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Role of Wood Production in Ecosystem Management

Proceedings of the Sustainable Forestry Working Group at the IUFRO All Division 5 Conference, Pullman, Washington, July 1997

International Union of
Forestry Research
Organizations

National Project on
Wood Utilization for Ecosystem Management

Abstract

The presentations at this symposium discussed concepts of ecosystem management and sustainability as viewed by various levels of government and private land managers. The theme was to integrate ecology, silviculture, forest operations, wood products, and economics to find ways to develop healthy sustainable ecosystems under financially sound management practices. Speakers discussed ways to manage disturbance to create landscapes with the desired level of diversity and resilience to fire, disease, and insects. Others identified technical aspects of improving the options for producing wood and promoting healthy ecosystems. The feasibility of the various modes of forest operation were considered along with methods to evaluate the financial aspects of activities in different stand types. Lastly, the concept of sustainability was discussed, both in theory and through case studies. A full paper is presented for the majority of presentations; an abstract is included for others.

Keywords: Ecosystem management, sustainable forestry, wood utilization, small-diameter timber, silviculture, forest operations, economic feasibility, wood quality, pulp quality

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Edited by
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Preface

An ecosystem approach to forest management uses new strategies to conserve biodiversity, improve the balance among forest values, and sustain healthy ecosystems. Ecosystem management retains the aesthetic, historic, and spiritual qualities of the land. Various silvicultural techniques maybe used to alter the developmental trajectory of existing stands and the composition of the landscape to provide this range of values.

In some cases, wood is removed as a secondary objective during treatments to improve forest health, restore wildlife habitat, create recreational opportunities, mitigate impacts of forest pests, or alter the vegetative mix for increased biodiversity. In other cases, ecosystem strategies will include removing wood as a primary goal.

Treatments that remove wood may yield materials different from those that the existing industry has historically processed. This material is often of similar quality to the traditional resource, but for various reasons it may be more expensive to manage or remove. The removed stems may be small, ranging from 4 to 12 inches (10 to 30 cm) in diameter at breast height. Silvicultural treatments maybe complex, in an effort to minimize site impacts or create specific conditions favorable to certain species of plants or wildlife. These changes increase handling or manufacturing costs associated with producing a given volume of end product. Tree species may also be those that were previously ignored, thus manufacturers have little experience processing them. Silvicultural systems are changed to alter current and future conditions of the stand and quality of wood in the stand. Harvesting systems may be unfamiliar to local operators and can be expensive to purchase, operate, and maintain. Layouts of forest operations are also becoming quite complicated, requiring more time to plan and implement, and this increases the cost.

Some types of treatments may evoke public opposition. Those who feel that extraction of wood is responsible for degradation of our forest resources are loath to accept the idea that wood removal, or sometimes active management, can play a positive role in restoring damaged ecosystems or maintaining healthy ones. In contrast, some members of the public feel that the sustainable yield of wood products is a good forest management policy and should not be changed. Somewhere among the range of views on natural resource management is the idea that, in some cases, natural resources can be actively managed to provide a range of benefits. A key feature, often unstated, of this view is that someone will have to pay for every management activity. On Federal land, many options are possible. The taxpayers could recognize the value to society of maintaining and restoring healthy ecosystems and choose to pay the fill cost. Receipts from the sale of timber or other forest products, such as mushrooms, floral greens, decorative plants, could be used to pay management costs. Fees could be charged to enter public land or subscriptions could be sought from people who do not use the land but want to see it managed in certain ways. All these techniques are now used in various combinations to pay for the management of public lands. As time goes on, other methods will be conceived and the relative importance of each will change.

As long as timber sales are used to aid in treatments, there will be a need to understand what types of materials have value and how those values can best be realized—with improved forest operation or utilization technologies. People will want to understand the costs associated with different activities and why some activities are economically viable in one location but not in others. They will want to know when silvicultural prescriptions are likely to result in the conditions they value and are trying to promote. Public resource managers will want to find ways to bring groups together and explain planned activities in ways that address their concerns honestly and openly while providing divergent groups with the information they need to understand the points of view of others.

The work and opinions presented during this symposium are intended to help achieve some of these goals. Some speakers talk about policy and how it is implemented. Others talk about how bringing together technical ideas from various disciplines can aid managers in plans to achieve ecosystem management goals. Another group talks about the concept of sustainability and how it is viewed by public and private land managers from around the world. The papers in this report are intended to illustrate how coordinated research in a range of disciplines can aid managers with specific problems in attaining ecosystem goals. Research is presented on silviculture, forest operations, wood quality, wood products, and economic feasibility. These papers show how forest products research contributes with other areas of research to help restore and maintain healthy ecosystems. These research activities and their application will help achieve the USDA Forest Service goal of caring for the land and serving the people.

R. James Barbour
Kenneth E. Skog

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The Role of Wood Removals in Implementation of Ecosystem Management on Federal Lands: A Multifaceted Perspective

Hal Salwasser and Barry Bollenbacher, USDA Forest Service, Northern Region

Abstract

Understanding the roles and function of measures to conserve, restore and produce wood resources from Federal lands requires an in-depth understanding of the bio-physical and socio-economic dimensions of Ecosystem Management. Key elements in our understanding of sustainable ecological conditions and sustainable resource production include knowledge about supply and demand for wood resources, integrated with our social wants and needs for a diversity of resources conditions all of which are influenced by the health and productivity of our forests. Many of our society's values are reflected in our legal mandates that provide guidance for management on Federal lands.

Currently per capita wood consumption in the United States approximates 75 ft^3 each year, with global demands expected to increase significantly by the year 2020. As an example, the supply of wood resources on National Forest lands within the Northern Region of the Forest Service are noteworthy. The Northern Region comprised of approximately 24 million acres in northern Idaho, Montana, and North Dakota, have forested ecosystems on 20.6 million acres. Under the current Forest Plans, approximately 8.7 million acres have associated wood utilization objectives, with an option for more limited opportunities on a portion of the remaining acres. A basic analysis of demand, and an understanding of current supply related to public and private lands managed at least in part for a wood utilization objective, gives us a rather incomplete picture of sustainable development over time.

To gain a more complete understanding of the above relations, a multiple scale understanding of ecological processes and the integration of many other resources needs which our society values must be included.

Developing, implementing, and securing a sustainable Ecosystem Management strategy on Federal lands will require conservation, restoration, and intensive forest culture and production. Silvicultural treatments and investments consistent with ecological capabilities of the land will require us to use traditional tried and true methods in some cases, while in other situations implementation of restoration techniques will involve new challenges on a fairly broad scale. Due to several factors, many of our forests have a large component of smaller diameter trees, with few associated product markets. For our overall Ecosystem Management strategy to be successful, the restoration component will require the implementation of creative silvicultural prescriptions that typically require expensive harvesting systems, producing smaller diameter materials than have traditionally been common. For these creative treatments to be successful, part of the solution to the restoration challenge will be the development of new markets for small diameter trees of many species.

Exploring Ecosystem Management

Definition

Principles

Need

Role of wood removal

Ecosystem Management

The use of an ecological approach that blends the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive and sustainable ecosystems.

Ecosystem Management Principles

USDA Forest Service (1994)

- Protect ecosystem health and diversity while meeting people's needs: renewability, resilience
- Restore deteriorated ecosystems for diversity, sustainability, productivity, future options
- Provide multiple benefits for people within ecosystem capabilities; values, uses, assistance, conservation
- Ensure organizational effectiveness: science based, multicultural, multidisciplinary, collaboration, partnerships, accountability

Why Ecosystem Management?

Address growing challenges:

- Human population, resource needs
- Large-scale issues
- Long-term issues
- Interconnected issues
- Insufficient information
- Equity gap
- Sustainable development
- Decisionmaking gridlock
- Conflict over shared use of resources

Global Future

Projected Trends 1990-2010

- More people: +33%
- Greater demand for ag. land: +5%
- Less forest: -7% total area; -30% area per person
- More pressure on remaining forest: +40% wood use; increase demand for all other forest values

U.S. Future

Projected trends 1990-2010

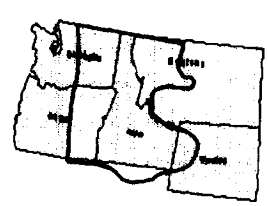
- More people: +18%, increased ethnic diversity
- Relative stability in agricultural and forest area
- 14% increase in domestic timber supply
- 16% increase in housing starts
- Increased demand for non-wood forest values: recreation, water, wildlife, wilderness
- Increased importation of wood
- Increased biomass/ac leading to more fire and forest health problems

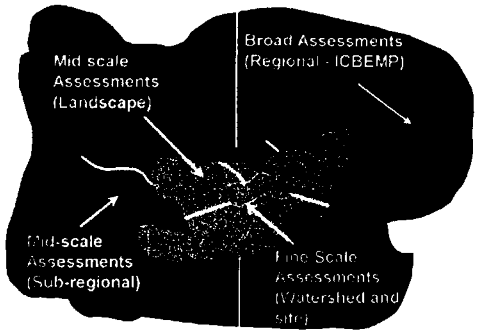
U.S. Forest Issues for the 21st Century

- Ecological sustainability: forest products, forest health, ecosystem services, biodiversity, endangered species, late-successional forests, forest-based institutions and lifestyles
- Political sustainability: decision-making processes, responsibility, accountability, public participation, trust
- Economic sustainability: adaptation to changing resources and values, equitable allocation of costs and benefits among social sectors
- Expanding world population: increasing per capita and total consumption of resources and energy

Interior Columbia Basin Ecosystem Management Project

Broadscale Context For Management of Federal Lands Within The Basin

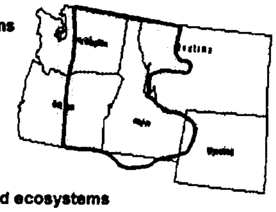




Assessments Scales

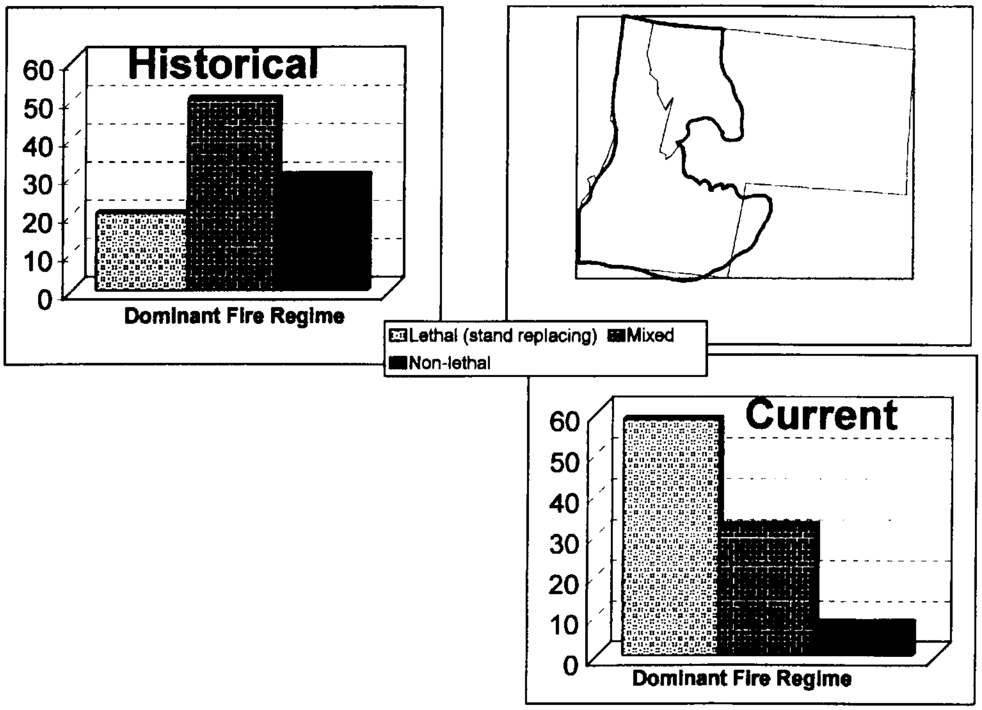
Interior Columbia Basin Ecosystem Management Project

- Protecting ecosystems



- Restoring deteriorated ecosystems
- Providing multiple benefits for people within the capabilities of ecosystems

Upper Columbia Basin Fire Regimes on Forested Lands on BLM / Forest Service Lands

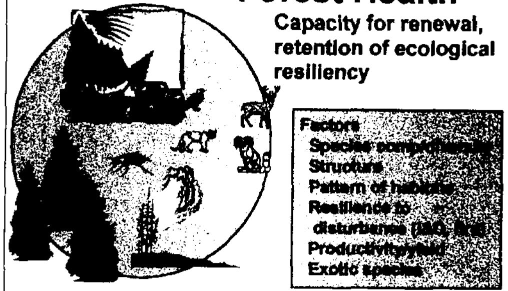


Roles of Wood Removal

- Ecological: desired future conditions
  - * Forest health, productivity
- Economic: resources, jobs for society

Forest Health

Capacity for renewal, retention of ecological resiliency



Sustainable Composition and Structure

Forest Conditions Within

Low elevation	Warm & dry types
Mid-elevation	Warm / moist types
Upper elevation	Cool / moist types

Low Elevation Warm & Dry Types

- Significant increase in tree density
- Loss of large ponderosa pine structure
- Increase in spruce budworm infestation
- Shift to stand-replacing fire from non-lethal
- High potential for urban interface fire losses

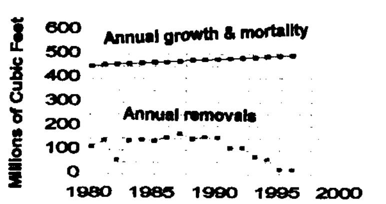
Mid-elevation Warm / Moist Types

- Similar fire regime as historical
- Much greater extent of mid-seral stage
- Greater potential for mountain pine beetle
- Loss of western white pine type due to mountain pine beetle and blister rust
- Increase in root disease

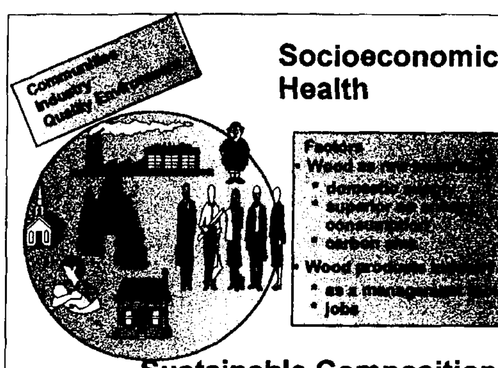
Upper Elevation Cool / Moist types

- Higher density forest structure
- Loss of whitebark pine
  - * succession
  - * white pine blister rust
- Shift to stand-replacing fire from mixed severity regime

Region One Forest Service Annual Accumulation of Wood Fiber Compared to Removals



Socioeconomic Health



Sustainable Composition and Structure

Considerations in Sustainable Forestry & Ecosystem Health

Risk of catastrophic disturbance

Loss of associated values, e.g., wildlife habitat and scenic quality

Socio-economic needs

- Impacts and values of how forests are managed differ by management intensity: tree farms to extensive management with long rotations

  The role of conservation, restoration and production - examples

Habitat Conservation:

- Natural areas
- Old growth
- Endangered species
- Riparian conservation areas
- Forest diversity

Restoration:

Thinning at stand and landscape scales in some areas can significantly restore ecological integrity and forest health

Restoration of key species in decline, e.g., western white pine, can reverse current trend of high levels of root disease

Reduce potential for catastrophic fire and loss of life and property within the forest / urban interface

Production:

High production forestry through intensive silvicultural investments yields high fiber returns on key sites.

