Richard Haynes, Roger Fight, Eini Lowell, Pacific Northwest Research Station, Forestry Sciences Laboratory, 1221 SW Yamhill St., Suite 200, Portland, Oregon 97205 email: rhaynes@fs.fed.us

Jim Stevens, The Campbell Group, 1 SW Columbia. Suite 1720, Portland, Oregon 97258

and

Jamie Barbour, Pacific Northwest Research Station, Forestry Sciences Laboratory, 1221 SW Yamhill St., Suite 200, Portland, Oregon 97205.

Economic Aspects of Thinning and Harvest for Forest Health Improvement in Eastern Oregon and Washington

Abstract

Management activities that affect forest health and productivity are driven by social, political, and economic processes. Economic feasibility is important in determining the extent to which various treatments proposed to improve forest health will actually be applied. Three socioeconomic institutions create incentives that are important determinants: markets, land uses, and the processing industry. We have extensive information on timber markets, and land uses have been studied at broad scales. Thinning undertaken for forest health improvement provides mostly small-diameter and dead material, but markets for products from small and dead logs are limited. Harvesting and manufacturing costs, resource characteristics, and lumber prices influence the way timber is processed (i.e. what products are made): design of timber sales (i.e. amount and size of raw materials offered) influences harvest cost. Processing equipment that scans logs and processes them according to shape can greatly improve product yield. Decision tools that incorporate these factors into financial evaluations can assist in harvest and other treatment decisions.

Introduction

For much of the past decade, different perspectives on the forest health issue have been acknowledged (see Kolb et al. 1994), but in general the available economics literature tends towards the utilitarian point of view. That is, a forest is considered healthy where biotic and abiotic influences on forests do not threaten management objectives. The purpose of this paper is to summarize and assess the economic and utilization information that influences both the incentives for changes in forest health and productivity conditions and our ability to judge consequences of strategies to cope with natural disturbances. Much of this work deals with forest management in eastern Oregon and Washington. In the economics literature (as elsewhere) this region goes by names such as the Pacific Northwest–eastside (abbreviated PNWE) or the ponderosa pine subregion.

There are a number of management activities done to improve forest health such as the use of prescribed fire, commercial and noncommercial thinning, introduction of insect predators, eradication or control of invasive species, fire suppression, ungulate herbivory, use of pheromones to manage insect populations, and insect and disease suppression. Many of these are treated not in an economic sense but rather in financial terms such as minimizing treatment costs or determining the number of acres to be treated subject to budget limitations. Only a small subset of these activities has been treated in economics research. In this paper we will focus mostly on thinning and harvesting with some treatment of grazing as part of stand management regimes. Much of the discussion will use examples from public timberlands, but many of the results are equally applicable to the private sector.

Economic Incentives that Drive Changes in Forest Health and Productivity (FH&P) Conditions and Treatments

Three types of socioeconomic institutions create incentives that are important determinants of changes in FH&P: markets, land uses, and the processing industry. Local, regional, national, and international markets for forest products determine the types and quantity of material that can be readily harvested without subsidies. The Forest Service has a long history of market assessments that have in the past 25 years focused on the evolution of harvest, resource conditions, and product production (see Haynes 1990, Haynes et al. 1995). There is also extensive information about timber markets in the PNWE. Uniformly defined stumpage prices are continuous from 1932. In general, sawtimber stumpage prices have increased 1.03% per year in real terms (see Haynes 1998 for the 1973 to 1996 data). Recently, however, growth in sawtimber prices has slowed, and there continue to be differences in the trends for sawtimber and chip log prices (see Figure 1; Haynes 1999). Figure 1 also shows the volatility in timber markets where it is not uncommon for stumpage prices to double or fall by half over a period as short as 2 years. Such rapid changes introduce nearly equivalent changes in harvest volumes and area disturbed by harvest.

The second type of economic activity that drives changes in FH&P conditions is changing land uses among timberland acres, especially on private timberlands where these changes mask three underlying issues: changes in land use, type transition following harvest, and shifts in management intensities on private timberlands. These issues have been studied at broader scales (ecoregion and higher) and are summarized by Alig et al.[1] Some of these findings are applicable at lower spatial scales, especially those that relate to private landowner behavior.

