United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-616
September 2004

# Contemporary Wood Utilization Research Needs in the Western United States

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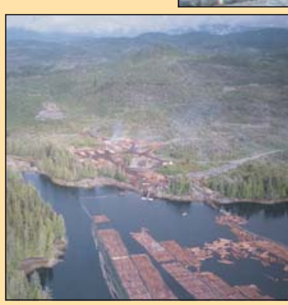

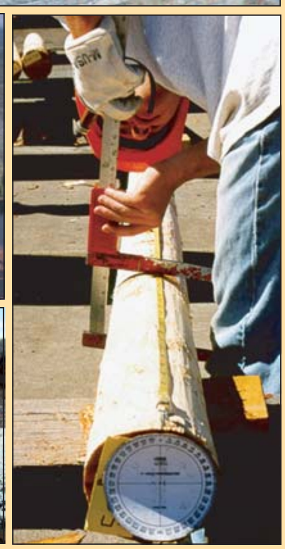

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## Abstract

**Monserud, Robert A.; Lowell, Eini C.; Becker, Dennis R.; Hummel, Susan Stevens; Donoghue, Ellen M.; Barbour, R. James; Kilborn, Kenneth A.; Nicholls, David L.; Roos, Joe; Cantrell, Randall A. 2004.** Contemporary wood utilization research needs in the Western United States. Gen. Tech. Rep. PNW-GTR-616. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 49 p.

Contemporary wood utilization research needs in the Western United States are examined in this problem analysis. Key focal areas include: A. Changes in forest management actions and policies affect forest conditions and people, which in turn affect wood quality and wood utilization opportunities. B. Effects of natural disturbances (e.g., wildfire, insect outbreaks) on wood quality, wood utilization, and people are poorly understood. C. Regional differences throughout the Western States are poorly understood in the context of wood utilization. D. Technical assistance and feasibility analyses are needed by resource managers, technical organizations, users of natural resources, and others interested in the physical characteristics, processing, and marketing of forest products.

Keywords: Wood utilization, forest products, forest management, wood quality, small-diameter wood utilization.

## Summary

There are two wood utilization teams within the USDA Forest Service Pacific Northwest Research Station. The Ecologically Sustainable Production (ESP) of Forest Resources team focuses on wood utilization and its relation to forest resource characterization in the Western United States, including Alaska. The Alaska Wood Utilization Research and Development Center (WUC) in Sitka addresses research needs only in Alaska, with a strong emphasis on marketing and processing Alaska wood products. Together our work provides information to clients on the relations between forest management practices, wood quality, and product options. This problem analysis serves to focus and prioritize the research conducted by these two teams.

The ESP and WUC teams are successfully addressing a wide range of wood utilization issues throughout the Western United States. Of particular note is an estimated 190 million acres of federal forests and rangelands in the United States that face high risk of catastrophic fire (GAO 1999, USDA FS 2003). As a result, there are increasing calls for ways to use wood from trees that have traditionally

been underutilized—material that previously went to chips, was left as slash, or was left untouched. And where products or markets are not available, there is also a need to find cost-effective and efficient methods for disposing of or removing the material, thereby reducing fire hazard.

The ESP and WUC teams have a significant role to play in this effort. We have a continuing focus on finding solutions to problems related to utilization of small-diameter trees. We seek solutions that are ecologically, economically, and socially sustainable. Research in this area addresses new technologies such as composites, biofuels, biomass feedstock for heating and energy, small-scale portable and semiportable sawmills, as well as more traditional research on deterioration of fire- and insect-killed trees, and the effects of thinning on residual tree development and quality. There is also the effect current management practices will have on the wood quality of trees harvested years from now. The interface between utilization and community development is addressed through cooperative efforts with groups such as the Greater Flagstaff Forests Partnership and Alaska’s Denali Commission. The ESP and WUC teams are poised to expand our efforts in small-diameter wood utilization in response to new programs such as the Healthy Forests Restoration Act of 2003 and to emerging public and partner needs.

Different people push different wood utilization technologies, with little integration of financial, social, or forest management implications. Because many of these technologies will rest, to a large degree, on private investment, we need to understand the implications of using various technologies for improving wood utilization. We envision a three-pronged approach. First, develop and transfer technologies adapted to the scale of the problem. Second, develop and deliver marketing strategies to promote improved wood utilization. Third, link wood utilization to forest management objectives over a range of ownerships throughout the Western United States. Research that includes one or more of these three elements should lead to successful accomplishments with our various partners.

## Background

Contemporary questions about the utilization of wood are best addressed within the context of social, economic, and ecological systems because forest management activities have widespread effects. These effects, and their interactions, compel us to identify and study wood utilization problems by using an approach that is more interdisciplinary than in the past.

One contemporary but nontraditional area of utilization research focuses on forest management when the objective is to reduce fire hazard or improve wildlife habitat in the most efficient and socially acceptable manner. Recent episodes of catastrophic wildfires and insect or disease epidemics in Colorado, Arizona, Oregon, Alaska, California, and other Western States have led to the enactment of the National Fire Plan and passage of the Healthy Forests Restoration Act (2003), which significantly affect management of national forest land. Research is urgently needed on how to effectively remove large amounts of forest biomass as quickly and cost-effectively as possible. Utilization research is needed on new technologies and products such as wood composites, biofuels, biomass feedstock for heating and energy, and small-scale semiportable sawmills, as well as more traditional research on degradation of fire- and insect-killed trees, the effects of thinning on residual tree development and quality, and development of value-added products.

In recent years the forest management debate in the United States has become increasingly contentious, with the result that forest management practices on public and private land are diverging strongly (Haynes et al. 2003). This divergence in management has the potential to create sufficient differences and variation in wood characteristics to influence the value and marketability of trees harvested by different landowners (Barbour et al. 2003).

In the 1990s, for example, shifting public perceptions about the role of forests as reservoirs of biological diversity resulted in new land management strategies for the Northwestern United States (USDA USDI 1994). Changes in public expectations, and the regulations resulting from them, make it difficult for landowners to focus solely on commodity production, as was the case in earlier decades. Human demands have amplified the differences between resource management objectives on public and private lands in the West, which has led to an expanded scope for research on forest resource characterization and wood utilization (Monserud et al. 2003). Thus, there is a need to understand the relationships among resource management goals, wood products opportunities, and the values and products that people desire from forested landscapes.

**Human demands have amplified the differences between resource management objectives on public and private lands in the West.**

Although commodity production is no longer the primary focus on many public lands, there remain research questions about management practices that remove trees from a site. For example, management objectives to provide habitat for endangered species or to restore degraded sites require information on how removing trees affects key forest structures and if such removals can provide income from wood products to offset the costs of restoration (Hummel et al. 2001). Questions abound in current forest management debates related to wildland fire risk-reduction treatments and opportunities to use wood removals to recover cost of treatments. In addition, changes in forest management, commodity production, and processing options affect the socioeconomic well-being of forest-based communities in ways that are not well understood. This gives rise to questions about how innovative combinations of forest engineering and wood processing options (e.g., wood composites) can accomplish management objectives while supporting human communities.

Variation in tree size, age, physical properties, and species distribution of the current forest resource along with the uncertainty of a consistent supply of raw material make it difficult for some producers, especially those in remote locations, to compete in regional, national, and global markets. Those processors located closer to retail markets, existing infrastructure, or with access to less expensive sources of supply are at a competitive advantage (Braden et. al. 1998). Much of the available old-growth and unmanaged second-growth forest in the West that was suitable for manufacturing high-value products has already been harvested or is unavailable for harvest (e.g., wilderness areas and preserves). As a result, most of the West, with the exception of southeastern Alaska, now has extensive areas of suppressed, small-diameter trees. Because these suppressed trees have small branches, are generally straight, and have wood that contains little juvenile wood, they have average or even desirable wood properties. However, harvesting costs are often quite high for this small-diameter material. Even where larger, high-value trees can be harvested, market premiums still may not be available because of mill closures and the restructuring of the wood products industry to process smaller second-growth trees. The shift toward harvesting smaller material with a lighter touch on the land has created tremendous technical challenges for both resource managers and forestry contractors searching for acceptable, cost-effective treatments.

**Suppressed trees... have average or even desirable wood properties.**

A second line of emerging resource characterization and wood utilization research addresses the needs of private landowners and conventional mill operators who grow and process timber in the West. These landowners and mill operators must find ways to compete in global and regional markets while at the same time adjusting to changing land use regulations. Although increased regulation of forestry activities continues to alter the economic climate for Western forest products firms, other factors that are largely unrelated to regulation also have contributed to the restructuring of the Western wood products industry. The increase in the availability of plantation-grown wood (both here and in other timber-producing regions such as the South), a gradual change in forest resource characteristics (forest succession, invasive species), and dispersal of human populations in the Western States to the forest wildland-urban interface are important drivers of this change. Research that recognizes the linkages among the divergent aspects of forest management will provide integrated and more effective solutions to today's forest operations, resource characterization, and wood utilization information needs.

Recent changes in public perceptions and attitudes regarding forestry, and the regulations resulting from them, create a need for understanding the relationship between wood products production and the values and products people desire from forested landscapes (Monserud et al. 2003). This research is focused on the interconnectivity among forest management, wood quality characteristics, forest products, and communities. The diagram in figure 1 and the following list of research needs illustrate the integrated nature of the utilization research that we envision today and in the near future.

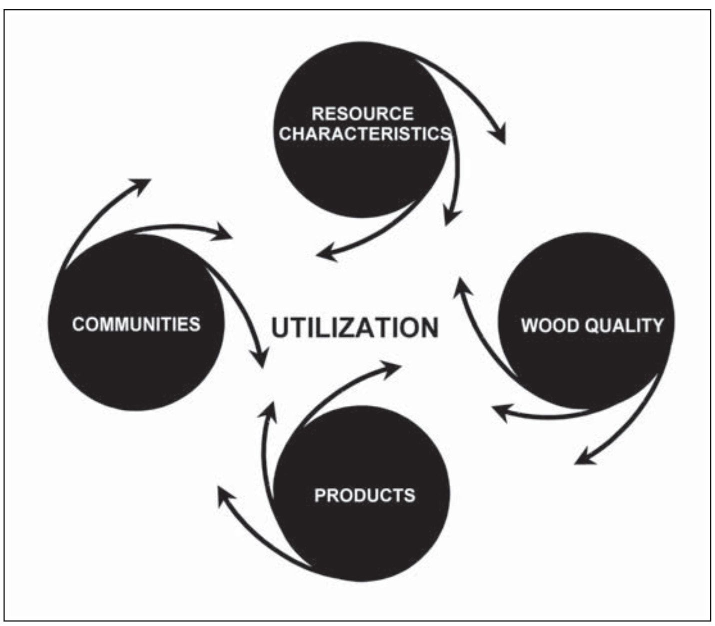


Figure 1—Wood utilization problems have social, ecological, and management dimensions that affect forests, products, and people.

There are two wood utilization teams within the USDA Forest Service Pacific Northwest Research Station (PNW). The Ecologically Sustainable Production (ESP) of Forest Resources team focuses on wood utilization and forest resource characterization in the Western United States, including Alaska. The Alaska Wood Utilization Research and Development Center (WUC) in Sitka addresses research needs only in Alaska, with a strong emphasis on marketing and processing Alaska wood products. Together our work provides information to clients on the relations between forest management practices, wood quality, and product options.

Over the next 5 to 10 years, we anticipate that wood utilization and resource characterization research needs in the Western United States are likely to focus on the following topics:

A. Changes in forest management actions and policies affect forest conditions and people, which in turn affect wood quality and wood utilization opportunities.
B. Effects of natural disturbances (e.g., wildfire, insect outbreaks) on wood quality, wood utilization, and people are poorly understood.
C. Regional differences throughout the Western States are poorly understood in the context of wood utilization. These include biophysical and ecological (e.g., species, stand structure, climate), technical (e.g., infrastructure, manufacturing capacity), and social (e.g., communities, institutional) differences and the interactions among them.
D. Technical assistance and feasibility analyses are needed by resource managers, technical organizations, users of natural resources, and others interested in the physical characteristics, processing, and marketing of forest products.

Additional research and development topics focused on Alaska include:

E. Products and markets for Alaska’s underutilized species, including value-added products.
F. Community-level business development, including niche markets and opportunities for family-based enterprises.
G. Complete resource utilization, including solid wood products, wood residues, and nontimber forest products.