Intensive management regimes must include recognition of disturbance factors, e.g., fire, insect and disease and wind.

A landscape scale strategy will sustain forest productivity and health, allowing for high production forestry on key sites.

Wood / product values differ, related to management intensities in an overall wood utilization strategy

High-value speciality products long rotations with periodic harvest of high-valued trees, e.g., clear grade ponderosa pine.

Medium-value, high-volume wood products, e.g., intensive forestry regimes.

Lower value, high-volume wood products, e.g., pulp, small-diameter restoration efforts.

- Management of forests are place based, no one size fits all

Selecting a wood production strategy considers:

Multiple management objectives & human values of a specific landscape

Production capability of the land given site quality potential & associated disturbance factors

- Forest products are an explicit part of EM, not only incidental

Wood utilization strategy based on specific landscape objectives; balance of ecological integrity and production and utilization of a sustainable supply of wood fiber to meet our needs

Incentives

A "market basket" of carrots and sticks to fit the situation:

- Information
- Assistance
- Recognition
- Relief from regulation
- Economic benefits
- Penalties

Conservation

Balancing supply and demand ... shared and ethical use of resources to:

- Nurture prosperity
- Reduce consumption, waste
- Reuse materials
- Renew value
- Recycle resources

Ecosystem Stewardship: From Sites to the Biosphere

- Native ecosystems
- Multi-benefit ecosystems
- Production ecosystems
- Residential ecosystems

Native Ecosystems

Parks, wilderness and preserves

- Passive values, "nature"> resource uses
- Natural process Rx
- Diversity variable
- Net productivity low, high biomass
- Older stages likely

Multi-Benefit Ecosystems

Federal + some state and private

- Multiple values + multiple uses
- Extensive management Rx
- Stand & landscape diversity
- Net productivity moderate
- Mixed stages & patterns

Production Ecosystems

Private + some state and federal

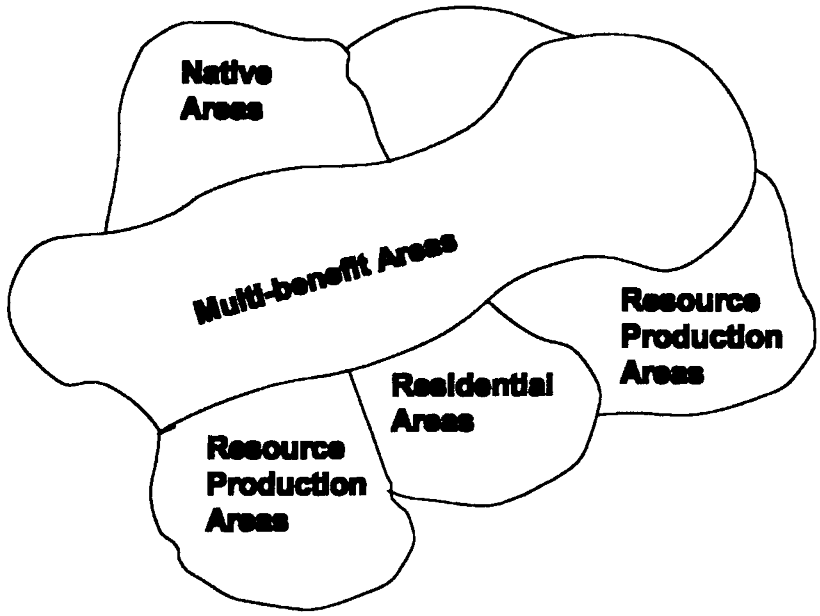
- Efficient resource production: crops, wood, minerals, forage, recreation
- Intensive management Rx
- Diversity low to moderate
- Net productivity high in forests, croplands
- Younger stages due to frequent disturbance

Residential Ecosystems

Predominantly private urban forests

- Support individual, family, community life
- Manage for economic, community vitality
- Diversity depends on cultures, economies
- Safety, prosperity, high values
- Young, old stages in constant flux

Regional Ecosystems



A Demonstration of Ecosystem Management, Incorporating Private Land

Brad A. Holt, Stephen P. Warren, Boise Cascade Corporation, Boise, Idaho

Abstract

Implementation of Ecosystem Management requires the linking of multi-resource inventory data with detailed spatial data to support ecosystem analysis at a variety of spatial scales. The planning landscape is first quantified through the use of an ecological land classification system to determine a measure of ecological complexity and temporal stage of forest development. A classification tool called the Ecosystem Diversity Matrix is described along with the data management processes to facilitate use of the classification system within the planning landscape of the Idaho Southern Batholith. The framework of the matrix is used to describe historical disturbance regimes, existing landscape conditions required to support biodiversity, and to determine desired future conditions.

Keywords: ecological complexity, ecosystem management, Ecosystem Diversity Matrix, ecological land classification, biodiversity.

Introduction

Today, there are many different agencies, organizations and private corporations proposing various strategies for implementing and addressing the social, economic and ecological objectives of ecosystem management. Unlike traditional resource management which has focused on individual resource values, ecosystem management focuses on managing multiple resource values across ecological communities and plans for the sustainability of all of its resource values. In other words, it integrates and considers a variety of resources together as opposed to planning for each resource separately. It also extends beyond traditional ownership boundaries and considers the ecological integrity of the landscape.

This fundamental change to the larger context of ecological communities and the environment requires data that describes ecological processes and interactions among components at a variety of spatial scales, from a sub-forest stand scale to the landscape. Currently, there are many efforts to develop resource management tools and collect resource inventories which meet ecosystem management objectives at the landscape scale. This paper describes some of the resource tools that have been developed for integrating forest and ecological inventories into resource and GIS databases and then illustrates how these tools can be used to implement a ecosystem management process in west-central Idaho.

In 1994, Boise Cascade Corporation initiated an ecosystem management project to develop an ecosystem strategy for the 5.8 million acre Idaho Southern Batholith landscape. The Idaho Ecosystem Management Project has implemented an existing ecological land classification system known as the Ecosystem Diversity Matrix (Haufler 1994) to quantify ecological diversity in the Idaho Southern Batholith landscape. As a ecological land classification system, the (EDM) provides the foundation for ecosystem management planning and represents the primary tool for quantifying existing conditions, describing historical conditions, and developing targets for desired future conditions. The EDM also provides an avenue for Boise Cascade to quantify its contribution to ecosystem diversity both today and into the future by incorporating its knowledge of existing forest conditions with potential plant community successional pathways to predict potential outcomes over time.

Developing An Ecosystem Diversity Matrix

The purpose of the EDM is to describe the planning landscape in an ecological context. To accomplish this task the matrix is comprised of two axes. The horizontal axis describes ecological complexity through habitat type classes which characterizes combinations of overstory and understory vegetation associations. A habitat type class system is an ecological classification system which describes the biotic potential of the land as expressed through combinations of environmental interactions which determine the vegetation found on any given site (Daubenmire 1968). A habitat type classification system describing potential or climax vegetation has been developed for central Idaho by Steele et al. (1981) and is the basis for describing ecological complexity in horizontal axis of the EDM. The habitat type classes (i.e. columns on the horizontal axis of the EDM) are groups of individual habitat types that have been combined due to similar productivity potential, influence of historical disturbance patterns and ecological functions. This classification of habitat type classes allows an understanding of successional trajectories, provides the predictability of future seral variants of plant communities, an describes the productivity of a given site for different tree species.

In contrast, the vertical axis describes vegetation growth stages or vertical forest structure by characterizing the physical attributes of overstory and understory in a forest stand. More importantly, it describes and quantifies the sequential development of vertical forest structure systematically over time and space from a shrub seedling vegetation growth stage to an old growth or old forest growth stage. The quantification of such forest structure and analysis of the variation found within the forest across the landscape is a measure of overall ecosystem health and is a potential indicator of wildlife habitat suitability.

The intersection and combination of habitat type classes and vegetation growth stages (e.g. an individual cell in the EDM) results in new information classes defined as ecological land units or ELU's (Table 1.). Each ELU describes the existing vegetation for both overstory and understory characteristics, and predicts the ecological processes associated with the forest site such as successional pathways, site productivity, forest health, and habitat suitability. When ELU's are mapped across the entire landscape, the EDM becomes the framework for quantitatively characterizing region ecosystem diversity, it provides a basis for assessment of wildlife habitat quality, it quantifies the contributions of ecosystem diversity by all land owners, and it forces land managers and planners to recognize the dynamic nature inherent in ecosystems.

Table 1 - Simplified Ecosystem Diversity Matrix Populated with Acres by Ecological Land Unit.

Vegetation Growth Stage	Habitat Type Class: Pine	Douglas-fir	Grand Fir	Alpine Fir
Seedling	100	100	500	
Sapling		100		
Small Tree		100	50	
Medium Tree		100		200
Old Growth		100	300	200
Total Acres	100	500	650	400

Inventory Base For The Ecosystem Diversity Matrix

Once the landscape is classified, ecological land units (ELU's) become the base unit for field inventory sampling. Inventory field staff collect a variety of resource data to describe forest stand attributes associated with each ELU on the landscape to support data requirements for timber and wildlife resource planning models and tactical management decisions. Field data including measures of overstory and understory vegetation, down-woody material, snags, stumps, and horizontal cover are entered directly into hand-held data recorders. Each data recorder is equipped with a Global Positioning System receiver which collects the real-world coordinate of each plot location. The plot data is tagged with the spatial position and down-loaded into a resource data base to store and maintain information on ELU's overtime.

GIS Support For The Ecosystem Diversity Matrix

Implementing the ecosystem diversity matrix in GIS requires two essential layers of mapped resource information. First, habitat type classes need to be identified. Typically this has been achieved by using habitat type classification system dichotomous keys and field mapping techniques to identify individual habitat type polygons. Once mapped digitally into GIS, habitat types are then reclassified into habitat type classes and a new GIS habitat type class input layer is created. Secondly, a separate layer of existing vegetative characteristics is needed to supply information on the current vegetation growth stage present. Currently the vegetation growth stage GIS layer is generated from an existing forest stand layer. For each forest stand polygon, a set of forest structure decision rules are applied to the forest inventory information associated with that forest stand and a vegetation growth stage classification is made. When each of these layers have been processed, the habitat type class layer (i.e. the columns in the EDM) is overlaid with vegetation growth stage layer (i.e. the rows in the EDM) within the GIS and the resulting union of map polygons creates the ecological land unit layer (Figure 1), With the creation of a new ELU map layer, the number of acres by ELU can be calculated and used to populate the individual cells of the EDM.

GIS Ecological Land Unit Layer Link To The Ecosystem Diversity Matrix

With an Ecosystem Diversity Matrix classification system and GIS ecological land unit (ELU) layer in place, the challenge is to develop the capability to electronically link GIS information to the matrix and visually display the quantity of acres or other significant ecological variables for the entire landscape both presently and into the future. To accomplish this, a program was written to graphically display quantitative values associated with the ecological land unit coverage, in the form of a 3-D bar chart. Figure 2. illustrates an example of the graphical display of acres for each ecological land unit in the matrix for the entire landscape.

Using The EDM As A Basis For Implementing An Ecosystem Management Process

With the mapped ecological land unit GIS layer linked to the 3-D graphical display of the Ecosystem Diversity Matrix (EDM), the matrix can then be used to implement specific steps in an ecosystem management process. In the Idaho Ecosystem Management Project, the staff and project partners are using the EDM as a framework for describing historical disturbance regimes, existing landscape conditions, ecological land unit thresholds overtime and desired future conditions required to support biodiversity. The following discussion describes each of the primary components that the project and cooperators are pursuing in the ecosystem management process (Haufler et al. 1996) and how the EDM is used as a foundational element to support the development of each process component.

Figure 1 - Overlay of Habitat Type Classes with Vegetation Growth Stages to Create Ecological Land Units.

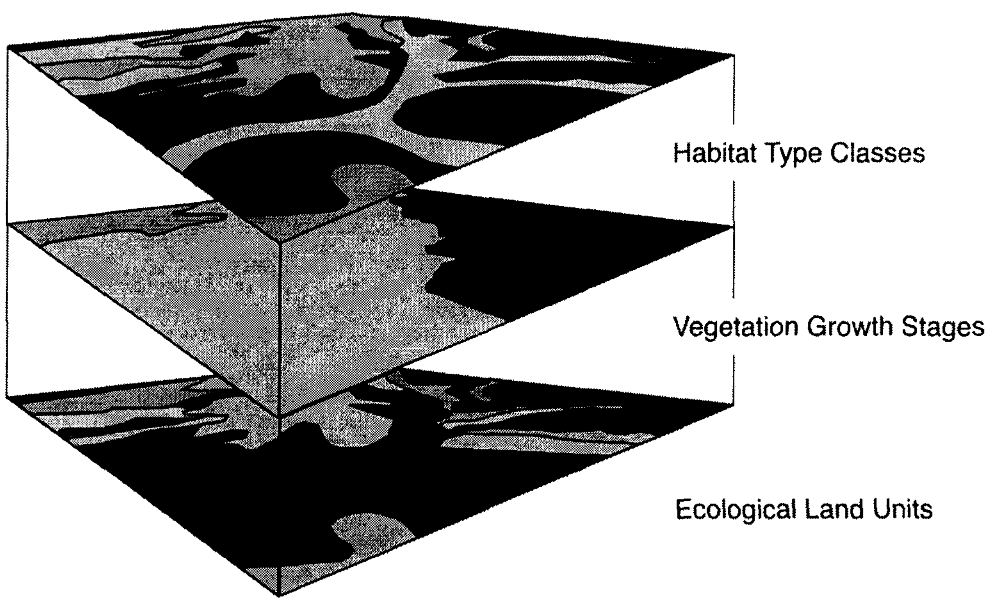
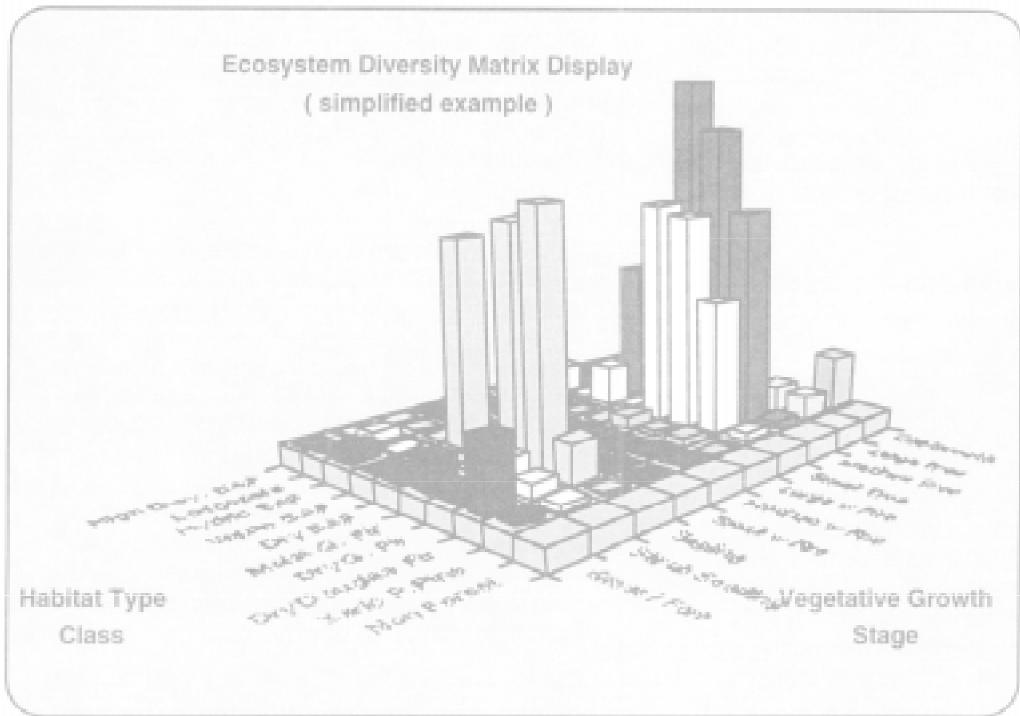


Figure 2- 3-D Graphical Display of Ecosystem Diversity Matrix Linked to mapped GIS Ecological Land Unit Ploygons.



