An estimation of opportunity cost for sustainable ecosystems

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SUMMARY

The objective of this study was to provide a method for estimating the opportunity cost of meeting selected sustainable ecosystem objectives on the Olympic National Forest in Washington State. The Forest Vegetation Simulator (FVS) was used to simulate several silvicultural management regimes. Soil expectation values (SEVs) were calculated using the FVS system and CHEAPO II, a silvicultural and economic analysis system. The SEVs were used first to evaluate different FVS structured silvicultural alternatives for a 200-year rotation period and then to determine the opportunity cost of managing a sustainable ecosystem. This approach resulted in a shift of emphasis from the traditional approach of managing the forest for timber production to managing the forest ecosystem. The findings indicate reduced revenue from harvesting; the opportunity cost of maintaining certain ecosystem features was US$ 43 023/ha. This estimate would be lower after deducting the difference in harvesting costs between alternatives. This work is the first attempt to use and adapt the FVS system to long-rotation forestry. The methodology used here can be used to estimate sustainable ecosystem objectives on any forested land.

Keywords: Sustainable ecosystem, opportunity cost, simulation.

INTRODUCTION

Sustaining ecosystems is a key objective in the ecosystem approach to management that the United States Department of Agriculture (USDA) Forest Service has embraced for National Forest System lands. This approach shifts the emphasis from managing the forest for timber production to managing the entire forest ecosystem. The traditional approach altered many habitats, and consequently many species have been endangered (2). Ecosystem management is, in part, an attempt to save for future generations plant and animal species that are declining as a result of ecosystem modification. The primary objective of ecosystem management is to sustain the integrity of ecosystems while providing goods and services to an increasingly diverse set of public interests.

On 13 April 1994. President Clinton convened a Forest Conference in Portland. Oregon to address the human and environmental needs served by the Federal forests of the Pacific Northwest and northern California. The President directed his Cabinet to craft a balanced. comprehensive, and long-term policy for the management of 10 million ha of public lands. On 1 July 1994, President Clinton announced his proposed “Forest Plan for a Sustainable Economy and a Sustainable Environment.” This Forest Plan emphasizes the management of various land and resource allocations to achieve multiple-use

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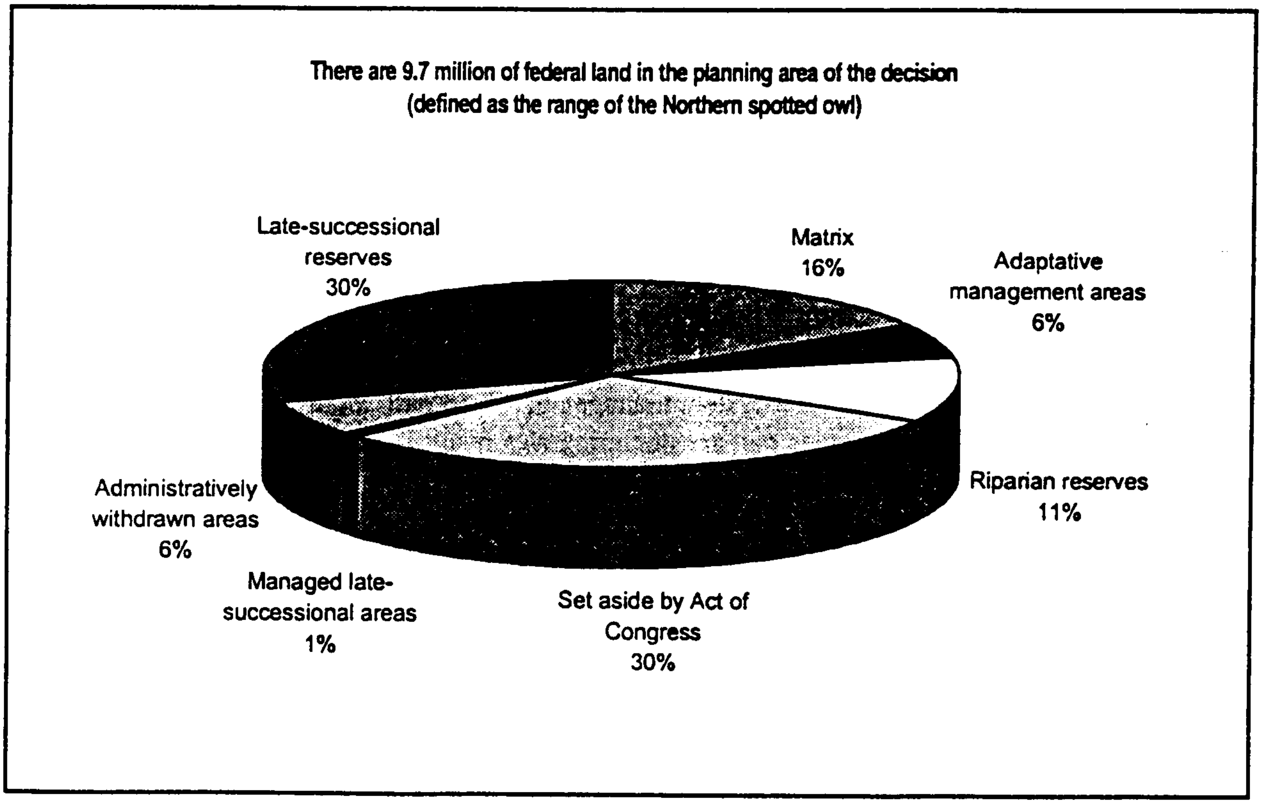
objectives in an economically efficient and environmentally sound manner. The decision stipulated the use of a sustainable forest management approach. The planning area was defined as the Federally administered lands within the range of the northern spotted owl (USDA Forest Service 1990; USDA Forest Service, Department of Interior Bureau of Land Management 1994). There are 10 million ha of Forest Service, Bureau of Land Management (BLM), and other Federally administered lands within the range of the northern spotted owl. The land was allocated to seven different land designations (Figure 1), each with its own land management objectives.