The third type of incentive is change in the mix, efficiency, capacity, and spatial distribution of the forest products industry as a function of the expected profitability of converting stumpage into forest products. For the PNWE, much is known about the forest product industries, the functional economies in which they operate, and the potential for market forces to resolve forest health issues. Much of this information is collected and compiled for various assessment efforts such as those done as part of the Resource Planning Act (see Haynes et al. 1995) and the recent Interior Columbia Basin Ecosystem Management Project (see Haynes and Horne 1997). Other market-related information is reported on a regular basis by Warren (1999) and in the periodic mill surveys done for each state (see Ward et al. 1998). As Figure 2 shows, the number of sawmills in eastern Oregon (and Washington) has declined dramatically since 1988. This affects the economic feasibility of utilizing small trees by increasing the transportation cost in those areas that are now further from a sawmill than they used to be.

Much of this information can be summarized quickly as shown in Table 1 (from Haynes et al. 1995). In absolute terms, timber harvests for PNWE peaked at just under 700 million cubic feet (roughly 6 % of total US softwood harvest) in the late 1980s. But in relative terms, the region peaked a decade earlier, and since then most industry expansion has come in other US regions, especially in the

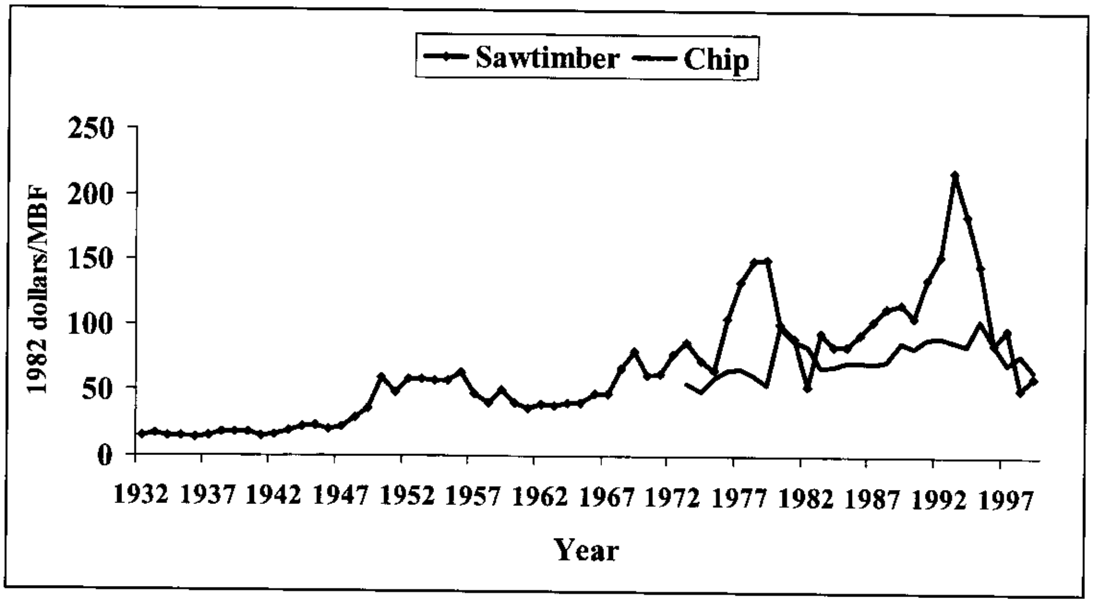

Figure 1. Stumpage prices for sawlogs and chip logs have been subject to wide swings and have recently converged (Haynes 1999).

TABLE 1. Softwood timber harvest in the United States and Pacific Northwest Eastside by land ownership

Item	1952	1962	1970	1976	1986	1991	1998
	Million cubic feet						
Pacific Northwest Eastside							
National Forest	100	232	286	292	378	352	115
Other Public	48	61	97	89	31	26	56
Forest Industry	100	94	117	151	166	100	130
Other private	100	67	48	60	111	116	86
Total	348	454	548	592	686	594	387
United States:							
National Forest	961	1,635	1,918	1,867	2,153	1,789	589
Other Public	403	562	702	822	772	672	575
Forest Industry	2,668	2,144	2,758	3,302	4,043	3,936	4,303
Other private	3,490	2,981	3,317	3,518	4,295	4,335	4,862
Total	7,522	7,322	8,695	9,509	11,263	10,732	10,329
	Percent						
Eastside proportion of total harvest	4.6	6.2	6.3	6.2	6.1	5.5	3.7