Describe Historical Disturbance Regimes

Understanding past disturbance regimes and how they operated across a landscape provides essential reference information for ecosystem management. First, it provides information on the ecology of vegetation growth stages described in the Ecosystem Diversity Matrix and describes a rationale for their distribution across the landscape. Secondly, it provides information on the natural history of the area and conditions to which native species were adapted. In the Idaho project, a 1915 timber cruise was used to reconstruct historical stand conditions for low elevation habitat type classes. The results revealed that under past historical disturbance regimes, the forest stands on lower elevation habitats were influenced in structure and species composition by frequent low to moderate intensity understory fires. With this and other historical information, an Ecosystem Diversity Matrix (i.e. Historical EDM) describing the range of historical conditions can be developed for the planning landscape.

Quantify Existing Conditions

Another component of the ecosystem management process is the quantification of existing landscape conditions. The EDM provides a means of quantifying ecological land unit contributions by each landowner in the landscape planning area. Once the habitat type class and vegetation growth stages for the entire landscape have been overlaid to create a ELU layer and the acres of ELU's have been quantified, further analysis of the existing landscape can be conducted. For example, a newly constructed EDM with ELU's provides a framework for understanding, documenting and quantifying both biodiversity and the available habitat components for dependent species across the landscape. In addition, the matrix, in combination with mapped ELU polygons in a GIS, also provides information on the potential spatial distribution of native species habitat in the planning landscape.

Check Adequate Ecological Representation

Another primary component of the ecosystem management process is the concept of adequate ecological representation. Adequate ecological representation is defined as the sufficient size and distribution of inherent ecosystems to maintain viable populations of all native species dependent on these ecosystems (Haufler 1994). Determination of adequate ecological representation is based on understanding historical disturbance regimes and characteristics of the ecological land units that occurred under these regimes.

Coarse Filter Examination of the Landscape - The development of adequate ecological representation is dependent on a coarse filter examination of the landscape. In this approach, coarse filter refers to the use of an appropriate classification of the landscape, the EDM, to quantify acreage thresholds of ecological land units. In essence, the EDM is the classification tool for performing a coarse filter assessment of the number of ecological land units which are essential for maintaining ecosystem diversity and function across the landscape. The 3-D graphic display along with quantitative acreage measures is an important tool for both developing and evaluating the appropriate acreage thresholds for maintaining ecosystem integrity and viable populations of native species.

Fine Filter Examination of the Landscape - Once the coarse filter examination is complete and an EDM describing adequate ecological representation is established, a fine filter examination must occur. A fine filter examination of the landscape refers to assessing land management decisions based on the needs of individual species or guilds (Roloff 1994). In other words, the adequate ecological representation EDM must be further evaluated with single species or guild assessments to assure that there is sufficient habitat within the established ELU acreage thresholds to maintain viable populations of any native species of concern. The fine filter or species assessment approach examines both the quantity of ELU's as well as the quality or spatial distribution of ELU habitat across the landscape.

In the Idaho Ecosystem Management Project, the tine filter/species assessment process is supported through habitat suitability index models for selected species. Vegetation variables related to species needs are identified and quantified in the habitat model for each ecological land unit in the matrix. The habitat models are programmed into a GIS to incorporate the spatial arrangement of species' requirements. These models are typically developed in ARC/INFO Grid and use focal functions or "moving windows" to assess the quality of habitat within a species home range or territory. The resulting GIS output layers represent habitat suitability surfaces that are derived from and reflect the spatial distribution of habitat quality for the existing landscape of ecological land units. These habitat map surfaces of habitat potential (see Figure 3.) are then assessed for the selected wildlife species to determine whether the existing habitat quantity, quality, and spatial distribution is adequate.

Together, the mapped ecological land units describing adequate ecological representation, the coarse filter 3-D bar chart illustrating the quantity of ecological land units, and the species assessment GIS surfaces can be used to benchmark future ecological objectives. If the coarse-filter evaluation indicates that these baseline conditions are provided over time, it is assumed that habitat conditions for native species are being met. The species habitat assessments are used as checks to assure the proper functioning of the coarse filter thresholds. This coarse and fine filter approach should be made prior to and throughout the forest planning period to ensure that ecological objectives are maintained in future forest plans.

Figure 3 - Habitat Suitability Index Map Surface for Flammulated Owls Derived from ELU GIS Layer in the Idaho Southern Batholith.

Determine Desired Future Conditions

The last component of the ecosystem management process is the determination of desired future conditions. With ecological objectives defined, successful ecosystem management then integrates social and economic objectives for the landscape. Economic considerations include needs of natural resource based economies while social considerations include diverse demands for natural resource based recreation and aesthetics, cultural and archeological values, and other concerns unique to the landscape. Identification and quantification of these values are necessary to determine the desired conditions for the landscape. The culmination of the ecosystem management process is determination of desired future conditions. The EDM is important for understanding the contributions of each landowner at any point in the planning horizon. The adequate ecological representation matrix is used to set the needed threshold requirements for ecological objectives. The existing conditions matrix depicts landowner contributions toward these thresholds and where future contributions may be needed. The Ecosystem Diversity Matrices in concert with economic and social objectives are then used to define desired future conditions. Once desired future conditions have been identified, the management activities needed to produce them overtime need to be identified, implemented, monitored, evaluated, and adjusted to maintain adequate ecological representation while providing the optimum mix of social and economic benefits.

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Disturbance Management and Resource Product Availability

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Abstract

Disturbance is an integral part of ecosystem process; its conservation is of equal importance as the conservation of species or habitats, and it provides an ecological approach to resource product availability. Disturbance management is a technique that can be used to maintain ecosystem integrity and associated sustainable levels of commodity extraction on public lands. Public expectations for resource conditions and resource extraction need to be grounded in the reality of required disturbance regimes to maintain ecosystem integrity. The mosaic of post-disturbance vegetation patches contributing to biodiversity also represents a portfolio of economic opportunities. Management for disturbances and resulting patch dynamics across large landscapes in "whole-unit management" is suggested as a flexible institutional approach to resource management that incorporates planned and unplanned disturbances into long-term management goals for ecosystem integrity and resource extraction.

Keywords: Inherent disturbance regimes, patch dynamics, whole-unit management, economic opportunities, resource extraction.

Introduction

Disturbance management is managing for the disturbance effects that maintain ecosystem integrity (Agee and Johnson 1988) and provide commodity outflows (Oliver 1992). The management of disturbances provides a linkage between the biocentric and anthropocentric approaches to ecosystem management as defined by Stanley (1993).

The biocentric approach recognizes the role of disturbance in the dynamic nature of ecosystems and the anthropocentric approach recognizes the need for disturbance in extracting resources to meet human desires. Disturbance management provides a process that can work with nature in increasing ecosystem resiliency while facilitating resource extraction. The restoration of ecological processes, including disturbance, required to maintain ecosystems is a tenet of conservation biology and a prime consideration in defining the size of biological reserves (Pickett and White 1985, White 1987). Everett and Lehmkuhl (1996) and Pienkowski et al. (1996) expressed the need to expand disturbance management beyond reserve boundaries to maintain ecosystem integrity of larger systems.

Anthropocentric approaches that emphasize human needs over maintenance of ecological integrity may attempt to minimize disturbance to maintain "static" resource conditions or may increase severity and duration of disturbance to extract resources. Neither the static preservation of conditions nor excessive extraction activities are likely to be within the long-term biological capacity of many forest settings nor are these options designed to accommodate unplanned disturbance events.

Serious hazards to ecosystem resiliency and economic stability occur when disturbance is prescribed that is inconsistent with long-term maintenance of ecosystem integrity. In systems where "feedback" loops are delayed, indirect, or unmonitored, the loss of species and habitat (Endangered Species Act 1978) and long-term site productivity (Forest Management Practices Act 1976) is possible and contrary to governing regulations and legislation (Pulliam and O'Malley 1996). Stability in economic returns from both non-consumptive use and extractive products are directly related to maintenance of the integrity of ecosystems on which they are based. There are several stable states for a given biophysical area (Stone and Ezrati 1996); the challenge is to define the conditions and the rate of change that best conserves biodiversity, and long-term site productivity and that meets public expectations for resource conditions and commodity outputs.

Disturbance and Recovery Processes

Disturbance is a core process of ecosystems (Sprugel 1991) and forests systems are in a constant state of change (Botkin and Sobel 1975). Change is one of the few constants in nature and ecological change is often not continuous and gradual, but episodic with a sudden release and reorganization of biomass accumulated over long periods (Hollings 1996). Species have adapted to and are dependent upon pulses of disturbance such as seasonal flooding in aquatic and riparian systems or periodic fire in California chaparral (Odum 1969). The need for periodic loss of forest cover to provide habitat for edge and open canopy species is well known (Oliver et al. 1994).

The need for disturbance is balanced by the need for sufficient recovery periods between disturbances to prevent long-term site degradation (Perry and Amaranthus 1997). Turner et al. (1993) describe stable and unstable, equilibrium and non-equilibrium landscapes based on the ratio of disturbance and recovery periods and the relative extent of the disturbance on the landscape.

Ecosystem integrity is at risk when disturbance occurs too often or with too great a severity for recovery prior to the next disturbance. Also, ecosystem integrity is at risk when disturbance is excluded and excessive biomass accumulates with subsequent severe disturbance events (Harvey et al. 1995). Disturbance management is recommended to ensure periodic disturbances within historical ranges of variability rather than large-scale catastrophic events with long-term impacts on species, habitats, and site productivity (Morgan et al. 1994). As a result of periodic disturbance events or stem exclusion phases in stand development there may be opportunities to extract forest products not required as future forest legacies (Oliver et al. 1994).

Inherent and Altered Disturbance Regimes

All forest stands pass through stages of initiation, development, and eventual collapse or destruction. In the progression of a stand to old growth status the stand must pass through a myriad of disturbance events that can partially or completely reinitiate stand development. In eastern Washington Cascades Camp et al. (1996) found only 10 to 16% of forest stands in pristine forests of the Swauk Late Successional Reserve were late-successional old growth: conversely 88% of the landscape had been subjected to at least partial stand disturbance.

Each biophysical environment is characterized by disturbance and recovery periods indigenous to the biological and physical attributes of the site and associated landscape. Inherent disturbance regimes for fire, insect, pathogens, blowdown, and mass wasting define the frequency, extent, and severity of disturbance and the vegetation structure and composition that can be maintained (Wargo 1995). For example, Agee (1994) described frequency and severity of fire regimes for the Pacific Northwest forest types. Probabilities for insect epidemics can be inferred from stand stress and host species representation and continuity across the landscape (Hessburg et al. 1994, Harvey et al. 1995). Knowledge of root rot pathogen presence and rates of spread provide insight into potential for tree mortality and rate of change (Filip and Goheen 1984, Hagle et al. 1995). Different types of disturbances can be closely related (fire, insect and pathogens) such that composite disturbance regimes are defined for an area (Hagle et al. 1995). This composite or inherent disturbance regime defines the character of the landscape, the spatial and temporal arrangement of stands, and their structure and composition (Wargo 1995). This array of vegetation patches and their rate of change provide a first approximation of resource conditions and resource extraction potential characteristic of high integrity ecosystems.

Given the wealth of information on disturbance regimes for forest types, these are only probabilities of occurrence and are not absolute site-specific events, otherwise old growth stands would not occur. Although sufficiently strong disturbance events may transgress local environmental effects, there are opportunities to predict where disturbances are more likely to occur on the landscape. Forest landscapes comprised of varying aspects, elevations, and topographic settings contain heterogeneous forest types, rates of development, and susceptibility to disturbance events (Camp et al. 1996). As the probability of an event to occur increases with area considered, our ability to manage for disturbance increases with the size of the management area as described in the “whole-unit” management approach (Everett et al. [in press]),

Dry forest and woodland disturbance regimes have been significantly altered since eurosettlement, resulting in dramatic changes in forest composition and structure (Arno 1988, Covington and Moore 1994, Harvey et al. 1995). As a result of reduced fire effects and livestock grazing, pinyon-juniper woodlands have expanded off ridge tops into adjacent sagebrush-grass communities (Everett 1984). Fine fuels contributed by grass and shrub species declined and the previous high-frequenc /low-severity fire regime of grasslands has been replaced with one of indeterminate frequency and catastrophic severity.

Arno (1988) and Agee (1994) have shown that fire regimes for dry pine and fir forests have been altered from high-frequency/low-severity to low-frequency/high-severity fire regimes. Prolonged fire-free intervals allowed tree densities in ponderosa pine sites to increase from less than 30 trees per acre in the 1700’s to over 500 trees per acre in the 1990’s (Harvey et al. 1995). Without periodic fire, tree composition shifted to more shade-tolerant fir species and forest structure shifted to smaller diameter classes (Arno 1988). In the southwest, tree density increased from 12 to 757 trees/acre, basal area doubled (63 to 120 sq. ft./acre) and fuel loadings increased from less than 1 to 19 tons/acre since eurosettlement (Covington and Moore 1994). Harvey et al. (1995) demonstrated an increase in biomass as a result of shifting from short to long fire-free intervals for dry forest sites (Figure 1). Biomass in excess of that which can be supported by inherent disturbance regimes of this dry forest type is likely to be lost over time with an increase in the severity of the disturbance event as biomass continues to accumulate (Harvey et al. 1995).

Biomass conversions during catastrophic events are inefficient both biologically and economically. A previous shortage of snags and logs for wildlife becomes an overabundance that may lead to increased severity of future fires (Wellner 1973) and long-term loss of deed wood structure. On large burns the abundance of dead trees may prohibit efficient timber extraction prior to decline in wood quality and market value. Oliver et al. (1994) suggests periodic harvesting of surplus biomass, that amount subject to loss by fire (Figure 1, left side), rather than waiting for catastrophic fire events (Figure 1, right side). Given the large amounts of biomass accumulation

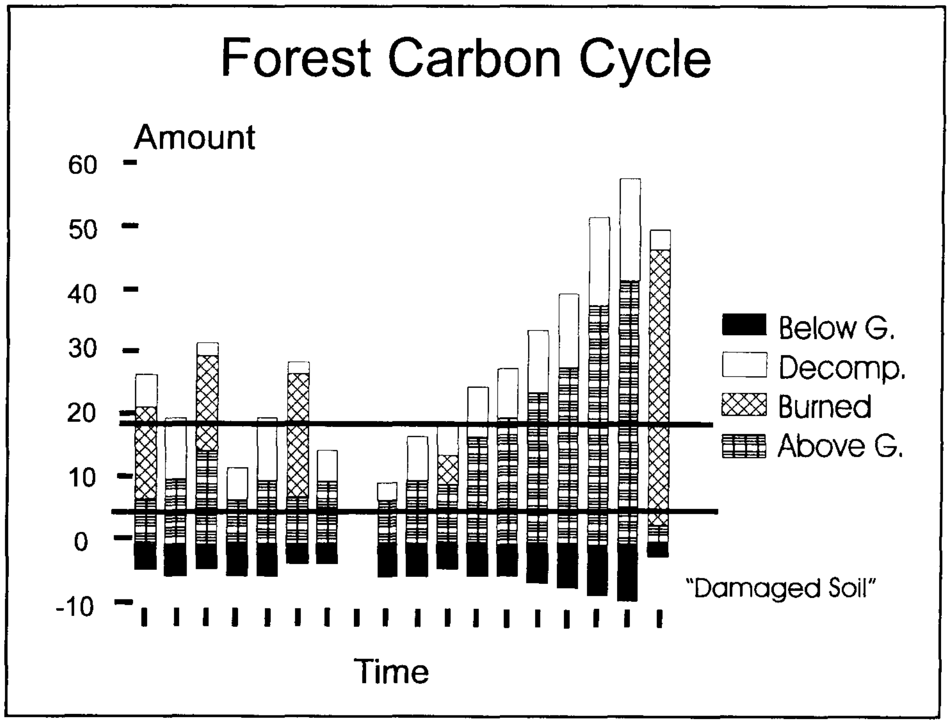

Figure 1—Carbon accumulation and cycling under short (left) and long (right)fire-free intervals for dry forest sites. Bars reflect historical range of values with common conditions between horizontal lines. Below ground C is shown as a negative. (Figure taken directly from Harvey et al. 1995 and Oliver et al. 1994).

over historical levels there are opportunities for periodic removal of biomass for timber while leaving adequate coarse woody debris for wildlife and soil organic matter. Under periodic biomass removal we have better opportunities for maintaining continuous coarse woody debris availability than if we are responding to catastrophic fire events.