This paper evaluates certain costs associated with achieving sustainable ecosystem management on the Olympic National Forest, using silvicultural projection modelling as an analytical tool. The ecosystem management objective was maintenance of habitat for three species: the northern spotted owl, pileated woodpecker, and marbled murrelet. The ecological processes that support certain ecosystem features or endangered species include natural changes that develop and maintain late-successional and old-growth forest ecosystems (Franklin *et al.* 1981). To provide discounted returns of specific intrinsic value demands of the public, the management approach being considered for the Olympic National Forest is harvest scheduling using the Forest Vegetation Simulator (FVS), a system of silvicultural and economic modelling (USDA Forest Service 1993). There is growing consensus that sustainable ecosystem management requires the synthesis of both ecological and economic objectives. There is also recognition that long-term economic health depends upon environmental health and vice versa.

Figure 1. Land structure



PURPOSE OF STUDY

The purpose of this study was to provide a method for evaluating the opportunity cost of meeting selected sustainable ecosystem management objectives. The approach was twofold: (1) determination of the opportunity cost of maintaining certain ecosystem features to achieve sustainability; and (2) determination of the capability of the FVS system to estimate opportunity costs.

Opportunity cost of a management choice is defined as the additional value that could be obtained with the most highly valued of the rejected alternatives or opportunities. In the economic analysis of forest planning, opportunity costs can be measured by differences in the soil expectation value (SEV) associated with various alternatives. Alternatives with lower SEVs may be required by legal interpretations of existing laws such as the National Forest Management Act to manage for an endangered species, like the marbled murrelet on the Olympic National Forest. The SEV is a measure of present net value of land devoted to timber production in perpetuity. Opportunity costs are measured by the change in SEV associated with changes in the output of priced resources, such as timber, and they can be used to assess the relative value traded off to produce particular unpriced outputs.

Simulations of 200-year rotations were used to determine whether the FVS system can estimate opportunity costs. SEVs were estimated for different sustainable ecosystem management regimes or harvest scheduling plans on the Olympic National Forest and were compared to SEV estimates from other studies.

STATEMENT OF PROBLEM

One of the major objectives of forest management continues to be to produce wood. In fact, this is often the dominant goal for commercial forests. On public forests, an adequate balance between timber, recreation, water, and wildlife is almost always required. The non-timber goals of sustainability and ecosystem management constrain timber production by reducing harvest levels. In many cases, such as in the western United States, there are legal constraints to harvesting, which have often resulted from organized attempts to preserve ecosystems and associated wildlife. However, within these constraints, it is still desirable to organize timber production in the best possible way. Silvicultural simulation models have been helpful with this task in the past. The research question that is being explored here is: What would be the value or opportunity cost of sustaining certain features of ecosystems if sustaining these features requires that the rotation schedules shift from 100 to 200 years and that some timber values be foregone?

VALUE CONCEPTS

The many value concepts recognized by economists include both market (priced) and non-market (unpriced) values. Non-market values fail into several categories: consumptive, non-consumptive, existence, bequest, and option values. Over the years, economists have attempted to find methodologies for identifying society's preference for unpriced values. Non-market values are associated with issues as wide-ranging as recreation, water and air quality, old-growth forest, hunting, and preservation of endangered species. Numerous methods have been developed to derive monetary estimates of non-market values. One such method is the opportunity cost method. Growing concerns about nature and the environment have spurred a number of research initiatives in recent years. One is the attempt to assign monetary values to a wide range of environmental goods and services, which would allow for an economic basis for decisions governing resource use to include both priced and unpriced values. Economic analysis is used to help identify what society might have to be prepared to give up to maintain a particular form of intrinsic value, which is defined as a value dealing with the inherent right of other life forms to exist.