## Organizational Context

Wood utilization and forest resource characterization research, established at the PNW Research Station in the late 1950s, continues to be an important component of the PNW Research Station’s strategic plan. The ESP team, under the Human and Natural Resources Interactions Program (HNRI), examines relations among planned (e.g., harvesting) and unplanned (e.g., insect epidemics) disturbances and their impacts on the characteristics of goods and services that people desire from forested landscapes. The ESP team has been conducting research on all aspects of wood utilization for well over 40 years throughtout the West.

The WUC team in Sitka, established in 1998 in response to the loss of an integrated wood products industry in Alaska and its impact on associated communities, is also under this HNRI charter. The WUC researches processing, economics, and marketing, and disseminates information to broad audiences through workshops and other technology transfer activities in Alaska. Additionally, WUC focuses resources on industry outreach. The team has sponsored several small business workshops covering topics such as developing value-added products, marketing strategies, and international trade.

## Strategic Plan

Our research fits under the broader umbrella of the PNW Research Station's strategic plan (USDA FS 2002). Both the PNW Station in general and the ESP and WUC teams in particular seek to:

- Find interdisciplinary and integrated solutions.
- Work at multiple scales and ownerships to solve increasingly complex natural resource issues that society faces.
- Develop a balanced portfolio of long- and short-term research.
- Inform the debate about controversial natural resource policy issues.

Specific Station goals and priorities that are relevant to the ESP team's research include:

**Goal 1. Develop a fundamental understanding of ecological, social, and economic systems and their interactions.**

Priority 1.3 Improve the understanding of social and economic processes and their interaction with natural resource values and uses.

**Goal 3. Develop science-based options that enhance management.**

Priority 3.1 Restore ecosystems at risk and reduce the risks people face.

Priority 3.4 Produce wood within sustainable frameworks.

**Goal 4. Communicate science findings and enhance their application.**

Priority 4.1 Respond to emerging issues.

Priority 4.2 Bridge the gap between information generation and its use.

## Program Charter

While operating under the broad guidelines of the PNW Research Station strategic plan, the Human and Natural Resource Interaction (HNRI) Program charter provides much more specific guidelines for the ESP and WUC teams. There are five broad problem areas that have evolved from existing work within the Station and with the public that are documented in the HNRI charter. The first is the need for understanding economic **market processes at multiple scales** and their role in the forest sector. Market processes provide a powerful framework for policy studies and to understand how processes work in the forest sector. The second problem area is **economics of land management**. This is a broad problem area that includes the economics of selected management regimes, links between land management and rural communities, the integration of economic and ecological values in decision processes, and the supply and demand for natural-resource-based commodities, amenities, and other values. The third problem area concerns the **institutions for natural resource management**. This problem area is interpreted broadly, including both formal and informal institutions, and links to the first problem area where markets are seen as one type of institution. The fourth problem area deals with the **community and natural resource interactions at multiple scales**. The fifth problem area covers **characterizing forest resources and evaluating their uses**. This problem area links to issues associated with timber supply and demand, rural development, and ecosystem management. Each of these problems includes issues that deal with the interface of science and policy.

The ESP team focuses heavily on problem 5, but also has partial responsibility for addressing certain elements of research problems 2, 3, and 4 from the research charter of the HNRI Program:

**Problem 2: The shift in management emphasis from stands to ecosystems poses challenges of how to reframe much of the existing information that has been done in the context of stand and forest (region) levels to dealing with linked and multiple scales.**

> Element 2.2 Develop methods for evaluating the costs and benefits of alternative land management regimes, cultural practices, and policies to provide a range of commodity, amenity, and ecosystem values within the context of sustainable forest management.
>
> Element 2.3 Develop methods for understanding land use and land cover changes and their effects on biodiversity, timber supply, forest carbon, and other goods and services.

**Problem 3: Effective, responsive, and efficient resource management requires information that identifies and evaluates alternative institutional (both formal and informal) structures and processes.**

Element 3.3 Identify and evaluate the role that institutional barriers and opportunities play in resource management policymaking, implementation, and evaluation.

Element 3.4 Given different social and political contexts and scales, develop theory, frameworks, methods, and mechanisms to assess and evaluate existing and emerging institutional structures, processes, and arrangements.

**Problem 4: There is a need to expand our understanding of community and natural resource interactions at multiple scales.**

Element 4.1 Improve understanding of the interdependencies between public knowledge, values, and uses of natural resources (e.g., wildlife, forests, water) and how they are managed.

Element 4.2 Improve understanding of communities (both interest and place based) and how they are related to natural resources and their management.

Element 4.3 Develop and evaluate frameworks and tools for understanding and assessing the role of places important to people with respect to natural resource values, uses, and management of those resources.

**Problem 5: There is a need to use forest resources more effectively.**

The missions for both the ESP and WUC teams concentrate heavily on research problem 5. This problem contains four elements and corresponds closely with Priority 3.4 in the PNW Research Station's strategic plan (USDA FS 2002): **Produce wood within sustainable frameworks.** The ESP and WUC teams complement each other and address all five research problems, either indirectly or directly as appropriate, given the interdisciplinary nature of resource characterization and wood utilization research.

Research conducted under research problem 5 examines fundamental relations among forest management alternatives and the availability and characteristics of the goods and services that humans desire from forested landscapes. Development activities consider the application of concepts in resource characterization and support efficient and wise use of forest resources.

**Our research will help individuals and society quantify, characterize, and assign worth to the possible mixes of outputs from forests.**

This is a critical time for understanding what role wood removals play in the broad set of outputs people desire from forests. Society will pay for a subset of these goods and services; our research will help individuals and society quantify, characterize, and assign worth to the possible mixes of outputs from forests. In situations where wood products are the desired output, our research evaluates current and future wood removals. We provide information on the potential of primary and secondary products from the available resource, evaluate how communities might benefit from processing the resource, and provide technical support to assist in matching utilization options to community needs. When the primary output is something other than wood products, our research illustrates how different management strategies may alter forest structure through time and at various scales, and how wood removals might offset management costs or help to attain other resource objectives. The types of information generated during these efforts are suitable for use by researchers, resource managers, and members of the public interested in a variety of questions about the future of our forests. Work in this area builds on the long history of successful collaboration between resource characterization (this problem) and economics of forest management.

Elements of the ESP and WUC research programs are highly useful in ongoing knowledge development, as well as in making forest management decisions. For example, the ESP team's long history in conducting wood product recovery studies continues to play a central role in our research (e.g., Christensen and Barbour 1999, Christensen et al. 2002, Fahey et al. 1991, Lowell and Plank 1997, Lowell and Willits 1998, Stevens and Barbour 2000). Furthermore, WUC has examined the potential increased profitability gained through increased Alaska sawmill efficiency (Kilborn 2002). These studies also provide applicable information that can be used by government, industry, and private landowners. Activities like technical assistance to forest-based communities are effective in providing critical information, although the usefulness of that knowledge is also dependent upon the capacity of the communities to adopt, adapt, and apply that information. Continued research is required in this vein, and to expand and aggregate our base of knowledge from the scale of individual trees and forest stands to that of broad landscapes and ecosystems. Similarly, the ability to integrate information about resource characterization and utilization with other disciplines is necessary to generate new ways of looking at forest management. Success in this area will require a high level of knowledge discovery, interpersonal skills, and the ability to understand the way scientists in other disciplines approach problems and evaluate information.

The four elements contained in **research problem 5**, including a discussion of how our work addresses each, are:

> Element 5.1 Assess the technical feasibility of new technologies, of producing primary and secondary wood products, and producing nontimber forest products through empirical studies and simulation.

The issues that compel wood utilization and resource characterization research topics are broad. They include physical characteristics of the resource, existing harvesting and processing infrastructure, skills available in a community, location of the resource, and design of management activities; all interact to create positive or negative net financial returns. Some of the most important research is on the use of simulation techniques. These involve a variety of approaches: the modeling of wood quality in stand simulation models (ORGANON), the development of log diagramming techniques (Barbour et al. 1999), the adaptation of the AUTOSAW sawing simulator (Todoroki 1990) for use in North America, veneer peeling simulators (Mothe et al. 2004), and use of the ROMI Rip and ROMI Cross (Thomas 1997, 1999) simulation software with small-diameter softwoods (Lowell et al. 2004). Both ESP and WUC work in conjunction with the Ketchikan Wood Technology Center. Recent research examines the potential for machine-stress-rated (MSR) graded lumber from Alaska species.

> Element 5.2 Evaluate the influence of alternative forest management options on the abundance and characteristics of forest-based goods and services.

There is a research need to quantify how different management objectives balance against each other and to illustrate opportunities for achieving multiple goals. Timber production is no longer the primary objective on public land; for most private landowners, timber production is no longer the only objective. Most landowners need information that displays how management for commodities, such as timber, can enhance or detract from management for noncommodity outputs from forests, such as water or wildlife. Work with partners such as the members of the Stand Management Cooperative, based at the University of Washington, helps to evaluate the effects of stand management practices on wood quality characteristics (Fahey et al. 1991).

**There is a research need to quantify [and]...illustrate opportunities for achieving multiple goals.**

> Element 5.3 Characterize resource outputs at multiple scales associated with different management practices.

Land management agencies and landowners need to understand how different forest management activities affect forest outputs over time and at different geographic scales. This understanding should include the financial costs of activities as well as the quantities of commodity and noncommodity outputs. This raises the issue of what mix of these outputs we, as a society, want and can afford both financially and ecologically. Implementation of land management decisions influences the morphological characteristics of trees or logs that, in turn, may affect both ecological function and wood quality. Comprehensive consideration of these issues requires that we link our work with that of biologists, ecologists, physical scientists, and other social scientists. In doing this we enhance integrated learning and understanding of opportunities for achieving joint production of goods and services from forested landscapes.

> Element 5.4 Provide technical assistance to natural resource managers, technical organizations, users of natural resources, and others interested in the physical characteristics, processing, or marketing of forest resources.

The WUC has research and development responsibilities for Alaska that are addressed under this element, especially the marketing aspect. The ESP team also plays a technical assistance role, with responsibility across the entire Western United States.

The issues that compel wood utilization and resource characterization research topics differ by geographic region because the characteristics of the resource and the economic and business climates differ by region. The two teams focus select studies where the results can be broadly applied or adapted by similar groups or organizations. Delivery of technical information is often difficult when working with local processors who have limited experience with types of products for which emerging resources are suitable. Work can be complicated by risks associated with lower economic incentives to enter markets in certain areas, particularly those where the federal government is the predominant landowner.

**We approach questions about wood utilization in the context of ecological, social, and economic systems.**

## Research Focus

The ESP and WUC teams are charged with conducting research under the broad guidelines of the PNW Research Station's strategic plan (USDA FS 2001) and the more specific guidelines of the HNRI Program charter. Our approach is multidisciplinary (see fig. 1). We approach questions about wood utilization in the context of ecological, social, and economic systems. The ESP team conducts research on each of the four focal areas discussed below (A through D). Each crosses boundaries among the PNW Station's goals and both problems and elements in the HNRI Program charter. The WUC team conducts research and development (i.e., marketing and technology transfer) primarily within focal area D, but also in area C.

**A. Changes in forest management actions and policies affect forest conditions and people, which in turn affect wood quality and wood utilization opportunities.**

The geographic scale and intensity of management actions depend on their objectives. For example, actions taken to change the severity and behavior of wildfire would likely involve treating (e.g., mechanical thinning or prescribed burning) a collection of forest stands because in much of the Western United States wildfire is a widespread phenomenon (NCASI 2004). In contrast, actions taken to control branch size might involve promoting self-pruning by keeping stand densities relatively high. The ESP team studies the effects of management actions by using scale-appropriate techniques that include in-woods and mill studies (Christensen and Barbour 1999, Christensen et al. 2002, Fahey et al. 1991, Lowell and Green 2001, Stevens and Barbour 2000 ) and simulation models (Barbour et al. 1999, Hummel et al. 2002, Todoroki 1990, Wykoff et al. 1982). The simulation models are tools that enable us to estimate the effects of management actions at scales ranging from individual boards to many thousand acres, and include AUTOSAW (Todoroki 1990), ORGANON (Hann et al. 1997), and the Forest Vegetation Simulator (FVS) (Wykoff et al. 1982) and its Fire and Fuels Extension (FVS-FFE) (Reinhardt and Crookston 2003). Figure 2 shows a Stand Visualization System (SVS) image (McGaughey 1998) of a stand before treatment and after thinning and burning in an FVS simulation. The FVS allows us to evaluate the species and dimensions of cut trees for wood products and also to predict how the residual stand will grow over time to meet forest management objectives.