Increased Flexibility in Forest Policy and Institutions

Given dynamic and somewhat unpredictable forest ecosystems on a constant land base and increasing public demands for both old growth forest conditions and extractive resources we need increased institutional flexibility to prevent loss in ecosystem integrity (Hollings 1996) and to maintain economic stability. New guidelines that use historical range in variability (HRV, Morgan et al. 1994) or inherent disturbance regimes (IDR, Everett et al. [in press]) key management to inevitable change in forest systems, disturbance requirements, and resulting patch dynamics. By maintaining forests in a dynamic mosaic of vegetation patches (Oliver et al. 1994) characteristic of historic conditions, species and processes (both known and unknown) are maintained (Hunter 1991).

Previous land-use allocations based on concepts of static vegetation conditions and historical uses may prevent meeting current public expectations for extractive resources while maintaining ecosystem integrity. Ehrenfeld (1991) suggested the "loose coupling" of sites to previous land-use allocation protocols to maximize individual patch management and ecosystem integrity within biological reserves. This concept has been expanded to "whole-unit" management where disturbances and patch dynamics would be managed across large landscapes to provide desired resource conditions and extractive resources from an entire area rather than individual land-use allocations (Everett et al. [in press]). Continuity in disturbance regimes across land-use allocations is encouraged and land-use protocols minimized such that patch management is practical over large landscapes. The large landscape approach allows experimentation at the scale appropriate to the size of the major disturbance events and the scale required for adaptive environmental and resource management (Hollings 1996). Both whole-unit and disturbance management concepts embrace required disturbance events and maximize institutional flexibility in dealing with unplanned disturbance in uncertain environments. As such these concepts meet Hollings (1996) criteria for adaptive management tools in maintaining resilient ecosystems and flexible management systems. Also, these concepts are in line with the 'flexible systems" bottom-up management approach promoted by Reich (1983) and Oliver et al. (1994) because they allow rapid response to unplanned disturbances by shifting patch goals among disturbed and undisturbed patches.

Disturbance and patch dynamics have both biological and economic significance. Resource conditions and sources of extractive resources are "patchy" on the landscape and the management of disturbance affects the types, amounts, and spatial locations of resources. Geographically-based decision support systems allow multiple landscape scenarios to be evaluated for desired resource conditions and commodity outputs and the ecological and economic benefits defined for each scenario (Wood et al. 1989, Oliver et al. 1994).

Environmental and Economic Interactions

The linkage between economics and ecosystem integrity can be improved by using the conservation of disturbance and ecosystem integrity as a component for long-term economic stability, capitalizing on sequential economic opportunities following disturbance, and increasing economic benefits from unplanned disturbance events. Pulliam and O'Malley (1995) recommended integration of environmental perspectives with economic policy to prevent short-term economic gains from contributing to long-term ecosystem degradation. Public expectations for socioeconomic benefits need to be coupled to the realities of disturbance events and recovery periods required to maintain ecosystem integrity. As a case example, the American Indian realized the need for disturbance to create and maintain forest conditions that supported their cultural and economic needs (Kay 1995). They used fire to maintain open forest settings to graze their horses, provide wildlife habitat (Robbins and Wolf 1994), and to maintain favored root and berry gathering areas (Ubelacker 1986). Overutilization of preferred food sometimes occurred requiring shifts in resource utilization, and subsequent social adjustments (Kay 1995). Similarly, information should be provided to the American public on economic opportunities resulting from disturbances and also on potential problems when disturbance is in excess or insufficient to maintain ecosystem integrity. As ecosystem integrity is a primary management goal on public lands, maximum economic return may be foregone to accomplish other holistic ecosystem objectives (Oliver et al. 1994), but economics will play an important role in defining our ability to practice holistic management.

Knowledge of post-disturbance vegetation response provides guidelines to the sequential occurrence of resource conditions and availability of extractive resources (Figure 2, Everett et al. 1996). Economic gain can be made directly from a series of cash crops occurring on the same site over time: salvage logging, livestock grazing, Christmas tree harvest, and commercial thinning. Indirect economic benefits to rural communities may also arise from an array of recreational opportunities and associated tourist dollars from berry picking, hunting, or wildlife viewing that result from disturbance and loss of canopy cover. These post-disturbance product models provide improved planning or at least awareness of changes in the resource base to the local public. With the knowledge of post-disturbance vegetation response, resource-dependent communities would be better able to respond to both planned and unplanned disturbance events. Integration of ecosystem principles of disturbance and patch dynamics into local and regional economic planning identifies economic opportunities consistent with maintaining ecosystem integrity.

Maintenance of inherent disturbance regimes and an array of stand structures across the landscape to conserve biodiversity (Oliver et al. 1994) is also a process of maintaining a diverse portfolio of economic opportunities. Forest-derived revenues are increasing from non-timber sources such as recreation and special forest products. For example, it is of economic importance to maintain, through disturbance, a portion of the western hemlock zone landscape in mid-successional stage for continued availability of some specialty forest products such as floral greenery and berry production (Schlosser et al. 1992). The special forest products industry of the Pacific Northwest generated an estimated $47.7 million in raw products and $128.5 million in finished product sales and employed over 10,000 people in 1989 (Schlosser et al. 1991).

Unplanned disturbance are ubiquitous in the environment and are a significant part of any attempt to manage resources in the long term. Although we acknowledge the high probability of unplanned disturbances, we treat each occurrence as a unique event. We have streamlined the process of ecosystem restoration, but have done little to streamline the process of capturing economic benefits. Salvage sales following insect or fire events are reinvented with each occurrence. During the lengthy process of defining where, how, and what tree biomass to remove, the wood quality (Hadfield and Magelssen 1997) and associated market value and the economic capability to remove biomass may decline

With the increase in fire sizes in the inland forest types (Covington et al. 1994) much of the burned area may not be treated to reduce biomass loading because of economic and environmental considerations. On the 140,000 acre Tyee fire in eastern Washington only 30% of the area was salvaged logged. Although this would appear to be a gentle management practice on the land, the remaining 70% of the area with excessive snag and log loadings now represents a hazard for future fire events (Habeck and Mutch 1973, Wellner 1973). Salvage logging protocols for different forest types, based on historical stand characteristics and amounts of coarse woody debris supported by inherent disturbance regimes, could streamline the process of defining the acceptable range in biomass to remove and what coarse woody debris to leave on site as future forest legacies.

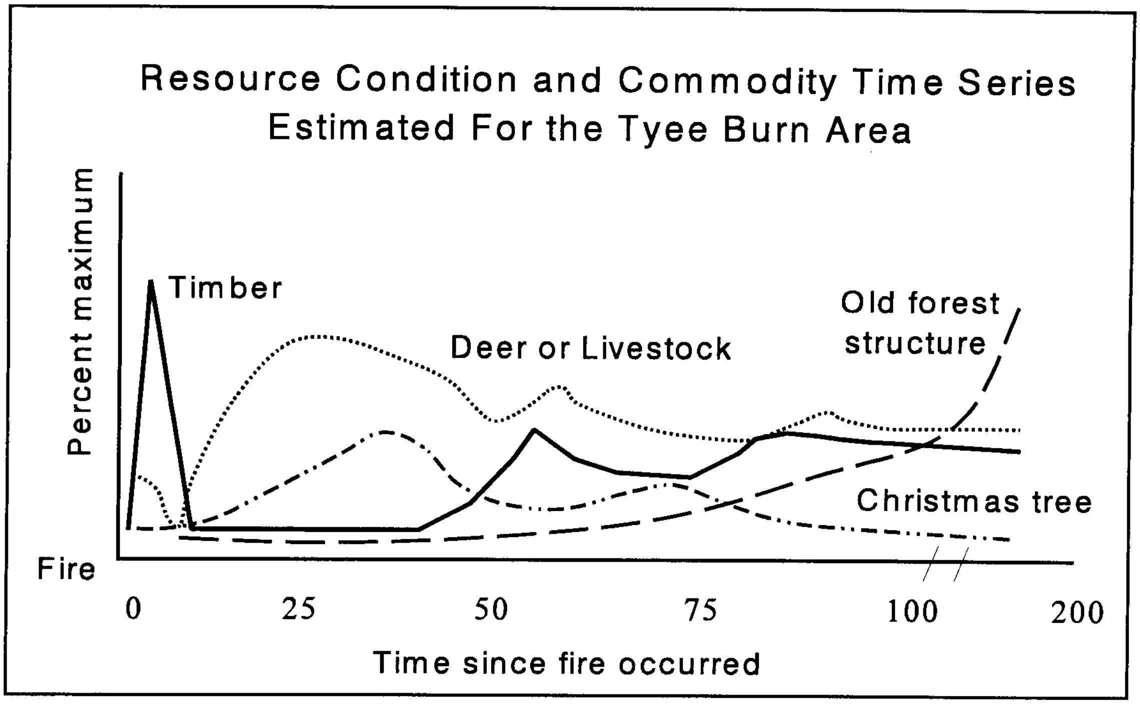

Figure 2—Hypothetical example of resource conditions and commodity availability following stand-replacement fires (Everett et al. 1996).

There are costs associated with managing forest ecosystems actively or custodially. But in the long run "proactive management [disturbance management] will be less costly than fire fighting and associated rehabilitation, especially if done jointly with environmentally-sound production of commodities" (Oliver et al 1994). With catastrophic disturbance, rehabilitation costs will ensue. If rehabilitation budgets are not sufficient then the payment will occur in lower site potential and commodity production foregone (Weigand and Everett 1995).

Decades of Opportunity or Increased Hazard

Because of increased tree densities and biomass in excess of historical ranges of variability for dry forest types there may be decades of opportunity to extract wood resources and still retain historical levels of snags and logs for future forest legacies. The challenge will be in the technological capacity to remove fiber without long-term impacts on site productivity and increasing the flexibility of existing institutions and regulations to allow removal of excess biomass in a timely manner. The inability to reduce biomass loads to within the carrying capacity defined by inherent disturbance regimes may create catastrophic disturbance events with excessive erosion and slow regrowth of vegetation (Harvey et al. 1989). Such events could contribute to the loss of critical wildlife habitat, sensitive species, long-term soil productivity and reduced short and long-term economic benefits.

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Utilization as a Component of Restoring Ecological Processes in Ponderosa Pine Forests

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Abstract

Ecological restoration of western ponderosa pine forests to a semblance of their historic conditions has been recommended by numerous ecologists and foresters. Prior to the early 1900s, frequent low-intensity fires maintained these forests as mostly open stands of large, fire-resistant trees. Many of the stands were perpetuated in uneven-aged structures by tires which thinned stands from below. Exclusion of tiequent fires, coupled with selective logging of large trees, has resulted in dense thicket stands that are at high risk from insect and disease epidemics, and severe stand-replacing wildfires. Restoration treatments in pine forests are often considered to be uneconomical; however, their feasibility has not been evaluated relative to typical stand structures, timber values, and associated harvest costs. We have evaluated two stands, each representing widespread conditions in ponderosa pine forests, and report some general conclusions here. Restoration treatments are economically feasible in many previously-logged ponderosa pine stands, including some on terrain requiring cable harvest systems.

Keywords: ponderosa pine, ecological restoration, utilization, prescribed burning, thinning, product values.

Elimination of the historic pattern of frequent low-intensity fires in ponderosa pine (Pinus ponderosa) and pine-mixed conifer forests has resulted in major ecological disruptions that are of concern to managers of federal wildlands, such as National Forests. Prior to 1900, open stands of large, fire-resistant ponderosa pine were typical. These were accompanied in some areas by other long-lived, fire-dependent species such as western larch (Larix occidentalis). Today, as a result of exclusion of low-intensity fires and early-day logging of larger trees, particularly ponderosa pines, many stands are comprised of dense thickets of late successional species, with varying amounts of larger trees in the overstory. These overstocked stands are now experiencing increased insect and disease epidemics, and severe wildfires (Mutch and others 1993).

Restoring more natural and sustainable conditions in these stands is complicated not only by profound changes in stand composition, structure, and overall vigor, but also by an accumulation of fuels. Numerous studies have determined that low-intensity fires at 5- to 30-year intervals were influential in maintaining open stands dominated by pine and associated seral tree species (Arno 1988; Agee 1993; Covington and Moore 1994). Many stands were self-perpetuating in uneven-aged structures as a result of mortality of individual trees or small groups (White

1985; Arno and others 1995a, 1997). When the small openings containing dead trees burned conditions favored establishment and survival of the most fire-resistant saplings--pine and larch. Historic stands in ponderosa pine-interior Douglas-fir (Pseudotsuga menziesii var. glauca) forests commonly supported 100 to 250 trees/ha (40 to 100 trees/ac), many being greater than 25 cm (10 in) in diameter (Habeck 1994; Arno and others 1995a, 1997). In contrast, present-day stands support 750 to 1,500 trees/ha (300 to 600/ac), with the majority less than 20 cm (8 in) in diameter. Figure 1 illustrates stand structure in the pine/fir type in the Bitterroot National Forest in circa. 1900, prior to logging (Arno and others 1995a), compared with typical conditions in the 1990's.

The scope of the problem and the need for reintroducing fire and fire substitutes on the landscape is staggering. In the Inland West, pure ponderosa pine and mixed pine/fir types are the most extensive fire-dependant forests (Arno and others 1995b). Threatened stands cover about 16 million ha (40 million ac) in the western United States, and are the focus of concerns about declining forest health (American Forests 1995, Phillips 1995).

It is difticult to devise acceptable methods for restoring fiee-dependent ecosystems, which are characteristic of much of the West, because prescribed fire alone will often not accomplish restoration goals in ponderosa pine forests. Historic fires maintained relatively open stand structures, primarily by thinning sapling-sized trees growing beneath large, open-grown trees. Because several natural fire cycles have been missed due to successful tire exclusion efforts, overstocked regeneration layers have now developed into densely stocked stands with a large component of late successional trees. These trees cannot be selectively thinned by burning. Fires sufficiently intense to thin significant numbers of these unwanted trees would torch and kill or damage many of the larger, early successional trees that managers want to leave and feature in the restored stand (Harrington 1996).