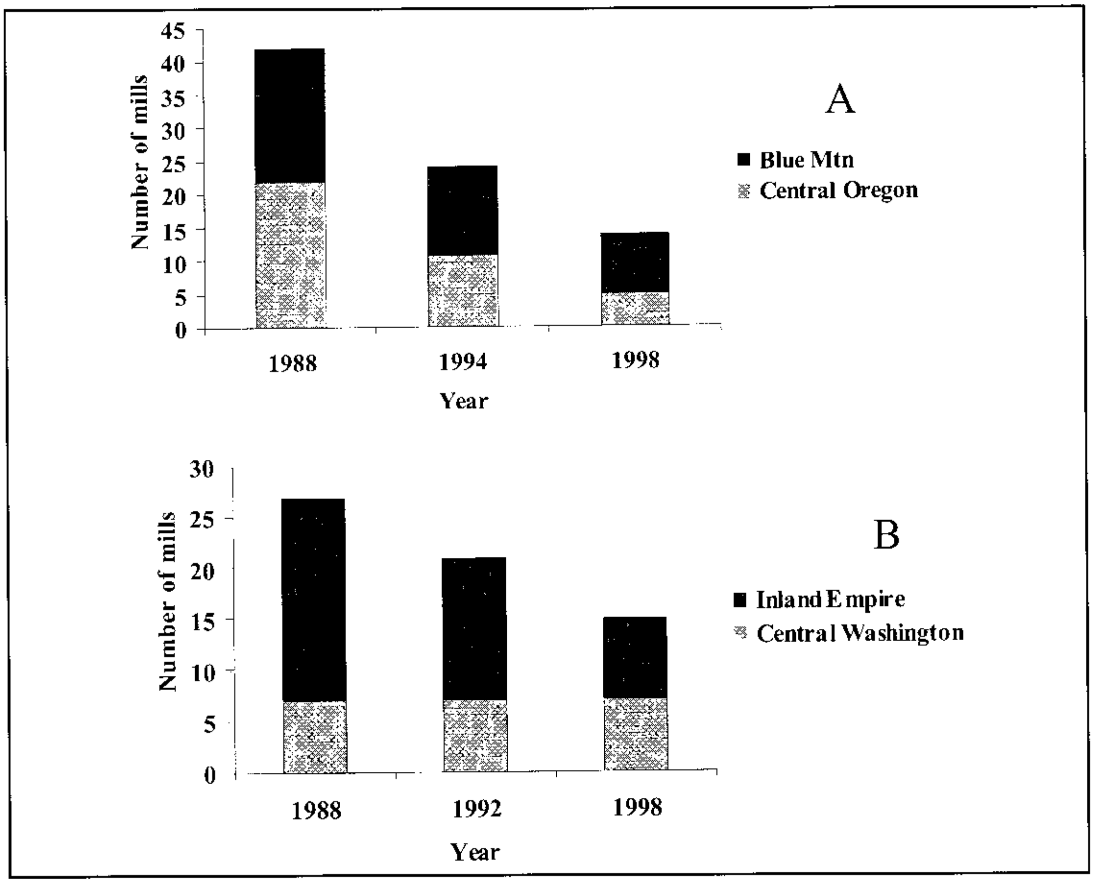

Figure 2. Number of sawmills in eastern Oregon (A) and Washington (B).

South. Table 1 also shows a steady shift among landowners, each with a different propensity for harvest. Among U.S. regions, the PNWE has the highest dependence on public harvest, and reduction in National Forest harvest since 1993 has diminished the industrial base. In terms of the mix of products, lumber and structural panels dominate production in the PNWE and lead to stumpage markets that focus mostly on sawlogs.

There are some broad inferences that can be drawn from this quick summary. First, the forest products industry is in decline in the PNWE, raising concerns about the demand for most types of stumpage. Second, limited product diversity will limit the opportunity for non-traditional material (small, dead logs), and as a result the potential for markets to aid in the solution of forest health issues is in decline.

Effects on Economic Factors of FH&P Treatments

Land managers have an array of management tools for altering stand conditions. Often, however, in eastside forest types the lower stumpage values and lower inherent productivity makes the cost efficiency of management practices especially important. Reducing costs early in rotations is especially important in making management regimes financially feasible. Other alternative management regimes that combine natural regeneration, ungulate herbivory, and fire can improve the financial feasibility of stand management (see Weigand et al. 1993 for a more compete discussion).

Altering Stand Conditions

From an operations standpoint there are two approaches to altering stand conditions as part of forest health treatments. One involves non-harvest activities to reduce stocking levels or to alter stand structures. The feasibility of this approach is determined by available budgets and involves slashing and often piling small material. In the USDA Forest Service, Pacific Northwest Region (Region 6), this was budgeted at $86 per acre in FY98, and its expected job creation is 1 person-year of employment per 500 acres treated (USDA and USDI 2000). A second approach involves using timber sales to remove material that can be processed into wood products including chips for fuel and pulp. The economic feasibility of harvest activities for public or private lands is determined by three design features: the type of logging system that can be used (often specified for federal sales as a function of topography and site conditions); volume of material removed per acre; and the size of material removed. The choice of the logging system has a large impact on the potential economic feasibility. Cable systems generally have higher costs than ground-based systems. Figure 3 compares the costs of harvesting with a

