opportunities associated with roads relate to both roaded and roadless areas. In roaded areas, these effects are associated with increased timber harvest-related traffic and noise. In roadless areas, the effects relate to opportunities forgone to pursue road-related dispersed recreation.

Adverse effects on dispersed recreation opportunities away from roads would occur in the roaded areas of the Sierra National Forest as a result of decreased acreage in the roaded areas that are compatible to this type of dispersed recreation.

The last major adverse effect involves visual resources in the road areas that are more intensively managed to promote timber production. The visual resources may be adversely affected as the total area of naturally appearing forest landscapes declines.

Table 7—*Estimated effects of withdrawing roadless areas and intensifying timber management on remaining land in the Sierra National Forest*[1]

Resource	Assessment of Effects				
	Beneficial		Neutral	Adverse	
	Major	Minor	No change from base	Minor	Major[2]
Water quality		R		A	
Water quantity		A	R		
Water flow		A	R		
Soil stability		R		A	
Soil productivity		R		A	
Forage production (domestic)		A		R	
Fish populations (residential)	R				A
Wildlife populations (game species)	A				R
Wildlife populations (threatened and endangered species)	R	A			
Recreation opportunities (developed)				R	A
Opportunities for dispersed recreation related to roads					AR
Opportunities for dispersed recreation away from roads		R			A
Visual resources	R				A
Air quality		R	A		
Mineral and energy development			A	R	

[1]R = Roadless areas, A = "Accessible" areas.

[2]Major adverse effects, while undesirable, are within limits considered acceptable under current interpretation of multiple use objectives.

CONCLUSIONS

This study set out to answer the question: Can the programed harvest level on the Sierra National Forest be maintained when roadless areas are removed from future harvests and road construction funds are reallocated to intensive timber management? The results show that—given the study assumptions—the answer is no. Spending more money in timber management is not a viable option for maintaining programed harvest levels in the face of a declining land base. Why is this strategy, so commonly assumed to be viable, insufficient? Study results indicate that factors other than available investment funds also serve to limit the programed harvest level on the Sierra National Forest. Scheduling restrictions such as clearcut dispersion requirements and nondeclining even-flow may play a greater role in shaping programed harvest levels than the money available for investment in timber management. In general, these scheduling restrictions are induced from environmental and/or multiple-use considerations.

The study also found that while programed harvest levels cannot be maintained, it is possible to maintain the current actual harvest level on the Sierra National Forest. The implication of this finding is that the effect of the land withdrawal and investment reallocation is best described as a loss in the *capacity* of the Sierra National Forest to offer timber on the market within the limits imposed by environmental and multiple-use considerations.

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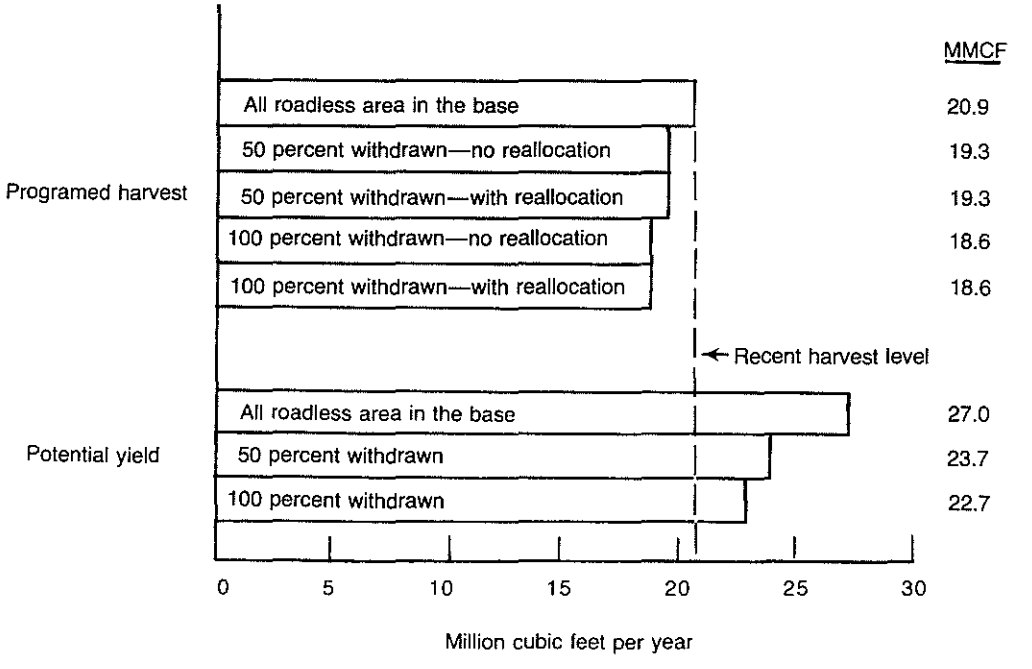
APPENDIX

Harvest levels when genetically improved growing stock is not assumed to be available and efficiency levels are 89 percent for the standard component and 30 percent for the marginal component (million ft³/yr):



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Hrubes, Robert J., Kent P. Connaughton, and Robert W. Sassaman.
1979. **Roadless area-intensive management tradeoffs on the Sierra National Forest, California.** Res. Paper PSW-149, 11 p. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

This hypothesis was tested by a linear programing model: Roadless areas on the Sierra National Forest precluded from planned future development would be candidates for wilderness designation, and the associated loss in present and future timber harvests could be offset by investing in more intensive management. The results of this simulation test suggest that levels of programed harvesting cannot be maintained when roadless areas are withdrawn and funds are reallocated for intensive management on other areas. Additional tradeoffs were found in estimating the effects on fish, wildlife, recreation, and visual resources.

Retrieval Terms: wilderness areas, roadless areas, allocations, timber management, timber supply, alternatives, Sierra National Forest, simulation, statistical methods.

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