Therefore, restoring ponderosa pine forests to more healthy and sustainable conditions generally requires some kind of silvicultural cutting. Cutting and removal of excessive fuels can create the appropriate structural conditions and improve tree vigor, thereby allowing successful reintroduction of fire.

Conceptually, it is desirable to combine cutting, fuel removal, and prescribed burning for the initial restoration treatment. Thinning coupled with fuel reduction treatments is considered especially important for reducing wildfire damage in the suburban/wildland interface (Anderson and Brown

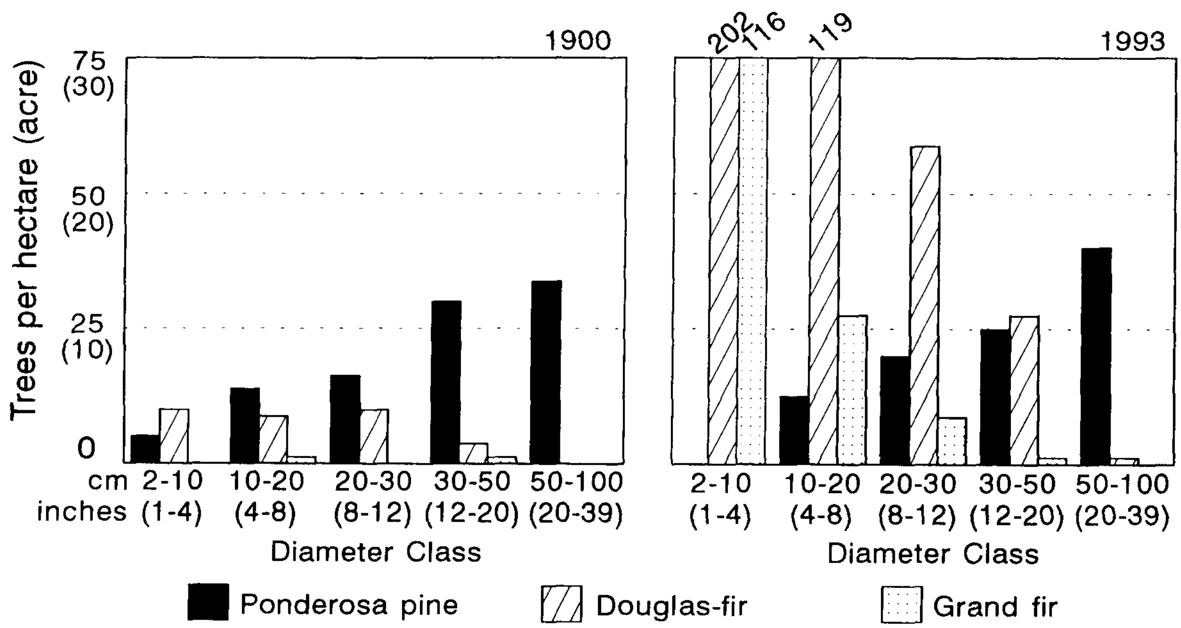

Figure 1 —Structure of an old growth stand west of Hamilton, MT, in 1993 and as reconstructed in ca. 1900 (B-4 in Arno and others 1995a).

1988; Schmidt and Wakimoto 1988; Babbitt 1996), After the initiat treatment, conditions can be maintained with cutting and burning carried out at intervals of perhaps 20 to 30 years. Fire's contribution is in thinning saplings, reducing ground fuels, and recycling nutrients.

A primary advantage of cutting is that it allows for the controlled removal of specific trees in terms of number, size, species, and location to more precisely develop the desired stand condition (Fiedler and others 1996). A major concern of land managers is how to pay for restoration treatments. Cutting trees allows them to be used for forest products, generating income to offset treatment costs. These treatments also can provide indirect economic benefits by reducing potential losses from severe wildfires.

Before cutting treatments are initiated, general restoration goals need to be established in the form of a target stand or desired future condition. Historical descriptions, old photographs, forest inventory records, and ecological reconstruction studies can be interpreted to provide ideas for restoration goals (Fiedler 1996), For example, plot data can provide density targets for thinning (to improve vigor) and for shelterwood and selection cutting (to secure regeneration) in second-growth ponderosa pine stands (Barrett 1979; Fiedler and others 1988). Actual targets can diverge considerably from historic conditions, but still feature relatively open stands dominated by seral species over significant areas of the forest. In contrast, present-day stands commonly manifest a dense growth of climax species.

In this paper, we describe two different stands -- 1) overstocked, second-growth pine/fir, and 2) mosaic of fir thickets, with scattered pine/fir overstory -- each reflecting a widespread condition in ponderosa pine forests in the West. We then present restoration treatment prescriptions appropriate for each condition. Finally, we evaluate the degree to which the value of product removals under the respective prescriptions might underwrite treatment costs. Net product values are determined as the difference between potential mill-delivered values of the trees to be removed, less harvest and haul costs (Pfister and others 1997). Harvest costs are estimated using a methodology developed in an earlier study (Keegan and others 1995).

Timber product uses are based on species, diameter, and value using reported mill-delivered prices from 1994-1996 (BBER Log Price Reporting System 1997). Studlogs, sawlogs, veneer logs, and pulpwood are the major timber products identified for the two stands in our example. Since the market for roundwood pulpwood ranges from strong to nonexistent as paper markets and lumber production fluctuate (Keegan and others 1995), we estimate the net value per acre with and without a roundwood pulpwood market. We also estimate net values on both moderate terrain using ground-based harvest equipment, and steep ground requiring cable yarding systems.

Restoration Approach

Stand 1: Our first example is an overstocked second-growth pine/fir stand comprised of 1,500 trees/ha (600/ac), of which 600 trees/ha (240/ac) are 218 cm (7 in) in diameter. This stand has a basal area of 28 m^2/ha (120 ft^2/ac). Most of the overstory trees are ponderosa pine, with lesser amounts of Douglas-fir. Symptoms of declining vigor include narrow growth rings in recent years, and scattered pockets of bark beetle mortality. The restoration prescription calls for a reserve density of 11 m^2/ha (50 ft^2/ac), comprised of the largest and best pines to provide site protection and a well distributed seed source. While this cutting resembles a shelterwood, it is the first step in a long-term restoration effort to develop an uneven-aged stand structure, so is best described as the initial cut in the implementation of the selection system. Future cuttings would occur at 20- to 30-year intervals, with the purpose of reducing stand density and regenerating pine in newly created openings following each entry. The long-term goal is to create a relatively open, multi-aged ponderosa pine stand with smaller amounts of Douglas-fir, allowing some overstory trees to reach a very large size, and a few to senesce, Most of the sapling and pole ladder fuels (primarily firs) would be killed in the harvesting operation or removed in a subsequent thinning. Of those that remained, most would be killed by the follow-up prescribed underburn.

On gentle terrain, trees cut under the restoration prescription for the overstocked second-growth pine/fir stand have a net product value of approximately $750/ha ($300/ac) with a pulpwood market, and $500/ha ($200/ac) without one. Implementing this same prescription on steep ground with a cable yarding system has a small positive value of about $250/ha ($100/ac) with a roundwood pulpwood market. In the absence of such a market, the timber product values are not sufficient to cover harvest and haul costs.

Stand 2: Our second example is a mosaic of fir thickets, with a scattered overstory of large ponderosa pine and Douglas-fir. This stand is comprised of 1,200 tree/ha (485/ac), with a basal area of 31 m^2/ha (135 ft^2/ac). Approximately 85 percent of the trees are $\leq$ 23 cm (9 in) in diameter. Of the 37 overstory trees/ha (15/ac) $\geq$ 46 cm (18 in) in diameter, two-thirds are Douglas-fir, and about one-third ponderosa pine. Douglas-fir outnumber ponderosa pine by over 20 to 1 in the understory, and many of the Douglas-fir, including most large firs, are heavily infected with mistletoe. The existing stand manifests high fire hazard, declining vigor due to pathogen infection of the major stand component (fir), and successional transition from an early seral to climax species composition. The restoration prescription has a target reserve basal area of 11 m^2/ha (50 ft^2/ac). All ponderosa pine (7 m^2/ha; 30 ft^2/ac) would be marked for leave to provide both a current and future pine seed source. The remaining 4 m^2/ha (20 ft^2/ac) of leave trees needed to reach the 11 m^2/ha (50 ft^2/ac) basal area target would be comprised of the biggest and best non-infected Douglas-firs. Small firs would be greatly redued by the logging operation, slashing, and prescribed burning. Scattered openings of 0.1 to 0.2 ha (0.25 to 0.5 ac) would be created from the removal of fir thickets. The associated slash would be burned and the openings subsequently planted with ponderosa pine. The immediate post-treatment goal is to establish anew age class of ponderosa pine; longer-term, the goal is to create a relatively open, multi-aged stand dominated by ponderosa pine, with some very large-diameter trees.

On terrain suitable for ground based skidding systems, the stand comprised of dense thickets and scattered overstory trees has a net value just over $5,000/ha ($2,000/ac) with a roundwod pulpwood market, and $4,700/ha ($1,900/ac) without one. On steeper ground requiring a cable harvest system, net product value is over $2,500/ha ($1,000/ac) even without a roundwood pulpwood market.

Summary and Conclusions

The role of utilization in restoration harvest treatments was demonstrated for two different stands representing considerable acreages of ponderosa pine forest in the West. On moderate terrain, the ecological restoration prescription developed for each condition generated a positive revenue flow, with or without a roundwood pulpwood market. Even on steeper ground requiring cable harvest systems, the stand with large diameter, late successional trees needing removal has the potential for substantial positive cash flow.

The positive dollar return associated with removing trees to restore desired species compositions and stand structures in two different stand conditions is encouraging. Furthermore, the considerable revenue generated from some restoration prescription/harvest system combinations is sufficient to carry substantial additional treatment costs, such as prescribed burning or planting. This is especially true on terrain that permits use of feller-bunchers and grapple skidders. Presence of a roundwood pulpwood market is also moderately beneficial in both examples.

Some stand conditions requiring restoration treatment will require considerable investment. Stands on steep ground with little timber over 20 cm (8 in) in diameter to be removed would generally not provide a positive cash flow from timber products, particularly during periods of weak demand for roundwood pulpwood. However, such stands could be blended into larger projects with other stands that do provide a positive return.

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Developing a Comprehensive Reforestation Program in the Russian Far East

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Abstract

Timber harvesting and excessive wild fires combine in the Russian Far East (RFE) to create a large demand for conifer seedlings. Working under intergovernmental cooperative project of the USA and Russia the Environmental Policy and Technology Project (EPT) has developed and implemented a world class containerized seedlings program in the RFE at two greenhouse locations. The program involved US based training for Russian greenhouse specialists, Russia based training by US specialists consulting in the RFE, redesign of greenhouses, and the installation of new technologies and equipment such as; seed processing equipment, a seed freezer, a seedling cooler, a peat moss shredder, seed sowing line, new seedling containers, water supply systems, fertilizer injectors, irrigation systems, and other technologies needed to operate the two complexes. The short term results of the program have increased the production of two green house complexes from 3,000 in 1995 to 1.2 million seedlings expected in 1997. The main species produced from the efforts include Korean pine, Siberian larch, and Siberian spruce.

Identifying Wood Utilization Options for Ecosystem Management: Summary of a National Research Project

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Abstract

Using an ecosystem approach to forest management will change silvicultural practices, thus requiring utilization options to provide revenue and to help offset the costs of the silviculture treatments. The Forest Service, university cooperators, and several industry mills in the southern, western, and northeastern United States have been involved in a national multidisciplinary research project to provide information and methods to evaluate current and future product opportunities for woody materials removed from ecosystem-managed forests. This paper explains how research from a range of disciplines is providing information to aid in making management decisions.

Keywords: ecosystem management, wood utilization, forest management, silvicukure, forest operations, economics

Introduction

The ecosystem approach to forest management is changing silvicultural practices. Some approaches include removing woody materials to achieve desired ecosystem management objectives, As a result of the change in the species, size, and quality of wood that is being removed from the forest, utilization options are needed to provide revenue and help offset the cost of silviculture treatments.

Since 1994, eleven Forest Service research units, nine National Forests, nine university cooperators, and several industry mills have been involved in a national project called Wood Utilization Options for Ecosystem Management (WUEM). The objective of this project is to provide methods for evaluating the economic feasibility of different silvicultural treatments, various harvesting methods, and current and future product options for woody materials removed from forests maintained under an ecosystem approach.

To achieve this objective, multidisciplinary research is being conducted to (i) develop alternative silvicultural, harvesting, and utilization options, and (ii) incorporate understanding of these options in management decision models to aid National Forests (NF) in treating specific ecosystem conditions in three U.S. regions: the South, West, and Northeast. This research, specifically, is linking options for silvicultural treatments with forest operations, with impacts on current and future wood qualities, and with options for current and future wood products. In addition, economic evaluation tools are being developed to help managers evaluate the feasibility of various silvicultural treatments, forest operations, and wood products. This paper presents the ongoing progress of multidisciplinary research for the WUEM project.

Uneven-Aged Mixed-Species Forests in the Piedmont Region of the South

Research studies in the South are designed to identify the effect of ecosystem management strategies and resultant silvicultural treatments on species composition, growth, survival, properties, and product quality from forest stands in the Piedmont Region. The purpose of this research is to link silviculture, harvesting, wood quality, and economic models to evaluate alternative silviculture treatments for moving the ecosystem toward uneven-aged pine mixed hardwoods.

The Piedmont physiographic region is located east and south of the Appalachian Mountains and west and north of the fall-line of the Coastal Plain in the Southeast. The Piedmont contains about 8.5 million ha (21 million acres).

Before European settlers arrived in the Piedmont, nearly one-half of the area was probably occupied by pine mixed hardwood stands and the other half by other hardwood stands. The Piedmont had been extensively cleared for cotton and other row crop production by 1860. By the 1930s, most top soil had eroded away. Subsequent abandonment of agriculture and reforestation stabilized the land, and by 1990, only a small percentage was still row cropped. Most agricultural land has been converted to pasture, naturally seeded to pine forests, or planted to pine plantations.

Current Forest Conditions

The Piedmont area contains 8.78 x $10^8 m^3$ (31 x 10^9 ft^3) of growing stock: 44 percent pine, 1 percent other softwoods, 26 percent soft hardwoods, and 29 percent hard hardwoods. The NF land in the area was purchased by the government in the 1930s. At present, Piedmont NF growing stock is 58 percent pine, 3 percent other softwoods, 18 percent soft hardwoods, and 21 percent hard hardwoods. The NF account for 2 percent of the timberland in the Piedmont. The majority of stands are natural even-aged pine or pine–hardwood.

Desired Forest Ecosystem Conditions

Forest soils in the Piedmont Region are in a highly depleted condition. In many cases, centuries of careful management will be needed to restore them to their original fertility. Nevertheless, the general health of the forests is good, except for problems with fusiform rust and outbreaks of southern pine beetle.

National forest lands have been managed under the multiple use concept since the 1960s. In the past, timber management objectives were to improve the health, quality, and volume of pine stands. Older pine stands were often clear cut and replanted with pine or harvested using seedtree cuts to regenerate pine. Younger stands were thinned using various partial-cut management systems to stimulate pine sawtimber growth.

Under ecosystem management objectives, pine and pine–hardwood stands on Piedmont NF are being converted from even-aged to uneven-aged mixed species stands or to two-aged pine stands. Silvicultural treatments include single tree, group selection, shelterwood, and seedtree harvests.