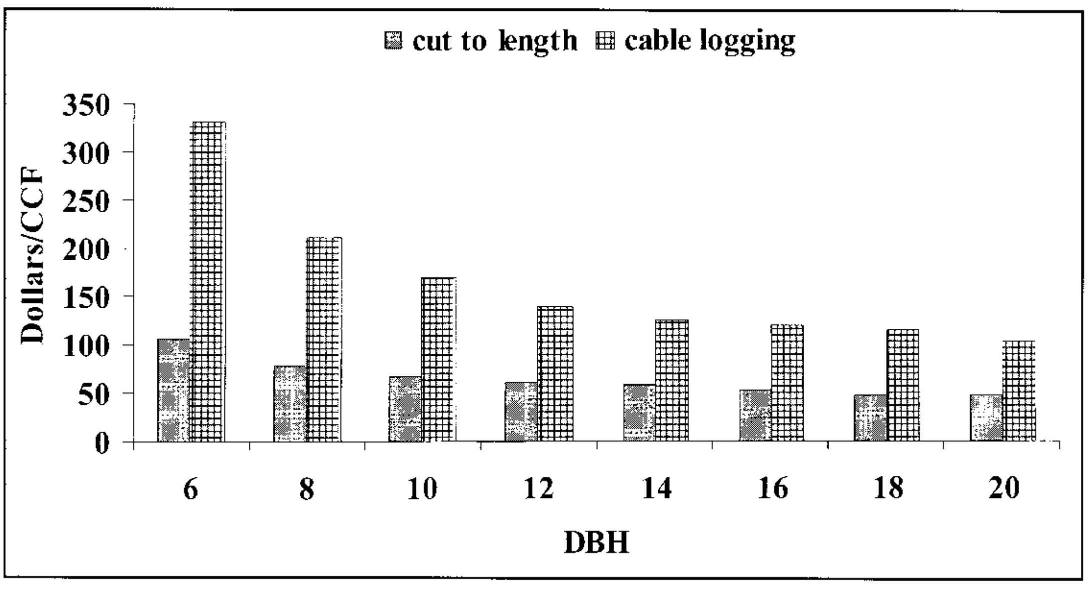

Figure 3. Harvesting cost studies show that costs decline with increasing tree size, and that cable systems are more expensive—dramatically so for smaller trees.

cable system and a cut-to-length forwarder system. Figure 3 also shows how the size of material affects logging costs. These higher costs make small log sales difficult. Related to size is volume removed per acre. Figure 4 shows the sensitivity of harvest costs (assuming a cut-to-length forwarder system) to volume removed. It shows that costs increase at an increasing rate at harvests of less than about 1000 CF per acre. A significant implication of these cost relations is that thinning strictly from below will generally have lower financial feasibility. While the small material is generally of good quality for products, the resulting smaller average tree size will increase logging costs and the smaller average log size will increase manufacturing costs. In some cases thinning from across a wider range of diameter classes will make the difference between financial feasibility and financial infeasibility.

Utilization

There are extensive studies that compare the volume and value recovery of products manufactured from dead trees (Ernst et al. 1986); killed by fire (Willits and Sampson, 1988, Lowell and Cahill 1996), or insects (Fahey et al. 1986; Willits et al. 1990; Scott et al. 1996; Parry et al. 1996; Lowell and Willits, 1998; Lowell, *In press*). Many factors influence rate of deterioration including, but not limited to, tree species and characteristics (e.g. bark thickness, sapwood depth), diameter, and local site conditions (Lowell et al. 1992).

A decrease in both volume and value recovery (depending on end use) is not uncommon after as little as 1 year—a result of sap rot, weather checking, stain, and insect bore holes. Losses in volume recovery are often insignificant in the first year following death if lumber or pulp is being produced. Value loss after 1 year may be significant in species susceptible to blue-stain or if logs have a high proportion of weather check that causes splits or decreases the width of boards recovered. Smaller trees and tops of larger trees, where the bark is thinner, tend to weather check more readily. Veneer production losses are more sensitive, with both volume and value losses from recently dead material (1 year or less), primarily a result of checking. Pulp as an end use is less affected.

In subsequent years, losses increase dramatically as sap rot develops, moisture continues to be lost from trees or logs, and insect damage increases. Additional losses may be attributed to breakage during harvesting, especially as the time since death increases.