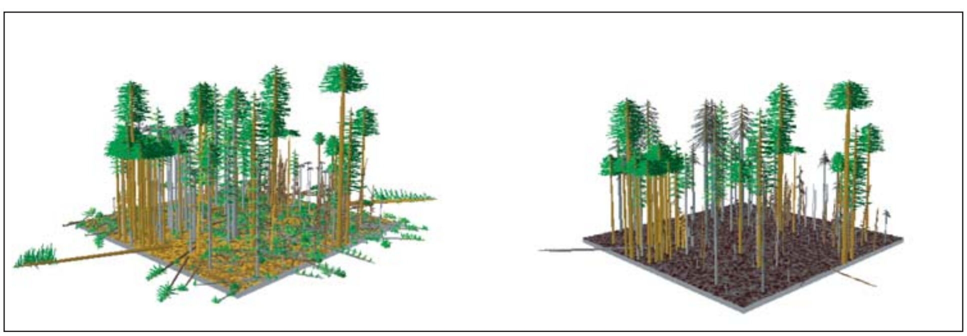

Figure 2—A Stand Visualization System image (McGaughey 1998) of a stand before treatment and after thinning and burning, created by using the Forest Vegetation Simulator.

Management actions to restore forest conditions over extensive areas could include treating stands that have considerably different characteristics (Hummel et al. 2001). This might include suppressed stands exhibiting a narrow range of tree diameters but multiple species and ages, single-species plantations of young trees, and naturally regenerated multispecies stands with a range of tree diameters and ages. Variation in forest conditions and in treatments applied implies variation in the social acceptability of treatments (Wooley and McGinnis 2000), the quality of wood generated by them (Barbour et al. 1998, 2003), and associated product opportunities (Han et al. 2002, Spelter et al. 1996) and community impacts (Shindler et al. 2002) of using the wood.

Changes in forest management, commodity production, and processing options affect the socioeconomic well-being of forest-based communities in ways that are not well understood. Social science that clarifies the relations between communities and forests may help identify opportunities for economic development linked to forest products. Communities have different capacities to adapt to changing forest management policies and take advantage of economic development opportunities. Community capacity is a dynamic property of community life. It is made up of related social, economic, and physical attributes that are continually being eroded or built. Attributes, such as leadership, community cohesion, equity, economic diversity, and education are often used to represent dynamic components of social capital (Coleman 1988, Flora 1994, Putnam 1993), human capital (Becker 1975, Pretty 2000), and physical capital (Flora and Flora 1993). Community capacity is often referred to as the ability of a community to meet local needs and expectations, respond to internal and external stresses, and take advantage of opportunities of all kinds (Doak and Kusel 1996, Harris et al. 2000).

Although social scientists generally agree on the notion of community capacity, there is no definitive set of indicators used to measure attributes. One challenge is identifying measures that reflect the dynamic as well as multidimensional properties of community capacity while at the same time producing measures that can be compared across large regions. As forest management practices and forest conditions change, so too will opportunities for developing forest product industries. A better understanding of community capacity will help managers, residents, development specialists, and others who are looking for ways to assist and partner with communities to provide economic development opportunities that jointly meet forest management objectives.

Research questions under focal area A:

1. How can empirical wood product recovery studies be used to answer management and policy questions about timber harvest, timber valuation, timber measurement systems, community assistance, and basic wood properties?
2. What are techniques to simulate recovery of primary and secondary wood products? Can stand and landscape simulation models make the connection between management practices and resultant wood quality and wood properties? Can AUTOSAW be modified to simulate curve sawing and link primary and secondary simulations systems? Can other processing simulation models (e.g., veneer) be used to make the connection between management practices and product quality?
3. How can we increase our understanding of how different spatial arrangements of trees influence the production and characteristics of wood and other outputs at the stand level? Can we expand this to the landscape level?
4. How does management for noncommodity objectives on public land influence the quantity and quality of wood that can be harvested many years from now?
5. How is the socioeconomic well-being of forest-based communities affected by changing forest conditions that result from management actions? How do changes in forest management policies and practices affect forest product industries in communities? What are the links between changes in forest products industries and other socioeconomic changes in communities?
6. What indicators and measures are most appropriate for assessing the capacity of communities to engage in opportunities related to small-diameter wood utilization, wood and nonwood forest product utilization, and wildfire preparedness?

**B. Effects of natural disturbances (e.g., wildfire, insect outbreaks) on wood quality, wood utilization, and people are poorly understood.**

A history of fire suppression, changes in the intensity and type of land management activities, and prolonged periods of climatic change (e.g., drought) have contributed to conditions in national forests that make them prone to insect epidemics and uncharacteristically severe wildfires.

One challenge to the research community is to identify how the effects of these and other natural disturbances influence utilization opportunities on a temporal scale. Predisturbance stressors associated with competition and changes in structure in mixed-conifer forests may influence postdisturbance wood deterioration and the rate at which it occurs. Previous work (Lowell and Cahill 1996) and current observations (see Stevens and Barbour 2000) indicate an accelerating rate of wood deterioration in fire-killed Western tree species (fig. 3). Identifying the factors that are influencing this change could lead to development of alternative land management practices to reduce this effect and aid in understanding postdisturbance restoration options involving wood utilization.

**Rapid, onsite determination of the suitability of wood for specific products will allow managers to better understand the range of options available.**

Insect infestations are also observed more frequently and are prolonged in their cycle. These infestations can result in extensive forest mortality over millions of acres (Spruce Bark Beetle Task Force 1998). Infestations typically will follow fire and are not confined to trees that have been killed by the fire. Many species will attack stressed trees and even adjacent green trees leading to delayed morality. Pathogens (wood decay fungi) are an additional factor in determining product opportunities for affected trees (fig. 4). Rapid, onsite determination of the suitability of wood for specific products early in the postdisturbance planning process will allow managers to better understand the range of options available to them if they choose to remove dead or dying trees.


Figure 3—Log end showing extent of larval galleries in ponderosa pine tree harvested 1 year after fire kill.

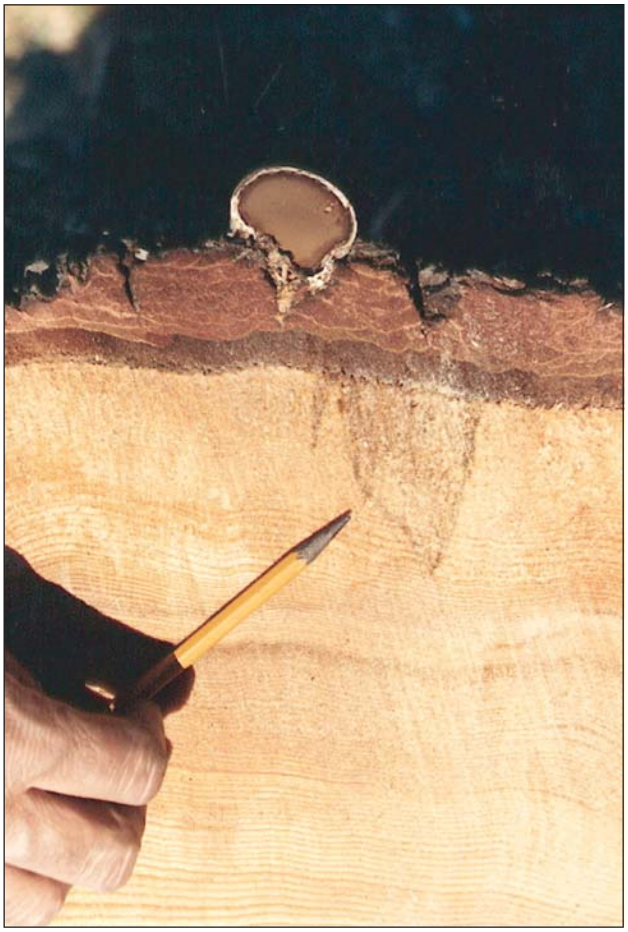

Figure 4—Decay fungi fruiting body and sap rot in Douglas-fir log 2 years after fire kill.

Information is lacking on the suitability of dead or dying trees as an input raw material for several new and emerging wood processing technologies. Wood unsuitable for solid wood appearance-grade or structural-grade products could be suitable for engineered wood products. Biomass energy can also play an important role in using this material while meeting the energy needs of communities and contributing significantly to the economic development of rural areas. In Alaska's Kenai Peninsula, a spruce bark-beetle (*Dendroctonous rufipennis* Kirby) infestation has affected over 1.5 million acres, resulting in lost value for lumber (Lowell and Willits 1998) and other solid wood products (Lowell 2001). The real concern, however, is catastrophic fire risk with all the dead material greatly increasing fuel loads. Researchers at the WUC have completed biomass energy and resource feasibility evaluations for communities in south-central and southeast Alaska. Both studies indicated favorable economic and environmental benefits from using local waste resources for small-scale energy to meet community heating needs. Additional work will include evaluations of beetle-killed material for manufacture of wood-plastic composites.

The small-diameter timber resource is also important in many regions of Alaska. Boreal forests experience wildfire and disease hazard associated with prevalent species such as white spruce (*Picea glauca* (Moench) Voss) and black spruce (*Picea mariana* (P. Mill.) B.S.P.)—trees that often can have breast-height diameters of less than 9 inches. Harvested coastal forests, especially in southeast Alaska, experience robust regeneration that is often thinned early (precommercially). However, the Alaska small-diameter roundwood problems, to date, have received less publicity than those associated with the Rocky Mountain West or Southwest because there is little wildland-urban interface in Alaska.

Effects of natural disturbance are felt at the personal level (loss of lives) and the community level (wildland-urban interface and the loss of homes, perceived risk of wildfire) in both economic (cost of containment) and social terms (loss of natural resources and amenities) (fig. 5). Reactions to natural disturbance reflect the diversity of values toward and uses of natural resources, including economic, recreational, amenity, water quality, spiritual, and cultural. A better understanding of values and how people are affected by, and engage in, management practices in response to disturbances may help with developing policies that are more relevant to the people closely associated with natural disturbances.

Research questions under focal area B:

1. How can we conduct watershed-scale analyses of management alternatives that reduce risk of major disturbances such as fire and insect outbreaks? How can analyses be structured to include different spatial arrangements of treatments over space and time and consider several resource values?
2. When does wood utilization make sense? Does removing the wood create conditions that are different than when the wood is left on the site or burned on the site? Are the benefits of removing the wood greater than the costs?
3. What are the time constraints and the tradeoffs made in waiting to use fire- and insect-killed or damaged trees?
4. How does the timing and intensity of disturbance (e.g., wildfire or insect infestation) affect the wood in trees? How do the effects differ by tree species, size, and time following the disturbance?
5. Are there new or emerging technologies that can use wood damaged by fire and insects for a higher value product?
6. How do forest-based communities perceive and understand natural disturbances (including fire and insect outbreaks), and how does this shape reaction to disturbances and engagement in collaborative stewardship resource management processes (e.g., fire preparedness)?

Figure 5—Fire in the wildland-urban interface is an increasing hazard to homeowners.

**C. Regional differences throughout the Western States are not well understood in the context of wood utilization. These include biophysical and ecological (e.g., species, stand structure, climate), technical (e.g., infrastructure, manufacturing capacity), and social (e.g., communities, institutional) differences and the interactions among them.**

The Western United States is a vast area with considerable variation in biophysical characteristics, climate, population density, sociocultural traditions, transportation systems, processing infrastructure, and other factors that interact to affect the feasibility of resource utilization. We need to understand these differences if our research findings are to be successfully applied to localized problems. For example, the volume of forest resource available for harvest may be greater in southeastern Alaska than in northern California, but it might be easier to develop a wood processing industry in northern California because of its proximity to markets, an existing road network, and availability of a skilled workforce. Similarly, the physical characteristics of tree species in Idaho and Montana may be different than those in the Southwest, dictating the available range of utilization options. We need to improve our ability to characterize forest resources and evaluate uses that are compatible with regional differences in the resource. We also need to improve our ability to link management objectives and actions with human values and uses of natural resources in various times and places.

Resource extraction, management, and conservation issues often involve complex interactions of human desires, technical feasibility, and economic constraints. As a result, resource management decisions affect individuals from different regions differently, with the desires of individuals in a specific region sometimes outweighed by the costs and benefits to society as a whole. What people do, what they know and care about, what values and perceptions they hold, and what they find acceptable affect natural resources and are affected by natural resource management. Yet, this dynamic process is poorly understood. The use of natural resources can alter natural systems in ways that are not easy to predict. There is continual uncertainty about how to define "best" management practices. Furthermore, the distribution of costs and benefits within and across regions can differ greatly.