Research Activities

The research objective for the Piedmont Region is to link ecosystem management strategies and resultant silviculture to species composition, wood quality, and economic models that evaluate the economic feasibility of alternative silviculture treatments.

To develop the link between silviculture and wood quality and wood products, 55 monitoring plots have been established on NF and other sites in stands with histories that represent a range of silvicultural practices. Piedmont NF in the study include the Oconee, Sumter, and Uwharrie. Characteristics inventoried include a new tree grade measure that is being used to provide estimates of volume and grade yield for lumber under alternative silvicultural regimes (Clark and McMinn 1997).

Several mill studies have been conducted to determine grades of lumber from trees of various grades grown under different regimes. Nondestructive evaluation (NDE) tests have been conducted to link speed of sound in logs to strength of lumber. Use of NDE helps identify the highest value use for each log, including machine stress-rated (MSR) lumber and laminated veneer lumber (LVL) (Ross et al. 1996, Schad et al. 1996).

A special growth projection model has been developed for loblolly–hardwood stands to project growth under alternative uneven-aged silvicultural regimes. An economic optimization model is being developed to estimate the degree to which alternative silvicultural regimes can meet economic return criteria and/or tree size and species diversity criteria. This model incorporates data on wood utilization options and indicates tradeoffs between economic return and tree size and species diversity (Lin et al. 1995).

Harvest productivity and cost estimates as a function of removal levels for uneven-aged management of pine stands in the South have been developed. Equations were developed for chain saw felling, grapple skidding, and tree-length loading that link harvesting productivity to level of removals for a range of silvicultural treatments (Rummer et al. 1997).

Treatments include single tree, group selection, seedtree, shelterwood, and clear cut. This information is used in the growth projection model (previously mentioned) for evaluating economic return from alternative silvicultural and utilization regimes. An initial version of the uneven-aged pine growth and economic evaluation model has been distributed to all NF in the South.

Dense Small-Diameter Stands in the West

Dense, small-diameter stands are widespread in the West. To improve ecosystem health and biological diversity, in some cases, thinning or other silvicultural treatments may be used.

Current Forest Conditions

Fire suppression has resulted in small-diameter, densely stocked stands throughout the interior West. These stands typically lack vegetative and structural diversity and are more susceptible to attack from insects and disease, compared with uneven-aged, sparsely stocked stands. Mortality from competition, insects, or disease leads to an increase in fuel materials (fuel loading) and consequent increased risk of catastrophic fires.

Research has focused on the representative conditions on the Colville NF in northeast Washington. Under a program known as Creating Opportunities (CROP), the Colville NF surveyed 44,516 ha (110,000 acres) with trees 102 to 178 mm (4–7 in.) diameter at breast height (dbh) and 1,300 to 2,000 stems per acre. Natural development has led to stands mostly consisting of fire-origin lodgepole pine, western larch, and Douglas-fir. These stand conditions are common in northeast Washington, northern Idaho, and northwest Montana. A heavy western redcedar understory is also present in many stands on the east side of the Colville NF.

Desired Forest Ecosystem Conditions

The desired outcome for the Colville stands is to create healthy, vigorous stands that contain structural components (age, species) within the historic range of variation for the region and that support wildlife. To achieve this outcome requires creating a higher proportion of late successional forest structure as quickly as possible. The objective is to improve wildlife, forest health, and forest aesthetics.

Research Activities

Simulation of various silvicultural prescriptions for the next 150 years suggests that the no treatment option is unlikely to result in development of desired stand conditions. The simulations also suggest that active management options are more likely to result in desired conditions (Ryland 1996, Willits et al. 1996).

Thinning operations, studied on the Colville NF, identified how operation costs decrease with increasing tree size. Results indicate how, with current markets for timber in that locality, a small difference in average diameter of trees selected for harvest from a stand can affect economic viability of the timber sale (Barbour et al. 1995, 1997).

Harvesting system alternatives, used for improvement cuttings to manipulate ecosystem structure and composition in western stands, were compared and contrasted (Wang and Greene 1996, Hartsough et al. 1995). The harvesting cost estimates were then used to determine potential economic return to stumpage, when using small-diameter trees for a range of specific products. The study estimated manufacturing costs, capital costs, and return to stumpage for oriented strandboard, stud lumber, random-length dimension lumber, MSR lumber, LVL, and pulp for paper. Results indicate that pulp and LVL are likely to yield the greatest return to stumpage among the realistic processing alternatives (Spelter et al. 1996).

Studies are also underway to evaluate the palpability of wood from dense, small-diameter stands. Wood chips from the Colville NF have been tested for mechanical and chemical pulpability. Raw materials include small-diameter Douglas-fir, western larch, and lodgepole pine.

Mechanical pulping tests at the Forest Products Laboratory indicate that lodgepole pine consumed the most energy but yielded the strongest handsheets of paper (Myers et al. 1997).

Three mill studies have been done to link log quality to that of the resulting lumber or veneer using NDE. Data collected from the mills indicated a strong correlation between log quality and lumber quality. Such correlations provide a means to assess the highest value-added product that can be achieved from each individual log (Green and Ross 1997, Will its et al. 1997).

Financial analysis software is currently being developed that will allow resource managers to understand how different mixes of species, classes, and sites of timber affect the economic projection for a particular sale. This software also considers how different product possibilities can alter the economic feasibility of a treatment (Fight 1997).

Central Appalachian Hardwood Forests

Studies in the Northeast are designed to identify the short- and long-term links between ecosystem management and wood utilization opportunities (Baumgras 1996, Miller 1996). Initial research focused on central Appalachian hardwood stands in the

Monongahela NF in West Virginia and the Allegheny NF in Pennsylvania. Innovative silvicultural practices are being evaluated as a means for meeting ecosystem objectives for a wide variety of forest types and stand conditions.

Current Forest Conditions

West Virginia has representative central Appalachian hardwood forests. In 1989, 79 percent of West Virginia was forested, with 4.9 million ha (12.1 million acres) forested. Two-thirds of this forest land is fully stocked or overstocked. Surveys indicated that sawtimber stands predominate, which indicates the maturing of the forests. However, two-thirds of the sawtimber volume is in low value grade 3 and 4 logs. Although oak–hickory and northern hardwood forest types dominate, species composition on a single treatment area can be extremely variable.

Desired Forest Ecosystem Conditions

The ecosystem management concerns associated with central Appalachian hardwood forests are (i) maintaining forest health and vigor, (ii) maintaining diversity of tree species, (iii) maintaining and regenerating oak species, and (iv) minimizing residual damage from forest operations.

Given the high proportion of sawtimber stands and fully or overstocked stands, maintaining forest vigor will require regeneration of maturing sawtimber stands and intermediate cuts in other fully stocked and overstocked stands.

Shade intolerant species such as yellow-poplar and black cherry cannot be adequately regenerated with the light partial cuts or diameter-limited cuts common on private land, and clear cutting is seldom an option on NF lands. The shade intolerant species are very important to wildlife and as wood products. Many wildlife species also require tall trees and crown structure diversity.

Oak species are essential to several species of wildlife and are important for wood products. Light cutting on mesic sites does not regenerate oak, but with heavy cutting, young oak cannot compete with shade intolerant species. One method may be to remove the understory without making canopy openings. It may be a significant challenge to arrange commercial harvesting and products to support such thinning. Silvicultural treatments are also needed to reduce susceptibility to gypsy moth defoliation in forests with an oak component.

Residual stand damage, which results from more frequent partial cuts, needs to be reduced to prevent loss to decay and loss in wood quality.

Research Activities

In 1995 and 1996, WUEM identified issues associated with specific NF ecosystem management activities that could affect wood utilization opportunities and determined the specific types of information required to accomplish ecosystem management objectives (Baumgras and LeDoux 1995, Baumgras et al. 1995). Many of these issues are closely related to the maturing of the Monongahela and Allegheny NF and the maintenance of their inherent diversity. Regeneration, maintaining species diversity, and maintaining health are the main issues in these forests. Two-aged management is a key system being studied (Rummer et al. 1997).

For the central Appalachian hardwoods, studies are underway to link silvicultural treatments to estimates of multiproduct volumes and to harvesting costs. One study, based on data from 100 forest plots in West Virginia, developed methods to estimate multiproduct volumes from hardwood trees. A second study linked cut stand attributes to forest operation costs for hardwood forests. Information from both studies is being used to improve a model that, for a given treatment, will estimate product yields, forest operation costs, and overall economic feasibility.

To evaluate implications of two-aged management for future stands, a study was conducted to assess regeneration and quality of trees left on the site. Data were collected on the Monongahela NF from 20 stands harvested under two-aged management.

A study is being conducted to evaluate residual stand damage in hardwood partial cuts harvested with several types of systems including conventional rubber-tired skidders, skyline yarding, helicopters, and fully mechanized operations. Given the significant reduction in clear cutting on NF and the implementation of longer rotations, the potential effects of residual stand damage on future product yields and value is an important concern.

Within the bounds of the WUEM project, work has expanded to the northern hardwoods in New England to examine links between silviculture and tree quality and utilization options. Data from 421 plots on the USDA Forest Service Bartlett Experimental Forest, which were grown under alternative silvicultural regimes, have been used to estimate lumber yields by species and grade.

Concluding Remarks

To summarize, the national project on Wood Utilization Options for Ecosystem Management (WUEM) is focusing on moving from even-aged pine stands to uneven-aged mixed species stands in the southern United States. In the West, the project is focusing on late successional structural diversity in areas now covered with densely stocked, small-diarneter stands. In the Northeast, focus is on management concerns for the central Appalachian and northern hardwood forests. The WUEM project is an effective means to pull together and focus research on silviculture, forest operations, wood quality, wood products, and economic feasibility of management decisions and to support outreach efforts that aid in managing specific ecosystem conditions (Skog et al. 1995).

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Link Between Southern Pine Silvicultural Treatments and Stand Value

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Abstract

An ecosystem approach to managing southern National Forests is being used to conserve biodiversity, improve the balance among forest values and achieve sustainable conditions. This paper reports on a study established to identify the implications of ecosystem management practices on loblolly *(Pinus teada* L.) and shortleaf *(P. echinata* Mill) pine stands in the Piedmont. Stand value is expressed in terms of species richness, diversity and evenness; in terms of wood properties for products and T&E habitat; in terms of tree quality for fiber and solid products. The impact of silvicultural practice, site productivity and stand age on species composition, wood properties and tree quality is discussed. Silvicultural practices include partial cuts, group selection cuts, seed tree cuts and no human disturbance.

Introduction

During the eighteenth century the Piedmont physiographic region of the Southeastern United States was extensively cleared for cotton and other row-crop production. By the 1930's, most topsoil had eroded and productive cultivation was difficult. Thus, in the 1930's the Federal government purchased abandoned farm land later included in the National Forest system. National forest lands account for only 2 percent of the timberland in the Piedmont. Currently, Piedmont National Forests contain 58 percent of their growing stock in pine, 3 percent in other softwoods, 18 percent in soft hardwoods, and 21 percent in hard hardwoods. The majority of stands are natural even-aged pine or pine/hardwood stands.

Piedmont National Forest lands have been managed under the multiple-use concept since the 1960's. Under this concept, objectives were to improve the health, quality and volume of pine stands. Older pine stands were clearcut and planted back to pine or harvested using seed tree cuts to establish pine regeneration. Younger stands were thinned to stimulate pine sawtimber growth.

In the early 1990's an ecosystem approach to managing National Forests was introduced to conserve biodiversity, improve the balance among forest values, and achieve sustainable, healthy conditions while retaining the esthetic, historic, and spiritual qualities of the land. Under ecosystem management pine and pine/hardwood stands on National Forests in the Piedmont are being converted from evenage monocultures to unevenaged or two aged pine and mixed species stands.

This paper reports on a study established to identfy the implications of ecosystem management practices on loblolly *(Pinus teada* L.) and shortleaf *(P. echinata* Mill) pine stands in the Piedmont of the Southeast. Stand value is expressed in terms of species richness, diversity, and evenness; in terms of wood properties for products and

T&E habitat; and in terms of tree quality for fiber and solid products. The impact of partial cuts, group selection cuts, seed tree cuts and no human disturbance on stand value of natural pine stands on National Forests in the Piedmont is described.

Methods

A series of permanent measurement plots have been established in loblolly/shortleaf pine stands in the Piedmont on the Oconee, Sumter and Uwharrier NF to monitor the response of these stands to a range of ecosystem management practices. The management practices included: (1) partial cuts, (2) group selection cuts, (3) seed tree cuts and (4) reserve areas. Included in the partial cuts are single tree selection, salvage cuts, stand improvement cuts and shelterwood cuts. Reserve areas are stands in which no human disturbance is planned. Each monitoring plot is a cluster group (CG) consisting of three 1/5 acre circular plots and is randomly located within each stand selected for monitoring. Cluster groups are inventoried at establishment, then prior to and following harvest treatments. Cluster groups will also be inventoried every five years and after any natural disturbances. Cluster groups were established in stands representative of five 20-year age classes (1, 20,40, 60, and 80 years) and two broad site-index (SI) classes (SI < 80 and SI ≥ 80) for each management practice. Table 1 shows the distribution of the 49 cluster groups established in the Piedmont by management practice, age class and SI class.

On each 1/5 acre plot all trees ≥ 5.0-inches in diameter at breast height (d.b.h.) were located by azimuth and distance from plot center. Species, d.b.h., total height, merchantable height, crown class, tree grade and defect indicators were recorded for each live and dead tree. Five 1/300 acre micro-plots were located 30 feet from plot center at 72° intervals within each 1/5 acre plot to tally seedlings and saplings. Seedlings (trees up to 1.0 d.b.h. inches) were tallied by species count. Saplings (trees 1.0 to 4.9 inches d.b.h.) were tallied by species, d.b.h. and total height. Softwoods 5.0 to 8.9 inches d.b.h. and hardwoods 5.0 to 10.9 inches d.b.h. were classified as pole timber. Softwoods ≥ 9.0- and hardwoods ≥ 11.0-inches d.b.h. were classified as sawtimber if they contain one or more 16-foot sawlog. Pine sawtimber trees were classtified using a tree classification system for natural pine developed by Clark and McAlister (1997) and hardwood sawtimber trees were classified using USDA Forest Service hardwood tree grades (Hanks, 1976). The sawtimber pine trees were classified based on size and frequency of branches, bole straightness and other visual defect indication. The pine classification system placed a tree into one of three grades where lumber yield would be expected to meet the following specifications:

Grade 1:	Tree of high quality which would yield ≥ 40% No. 1 & BTR lumber
Grade 2:	Tree of average quality which would yield ≥ 20% but < 40% No. 1 & BTR lumber
Grade 3:	Tree of below average quality which would yield < 20% No. 1 & BTR lumber

Increment cores (5 mm in diameter) for wood properties analysis were extracted from bark to pith 4.5 feet above ground from four trees in each 1/5 acre plot. The largest diameter pine at 90° intervals in each plot was selected for boring. A total of 408 trees were bored. Increment cores were analyzed to determine tree age, earlywood and latewood annual radial growth and amount of juvenile wood, sapwood and heartwood at breast height.

Species diversity and evenness were calculated using Shannon's indices of diversity and evenness based on species stem counts. (Magurran, 1988).

Results

Species Composition

A stand can be seen and valued through many different eyes. To many, species composition is an important measure of a stand's value. Species group composition was fairly uniform across the management practices sampled (Table 2). On average 81 to 87% of stand basal area was in pine species, 9 to 16% in soft hardwood species and 0 to 6% in oak species.