The utilization of small-diameter timber from eastern Washington and eastern Oregon is closely tied to log value, so factors that influence log value also influence the ability of manufacturers to utilize the material. Two major factors are harvesting costs

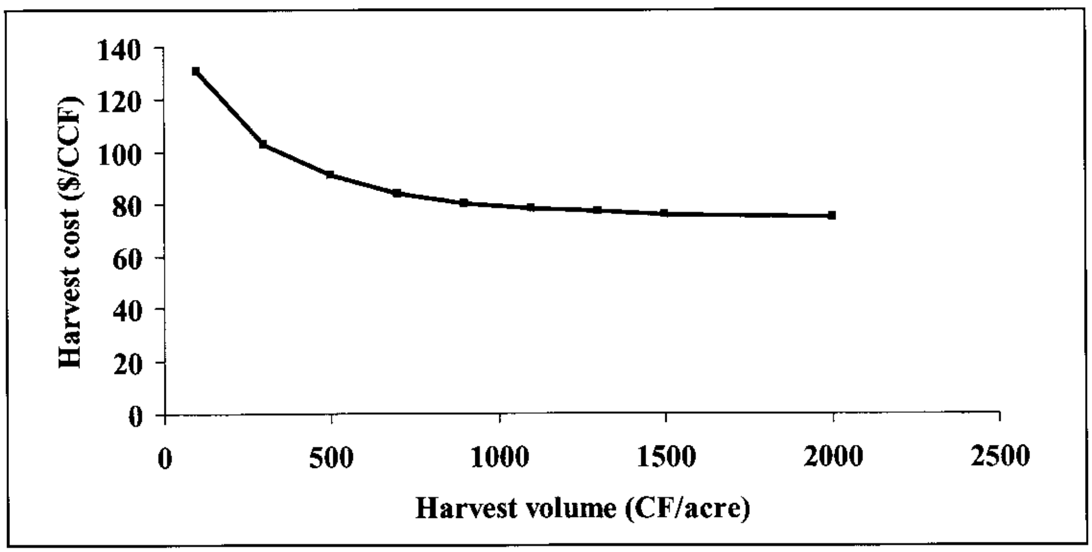

Figure 4. Harvest cost per ccf increases at low volumes per acre because fixed costs are spread over less volulme, and variable costs increase as the travel distance between harvested trees increases.

and lumber prices. The way timber sales are designed and the rules under which they are implemented can affect harvest costs. The price of lumber is determined by factors outside the control of landowners in eastern Washington and Oregon.

Volume recovery for lumber and veneer declines rapidly in all species when block diameter drops below about 8 inches. The industry in eastern Washington and Oregon is slowly adapting to processing small-diameter material. Chips, lumber, and veneer are the major product categories, but posts and poles or other small roundwood products are also manufactured. Stem shape and straightness as factors in determining volume recovery from material are more important for this size range than for larger logs. Processing equipment that scans logs for shape then processes them accordingly, and breakdown strategies that minimize block length can greatly improve recovery. Two examples are curve sawing for lumber, and technologies like COE Equipment's Perfect Edge system that uses a proprietary gluing technology to join two 4-foot veneer sheets into an 8-foot sheet.

Grade recovery is highly species dependent and is also related to management history. Small-diameter Douglas-fir, larch, and lodgepole pine grown in densely stocked stands yields lumber and veneer with structural properties as good or better than larger-diameter material grown under more open conditions. The structural characteristics of small-diameter trees from these species that were grown under open conditions such as plantations tend to be inferior to older, larger material. Small-diameter ponderosa pine seems to have inferior structural and appearance characteristics regardless of stand history.

Costs and Benefits of FH&P Treatments

We often see statements made asserting that policy makers have an interest in the costs and benefits of forest health treatments. But benefits of forest health treatments are often difficult to quantify. More typically various proxies such as jobs, timber volumes, and returns to treasury are used as the benefit measure. The shift to broader goals for ecosystem management has increased the interest in broader arrays of benefits derived from forests, but the work thus far has mostly dealt with relatively broad landscape management issues (see Bolon and others 1995 and Haynes and Horne 1997). Although the perceived environmental value of these treatments increases the motivation or desire to treat stands, it has little or no effect on the economic feasibility of the treatments unless there is a willingness to subsidize treatments.

There is research that addresses the cost of different types of treatments (see Ince and others 1984 or Hartsough and others 2001). Land managers also have extensive experience in using operational practices both in terms of budgeting and contracting, and there is a renewed interest in variations of service contracts on public lands. The treatment cost data helps determine the feasibility of different approaches, including the amount of material that needs to be removed in order to be economically feasible. In terms of assessing the economic benefits of forest health treatments, we are limited to proxies such as job effects for economic well-being or effects on selected communities for some of the concerns about social well-being.