Effective, responsive, and efficient resource management requires information that helps to identify and evaluate alternative institutional (both formal and informal) structures and processes. Informal institutions, such as social norms, may have strong local context. Formal institutions, such as management policies for harvesting wood and nonwood products, may have local and regional implications. A better understanding of the institutional opportunities and barriers to integrating human values and uses of natural resources with forest management may expand the options for forest management and may produce outcomes that are more socially acceptable.

The geographic scope of responsibility for the ESP team is the Western United States (Forest Service Regions 1 through 6) and Alaska (Region 10). The WUC team in Sitka has research and development responsibility for Alaska. Sources of variation across regions are numerous:

- Tree characteristics: species, size, age, relative density, stand history, stand composition, and stand structure.
- Scale: temporal (annual, decadal, century), spatial (tree, stand, landscape/watershed, region, community, individual).
- Forest health condition: managed stands and densely stocked, insect-infested, and burned areas.
- Ownership: federal (Forest Service, Bureau of Land Management, Bureau of Indian Affairs), state and private (industry, nonindustrial private) land.
- Proximity to human populations: rural and forest-based communities, urban areas, wildland-urban interface, demographic changes.

To illustrate this wide range of variation, we examine several regions in detail.

## Alaska

Alaska covers a large area, including several major forest types ranging from boreal forests to temperate rain forests, and includes at least six commercially important hardwood and softwood timber species. Forest-based businesses in

Figure 6—Log rafts at Smith Cove, Prince of Wales Island, ready for rafting to the sawmill in Ketchikan, Alaska.

Alaska (fig. 6) are often confronted with significant economic barriers, including relatively high costs for transportation, wages, and materials compared with their counterparts in other regions.

The coastal forests of southeastern Alaska make up the northernmost temperate rain forest in the world (Peterson and Monserud 2002). Although there are considerable second-growth stands in the accessible areas that were harvested in the past century, the region is dominated by extensive old-growth stands. A quarter-century ago, Harris and Farr (1974) reported that these old-growth stands were quite defective and decadent, with the defect averaging 30 percent of volume. Nevertheless, this resource can have unique physical characteristics that might be desirable for high-end appearance markets (Nicholls 2001). Even in these markets the costs of operations in southeastern Alaska could make profitable operations difficult. A major challenge will be finding markets for the moderate- and low-quality material that is produced when processing old-growth timber. This is partially true because there no longer are pulp mills or other appreciable markets for chips or other residues in southeastern Alaska, but also because high costs make it difficult for Alaska sawmills to compete even in the "domestic" (within Alaska) market for framing lumber. The overall grade of the logs being harvested from the Tongass National Forest for the five quarters from January 1999 to March 2000 is shown in the following tabulation (R. Griffen. 2000. Personal communication. Computer programmer analyst, USDA Forest Service, Alaska Region, 709 W 9th Street, P.O. Box 21628, Juneau, AK 99802-1628).

**Percentage of log volume in various grades for timber sold by the Tongass National Forest from January 1999 to March 2000**

| Peeler/Select | No. 1 Saw log | Special Mill | No. 2 Saw log | No. 3 Saw log | No. 4 Saw log | Utility |
|---|---|---|---|---|---|---|
| 0.9% | 4.6% | 4.6% | 43.8% | 27.9% | 3.8% | 14.5% |

In an earlier analysis for Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) in Washington and Oregon, Fight and Chmelik (1998) illustrated how small volumes of clear lumber or veneer can dramatically alter net returns from a resource. This analysis, however, assumed that there were markets for all products, including residues. That is unlikely to be the case in southeastern Alaska. There is a need to conduct a similar economic analysis for southeastern Alaska mills to determine if these mills would be profitable over the long term. Over the next several decades, handling low-grade material in southeast Alaska will present a challenge that might outweigh the benefit from the high-grade portion of the resource.

**High harvesting, transportation, manufacturing, and shipping costs in southeastern Alaska combined with the relatively low product potential of these trees might make it difficult to demonstrate profits under normal forestry accounting procedures.**

During the next few years, forest managers in southeastern Alaska will face difficult decisions about how to manage young-growth stands. There are basically two management scenarios. The first is to manage for rapid volume growth and shorter rotations. This requires techniques such as precommercial thinning and possible intermediate commercial thinnings and prunings that concentrate growth on fewer crop trees but have the unintended effect of keeping crowns long, which promotes branch diameter growth. The advantage of this management strategy is that rotations are shorter so investments are returned faster. The disadvantage is that trees with long crowns and large branches cannot typically be used to manufacture high-value lumber or veneer. Whether or not this is a good strategy for an individual landowner requires an analysis that involves specific management objectives. High harvesting, transportation, manufacturing, and shipping costs in southeastern Alaska combined with the relatively low product potential of these trees might make it difficult to demonstrate profits under normal forestry accounting procedures.

The second strategy is to manage extensively to reduce expenses for stand tending at the cost of slower growth. The possible advantage of this strategy is that stand conditions will result in reduced crown length and smaller average branch size. Christensen et al. (2002) recently conducted a lumber recovery study on this type of material and found that for Sitka spruce (*Picea sitchensis* (Bong.) Carr.) the yield of clear lumber was 6.7 percent of total lumber volume and for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) it was 3.7 percent. In addition, because the trees were relatively young, about 95 years old, they had very little defect so that even though logs were not graded, it is safe to infer that there was little or no volume in No. 4 Saw log and Utility log grades. The disadvantage of this strategy is that rotations would be from 50 to 100 percent longer than the rapid growth scenario.

Individual landowners and managers need to conduct economic analyses that are appropriate to their needs and conditions before choosing between these two general scenarios. The interesting point is that because of the unique circumstances in southeastern Alaska, e.g., high production costs with low opportunity costs for the land, there might be few nonforestry alternatives for private landowners. Because of the desire to manage for nontimber values such as wildlife, fisheries, and recreation, public management agencies might already be managing all or parts of their land in ways that are conducive to producing nontimber values (Wipfli et al. 2003). As a result, the economics of timber production might play a less important role in decisionmaking than the ability to provide economic activity in remote communities.

## Coastal Oregon and Washington

More industrial private land exists in coastal Oregon and Washington than elsewhere in the West, which is dominated by public land. In coastal Oregon and Washington, industrial forest land accounts for about 18 percent of the total forest land area. The remaining land is in private nonindustrial ownership (27 percent) and public ownership (55 percent) (Powell et al. 1993). A key issue in this region is the emerging divergence in the distribution of forest age classes across land ownership groups, and the potential implications for the properties of wood available for utilization in the future (Haynes et al. 2003, Spies et al. 2002). In general, private industrial landowners have wood production as a primary management objective and they use more intensive forest management practices than do public landowners. Nonindustrial private landowners have a variety of objectives, and thus their management practices are highly variable.

Landowners in the region have different needs with respect to information on wood utilization opportunities. Public landowners, for example, face questions about wood quality over a broader range of tree species and sizes than do private industrial landowners, who typically manage for a narrower range of species and rotation lengths. Nonindustrial private landowners might seek information on technology available to add value to small volumes of wood.

Rotation lengths have been declining in coastal Oregon and Washington for several decades, and private land managers are trying to find a mix of improved seed stock, initial stocking density, thinning, and fertilization that meets their objectives for growth yet still results in trees with acceptable wood characteristics.

Essentially all the industrial wood grown in this region is either processed domestically into structural products and pulp or it is exported as logs (Warren 2002). The domestically manufactured products require good mechanical properties and dimensional stability, but appearance-related characteristics such as knot frequency and distribution, grain texture, and color are not particularly important.

Work by Barrett and Kellogg (1989) and Fahey et al. (1991) suggest that it is possible to grow Douglas-fir with wood characteristics that are acceptable for structural products, especially when combinations of visual and mechanical grading systems are combined to select the lumber or veneer with the best properties under each system. There is, however, some cause for concern when Douglas-fir rotation ages drop below about 40 years (Briggs and Turnblom 1999). Results from the same study suggest that there is more cause for concern about the wood properties and product potential of young western hemlock trees managed for rapid growth. About half of the lumber volume of trees less than 40 years old was graded as No. 3 or Economy under visual lumber grading rules (WWPA 1998). Although the situation improved for trees 40 to 60 years old, the proportion of No. 2 and better lumber was still only around 80 percent, well below the >90 percent rule-of-thumb that mills in this region expect. The situation for machine-stress-rated lumber yields for hemlock managed for rapid growth was even less optimistic. If these preliminary results for western hemlock are confirmed by future work, they illustrate important challenges that processors will face when trying to convert young-growth hemlock into traditional structural wood products.

**Processors will face challenges when trying to convert young-growth hemlock into traditional structural wood products.**

## The Interior West

Nearly 70 percent of the commercially viable forest land in the interior West (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) is managed by federal or state agencies, 26 percent is owned by nonindustrial private landowners, and approximately 5 percent is owned and managed by the forest products industry (Powell et al. 1993). Moreover, there exists an abundance of private and public woodlands throughout the region that are dominated by noncommercial tree species such as pinyon (*Pinus edulis* Engelm.) and juniper (*Juniperus* spp.). Essentially all of the industrial private land is located in Idaho and Montana. This ownership pattern creates a different set of wood quality issues than those seen for other parts of the West. Forest products manufacturing facilities in this area have traditionally depended on the federal government for their wood supply. Keegan et al. (1997, 2001a, 2001b) report that the milling capacity in the interior West has dramatically declined over the past decade coinciding with a dramatic drop in the removal of timber from federal land.

The remaining milling capacity and technology to efficiently process small-diameter wood is highly variable across the interior West (Lowell et al. 2004). In many areas, the cost associated with the transport of small, raw logs is prohibitive because of diminished solid wood and biomass processing capacity and long haul distances between manufacturing facilities. In areas where there is little or no milling capacity, only trees with the highest value can be harvested with a positive net return given traditional wood product markets. The problem is further compounded by the fact that there is an abundance of suppressed small-diameter wood across the entire inland West region owing to decades of fire suppression and reduced logging activity.

In most areas within the region, the focus has necessarily shifted to finding new markets for products made from less-desirable, small-diameter timber (Barbour 1999a, LeVan-Green and Livingston 2001, Paun and Jackson 2000). The goal is to offset the costs of harvesting and processing, to reduce the threat of catastrophic wildfire in drought- and insect-prone landscapes, and to create jobs and generate income in traditionally natural-resource-dependent communities. The success of these endeavors will significantly influence future forest stand structures across the region and the livelihoods of rural communities. We discuss the northern interior (Idaho, Montana, and Wyoming) and the southern interior (all other Rocky Mountain and Southwest States) separately because of differences in wood products manufacturing infrastructure, species composition, wildland fire risks owing to insect infestations and drought conditions, and other factors influencing perceptions of wood quality.

**Northern interior—**

The wood processing infrastructure in Idaho, Montana, and Wyoming consists mainly of sawmills, but there are still a few veneer mills operating within reasonable haul distance of this region. The pulp market in the northern interior West is limited to very few mills (mostly in the north), so the disposal of low-value, small-diameter trees is a problem (Barbour 1999b). During market peaks, it is possible to sell chips to mills in western Oregon and Washington, but typically there is only a limited market.

There is a considerable body of literature on the wood characteristics and product potential of Douglas-fir, true firs (*Abies* spp.), western hemlock, lodgepole pine (*Pinus contorta* Dougl. ex Loud.), and ponderosa pine (*Pinus ponderosa* P. & C. Lawson), the major species that exist in the Northern region (Erickson et al. 2000, Koch 1996, Myers et al. 1997, Willits et al. 1997). With the exception of ponderosa pine, the properties of this small-diameter timber are typically as good as or better than the traditional resource (Barbour 1999a, Lowell et al. 2004). The primary resource harvested in the region is mixed conifers from suppressed stands of an age where juvenile wood is not a significant factor. The major quality issue is size. These trees are too small to manufacture many of the products traditionally sold from these species. Small piece size also significantly increases harvesting and processing costs (Barbour 1999a; Barbour et al. 1995; Christensen and Barbour 1999; Wagner et al. 1998, 2000). Without substantial processing capacity in the energy, chemical, fiber, or composite product streams, it is unlikely that forest thinnings and fuel reduction treatments will pay for themselves.