METHODOLOGY

The analytical method used in this analysis was that of simulation. It can be applied to many different problems, some of which have nothing to do with forestry or even with management science; nevertheless, simulation was designed (and is used primarily) to solve managerial problems. In fact, simulation was one of the first practical tools devised to tackle complex decision-making problems common to industry, agriculture, and government. The FVS was adapted to perform the task of calculating the SEV of wood products from the Olympic National Forest for long rotation schedules. This was done by taking the 100-year old portion of the Olympic National Forest, specifying a year zero of 1994, and projecting to the year 2194. In 2194, either a clear-cut or regeneration harvest was done. The thinnings and harvest activities were specified within the silvicultural component of the FVS, and SEVs were calculated by CHEAPO II, the economic component of the FVS system. The thinnings or regeneration harvest were planned to occur primarily on Adaptive Management areas. These are areas designed to develop and test new management approaches to integrate and achieve ecological, economic, and other social and community objectives (Figure 1). Nine timber stands were evaluated in this study; the SEV estimates are averages of those stands.

For the purpose of analysis, two management scenarios were developed for the Olympic National Forest. The Base scenario does not attempt to preserve habitat for species requiring old-growth forest. This scenario assumes a clear-cut harvest with commercial thinnings every 30 years from below or above in advance of final harvest. The per-hectare harvest for the Base scenario is 4000 ft^3, 405 ha/year, and the rotation period is 100 years. The Base scenario serves as an approximation of recent forestry practices on National Forests in the Pacific Northwest. The alternate scenario maintains old-growth habitat. It requires 200-year rotations, which conclude in year 200 (i.e., 2194), with commercial thinnings or commercial thinnings plus a regeneration harvest at 200 years rather than a clear-cut. This scenario requires thinnings every 30 years, with an annual harvest of 1.6 million ft^3, 1600 ft^3/ha, 405 ha/year. This represents a 60% decline of the annual harvest level from the Base scenario. The alternate scenario maintains the habitat for the northern spotted owl, pileated woodpecker, and marbled murrelet.

Harvest scheduling algorithms and associated computer programmes have grown in capability and complexity to the point that available documented programmed are costly to execute and require highly trained personnel to formulate problems and interpret results. The FVS was developed to solve simple to moderately complex problems in harvest scheduling. It is primarily designed to simulate harvest on a forest of any age.

MODEL STRUCTURE

The FVS is art individual-tree, distance-independent growth and yield model. The basic FVS model structure contains modules for growing trees, predicting mortality, establishing regeneration, performing management activities, calculating volumes, and producing reports. The FVS provides the user with the ability to calculate estimates of forest stand structure and species composition over time. It also allows the user to quantify this information as necessary in order to ask better questions, and it simplifies complex concepts of forest vegetation into user-defined indices and attributes for describing current and future conditions. One strength of the FVS system is its ability to incorporate local growth-rate data directly into the simulation results. Perhaps the most useful component of the system is the Event Monitor, a stand treatment module. The Event Monitor is used to develop custom variables associated with forest species composition, stand structure, wildlife habitat, and other attributes.

The FVS extensions include **insect and disease models** to simulate growth reductions, damage, and mortality caused by bark beetles, defoliators, dwarf mistletoe, and root disease; a **regeneration and establishment model** to incorporate regeneration into a projection; a **parallel processor** for landscape analysis where multiple stands are projected simultaneously through time incorporating interstand effects; a cover model for simulating the development of understorey vegetation; and an event monitor, which allows management activities to be conditionally scheduled on changing stand conditions.

RESULTS

The analytical results reflect the Base and alternate scenarios. The Base scenario, which does not preserve habitat for species requiring old-growth forest, reflects harvest levels before the President's Forest Plan. These harvest levels are higher than harvest levels in the alternate scenario because there are no environmental constraints. Historical annual harvest levels for the Olympic National Forest were 40 million ft^3 before the Plan. These harvest levels were based on old timber management plans, with a harvest base of about 202000 ha. The annual harvest levels since 1994 have been 1.6 million ft^3. The reduction in harvest levels is primarily due to three factors: (1) allocations for spotted owl habitat, (2) greater emphasis on recreational and environmental amenities, and (3) increased allocations to late-successional and riparian reserves. These factors reduced the harvestable land base from 142 000 ha in 1990 to 20 200 ha in 1994. The economic analysis summary for SEV ($/hectare) showed an average SEV/ha of US$ 68626, without deducting logging costs (Table 1). When a range of logging costs (US$ 426-US$ $1 409/103 ft^3) was included, the SEV ranged from US$ 22 682 to US$ -106 843/ha (Table 3). This reflects the higher harvest level before the President's Plan. The SEV estimates were calculated using average stumpage values expressed in terms of dollars per thousand cubic feet per hectare. The sensitivity analysis was done for the discount rate as well as logging costs. Intuitively, the results show the model to give predicted results. The SEV estimates reflect the average of high, medium, and low site values.