Given the number of acres or volume to be treated, job numbers can be computed. We can assume 1 person-year of employment per 500 acres treated where the activities do not include timber harvest. Where there is timber volume removed we can assume 4 person years of employment per million board feet harvested (see Haynes and Crone 2001). These job numbers serve as a proxy for effects on economic well-being. In recent discussions about restoration, concerns have been raised about focusing job creation in specific communities of place or among specific communities of interest.

Among the cost and benefit information available is research that deals with the dual issues of community stability and economic well-being. While the definition of community stability is problematic (see Richardson 1996), much is now known about community issues (see McCool et al. 1997) and community conditions (see Reyna 1998). As part of the Interior Columbia Basin Ecosystem Management Project, Haynes and Horne (1999) developed county-based measures of socioeconomic resiliency to help federal land managers gauge the longer-term effects of changes in land management. Measures like this can be used to show the relative effects of different restoration strategies.

Decision-Support Tools, Thresholds

Various decision-support tools exist to assist land managers and policy makers evaluate thinning and harvest as a means to improve forests; three are particularly relevant. First, the development and application of the FEEMA software (Financial Evaluation of Ecosystem Management Activities [Fight and Chmelik 1998]) is most relevant to disturbance processes. The FEEMA software is designed to address the feasibility of management activities involving removal of small trees either in dense single-storied stands or as an understory component in multi-storied stands. Understanding the financial feasibility of a wide range of management options is critical to understanding the feasibility of implementing ecosystem management.

Second, timber quality studies have established that the properties of small-diameter material are acceptable and sometimes superior for most conventional products. The crucial issue for financial feasibility is the cost of harvest and manufacturing operations involving small trees. This information is also a crucial input to the application of the FEEMA model. There have been a number of studies whose goal was to improve our ability to predict costs of harvesting operations and manufacturing in small-diameter timber. (Wagner et al. 1997, Coulter 1999, Hartsough et al. 2001).

Third, the TAMM/ATLAS/NAPAP model of the U.S. forest sector (Timber Assessment Market Model, Aggregate Timberland Assessment System, North American Pulp and Paper Model, see Adams and Haynes 1980, 1996; Mills and Kincaid 1992, Zhang et al. 1996) provides a tool for broad-scale decisions. Forest sector models (FSM) include the consideration of all aspects of forestry from the basic land tenure issues, to harvesting, production, and consumption decisions, to considerations of the effects of forest policies on environmental services derived from the forest or forest products. The FSM are characterized by a systems view of the biological and socioeconomic processes in forestry and, in today's terminology, could be called bioeconomic models because they combine both economic representations of various markets and biophyiscal representations. This systems point of view allows us to explore the biological development of forest resources and the attendant dynamics of the forest industry over time and space and under alternative futures and management strategies. The basic premise is that various biological and socioeconomic interactions can be described or mimicked. These models allow the estimation of both direct and indirect effects of various policy/program changes.

Closing

Jenkins (1997) has pointed out that forest health is a crisis of human proportions and that the real crisis is that we cannot agree on what constitutes a healthy forest. While many would like to protect ecosystems through regulations, managing to improve the health of forests means that land managers need to be keenly aware of what contributes to the economic feasibility of forest management strategies. Part of this awareness is an understanding of the need to work with the volatility inherent in markets, the shifting capacity and capabilities of the forest products industry, the variability of site conditions, and the need to address concerns about social conditions in nearby communities.

While recent concerns about Forest Heath may change the perspectives of forest managers and policy makers, they do not change the determinants of economic feasibility of forest operations. Forest heath prescriptions that rely on timber harvests have to meet the same standards as those designed for other goals. In these cases, the cost of removing and delivering timber from treatments designed to improve forest health have to be less than or equal to the prices for other timber delivered to forest product facilities unless the public is willing to subsidize higher costs for this material.

There are significant information gaps in the available economic literature. Foremost, there is a need to clearly understand the financial feasibility of prospective land management regimes including practices, outcomes, and timing. Equally significant we need to develop benefit measures of improved forest health that are more direct than relatively indirect proxies like employment. We also need to develop notions of the public's willingness to pay for forest health treatments that lead to improvements in stand conditions (often considered in economic terms) and more difficult-to-measure notions like scenic integrity at landscape scales.

Literature Cited

Adams, D.M., and R.W. Haynes. 1980. The 1980 softwood timber assessment market model: structure, projections and policy simulations. Forest Science. Monograph 22. Society of American Foresters, Washington, DC. 64 p.