Not surprisingly, mitigation of fire hazard is becoming the dominant management objective on public lands and many of the proposed treatments remove only small-diameter trees. There have been a few successful sales of small-diameter trees in the northern interior that were designed to mitigate fire hazard or otherwise remove the understory in densely stocked stands to meet wildlife aesthetic objectives. However, these activities achieved a positive net return only when they were located near manufacturing facilities that could take advantage of the small-diameter trees or were able to additionally harvest larger trees (Han et al. 2004). As a result, high-speed, technologically advanced small-diameter-log sawmill processing has become a focus in the region, but with the need to process large volumes of wood. Consistent access and the ability to purchase this material from within an acceptable transportation radius have been problems stunting the use of new sawing technologies. Emerging authorities (possibly the Healthy Forests Restoration Act of 2003) to secure long-range contracts for the purchase of forest resources will be key in establishing a viable industry using small-diameter trees.

As previously stated, most private industrial forest lands in the interior West are located in the northern interior. Large companies own most of this forest land and provide a significant amount of employment to residents in rural communities. However, their role in using small-diameter material also has been limited by poor product markets and long distances to processing facilities, even for those owned by the companies that own the land (Han et al. 2004). The prevalence of small-diameter trees on these private lands is perhaps not as vast as on federal lands because of more intensive logging, but they do exist in great numbers as a result of decades of fire suppression. As on federal lands, the abundance of these smaller trees threatens forest health (USDA FS 2003).

The ability to develop value-added products made from small-diameter material in the northern interior is contingent upon the availability of processing infrastructure within an acceptable distance, but also on the quality of products that can be developed and a consistent supply of raw materials. Integrating mobile processing operations with quality end products has the potential to offset associated costs of harvesting, handling, and delivering. It also has the potential to economically remove an abundance of small-diameter trees that threaten communities at risk from catastrophic wildfires.

**Integrating mobile processing operations with quality end products can offset associated costs of harvesting, handling, and delivering and can remove an abundance of small-diameter trees that threaten communities at risk.**

**Southern interior—**

Public forest land of the southern interior (Colorado, New Mexico, Utah, Arizona, and Nevada) is dominated by ponderosa pine forests, but can include extensive areas of lodgepole pine, Douglas-fir, mixed conifers, aspen (*Populus tremuloides* Michx.), and pinyon-juniper. Years of fire suppression have resulted in dense stands with low structural diversity and low species diversity. More recently, much of the region has been affected by severe drought, insect epidemics, and frequent occurrences of catastrophic wildfire. Environmental regulation and upper limits on the size of material that the public wishes to be harvested will continue to affect forest management in the region, as will the continued conversion of forests as a result of catastrophic wildfires and insect outbreaks. As a result, public forest managers are faced with the dual objectives of reducing the threat of wildfire while simultaneously improving forest health (NCASI 2004, USDA FS 2003). The management options available generally focus on forest thinning in the wildland-urban interface and the reintroduction of low-intensity fires to the ecosystem, but not necessarily on timber production. One objective is to restore and maintain conditions that favor the threatened and endangered species associated with old-growth forests. As a result, a majority of material available for wood production will be small diameter with limited product potential, given traditional markets.

The difficulty in finding suitable markets for this small-diameter material is magnified by the poor structural qualities of some species. In the Southwest, for instance, small-diameter ponderosa pine has mechanical properties that make it unsuitable for all but the least demanding structural uses (Erickson et al. 2000). It is characterized by suppressed growth, but with low tension and strength owing to a high ratio of juvenile wood and difficulty in product drying (Voorhies and Blake 1981). Research of the region will need to focus on finding competitive uses for small-diameter ponderosa pine (Lowell and Green 2001, Paun and Jackson 2000).

Finding suitable markets is further complicated by the fact that there are virtually no outlets for the types of timber that will be harvested. New processing facilities will have to match the types of wood material available with contemporary utilization techniques. To be successful, more wood processing facilities are required in areas close to the available resource, and consideration will need to be given to the types of activities possible in a given location. A primary focus on rebuilding the wood processing infrastructure of the region and the contribution of research in this endeavor will be on finding ways to collocate different types of processing facilities that are compatible with local resource characteristics and community desires (fig. 7).

Nonindustrial private land managers, in general, face a different set of wood utilization challenges. A majority of private forests and woodlands in the Southwest are characterized by dense stands of pinyon-juniper that are managed more for livestock grazing than for timber production. In fact, little attention has been given to restoring grasslands across the West in the context of forest management. Yet, these forests and woodlands provide a unique opportunity for increased biomass utilization, particularly within remote areas. Wood chips and pellets are being used to produce electricity and for district heating systems. Renewable portfolio standards (RPS) have been established or are being debated in many states within the southern interior that mandate purchases of energy from sustainable fuel sources, of which biomass from forest thinnings has received considerable attention. Research needs from this perspective focus on finding cost-effective uses of biomass by examining removal systems, consumer demands, and institutional incentives for renewable energy production.

Figure 7—Hand peeling bark for exposed ponderosa pine latillas in Arizona.

Other private lands predominately within or adjacent to the wildland-urban interface pose an added problem. Many of these lands are smaller than 40 acres but have sustained a significant portion of property damage from catastrophic wildfire in the past several years. Recent efforts to increase thinning in the wildland-urban interface have focused on landowner assistance and education, as well as federal funds to thin lands adjacent to communities and private lands. Forest byproducts generated from the thinning of these stands will be significant and provide a unique opportunity to create value-added processing close to the resource base. Research needs from this perspective focus on citizen perceptions of wildfire risks, on acceptability of thinning prescriptions, and on developing strategies for building effective community partnerships that encourage collaborative planning.

**Forest byproducts generated from the thinning can provide a unique opportunity to create value-added processing close to the resource base.**

Finding and developing markets for niche products is another area requiring significant research. Lowell and Green (2001) suggest that appearance-grade lumber might be a more valuable alternative than dimension lumber when processing logs in the 5- to 10-inch small-end-diameter (SED) classes. Much of the timber harvested in the region is also a competitive raw material source for wood chip and pellet heating. High-quality oriented strand board (OSB) can be made from small-diameter ponderosa pine because of unique species characteristics. In addition, a recent focus in the region is on engineered and composite wood products for signs, guardrails, laminated beams, and other value-added products (fig. 8).

Figure 8—Researchers tallying grade recovery of cants from small-diameter ponderosa pine from northern Arizona.

**California—**

Timberlands represent almost one-fifth of the state's entire land area, about half of which is privately owned (Smith et al. 2001). The remainder is on pubic land, managed by state and federal agencies. Already over 35 million people, California's population will continue to undergo rapid growth in coming decades. The population is projected to increase by 50 percent by 2025 and nearly double in the next 50 years (USDC Bureau of the Census 2004). This growth will not be distributed evenly over the state. Rate of population increase in the wildland-urban interface is likely to exceed statewide rates. With expanding population, demands on California forest land for commercial and noncommodity benefits will continue to intensify, especially in more urban southern California.

Higher population levels, increases in incomes and leisure time, and changing social preferences, will lead to ever-increasing demands on public forests for uses other than timber production. These collective demands and expectations of forest land portend unprecedented pressures and dilemmas. Development of viable strategies for accommodating multifaceted human demands will require the continuance of collaborative initiatives that have sprung up throughout the region. The benefits of these sustainable-timber-harvesting initiatives are inextricably linked to social and economic well-being.

The threat of catastrophic fires was evident in the most recent fires of 2003. More than 739,000 acres burned (90,000 acres of forest) with 22 civilian lives lost, 3,600 homes destroyed, and $250 million spent in containment. Public reaction to this catastrophe is likely to increase pressure to reduce fire risk, and to change the perception that fire risk is only a rural problem. Fuel reduction calls for the removal of brush and small-diameter material, with the consequent problem of either disposal or use as some product or energy source. A challenge of forest restoration in California is the lack of consensus over how to improve forest health and the role of timber harvesting in that process. Developing or maintaining an infrastructure capable of handling byproducts from these treatments is also a key to their success.

Fire risk reduction is not the only issue surrounding forest land in California. In rural areas, technical questions are being asked about processing underutilized species such as tanoak (*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.) and madrone (*Arbutus menziesii* Pursh). In the past, the ESP team worked on utilization of black oak (*Quercus kelloggii* Newberry) (Lowell and Plank 1997). Now northern California is faced with the more widespread problem of sudden oak disease (*Phytophthora ramorum*) and the associated effects of the disease on utilization of trees infected by this pathogen and the subsequent invasion of wood decay fungi.

Decreased harvest on federal land, consolidation and buyouts within private industry, and the disappearance of wood products manufacturers, have changed the infrastructure of the wood products industry in California. The challenge is to develop a capacity to process a variety of material that includes small-diameter trees removed in fire-risk-reduction treatments and also to maintain the capability of processing other species, such as the native hardwoods, for use in high-end wood products.

Research questions under focal area C:

1. What are the regional differences in the forest resource base (tree characteristics, scale, condition, and ownership)? How do these differences and their interactions influence utilization options in different types of communities?
2. How can wood product recovery studies be used throughout the Western States to answer management and policy questions? How much variation should be expected in a typical wood product recovery study?
3. What types of utilization options are most suitable for forest-based communities given different workforce skills, capacities to entice financial investment, and the physical characteristics and distance to the nearest resource supply?
4. What will be the long-term social and economic impacts of new small-diameter processing on forest-based communities? Will emerging markets and related industry provide a sustainable source of jobs to community residents?
5. How do institutional processes and structures create or modify barriers and opportunities for alternative forms of forest management, including those that have unique regional or local context?
6. How do classifications of rural forest-based communities across the West change with different measures of socioeconomic well-being and community-forest relations?

**D. Technical assistance and feasibility analyses are needed by resource managers, technical organizations, users of natural resources, and others interested in the physical characteristics, processing, and marketing of forest products.**

Much of the needed forest operations, resource characterization, and wood utilization research in this area will focus on improving the efficiency of harvesting and processing of economically marginal resources. There is, however, a need by private landowners, whose primary objective is income from timber-related activities, to develop and test new harvesting technologies that efficiently remove timber under increasingly intensive management regimes.

The wood product potential defines the ability of manufacturers to process raw material into products they can market at a profit. Although resource characteristics define and constrain a region’s ability to convert resources into valued products, a stable, high-quality supply of timber is not, by itself, sufficient to ensure a viable forest product industry in a given region. Wood products from the Pacific Northwest are sold in world markets at prices that reflect both world demand conditions and our competitors' costs and productivities. When analyzing a region's product potential and competitive position, understanding the nature of the present and potential competition is essential. In addition to the quality of raw material and timber supply, the competitive position of a region's wood-producing industry is dependent upon the perceived differentiation of quality, price, service, relative cost and productivity position, technological position capacity and resource utilization, transportation cost and distance to markets, distribution systems, entrepreneurial ability, and harvest and export regulations.

Producers face increasing competition from relatively low-cost wood products from the Southern region of the United States, the South Pacific, northern Europe, Russia, and Canada. Given the characteristics of much of the material currently removed from public land, an appropriate question might be, "If a manufacturer were provided this material free of charge, could resources be profitably converted to end products while meeting social goals or objectives?" Some of the other pertinent research questions involve technical capabilities, scale of operations, and access to markets. Areas where research questions still exist include identifying the range of products for which conversion technologies exist, providing information about the resource needed to implement these technologies, identifying technological advancements needed to process this type of resource, and size and scale requirements for competitive production consistent with the political and ecological landscape.

**Private landowners need information about the mechanical and physical properties of the younger, more quickly grown material that they are now producing.**

Much of the research needed under this heading is geared toward evaluation of the characteristics of different resource segments. Private landowners need information about the mechanical and physical properties of the younger, more quickly grown material they are now producing. Public land managers need capabilities to recognize meaningful differences in the characteristics of the economically marginal resources they now tend to offer for sale. For example, how can you distinguish between a small-diameter resource that is only suitable for use as biomass and one that has potential for higher value products like posts and poles or even sawn lumber or veneer? The answer to this question includes elements of resource characterization as well as information on location, harvesting systems, and local processing infrastructure. Most other questions in this area will require consideration of an equally complex set of interactions, and we need to become skilled at recognizing and isolating the contributing factors for study, then combining them to provide answers that are meaningful to our clients.

The mission of the WUC team presents an additional research challenge. The recent economic events within Alaska, including the closure of two major pulp mills, have made it difficult for wood products businesses to compete in domestic and global markets, underscoring the need to continue a transition from commodity-based products to differentiated (niche) products designed to serve more specialized markets. Assistance is needed in product differentiation and identification of market structures and barriers, determining potential for differentiating Alaska products from competitors', examining existing market structure and barriers to entry for the differentiated product, and determining competitive position of producers within the market. Feasibility studies are needed that address how much material is required and over what timeframe to make a specific technology feasible and whether implementation of new or existing technologies can be done profitably. Given the distance from markets and other cost disadvantages that Alaska producers face, effective product processing and marketing is an important component of business success. Marketing research by the WUC has included consumer preference studies for secondary wood products from Alaska hardwoods (Donovan and Nicholls 2003b). It was found that well-defined niche markets exist for specific types and grades of lumber, and that higher grades of lumber are not always associated with the most valuable products.