Average number of stems per acre for seedlings, saplings and pole & sawtimber was highest in the reserve stands and lowest in the seed tree cuts (Table 3). Species richness and diversity for sapling and pole & sawtimber trees were also highest in the reserve stands and lowest in the seed tree cuts as would be expected. The three most abundant species in the seedling class were red maple *(Acer rubrum* L.)(18%), loblolly pine (15%) and sweetgum *(Liquidombar styaciflua* L.)(13'%). In the sapling class the most abundant species were sweetgum (25%), loblolly pine (18%) and dogwood *(Cornus florida* L.)(1l%). The most abundant species in the pole & sawtimber class were loblolly pine (57%), sweetgum (13%), and shortleaf pine (6%).

Number of stems per acre in the seedling class in the younger natural pine stands was lower than that found in older stands (Table 4). This occurs because the young pine stands have a closed canopy and little sunlight reaches the forest floor. However, when these young

Table 1–Number of cluster groups[1] established in pine and pine/hardwood stands in the Piedmont by management practice, site index class, and age class

Age Class (Yrs)	Management Practice							
	Partial Cut		Group Selection		Seed Tree		Reserve	
	SI<80	≥80	SI<80	≥80	SI<80	≥80	SI<80	≥80
20	2	3		2				
40	2	2	2		1	1		
60	5	5		2	2	3	1	1
80+	3	2	2		3	3	1	1

[1]Cluster group = 3 1/5 acre plots

Table 2–Average basal area per acre and proportion of basal area by species group and by management practice in the Piedmont

Characteristic	Management Practice			
	Partial Cut	Group Selection	Seed Tree	Reserve
Stands Sampled (No.)	28	2	7	4
Basal Area/Acre (Ft^2)	99	101	29	134
Pine (%)	81	83	84	87
Oaks (%)	6	0	5	1
Other H. Hardwoods (%)	1	1	1	2
Soft Hardwoods (%)	11	16	10	9
Misc. Species (%)	2	0	0	1

stands are thinned the crown canopy is opened and the number of stems in the seedling class increases significantly. Species diversity and evenness for seedlings, however, decreases in the older stands (Table 4). Species diversity and evenness for pole & sawtimber trees was lowest in the young stands and highest in the oldest stands that have been thinned several times.

Wood Properties

The value of a stand may also be dependent on the properties of the wood in the trees. On National Forests managing for red-cockaded woodpecker *(Picoides boreales)* (RCW) habitat the effect of management practice, site productivity and tree characteristics on heartwood formation are important. The RCW, a T&E species, requires a minimum of five inches of heartwood at cavity height to envelop the nesting cavity. One result of this long-term study will be increased knowledge on how and where forest managers can expect to find increased heartwood for RCW cavity habitat.

A regression equation developed by Clark (1994) was used to estimate heartwood diameter at 22 feet based on d.b.h., tree age and heartwood diameter at 4.5 feet. Initial study results confirm that the diameter of heartwood at cavity height (22 feet) increases not only with tree age but site productivity (Figure 1). The proportion of trees bored that had 25 inches of heartwood at 22 feet was higher for pines growing in stands with SI $\geq$ 80 compared to trees growing in stand with SI < 80. This indicates that managers should concentrate RCW recruitment activities not only in older stands but also on high productivity sites.

Table 3–Average stems per acre, species richness, diversity and evenness for seedlings, saplings and pole & sawtimber by management practice for natural stands in the Piedmont

Characteristic	Management Practice			
	Partial Cut[1]	Group Selection[1]	Seed Tree	Reserve
Stands Sampled (No.)	28	2	7	4
	Seedlings (trees < 1.0 in. DBH)			
Stems/Acre (No.)	14,992	12,210	10,674	28,960
Richness	19	16	18	20
Diversity	1.9	1.8	2.0	1.6
Evenness	0.7	0.7	0.7	0.6
	Saplings (trees 1.0 to 4.9 in. DBH)			
Stems/Acre (No.)	446	510	346	630
Richness	5	4	3	7
Diversity	1.2	0.7	0.6	1.4
Evenness	0.8	0.6	0.5	0.7
	Pole & Sawtimber (trees ≥ 5 in. DBH)			
Stems/Acre (No.)	153	115	31	190
Richness	8	6	4	10
Diversity	1.2	1.1	0.8	1.4
Evenness	0.8	0.6	0.5	0.6

[1]Stand conditions before harvest

Tree Quality

The size and frequency of branches and size and straightness of tree boles can also determine the value of a stand. The proportion of pine basal area per acre in pulpwood, grade 1, 2 and 3 trees in the Piedmont changed significantly with increasing stand age (Figure 2). The proportion of stand basal area in pulpwood trees decreased and proportion in grade 1 trees increased significantly with increasing stand age, The proportion of pine basal area per acre in in grade 2 trees and dead standing trees increased slightly and proportion in grade 3 trees remained relatively constant with increasing stand age.

The stocking and tree quality of a stand can be altered based on the forest practice and quality of the trees marked for harvest. In the Piedmont three common practices prescribed under ecosystem management are single tree selection, shelterwood cuts and seed tree cuts. Table 5 shows the average proportion of pine basal area per acre before harvest, marked for harvest and left in the residual stands for the monitoring plots established in stands that were marked for harvest.

In the two stands marked for single tree selection an average of 30 ft^2 of basal area was removed of which 87% was in grade 1 trees, none in grade 2 trees and 8% in grade 3 trees. The tree quality of the residual stands changed little compared to that of the stands before harvest. In the 5 stands which were harvested using a shelterwood cut, an average of 55 ft^2 of basal area was harvested, of which 28% was grade 1 trees, 42% was grade 2 trees, 21% grade 3 trees and 9% pulpwood (Table 5). After harvesting these stands contained a higher proportion of their basal area in grade 1 trees (55%) and a lower proportion in pulpwood (2%) but still

Table 4–Average stand characteristics and species richness, diversity and evenness for seedlings, saplings and pole & sawtimber by stand age class for partial cut and group selection natural pine stands

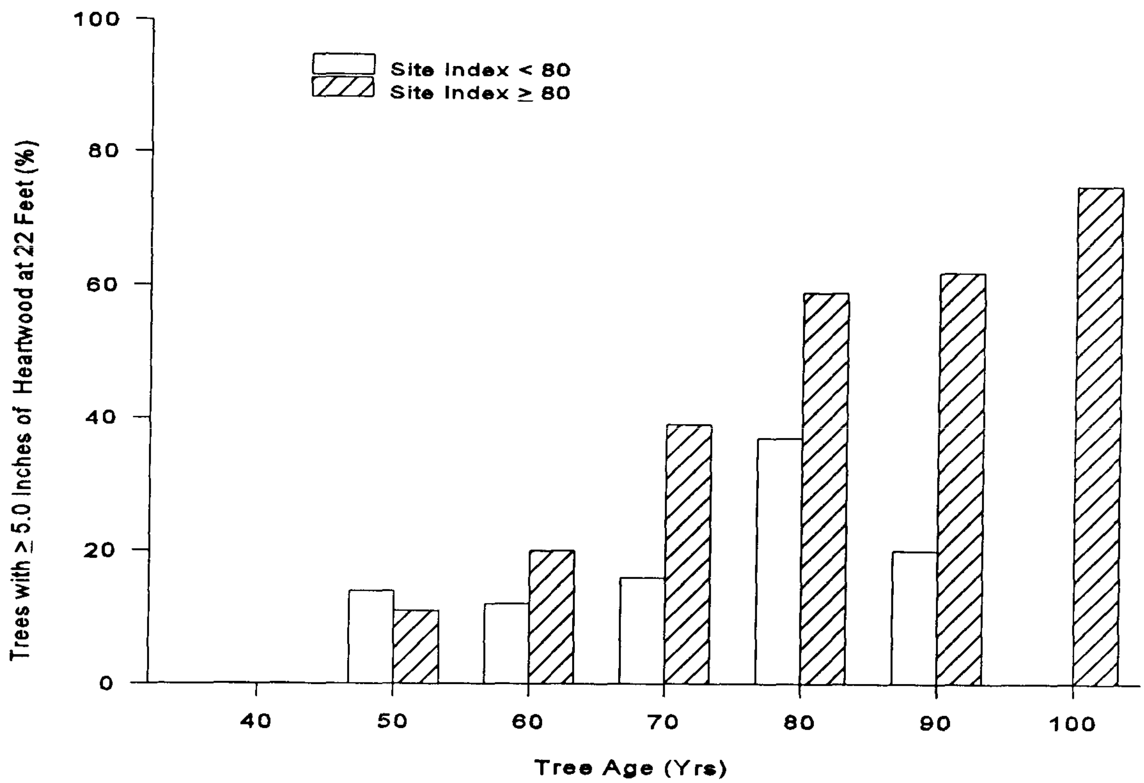
Characteristic	Stand Age Class (Years)			
	20	40	60	80
Stands sampled (No.)	2	4	16	8
	Seedlings (trees < 1.0 in. DBH)			
Stems/Acre (No.)	5,060	13,295	16,716	14,180
Richness	17	19	20	19
Diversity	2.3	1.9	2.0	1.8
Evenness	0.8	0.7	0.7	0.6
	Saplings (trees 1.0 to 4.9 in. DBH)			
Stems/Acre (No.)	550	725	310	570
Richness	4	7	4	7
Diversity	1.2	1.5	1.5	1.4
Evenness	0.9	0.8	0.8	0.8
	Pole & Sawtimber (trees ≥ 5 in. DBH)			
Stems/Acre (No.)	287	174	122	161
Basal Area/Acre (Ft^2)	77	90	97	113
Richness	5	8	8	10
Diversity	0.2	1.2	1.3	1.5
Evenness	0.1	0.6	0.6	0.7

contained 16% of their basal area in grade 3 trees. In the 4 stands marked for seed tree cuts an average of 86 ft^2 of basal area was harvested and 11 ft^2 left in the residual stand (Table 5). After harvest the residual seed tree stands contain an average of 32% of their basal in grade 1 trees and 38% in grade 2 trees. No grade 3 trees were left as a seed source, but 28% of the standing basal area was in dead trees.

Based on these monitoring plots the timber markers on National Forests in the Piedmont are doing a good job selecting trees for harvest and improving the overall quality of the residual stands.

The impact of harvest operations on volume of trees cut and harvested, cut and not removed, accidentally downed in harvest, and the health of the residual stand are important. After monitoring plots were established in the matural pine stands seven of the stands were harvested using some type of partial cut, two harvested using group selection, and four harvested using seed tree cuts. The monitoring plots were remeasured following this tree length harvesting. In the partial cut stands only 1% of the basal area marked was cut and not harvested, 1% was pushed down during harvest, 65% was left standing healthy, but 7% of the initial basal area or 11% of the residual timber contained logging damage (Table 6). In the group selection cuts, 5% of the initial stand basal area marked was cut but not removed. This increase in volume of trees cut and not removed was because the feller-buncher felled all the trees in the 1 ½ acre openings into a crisscross pile and then the skidder removed the felled trees. When operating in these small openings it appears best to cut and skid a portion of the

Figure 1-Proportion of trees sampled that have ≥ 5 inches of heartwood at 22 feet by site index class and age class for natural loblolly and shortleaf pine in the Piedmont



trees at a time.

In the stands marked for seed tree cuts, none of the marked trees were cut and not removed, 3 percent of the original basal area was pushed over during the harvest and 25% of the initial basal area was left standing and healthy. However, 5% of the initial basal area or 16% of the residual standing timber contained logging damage.

Summary

This paper describes a study established to monitor the implications of ecosystem management practices on loblolly/shortleaf pine stands on the Oconee, Sumter and Uwharrie National Forests in the Piedmont of Southeastern United States. Stand value is expressed in several ways. It is expressed in terms of species richness, diversity and evenness; in terms of wood properties for RCW habitat; and in terms of tree quality for lumber. The management practices examined include partial cuts (single tree selection, shelterwood cuts), group selection cuts, seed tree cuts, and no human disturbance.

Study results show that pole & sawtimber trees in older pine stands that have been thinned have a significantly higher species richness, diversity and eveness than young unthinned stands. Results also show that when managing for RCW cavity habitat, managers should concentrate RCW recruitment activities in older pine stands on high productivity sites. Results also indicate that rotation lengths of 60 to 80 years produce the highest proportion of stand basal area in grade 1 trees that are most capable of producing high quality lumber. Based on this study National Forests in the Piedmont are applying ecosystem management practices that are improving all stand values.

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Figure 2-Effect of stand age on proportion of pine basal area/acre in grade 1, 2, and 3 sawtimber, pulpwood and dead standing trees in natural pine stands in Piedmont (N = 41 cluster groups)

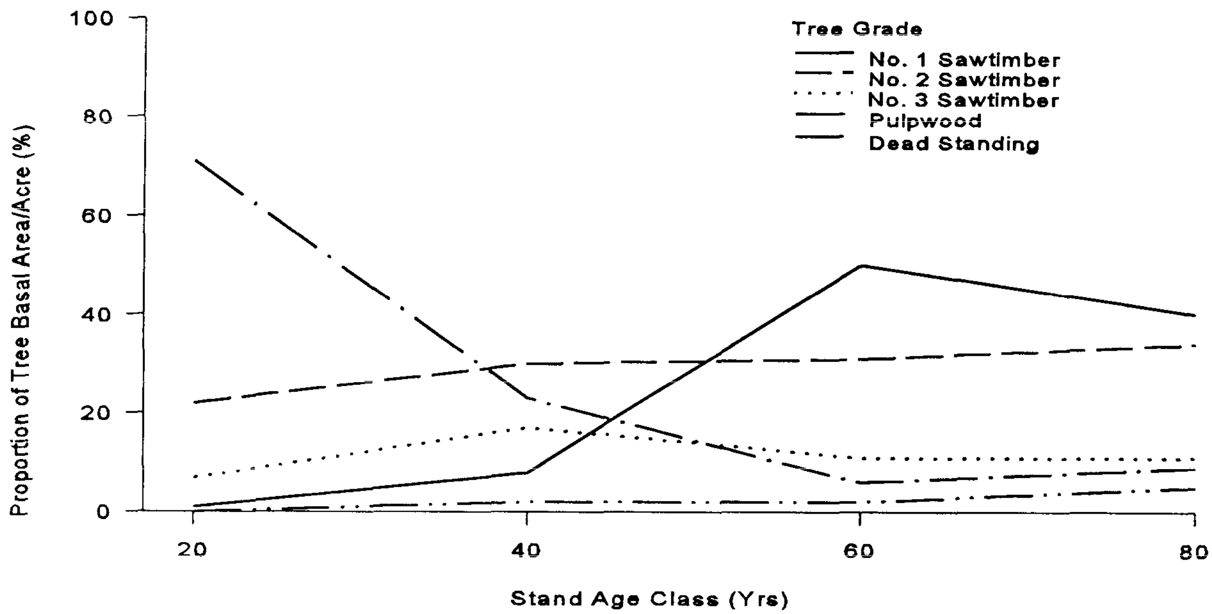

Table 5–Average proportion of pine basal area per acre by tree classification before harvest, marked for harvest and not marked for harvest for single tree selection cuts, shelterwood cuts and seed tree cuts in the Piedmont

Characteristic	Before Harvest	Marked for Harvest	Not Marked for Harvest
		Single Tree Selection	
Basal Area/Acre (Ft^2)	83	30	53
Tree Class (%)			
Grade 1	88	87	89
Grade 2	3	0	5
Grade 3	6	8	5
Pulp	3	5	1
Dead	0	0	0
		Shelterwood Cut	
Basal Area/Acre (Ft^2)	103	55	47
Tree Class (%)			
Grade 1	40	28	55
Grade 2	35	42	25
Grade 3	16	21	16
Pulp	7	9	2
Dead	2	0	2
		Seed Tree Cut	
Basal Area/Acre (Ft^2)	97	86	11
Tree Class (%)			
Grade 1	48	50	32
Grade 2	37	37	38
Grade 3	10	10	0
Pulp	2	3	2
Dead	3	0	28

Table 6–Proportion of initial stocking[1] harvested[2], cut & not harvested, down during harvest, residual standing healthy, and standing with logging damage by type of management practice for natural pine stands in Piedmont

Stocking Before Harvest	Trees Cut & Harvested	Trees Cut Not Harvested	Trees Down In Harvest	Residual Standing Healthy	Standing Logging Damage
BA/A Ft^2)	----------------	----------------	%	----------------	----------------
			Partial Cut (N=7)		
105	26	1	1	65	7
			Group Selection (N=2)		
98	90	5	2	3	0
			Seed Tree (N=4)		
109	73	0	3	27	5

[1]Trees ≥5 in. DBH
[2]Tree length logging

Forest Operations for Ecosystem Management

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Abstract
The evolution of modem forest resource management is focusing on ecologically-sensitive forest operations. This shift in management strategies is producing a new set of functional requirements for forest operations. Systems to implement ecosystem management prescriptions may need to be economically viable over a wider range of piece sizes, for example, Increasing demands for more efficient fiber utilization and recovery from forest operations also put pressure on merchandising the resource for maximum value recovery. Conventional forest operations are often not well-suited to meet these constraints. This paper reviews the development of functional requirements for forest operations in ecosystem management and summarizes regional investigations in the northeast, south, and Pacific Northwest.