Adams, D.M., and R.W. Haynes. 1996. The 1993 Timber Assessment Market Model: structure, projections and policy simulations. USDA Forest Service General Technical Report PNW-GTR-368. Pacific Northwest Research Station, Portland, OR. 58 p.

Bolon, N.A., C.S. Hansen-Murray, and R.W. Haynes. 1995. Estimated economic impacts on the timber, range, and recreation programs on NFS and BLM public lands from adopting the proposed interim PACFISH strategy. USDA Forest Service General Technical Report PNW-GTR-344. Pacific Northwest Research Station, Portland, OR. 80 p.

Coulter, E.D. 1999. Hungry Bob harvest production study: mechanical thinning for fuel reduction in the Blue Mountains of northeast Oregon. M.S. Thesis, Oregon State Unviersity, Corvallis. 96 p.

Ernst, S.A., M.E. Plank, and D. Fahey. 1986. Sitka spruce and western hemlock beach logs in southeast Alaska: suitability for lumber, pulp, and energy. USDA Forest Service Research Paper PNW-RP-352. Pacific Northwest Research Station, Portland, OR. 25 p.

Fahey, T.D., T.A. Snellgrove, and M.E. Plank. 1986. Changes in product recovery between live and dead lodgepole pine: a compendium. USDA Forest Service Research Paper PNW-RP-353. Pacific Northwest Research Station, Portland, OR. 25 p.

Fight, R.D., and J.T. Chmelik. 1998. Analysts guide to FEEMA for financial analysis of ecosystem management activities. USDA Forest Service General Technical Report FPL-GTR-111. Forest Products Lab, Madison, WI. 5 p.

Hartsough, B.R., X. Zhang, and R.D. Fight. 2001. Harvesting cost model for small trees in natural stands in the interior Northwest. Forest Products Journal 51(4):54-61.

Haynes, R.W. 1990. An analysis of the timber situation in the United States: 1989-2040. A technical document supporting the 1989 USDA Forest Service RPA Assessment. USDA Forest Service General Technical Report RM-199. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 268 p.

Haynes, R.W. 1998. Stumpage prices, volume sold and volumes harvested from the National Forests of the Pacific Northwest Region, 1984 to 1996. USDA Forest Service General Technical Report PNW-GTR-423. Pacific Northwest Research Station, Portland, OR. 91 p.

Haynes, R.W. 1999. Chip prices as a proxy for nonsawtimber prices in the Pacific Northwest. USDA Forest Service Research Note. PNW-RN-537. Pacific Northwest Research Station, Portland, OR. 25 p.

Haynes, R.W., D.M. Adams, and J.R. Mills. 1995. The 1993 RPA timber assessment update. USDA Forest Service General Technical Report RM-259. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 65 p.

Haynes, R.W., and Crone, L.K. 2001. Socioeconomic evaluation of broad scale land management. Journal of Forest Ecology and Management 153:147-160.

Haynes, R.W., and A.L. Horne. 1997. Economic assessment of the basin. Pages 1717-1869 *In* Quigley, T.M., and S.J. Arbelbide (technical editors), An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins. USDA Forest Service General Technical Report PNW-GTR-405. Pacific Northwest Research Station Portland, OR. Chapter 6. Vol. 4. (Quigley, Thomas M., tech. ed.; Interior Columbia Ecosystem Management Project: scientific assessment).

Haynes, R.W., and A.L. Horne. 1999. Developing measures of socioeconomic resiliency in the interior Columbia Basin. USDA Forest Service General Technical Report PNW-GTR-453. Pacific Northwest Research Station, Portland, Oregon. 41 p.

Ince, P.J., J.W. Henley, J.B.Grantham, and D.L. Hunt. 1984. Costs of harvesting beetle-killed lodgepole pine in eastern Oregon. USDA Forest Service General Technical Report PNW-GTR-165. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 26 p.

Jenkins, A.M. 1997. Forest health. A crisis of human proportions. Journal of Forestry. 97(9):11-14.

Kolb, W.E., M.R. Wagner, and W.W. Covington. 1994. Concepts of forest health: utilitarian and ecosystem perspectives. Journal of Forestry 92(7):10-15.

Lowell, E.C. *In Press*. Veneer recovery from beetle-killed spruce trees, Kenai Peninsula, Alaska. Western Journal of Applied Forestry.

Lowell, E.C., and J.M. Cahill. 1996. Deterioration of fire-killed timber in southern Oregon and northern California. Western Journal of Applied Forestry 11(4):125-131.

Lowell, E.C., and S.A. Willits. 1998. Lumber recovery from beetle-killed spruce trees on the Kenai Peninsula, Alaska. Western Journal of Applied Forestry 13(2):54-59.