The alternate scenario, which maintains old-growth habitat, reflects harvest levels after the Forest Plan that were constrained as a result of environmental restrictions; less timber was harvested. After the President's Plan, the average SEV (US$/ha) was US$ 25 602 (Table 1). The opportunity cost before adjusting for harvesting costs (US$ 43 023/ha) was derived by taking the difference between the two scenarios. The estimate would be lower after deducting the difference in logging costs between the scenarios. This amount indicates what dollar value per acre is given up when the forest is managed for endangered species. When clear-cuts or regeneration harvest were applied at the end of the rotation, little value was added to the per acre value of the opportunity cost (Table 2). When discounting over 200 years, value-added in year 200 contributed very little to the SEV.

The SEVs reflect that the FVS can simulate 200-year rotations adequately. Table 4 compares SEVs to estimates of the value of endangered species made in other studies.

CONCLUSION

The Forest Service is responsible for determining how to best manage National Forest lands, based on consideration of both public desires and production capabilities. Arriving at this determination is an extremely complex process, more so than ever before because of the legal constraints to management. These constraints have been brought about by various environmental groups through conservative interpretation of the law. Through such legal interpretations, groups have sought to curtail logging on the National Forest System in favour of old growth and protection of animal species. A wide range of public desires and concerns must be interfaced with limited resource production capabilities to develop possible answers to land management questions. Public desires have become widely varied and often compete with each other. For example, one segment of the public may wish to have maximum timber harvest oppotunity, while another may desire that old-growth timber stands be preserved as wildlife habitat. production capabilities are also complicated and are often mutually

Table 1. Summary of soil expectation values (SEVs) ($/ha)[1]

Year	Before President's forest plan	After President's forest plan	Opportunity cost
2194	68 626	25.602	43 023

[1] Discount rate = 4%.

Table 2. Clear-cut SEVs ($/ha)[1]

	Clear-cut without periodic thinnings		Clear-cut with periodic thinnings	
Year	2024	2194	2024	2194
Average	119 761	425	27 772	29 549

[1] Discount rate = 4%
Note: Data may not reflect accurate stocking.

Table 3. SEV sensitivity analysis of individual stand in Base scenario ($/ha)

Year	Before President's forest plan (SEV 4%)	Discount rate		Logging cost	
		2%	8%	Low range ($426)	High range ($1.409)
2194	$85 104	$167 860	$57 548	$22 682	-$106 843

Table 4. Comparison of existence and opportunity cost values for northern spotted owl habitat protection

Study	Resource valued	Value	Comment
Rubin *et al.* (1991)	Northern spotted owl habitat protection	$1 500 million/year	Value to U.S. households of protecting northern spotted owl habitat
Hagen *et al.* (1991)	Northern spotted owl habitat protection	$48-$190/household in Pacific Northwest	81% of U.S. households favor protection of old growth and northern spotted owl
Loomis & White (1996)	Northern spotted owl	$70/household in Pacific Northwest	Willingness to pay estimates per household for protecting northern spotted owl
Howard (in preparation)	Northern spotted owl	$43 023/ha	Opportunity cost estimate before adjusting for logging costs

exclusive. A given land area can provide timber for harvest or old-growth habitat, but not simultaneously. Because of the complexity of both desires and production possibilities, the number of solutions to land management problems is virtually infinite.

The principal public desires relating to management of the Olympic National Forest are embodied in the issues and concerns of the Northwest Forest Plan; i.e., how much timber can be produced while protecting old-growth timber and not endangering animal species? There are other concerns such as scenic quality and unroaded recreational opportunity. Although there is a need to examine a wide range of output mixes. this report is concerned only with harvesting of old-growth timber and maintenance of endangered species. Because of legal restrictions, harvesting of old-growth timber on the Olympic National Forest has been curtailed. The opportunity cost reflects the level of timber values foregone to manage for old-growth and endangered species.

The soil expectation values (SEVs reflect that the Forest Vegetation Simulator (FVS) can simulate 200-year rotations adequately. It is important to note that the SEV estimates are based on projecting what would happen over an idealized hectare, starting with 100-year-old timber stands, with no interaction with what might happen on the surrounding hectares.

The variety of public desires and the complexity of resource production interrelationships combine to make the problem of developing a comprehensive management strategy exceedingly complicated. Fortunately, the means for reducing the problem to manageable proportions are available. Advances in mathematical modelling, such as the FVS system, have made it possible to represent extremely complex problems in a relatively straightforward and understandable form.

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