An array of value-added wood products can be manufactured from commercially produced lumber in Alaska. Value-added processing of products such as furniture may involve several manufacturing stages, including drying, planing, moulding, sanding, and/or staining. By contrast, other value-added products may require little or no processing, and could include compost products, bioenergy products (heat and/or electricity), and nontimber forest products.

**Establishing dry kilns in Alaska is predicted to double the state-wide lumber drying capacity so that value-added products can be manufactured to the standards needed for domestic and export markets.**

Currently, value-added processing in Alaska mainly comprises sawmills, several of which are now producing kiln-dry lumber instead of green lumber. The WUC has been instrumental in establishing dry kilns in Alaska, an effort that is predicted to double the state-wide lumber drying capacity. Much of the planned WUC research in this area will focus on drying techniques for maintaining lumber quality so that value-added products can be manufactured to the standards needed for domestic and export markets. Other work has considered testing softwood species for use as railroad ties, timber bridges, and fence posts.

To better explore opportunities and stimulate interest in utilization of Alaska small-diameter roundwood, the WUC, in collaboration with the Juneau Economic Development Council (JEDC), was represented at a small-diameter structural applications conference at the University of Iowa in November 2003. As a result, JEDC recently acquired the necessary joint connectors from the conference's structural designer so that a mobile prototype (model) of the latest small-diameter roundwood structural applications technology can be transported and displayed throughout Alaska. Partnerships between the Wood Utilization Center and outside cooperators led to successful technology transfer of new methods and technologies.

Research questions under focal area D:

1. What new and emerging biobased product technologies are available that could enhance utilization of small-diameter material?
2. Can product recovery studies be expanded to include secondary manufacture of wood products or value-added opportunities such as cut stock or engineered products from small-diameter timber, kiln drying, and preservative treating of lumber in Alaska?
3. What is the best way to develop a vertically integrated forest products industry in a region?
4. How can technology transfer be improved to assist local communities, regional governments, the state, business, and private individuals in developing more efficient uses of forest products?
5. What information do forest-based communities need to expand or retain existing wood products processing infrastructure? Which utilization options and scale are most appropriate for community needs?

## Comparative Advantages

### The Ecologically Sustainable Production of Forest Resources (ESP) Team

We have a long history of conducting product recovery (mill) studies, with well over 100 completed in the past 40 years across the West (e.g., Christensen and Barbour 1999, Christensen et al. 2002, Fahey et al. 1991, Lowell and Plank 1997, Lowell and Willits 1998, Stevens and Barbour 2000). This tradition will continue as new questions arise. We are building a database that summarizes these studies by key variables. This will afford us several advantages. First, we will be able to quickly fill requests for information on specific topics (e.g., thinning effects on Douglas-fir). Second, we can use meta-analyses to test broad hypotheses covering many studies. Third, we can identify knowledge gaps, as well as identify areas where our knowledge is sufficient and no further study is needed.

The ESP team conducts research on forest operations, resource characterization, and wood utilization aimed at supporting and benefiting all landowners, public and private. Such topics can include characterization of the types and volumes of various products manufactured from plantations and other forests managed for timber production, the examination of new harvesting and processing technologies, and finding solutions to specific processing problems such as rate and degree of deterioration of fire-killed trees. They also include collaborative research that examines ways to conserve biological diversity and provide other nontimber values while minimizing fire risk.

Our general strategy is to approach problems in a multidisciplinary manner. We try to make the connections among wood utilization, wood quality, resource characterization, resource management, products, and people. Although it is difficult to integrate all these dimensions into a given research study, we always try to include at least two of the following three general elements: forest management, wood utilization, and people.

We also have a long history in evaluating new technologies. Current work involves wood-plastic composites that can be manufactured from small-diameter material. Another project involves portable and semiportable sawmills that can move to the resource for relatively short periods while fuel reduction and other thinning operations are active[1] (fig. 9).

The ESP team is quite responsive to research problems and requests posed by our clientele and partners. These cover a broad spectrum of research topics and

Figure 9—MicroMill outfeed after sawing small-diameter logs in Flagstaff, Arizona. (The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.)

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[1] Becker, D.R.; Hjerpe, E.E.; Lowell, E.C. [In review]. Economic feasibility study of using a mobile MicroMill for processing small-diameter ponderosa pine. On file with: Dennis Becker, Rocky Mountain Research Station, 2500 S Pine Knoll, Flagstaff, AZ 86001.

come from diverse organizations. Current examples include studying the effect of precommercial thinning in southeastern Alaska (Tongass National Forest), evaluating the utility of a new grading rule for fire-killed, worm-infested logs (Region 6 and the National Cubic Committee), the effect of juvenile wood in wood composites (Washington State University), suitability of using beetle-killed spruce on the Kenai Peninsula (Alaska) in wood composites (Washington State University), in-woods processing technology to reduce transportation costs (Joint Fire Science Program and the Greater Flagstaff Forests Partnership), prediction of wood quality in individual tree simulation (Oregon State University, University of Idaho), wood properties as affected by thinning and long rotations (Port Blakely and Weyerhaeuser), and testing wood strength properties (Wood Technology Center, Ketchikan), to name but a few.

We are also expanding our capacity to use simulation modeling to advantage. The AUTOSAW sawing simulator (Todoroki 1990), which is currently being expanded for use in U.S. mills, is a powerful interactive tool that efficiently addresses a wide range of questions that cannot otherwise be addressed. Recent examples using AUTOSAW include analyzing the effect of systematically increasing sweep in logs[2] and predicting internal lumber grade from log surface knots.[3]

**Simulation models are valuable tools that efficiently allow us to examine a broad range of questions.**

We are also using stand and landscape simulation models to address a variety of research problems. The effect of silvicultural treatments and management regimes on wood quality can be investigated by using ORGANON (Hann et al. 1997). Expansion of this capacity to FVS (Wykoff et al. 1982), the national standard of the USDA Forest Service, is currently underway. We can also address similar questions at the larger landscape scale by using tools such as the landscape management system (LMS) (McCarter 1997) that use both ORGANON and FVS (e.g., analysis of treatments to reduce fire risk in late-successional reserves). These simulation models are valuable tools that efficiently allow us to examine a broad range of questions relating forest management to wood quality and utilization. Combined with our expertise in community dynamics, we can use these tools to develop methods to characterize not only the resource but also the region as a whole so that we can understand what types of activities are possible and which are likely to be successful in a given location.

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[2] Monserud, R.A.; Parry, D.; Todoroki, C.L. [In review]. Recovery of simulated sawn logs with sweep. On file with: R.A. Monserud, Forestry Sciences Laboratory, 620 SW Main, Suite 400, Portland, OR 97205.

[3] Todoroki, C.L.; Monserud, R.A.; Parry, D.L. [In review]. Predicting internal lumber grade from log surface knots: actual and simulated results. On file with: R.A. Monserud, Pacific Forestry Sciences Laboratory, 620 SW Main, Suite 400, Portland, OR 97205.

We are quite adept at collaboration and forming partnerships to conduct and complete a given research problem. Our long history of mill studies is a clear testimony that we have established good working relationships with commercial sawmills and veneer mills to conduct our product recovery studies. We frequently form research collaborations with scientists from the Forest Products Laboratory (FPL) and other research laboratories, with university researchers (via joint venture agreements), and with scientists and managers from private industry (see app.). If the needed expertise is only available abroad (e.g., AUTOSAW in New Zealand, hybrid crown/tree modeling in Finland), then we will go abroad to form a partnership with the expert. The inverse also holds: we collaborate with the FPL and other labs to bring additional dimensions (e.g., wood engineering and product development) to bear on the problem at hand. We frequently participate in partnerships, associations, and cooperatives in order to reach resolution on complex research problems (e.g., Four Corners Sustainable Forests Partnership; Stand Management Cooperative). This strategy is particularly useful when addressing integrated questions that span wood technology, forest management, and community response and capacity.

## The Wood Utilization Center

The Alaska Wood Utilization Research and Development Center in Sitka has several comparative advantages that allow it to use its strengths to identify opportunities for wood products businesses in Alaska. These include the diversity of staff expertise, the range of research topics that it pursues, and its ability to communicate research findings through a variety of outlets to client groups throughout Alaska.

The WUC is a relatively new research center, having become fully staffed in 2000. It has identified primary and secondary manufacturing, wood products marketing (fig. 10), and economics research as tools for increasing wood utilization and technology transfer in Alaska. The many potential benefits to Alaska's wood products industry include higher market values for Alaska lumber under new grading rules and enhanced opportunities to supply domestic and export markets. The strengths enabling the WUC team to identify opportunities for wood products business in Alaska relate to its marketing and economics expertise. This greatly assists the team in developing strategies particularly important for many Alaska manufacturers because of the distances to and limited size of markets (Donovan et al. 2003). Recent studies have examined consumer preferences, willingness-to-pay


Figure 10—Trade-show preference study by the Wood Utilization Center team.

evaluations, and product attribute assessments (e.g., Donovan and Nicholls 2003a, 2003b; Nicholls et al. 2003b). Other research has considered opportunities for lower grades of lumber (containing knots and other defects) for making higher value specialty products (Nicholls et al., in press). Several marketing efforts have identified global markets for Alaska forest products (Eastin et al. 2003), including niche product opportunities for the specialized markets (e.g., birch crafts) that many Alaska producers serve (Eastin et al. 2003, Nicholls 2001). Recent small-diameter wood research identifies the problems and opportunities in using the resource as a structural building material (Cantrell et al., in press). Both the WUC and ESP teams cooperate with the Ketchikan Wood Technology Center in a lumber strength testing program that includes in-grade testing of commercially important Alaska softwoods and extensive testing for machine-stress-rating of lumber.

Technology transfer activities have played an important role in the WUC team's work and have included technical reports for trade journals, research summaries for clients, and online material for distribution via the team's Web site (http://www.fs.fed.us/pnw/sitka/). Technology transfer efforts have been directed toward a wide audience, including wood products entrepreneurs and natural resource professionals (Rapp 2003). The team has worked closely with many of Alaska's primary and secondary wood products businesses, including evaluations of sawmill efficiency (Kilborn 2002), lumber drying (Nicholls and Kilborn 2001), lumber moisture content (Nicholls et al. 2003a), and bioenergy potential from wood residues (Nicholls and Crimp 2002) (fig. 11). The team has sponsored several statewide conferences and workshops, and published newsletters highlighting WUC research and its benefits to end users (Rapp 2003). An important part of the technology transfer effort has been Web-based delivery, and has featured project descriptions, research summaries, and complete publications. The team has cooperated with numerous partners in hosting workshops and conferences, in particular the University of Alaska system. The WUC technology transfer efforts have also included site visits to wood products companies, interactions with

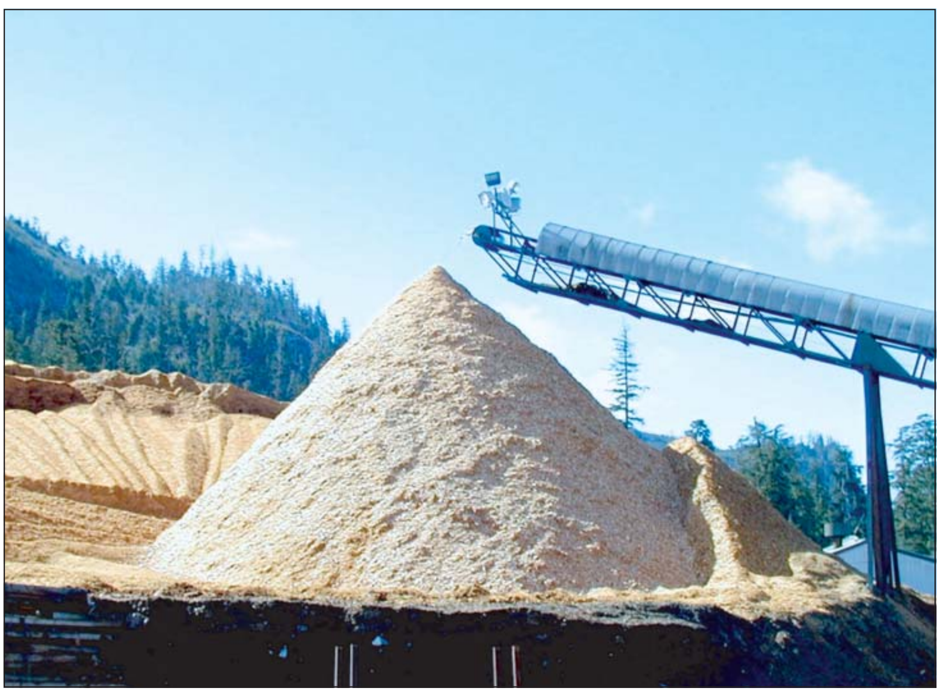

Figure 11—Sawmill manufacturing residues, found in abundance in southeast Alaska, can be used for energy or biobased products.

product consumers (e.g., at home shows), and interactions with wood products manufacturers (e.g., at industry trade shows).