Lowell, E.C., S.A. Willits, and R.L. Krahmer. 1992. Deterioration of fire-killed timber in the western United States. USDA Forest Service General Technical Report PNW-GTR-292. Pacific Northwest Research Station, Portland, Oregon. 27 p.

McCool, S.F., J.A. Burchfield, and S.D. Allen. 1997. Social assessment. Pages 1870-2009 *In* Quigley, T.M., and S.J. Arbelbide (technical editors), An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins. USDA Forest Service General Technical Report PNW-GTR-405. Pacific Northwest Research Station Portland, Oregon. Chapter 7, Vol. 4. (Quigley, Thomas M., technical editor. Interior Columbia Ecosystem Management Project: scientific assessment).

Mills, J.R., and J.C. Kincaid. 1992. The aggregate timberland assessment system-ATLAS: a comprehensive timber projection model. USDA Forest Service General Technical Report PNW-281. Pacific Northwest Research Station, Portland, Oregon. 160 p.

Parry, D.L., G. Filip, S. Willits, and C. Parks. 1996. Lumber recovery and deterioration of beetle-killed Douglas-fir and grand fir in the Blue Mountains of eastern Oregon. USDA Forest Service General Technical Report PNW-GTR-376. Pacific Northwest Research Station. Portland, Oregon. 24 p.

Reyna, N.E. 1998. Economic and social characteristics of communities in the interior Columbia basin. Part 1, pages 3-81 *In* Economic and Social Conditions of Communities: Economic and Social Characteristics of Interior Columbia Basin Communities and an Estimation of Effects on Communities from the Alternatives of the Eastside and Upper Columbia River Basin Draft Environmental Impact Statements. USDA Forest Service, Pacific Northwest Research Station: USDI Bureau of Land Management, Portland, Oregon.

Richardson, C.W. (compiler). 1996. Stability and change in forest-based communities: a selected bibliography. USDA Forest Service General Technical Report PNW-GTR-366. Pacific Northwest Research Station, Portland, Oregon. 36 p.

Scott, G.M., D.W. Bormett, N.R. Sutherland, S. Abubakr, and E. Lowell. 1996. Pulpability of beetle-killed spruce. USDA Forest Service Research Paper FPL-RP-557. Forest Products Laboratory, Madison, Wisconsin. 8 p.

USDA Forest Service, USDI Bureau of Land Management. 2000. Interior Columbia Basin supplemental draft environmental impact statement. BLM/OR/WA/Pt-00/019+1792. U.S. Department of the Interior, Bureau of Land Management, Portland, Oregon.

Wagner, F.G., C.E. Keegan, III, R.D. Fight, and S. Willits. 1997. Potential for small-diameter sawtimber utilization by the current sawmill industry in western North America. 1998. Forest Products Journal 48(9):30-34.

Ward, F.R., G.J. Lettman, and B.A. Hiserote. 1998. Oregon's forest product industry: 1998. USDA Forest Service, Pacific Northwest Research Station; Oregon Department of Forestry, Salem, Oregon. 82 p.

Warren, D.D. 1999. Production, prices, employment and trade in Northwest forest industries, Fourth Quarter 1997. USDA Forest Service Resource Bulletin PNW-RB-230. Pacific Northwest Research Station, Portland, Oregon. 130 p.

Weigand, J.F., R.W. Haynes, A.R. Tiedmann, R.A. Riggs, and T.M. Quigley. 1993. Economic assessment of ungulate herbivory in commercial forests of eastern Oregon and Washington, USA. Forest Ecology and Management 61:137-155.

Willits, S.A., and G. Sampson. 1988. Effect of forest fire on lumber recovery from white spruce in interior Alaska. Forest Products Journal 438(11/12):80-84.

Willits, S., R.O. Woodfin, and T.A. Snellgrove. 1990. Lumber recovery from dead ponderosa pine in the Colorado Front Range. USDA Forest Service Research Paper PNW-RP-428. Pacific Northwest Research Station, Portland, Oregon. 14 p.

Zhang, D., J. Buongiorno, and P.J. Ince. 1996. A recursive linear programming analysis of the future of the pulp and paper industry in the United States: changes in supplies and demands, and the effects of recycling. Annals of Operations Research 68:109-139.

Notes

This special issue of *Northwest Science* is a set of papers reviewing the state of knowledge about disturbance processes in eastern Oregon and Washington, related management practices, and effects on key management issues.

[1]Alig, R., F. Benford, R. Moulton, and A. Plantinga. Land use projections by region in the United States: 1997-2050. Manuscript in preparation. On file: Pacific Northwest Research Station, Corvallis Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, Oregon 97331.