## Conclusions

**There are increasing calls for ways to use wood from trees that traditionally have been underutilized.**

The ESP and WUC teams are successfully addressing a wide range of wood utilization issues throughout the Western United States. Of particular note is an estimated 190 million acres of federal forests and rangelands in the United States that face high risk of catastrophic fire (USDA FS 2003). Decades of accumulating dense undergrowth, along with drought conditions, insect and disease infestations, and invasion by exotic species make forests and rangelands in many areas of the West vulnerable to environmentally destructive wildfires. Through the Healthy Forests Initiative tools and the Healthy Forests Restoration Act of 2003 authorities, land management agencies are expected to manage public forests and rangelands to reduce the risk of catastrophic wildland fire. As a result, there are increasing calls for ways to use wood from trees that have traditionally been underutilized—material that previously went to chips or was left as slash. And where products or markets are not available, there is also a need to find cost-effective and efficient methods for disposing of or removing the material, thereby reducing fire hazard.

The ESP and WUC teams have a significant role to play in this effort. We have a continuing focus on problems related to utilization of small-diameter trees that are ecologically, economically, and socially sustainable. Research in this area addresses new technologies such as composites, biofuels, biomass feedstock for heating and energy, small-scale semiportable sawmills, as well as more traditional research on degradation of fire- and insect-killed trees, and the effects of thinning on residual tree development and quality. There is also the effect current management practices will have on the wood quality of trees harvested years from now. The interface between utilization of such material and community development is addressed through cooperative efforts with groups such as the Greater Flagstaff Forests Partnership and Alaska’s Denali Commission. The ESP and WUC teams are fundamentally poised to expand our efforts in small-diameter utilization in response to new programs such as the Healthy Forests Initiative and check on to emerging public and partner needs.

Different people push different wood utilization technologies, with little consideration of financial, social, or forest management implications. Because many of these technologies will rest, to a large degree, on private investment, we need to understand the implications of technologies for improving wood utilization. We envision a three-pronged approach. First, develop and transfer technologies adapted to the scale of the problem. Second, develop and deliver marketing strategies to assist in improving wood utilization. Third, link wood utilization to forest management objectives over a range of ownerships throughout the Western United States. Research that includes one or more of these elements should lead to successful accomplishments with our various partners.

## Metric Equivalents

| When you know: | Multiply by: | To get: |
|---|---|---|
| Inches | 2.54 | Centimeters |
| Acres | .405 | Hectares |

## Literature Cited

**Barbour, R.J. 1999a**. Diameter and gross product value for small trees. In: Proceedings of the 27th annual wood technology clinic and show. Atlanta, GA: Miller-Freeman: 40-46.

**Barbour, R.J. 1999b**. Wood production from ecosystem management activities in the Western United States. In: Proceedings of the TAPPI environmental conference. Atlanta, GA: TAPPI Press: 2: 491-500.

**Barbour, R.J.; Keegan, C.E.; Van Hooser, D.D. 1998**. Changing timber quality in the Western United States. In: Proceedings of forest management into the next century: What will make it work? Publ. 7276. Madison, WI: Forest Products Society: 126-138.

**Barbour, R.J.; Lowell, E.C.; Todoroki, C.L.; Parry, D.L.; Christensen, G. 1999**. Simulating North American lumber grade recovery with AUTOSAW using externally visible branch and stem form characteristics. In: Nepveu, G., ed. Proceedings, third workshop, connection between silviculture and wood quality though modelling approaches and simulation software. IUFRO WPS5.01-04. Nancy, France: Laboratoire d'Etude des Ressources Forêt-Bois, INRA-ENGREF: 493-504.

**Barbour, R.J.; Marshall, D.D.; Lowell, E.C. 2003**. Managing for wood quality. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 299-336. Chapter 11.

**Barbour, R.J.; McNeel, J.F.; Tesch, S.; Ryland, D.B. 1995**. Management and utilization of mixed species, small-diameter, densely stocked stands. In: Hassan, A.E.; Sherar, J., eds. Proceedings of Council on Forest Engineering 18th annual meeting. Cashieres, NC: Council on Forest Engineering: 187-195.

**Barrett, J.D.; Kellogg, R.M. 1989**. Strength and stiffness of dimension lumber. In: Kellogg, R.M., ed. Second growth Douglas-fir: its management and conversion for value. Special Publication No. SP-32. Vancouver, BC: Forintek Canada Corp.: 50-58.

**Becker, G.S. 1975**. Human capital: a theoretical and empirical analysis. The Journal of Political Economy. 70: 9-49.

**Braden, R.; Fossum, H.; Eastin, I.; Dirks, J.; Lowell, E. 1998**. The role of manufacturing clusters in the Pacific Northwest forest products industry. CINTRAFOR Work. Pap. 66. Seattle, WA: University of Washington, College of Forest Resources. 56 p.

**Briggs, D.G.; Turnblom, E.C. 1999**. Modeling number and size of branches in young coastal US Douglas-fir plantations as affected by silvicultural treatments. In: Nepveu, G., ed. Proceedings, third workshop, connection between silviculture and wood quality through modelling approaches and simulation software. IUFRO WPS5.01-04. Nancy, France: Laboratoire d'Etude des Ressources Forêt-Bois, INRA-ENGREF: 83-93.

**Cantrell, R.A.; Paun, D.A.; LeVan-Green, S.L. [In press]**. An empirical analysis of an innovative application for an underutilized resource: small diameter roundwood in recreational buildings. Forest Products Journal.

**Christensen, G.A.; Barbour, R.J. 1999**. Veneer recovery from small diameter logs. In: Proceedings, the 1999 Society of American Foresters national meeting. Bethesda, MD: Society of American Foresters: 299-304.

**Christensen, G.A.; Julin, K.R.; Ross, R.J.; Willits, S. 2002**. Volume recovery, grade yield, and properties of lumber from young-growth Sitka spruce and western hemlock in southeast Alaska. Forest Products Journal. 52(5): 81-87.

**Coleman, J.C. 1988**. Social capital in the creation of human capital. American Journal of Sociology. 94: 95-119.

**Doak, S.; Kusel, J. 1996**. Well-being in forest-dependent communities. Part II-A social assessment. In: Sierra Nevada Ecosystem Project: final report to Congress. Assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 375-402. Vol. II.

**Donovan, G.; Nicholls, D. 2003a**. Consumer preferences and willingness to pay for character-marked cabinets from Alaska birch. Forest Products Journal. 53(11/12): 27-32.

**Donovan, G.; Nicholls, D. 2003b**. Estimating consumer willingness to pay a price premium for Alaskan secondary wood products. Res. Note PNW-RN-553. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 7 p.

**Donovan, G.; Nicholls, D.; Roos, J. 2003**. Marketing recommendations for wood products from Alaska yellow-cedar, Alaska birch, and red alder. Gen. Tech. Rep. PNW-GTR-589. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

**Eastin, I.; Roos, J.; Tsournos, P. 2003**. Niche market opportunities for Alaskan forest products in Japan. CINTRAFOR Work. Pap. 91. Seattle, WA: University of Washington, College of Forest Resources. 67 p.

**Erickson, R.G.; Gorman, T.D.; Green, D.W.; Graham, D. 2000**. Mechanical grading of lumber sawn from small-diameter lodgepole pine, ponderosa pine, and grand fir trees from northern Idaho. Forest Products Journal. 50(7/8): 59-65.

**Fahey, T.D.; Cahill, J.M.; Snellgrove, T.A.; Heath, L.S. 1991**. Lumber and veneer recovery from intensively managed young-growth Douglas-fir. Res. Pap. PNW-RP-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 25 p.

**Fight, R.D.; Chmelik, J.T. 1998**. Analysts guide to FEEMA for financial analysis of ecosystem management activities. Gen. Tech. Rep. FPL-GTR-111. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 5 p.

**Flora, C.B. 1994**. Vital communities: combining environmental and social capital. Unpublished report. [Pages unknown]. On file with: North Central Regional Center for Rural Development, Iowa State University, 107 Curtiss Hall, Ames, IA 50011-1050.

**Flora, C.B.; Flora, J.L. 1993**. Entrepreneurial social infrastructure: a necessary ingredient. Annals of the American Academy of Political and Social Sciences. 539: 48-58.

**General Accounting Office [GAO]. 1999.** Western national forests: a cohesive strategy is needed to address catastrophic wildfire threats. GAO-RCED-99-65. Washington, DC. 64 p.

**Han, H.; Lee, H.W.; Johnson, L.R. 2004**. Economic feasibility of an integrated harvesting system for small-diameter trees in southwest Idaho. Forest Products Journal. 54(2): 21-27.

**Hann, D.W.; Hester, A.S.; Olsen, C.L. 1997**. ORGANON user's manual. Corvallis, OR: Oregon State University. 133 p.

**Harris, A.S.; Farr, W.A. 1974**. Forest ecology and timber management: the forest ecosystem of southeast Alaska. Gen. Tech. Rep. PNW-25. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 109 p.

**Harris, C.; McLaughlin, W.; Brown, G.; Becker, D.R. 2000**. Rural communities in the inland Northwest: an assessment of small rural communities in the interior and upper Columbia River basins. Gen. Tech. Rep. PNW-GTR-477. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 120 p.

**Haynes, R.W.; Adams, D.M.; Mills, J.R. 2003**. Contemporary management regimes in the Pacific Northwest: balancing biophysical and economic concerns. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 267-296. Chapter 10.

**Healthy Forests Restoration Act of 2003**. H.R. 1904, 108$^{th}$ Congress.

**Hummel, S.S.; Barbour, R.J.; Hessburg, P.F.; Lehmkuhl, J.F. 2001**. Ecological and financial assessment of late-successional reserve management. Res. Note PNW-RN-531. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 25 p.

**Hummel, S.S.; Calkin, D.E.; Barbour, R.J. 2002**. Landscape analysis with FVS and optimization techniques: efficient management planning for the Gotchen Late Successional Reserve. In: Crookston, N.L.; Havis, R.N., eds. Second Forest Vegetation Simulator conference. Proc. RMRS-P-25. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 78-82.

**Keegan, C.E.; Chase, A.L.; Morgan, T.A.; Bodmer, S.E.; Van Hooser, D.D.; Mortimer, M. 2001a**. Arizona's forest products industry: a descriptive analysis 1998. Missoula, MT: University of Montana, Bureau of Business and Economic Research. 20 p.

**Keegan, C.E.; Gebert, K.M.; Chase, A.L.; Morgan, T.A.; Bodmer, S.E.; Van Hooser, D.D. 1997**. Idaho's forest products industry: 1979-1996. Missoula, MT: University of Montana, Bureau of Business and Economic Research. 75 p.

**Keegan, C.E.; Gebert, K.M.; Chase, A.L.; Morgan, T.A.; Bodmer, S.E.; Van Hooser, D.D. 2001b**. Montana's forest products industry: a descriptive analysis 1969-2000. Missoula, MT: University of Montana, Bureau of Business and Economic Research. 67 p.

**Kilborn, K. 2002**. Lumber recovery studies of Alaska sawmills, 1997-1999. Gen. Tech. Rep. PNW-GTR-544. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 15 p.

**Koch, P. 1996**. Lodgepole pine in North America. Madison, WI: Forest Products Society. 343 p. Vols. 1-3.

**LeVan-Green, S.L.; Livingston, J. 2001**. Exploring the uses for small-diameter trees. Forest Products Journal. 51(9): 10-21.

**Lowell, E.C. 2001**. Veneer recovery from beetle-killed spruce trees, Kenai Peninsula, Alaska. Western Journal of Applied Forestry. 16(2): 65-70.

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

**Lowell, E.C.; Funck, J.; Brunner, C. 2000**. Small diameter trees in the Pacific Northwest: A resource for dimension lumber or cut-stock? In: Gazo, R., ed. Issues related to handling the influx of small-diameter timber in western North America: Proceedings of Forest Products Society annual meeting softwood lumber technical interest group. Madison, WI: Forest Products Society: 15-20.

**Lowell, E.C.; Green, D.W. 2001**. Lumber recovery from small-diameter ponderosa pine from Flagstaff, Arizona. In: Vance, R.K.; Covington, W.W.; Edminster, C.B., tech. coords. Ponderosa pine ecosystems restoration: steps toward stewardship. Proc. RMRS-P-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 161-165.

**Lowell, E.C.; Plank, M.E. 1997**. California black oak—from firewood to lumber, the lumber recovery story. In: Pillsbury, N.H.; Verner, J.; Tietje, W.D., tech. coords. Proceedings of a symposium on oak woodlands: ecology, management and urban interface issues. Gen. Tech. Rep. PSW-GTR-160. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 457-464.

**Lowell, E.C.; Thomas, R.E.; Todoroki, C.L. 2004.** Linking simulation of primary and secondary products from small-diameter Western softwoods. In: Nepveu, G., ed. Proceedings, fourth workshop, connection between forest resources and wood quality: modelling approaches and simulation software. IUFRO WPS5.01-04. Nancy, France: Laboratoire d'Etude des Ressources Forêt-Bois, INRA-ENGREF: 511-518.

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

**Lynch, D.L. 2001**. Financial results of ponderosa pine forest restoration in southwestern Colorado. In: Vance, R.K.; Edminster, C.B.; Covington, W.W.; Blake, J.A., comps. Proceedings, ponderosa pine ecosystems restoration and conservation: steps toward stewardship. Proc. RMRS-P-22. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 141-148.

**McCarter, J.B. 1997**. Integrating forest inventory, growth and yield, and computer visualization into a landscape management system. In: Teck, R.; Moeur, M.; Adams, J., comps. Proceedings of the Forest Vegetation Simulator conference. Gen. Tech. Rep. INT-GTR-373. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 159-167.

**McGaughey, R.J. 1998**. Techniques for visualizing the appearance of forestry operations. Journal of Forestry. 96(6): 9-14.

**Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. 2003**. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers. 519 p.

**Mothe, F.; Constant, T.; Leban, J.M. 2004**. Simulating veneering and plywood manufacturing of virtual trees described by a growth-wood quality software. In: Nepveu, G., ed. Proceedings, fourth workshop, connection between forest resources and wood quality: modelling approaches and simulation software. IUFRO WPS5.01-04. Nancy, France: Laboratoire d'Etude des Ressources Forêt-Bois, INRA-ENGREF: 519-527.

**Myers, G.C.; Kumar, S.; Gustafson, R.R.; Barbour, R.J.; Abubakr, S. 1997**. Pulp quality from small-diameter trees. In: Barbour, R.J.; Skog, K.E., eds. Role of wood production in ecosystem management. Proceedings of the sustainable forestry working group at the IUFRO all Division 5 conference. Gen. Tech. Rep. GTR-FPL-100. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 80-89.

**National Council for Air and Stream Improvement [NCASI]. 2004.** Primer for forest environmental issues: the West. Special Report No. 04-02. Research Triangle Park, NC: National Council for Air and Stream Improvement, Inc. 61 p.

**Nicholls, D.; Brackley, A.; Allen, T. 2003a**. Moisture distributions in western hemlock lumber from trees harvested near Sitka, Alaska. Res. Note PNW-RN-530. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 8 p.

**Nicholls, D.; Crimp, P. 2002**. Feasibility of using wood wastes to meet local heating requirements of communities in the Kenai Peninsula of Alaska. Gen. Tech. Rep. PNW-GTR-533. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

**Nicholls, D.; Donovan, G.; Roos, J. 2003b**. Red alder stacks up to other hardwoods. Wood & Wood Products. October: 61-64.

**Nicholls, D.; Kilborn, K. 2001**. An assessment of Alaska's lumber drying industry and current potential for value-added processing. Gen. Tech. Rep. PNW-GTR-522. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p.

**Nicholls, D.L. 2001**. An evaluation of the retail market potential for locally produced paper birch lumber in Alaska. Gen. Tech. Rep. PNW-GTR-493. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

**Nicholls, D.L.; Parrent, D.; Pavia, K.J. [In press]**. Investigating the potential for developing alternate grading rules for Alaska birch lumber. Forest Products Journal.

**Paun, D.; Jackson, G. 2000**. Potential for expanding small-diameter timber markets: assessing use of wood posts in highway applications. Gen. Tech. Rep. FPL-GTR-120. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 28 p.

**Peterson, C.E.; Monserud, R.A. 2002**. Compatibility between wood production and other values and uses on forested lands: a problem analysis. Gen. Tech. Rep. PNW-GTR-564. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 50 p.

**Powell, D.S.; Faulkner, J.L.; Darr, D.R.; Zhu, Z.; MacCleery, D.W. 1993**. Forest resources of the United States, 1992. Gen. Tech. Rep. RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 132 p.

**Pretty, J. 2000**. Towards sustainable food and farming systems in industrialized countries. International Journal of Agricultural Resources, Governance, and Ecology. 1(1): 77-94.

**Putnam, R.D. 1993**. The prosperous community: social capital and public life. The American Prospect. 13: 35-42.

**Rapp, V. 2003**. Alaska forest products: using resources well. Science Update 5. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 11 p.

**Reinhardt, E.; Crookston, N.L., tech. eds. 2003**. The Fire and Fuels Extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

**Shindler, B.A.; Brunson, M.; Stankey, G.H. 2002**. Social acceptability of forest conditions and management practices: a problem analysis. Gen. Tech. Rep. PNW-GTR-537. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 68 p.

**Smith, W.B.; Vissage, J.S.; Sheffield, R.; Darr, D.R. 2001**. Forest resources of the United States, 1997. Gen. Tech. Rep. NC-219. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 109 p.

**Spelter H.; Wang, R.; Ince, P. 1996**. Economic feasibility of products from inland West small-diameter timber. Gen. Tech. Rep. FPL-GTR-92. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 17 p.

**Spies, T.A.; Reeves, G.H.; Burnett, K.M. 2002**. Assessing the ecological consequences of forest policies in a multi-ownership province in Oregon. In: Liu, J.; Taylor, W.W., eds. Integrating landscape ecology into natural resource management. Cambridge, United Kingdom: Cambridge University Press: 179-207.

**Spruce Bark Beetle Task Force. 1998.** An action plan for rehabilitation in response to Alaska's spruce bark beetle infestation. Kenai Peninsula Borough, Soldotna, AK. http://www.borough.kenai.ak.us/sprucebeetle/Congress.htm. (16 August 2004).

**Stevens, J.A.; Barbour, R.J. 2000**. Managing the stands of the future based on the lessons of the past: estimating Western timber species lumber recovery using historical data. Res. Note. PNW-RN-528. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 9 p.

**Thomas, R.E. 1997**. ROMI_CROSS: rough mill crosscut-first simulator. Gen. Tech. Rep. NE-229. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 56 p.

**Thomas, R.E. 1999**. User's guide to ROMI-RIP: 2.0: a rough mill rip-first simulator. Gen. Tech. Rep. NE-259. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 64 p.

**Todoroki, C.L. 1990.** AUTOSAW system for sawing simulation. New Zealand Journal of Forestry Science. 25: 2, 246-255.

**U.S. Department of Agriculture, Forest Service [USDA FS]. 2001**. Strategic plan. Portland, OR: Pacific Northwest Research Station. 19 p.

**U.S. Department of Agriculture, Forest Service [USDA FS]. 2002**. Strategy for the future. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/publications/strategyplan. (March 2004).

**U.S. Department of Agriculture, Forest Service [USDA FS]. 2003**. A strategic assessment of forest biomass and fuel reduction treatments in Western States. Washington, DC. http://www.fs.fed.us/research/infocenter.html. (April 2004).

**U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994**. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. 74 p. [plus Attachment A: standards and guidelines].

**U.S. Department of Commerce, Bureau of the Census. 2004**. State population projections. http://www.census.gov/population/www/projections/stproj.html. (May 2004).

**Voorhies, G.; Blake, B.R. 1981**. Properties affecting drying characteristics of young-growth ponderosa pine. Arizona Forestry Note 14. Flagstaff, AZ: School of Forestry, Northern Arizona University. 11 p.

**Wagner, F.G.; Fiedler, C.E.; Keegan, C.E. 2000**. Processing value of small-diameter sawtimber at conventional and high-speed sawmills in the Western United States: a comparison. Western Journal of Applied Forestry. 15(4): 208-212.

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

**Warren, D.D. 2002**. Production, prices, employment, and trade in Northwest forest industries, all quarters 2000. Resour. Bull. PNW-RB-236. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 171 p.

**Western Wood Products Association [WWPA]. 1998.** Western lumber grading rules 98. Portland, OR. 248 p.

**Willits, S.; Barbour, R.J.; Tesch, S.; McNeel, J.; Kumar, S.; Myers, G.; Olson, B.; Mason, A. 1997.** The Colville Study: wood utilization for ecosystem management. Preliminary results of a study of product potential from small-diameter stands. Res. Pap. FPL-RP-559. Madison WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 11 p.

**Wipfli, M.S.; Deal, R.L.; Hennon, P.E.; Johnson, A.C.; Edwards, R.T.; De Santo, T.L.; Gomi, T.; Orlikowska, E.H.; Bryant, M.D.; Schultz, M.E.; LeSage, C.; Kimbirauskus, R.; D'Amore, D.V. 2003**. Compatible management of red alder-conifer ecosystems in southeastern Alaska. In: Monserud, R.A.; Haynes, R.W.; Johnson, A.C., eds. Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers: 55-81. Chapter 3.

**Wooley, J.T.; McGinnis, M.V. 2000**. The conflicting discourses of restoration. Society and Natural Resources. 13: 339-357.

**Wykoff, W.R.; Crookston, N.L.; Stage, A.R. 1982**. User's guide to the stand prognosis model. Gen. Tech. Rep. GTR-INT-133. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 122 p.

# Appendix

**Current collaborators and partners of the Ecologically Sustainable Production (ESP) of Forest Resources team**

| State and federal government | Universities, domestic | Private industry | Partnerships and associations |
|---|---|---|---|
| Forest Products Laboratory | Northern Arizona University, Ecological Restoration Institute | MicroMill, Inc. | Greater Flagstaff Forests Partnership |
| Colorado State Forestry | Southern Oregon University | Skyline Forest Resources | Arizona Sustainable Forest Partnership |
| Southern Research Station | Fort Lewis College | Perkins Timber Harvesting | Southwest Sustainable Forests Partnership |
| Pacific Southwest Research Station | Colorado State University | High Desert Investment | White Mountain Small Diameter Wood Products Association |
| Northeastern Research Station | Oregon State University | Savannah-Pacific Corporation | Four Corners Sustainable Forests Partnership |
| Joint Fire Science Program | University of Washington | Jefferson State Forest Products | Escalante Heritage Center |
| Forest Service Regions 1-6, 10 | University of Montana | Fremont Sawmill | Stand Management Cooperative |
| Rocky Mountain Research Station | Washington State University | The Collins Company | Hayfork Watershed and Research Center |
| Arizona Department of Commerce | University of Wisconsin | Weyerhaeuser | |
| Arizona Governor's Council | University of California-Berkeley | Port Blakely Tree Farms | |
| Bonneville Power Administration | University of Idaho | | |
| Bureau of Land Management | University of Alaska | | |
| Bureau of Indian Affairs | North Carolina State University | | |
| Washington Department of Natural Resources | Iowa State University | | |
| Idaho Department of Lands | | | |
| Alaska Department of Forestry | | | |
| North Central Research Station | | | |
| Juneau Economic Development Council | | | |
| State and Private Forestry | | | |
| USFS Collaborative Forests Restoration Program | | | |

| International organizations | Universities, international | Nongovernmental organizations (NGOs) and nonprofits |
|---|---|---|
| New Zealand Forest Research | University of Bodenkultur-Vienna, Austria | Sonoran Institute |
| Danish Forest and Landscape Research | University of Greenwich (UK) | Forest Trust |
| Government of Alberta | University of Joensuu, Finland | Grand Canyon Trust |
| BC Ministry of Forests | University of Helsinki, Finland | Sustainable Northwest |
| Forintek-Quebec | | Pinchot Institute for Conservation |
| Russian Academy of Sciences, Siberia | | American Forests |
| IIASA-Laxenburg, Austria | | National Forest Foundation |
| Finnish Forest Research Institute, Helsinki, Finland | | |
| IUFRO working parties | | |

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