Keywords: Costs, environmental impacts, forest operations, prescriptions

New Challenges for Forest Operations
Management is an active term. It implies applying knowledge and resources in an intentional method to achieve desired objectives. Resource managers are doers. What resource managers do, however, is being redefined by the evolution of the concept of ecosystem management. The ecosystem management approach specifies new objectives in resource management and places new constraints and values on the management process, Resource management is no longer about achieving single-commodity output targets, but rather about broader issues of restoring and maintaining healthy, productive ecosystems. Management performance is no longer measurable in cost/unit of production, but also considers the value of biodiversity, long-term site productivity, water quality, and esthetics.

True scientific management proceeds from principle to application (More 1997). As the underlying scientific principles of ecosystem management evolve, the questions shift from “what” to do to “how” to do it, Managers must have practical, cost-effective forest operations tools to manipulate the forest and achieve desired ecological conditions. However, the scientific principles of ecosystem management define the context, constraints, and value system within which management tools will operate and be judged. Developing management tools for ecosystem management is the new challenge for forest operations.

While there is still discussion about the definition of ecosystem management, some key principles and constraints which affect forest operations have been identified. One of the most basic principles is that, fundamentally, ecosystem management is about humans (Salwasser 1994). Human needs define resource consumption. With an expanding global population and a shrinking forest landbase, production of consumables such as paper, lumber, and fuel are placing an increasing demand on the forest resource. Human needs for non-commodity production of recreational, esthetic, and spiritual values are also part of the ecosystem management construct. Future human wants and needs are also considered by emphasizing sustainability— maintaining healthy and productive forest ecosystems for the use and enjoyment of future generations. As an integral component of the global ecosystem, humans demand both forest production and protection. While these two seemingly conflicting objectives are often at the core of debate, forests provide the opportunity to satisfy both if the underlying ecological processes of renewability and sustainability are understood.

A second key principle is that because of its broader, science-based approach, ecosystem management is inherently more complex than conventional single-output approaches. Considering the myriad ecological interactions requires an extensive knowledge base and detailed, site-specific prescriptions. Irland (1994) observed that the complexity and detail of ecosystem management will require an intensive application of resources to implement more sophisticated prescriptions. The complex prescriptions will be based on a mixture of quantifiable information, subjective assessments of intangible parameters, and informed judgments about incompletely understood ecological processes. Standardized "cookbook" prescriptions will be the exception and unique, flexible, adaptive strategies will be required.

As the principles of ecosystem management become clearer, new functional requirements are established for forest operations. For example, ecological requirements for natural regeneration in a particular forest type may specify certain light levels, soil conditions, and seed source spacing. These ecological requirements translate into functional requirements for the forest operation. The stand must be opened up to a certain density; stems selectively removed based on size, species, and spacing; the soil litter layer should be disturbed for seed catch, but not compacted. These functional requirements in turn define the management tool (forest operation) which can be employed to implement the management prescription.

Some examples of the implications of ecosystem management which affect functional requirements for forest operations include:

Older stands will be increasingly represented in the forest matrix. Older stands will contain a wider range of piece sizes which directly translate into equipment requirements for maximum cutting diameter and lift capacity. Older stands also contain a wider range of potential products. This should lead to a greater emphasis on sorting and merchandising capabilities.

Stands will be manipulated regardless of product value. Prescriptions for forest health, stocking reduction, certain wildlife prescriptions, can generate a significant volume of low-grade timber. The cost-effectiveness of such operations will depend on forest operations which can merchandise and transport the material to the highest value end use. Small-diameter timber is a special challenge to forest operations since many production costs are inversely related to piece size.

Protection of ecological values will be emphasized. Sustainability, uneven-aged management and longer rotations will put a premium on forest operations which minimize residual site impacts. Soil compaction and residual tree damage are long-term impacts which may reduce growth and promote mortality. In some cases, disturbance and damage to non-woody vegetation may be critical. These constraints require light-on-the-land technologies for forest access and extraction.

Prescriptions will attempt to fit within the range of natural disturbance. The scale of natural disturbances varies from single-tree mortality to watershed-scale disruption. Most disturbances, however, are at the smaller end of the scale. Mimicking natural disturbance will require operations that can move in for small, scattered areas. Therefore, move-in requirements for transport and access development will need to be minimal.

Large units of mature forest will be unroaded or minimally roaded. Timber extraction costs are primarily a function of transport distance and infrastructure capital costs. Reducing road networks will extend extraction distances beyond current practices. Generally this will require systems with larger payloads.

These few examples show how management requirements will affect the development and selection of forest operations. The challenge is to integrate ecological principle with engineering practice.

Table 1—Cut and residual stand attributes for three silvicultural prescriptions

Stand attribute	Conventional shelterwood Cut	Conventional shelterwood Residual	Irregular shelterwood Cut	Irregular shelterwood Residual	Thinning Cut	Thinning Residual
Trees/ha	124.3	63.3	143.3	46.2	67.2	113.7
Basal area (m^3/ha)	18.5	8.4	21.3	4.2	10.8	16.5
Mean d.b.h. (cm)	43.4	41.1	43.4	34.0	45.2	42.9
Total volume (m^3)	144.1	70.0	160.2	28.0	91.7	133.7

Recent Forest Operations Studies

In order to better understand the functional issues of applying ecosystem management prescriptions, a series of studies has been conducted in three forest regions of the United States. These studies are examining forest operations from both a technical perspective and an ecological perspective. What are the costs and performance capabilities of alternative systems used to implement ecosystem management prescriptions? Equally as important, what is the ecological performance of these systems, both in terms of attainment of ecological objectives and avoidance of adverse ecological impact? These studies have been coordinated and supported through the Wood Utilization in Ecosystem Management project at the USDA Forest Service Forest Products Laboratory.

Cable Logging in the Appalachians

Cable yarding has been used in the Appalachian hardwood region for timber extraction on steep slopes. Typically, cable systems are used in relatively large clearcut units. There is growing concern, however, about the visual and ecological effects of clearcutting. Thus, resource managers are searching for information about the effect of using conventional cable logging equipment in alternative prescriptions.

A case study was conducted on the Nantahala National Forest near Franklin, North Carolina to monitor production rates and costs, and to measure residual stand damage and soil disturbance, of cable logging in partial cut prescriptions. Three cutting units were harvested with the following silvicultural prescriptions: conventional shelterwood cut, irregular shelterwood cut to initiate a two-aged structure, and crown thinning (Table 1). All of the units were located in a yellow-poplar, white oak, and red oak forest type on good to excellent sites. The units averaged 2.8 ha on slopes of 30 to 50 percent.

The silvicultural prescriptions were marked and all of the designated cut trees were felled before yarding commenced. Four to five skyline corridors were located after felling, Each unit was harvested using a two-drum yarder with an 11 -meter tower. The system was rigged as a live skyline with a gravity carriage that locked to a stop on the skyline. Maximum uphill yarding distance ranged from 165 to 300 m. Average lateral yarding distances ranged from 8 to 14 meters with maximum lateral distances from 40 to 45 m.

Working from the detailed elemental production data, a cycle-time equation was developed and used with the THIN model (LeDoux and Butler 1981) to simulate cable yarding operations and estimate standardized production and costs. Computer simulation was used in a sensitivity analysis of harvesting costs and revenues for 13 variations of silvicultural treatments, including group selection and diameter limit cuts in addition to the three treatments actually studied in the field (Baumgras and LeDoux 1995). The simulations tested the effects of varying harvest intensity and cut tree size.

Results of the economic analysis demonstrate the sensitivity of cost and revenue to silvicultural treatments: logging costs ranged from \$5.64 to \$14.90/m^3, gross revenues from \$20,84 to \$46,26/m^3, and net revenues from \$143 to \$6938/ha. Due to the composition of the initial stands, the group-selection diameter-limit, and heavy shelterwood cuts all yielded large cash flows. However, treatments which required significant reductions in harvested volume per hectare and/or volume per cut tree resulted in large reductions in estimated net revenue--as much as \$4967/ha for the conventional shelterwood cuts and \$3727/ha for thinnings. There also were significant variations in net revenue resulting from location and dimensions oft h e group selection units. These estimates reflect the relatively low cost of a shop-built yarder, which is commonly used in southern Appalachia.

While cost is one significant consideration, the ecological performance of cable logging in partial cuts is also important. Soil disturbance was sampled immediately after yarding using randomly located transects. In addition, 0.0809-ha fixed-radius plots were installed to sample residual stand damage. Tree damage was classified by type and dimension. There was no significant difference among the three silvicultural treatments in terms of areal soil disturbance. More than 70 percent of the total stand area was undisturbed and only 10 percent of the area was deeply disturbed or compacted. Most of the deeply disturbed area was associated with portions of the corridors where skyline deflection was limited. The residual stand damage surveys indicate that logging damage was significantly greater on the two shelterwood units than on the thinning unit. Sixteen percent of the residual trees were destroyed on the conventional and irregular shelterwood units compared to only 5 percent on the thinning unit. Trees destroyed were uprooted or broken off, generally during felling operations. Bark wounds occurred on 13 percent of the shelterwood trees while only 1 percent of the residual stand in the thinning unit received this type of damage.

Cable logging can serve as a valuable management tool in a range of management prescriptions for upland hardwoods. This study quantified the impact of the specifications placed on forest operations by silvicultural prescriptions. Changing from a shelterwood cut removing 70 percent of basal area, for example, to one removing 50 percent of basal area reduced net revenues by about 40 percent. Selection criteria for residual trees which affect average cut tree volume also impact the costs of the operation. Stand damage measures highlighted the importance of proper planning and training to implement alternative harvest schemes. Soil disturbance was significantly affected by corridor placement and rigging which indicates that improved planning and control of harvesting operations can moderate environmental impacts. Residual stand damage was affected by corridor location and felling skill.

Alternative Operations in the Western U.S.

A significant percentage of the forested area in the western U.S. consists of stands that have been altered over time by human activities, especially fire suppression, and are now being damaged by drought, insect attack, and wildfire. In general, the ecological prescription to restore stand health focuses on reducing the number of trees per acre. Direct reduction of fuel loading can minimize the risk of a catastrophic wildfire and enable the re-introduction of natural fire cycles.

With a wide range of stand, terrain, and marketing options across the West, a range of alternative forest operations is needed which can perform selective removals in low-grade material. A series of operational trials was conducted to examine the costs and performance of forest operations for forest health prescriptions.

In California, a forest health prescription was developed for a mixed conifer stand that had been partially logged by railroad in the 1940's and had naturally regenerated. The stand had a wide distribution of diameter classes and a range of species. but was overstocked. Many of the larger trees had been killed during the drought of the previous years. A thinning prescription was developed with two primary objectives: enhance habitat for spotted owls, and reduce fuel loading. All live trees over 46 cm DBH and all snags over 41 cm DBH were retained. The understory was thinned, and pockets of small trees were left as wildlife screens. Three different forest operation systems were compared in this treatment (Hartsough et al. 1994).

A second operational trial was conducted on the Mescalero Reservation in New Mexico (Watson et al. 1995). Several stands were treated to reduce basal area through selection of dying and at-risk trees. A feller/buncher-skidder-chipper system was used to fell and extract material for chipping as pulpwood.

The third operational trail was conducted in northeast Washington, on the Colville National Forest (Barbour et al. 1995) These stands were characteristic of the 50-60-year-old fire-generated stands common in the intermountain region, Stocking averaged over 2470 stems per acre, and more than half the trees were smaller than the minimum utilization specification at local mills. These stands were thinned to increase growth, reduce mortality, decrease fuel loading, create winter browse sites, and to move the stands toward a later-older successional stage. A harvester-forwarder system was used to perform the operation.

Conventional time and motion studies were conducted in each trial to determine production and costs. Subjective observation of soil disturbance and measures of residual stand damage were also recorded. Table 2 compares the five different forest operations systems on an array of performance characteristics.

Some general trends are apparent from these studies. Harvester-forwarder systems are more expensive per unit volume handled. They become economically

Table 2—Characteristics of alternative forest operations used in forest health prescriptions

Characteristic	F/B[a]-skidder-flail-chipper	F/B-skidder-processor-load-chip	F/B-harvester-skidder-load-chip	Harvester-forwarder-load-chip	Harvester-forwarder
	Forest operation system				
Capital Cost ($)	1.2-1.5M	1.8M	2.0M	1.3M	600-900K
Hourly Cost ($/SH)	530-650	540	590	380	120-180
Stump to Truck ($/green ton)	10-18	15	18	26	3-7 (harvest only)
Product mix	Clean chips, sawlogs	Fuel chips, sawlogs	Fuel chips, sawlogs	Fuel chips, sawlogs	Sawlogs
Soil disturbance	medium to high	medium to high	medium to high	low	low
Slope limits	50%	50%	50%	30%	30%

[a]F/B is feller-buncher.

feasible by recovering higher value per unit volume. Single-entry chipping systems require a high volume of chippable material to justify move-in costs and to keep the expensive chipping equipment fully utilized. Cold decking material for subsequent chipping (a two-entry system) can operate with a wider range of product mixes since the chipper can be fully utilized when it is on site. Whole-tree systems realize higher recovery rates and may be appropriate where markets exist for fuel chips and the silvicultural prescription permits high biomass removal.

Harvesting costs for all systems decrease as tree size increases. Since diameters are generally small in the overstocked stands typical of forest health cuttings, smaller, cheaper machinery can be utilized. However, it is important to be able to handle the occasional large diameter trees. Harvesters and forwarders tend to be more sensitive to tree size effects than feller-bunchers and skidders.

Forwarding products from the woods, in general, results in lower residual stand impacts. Soil disturbance is reduced and damage to residual stems is minimized when logs are carried rather than dragged. Systems which incorporate harvesters may further reduce soil disturbance by providing a mat of limbs and tops on the trails. Leaving residues in the woods avoids disposal problems at landings, enhances nutrient cycling, and provides better visual quality. However, in stands where existing fuel loading is high it may be inappropriate to leave residues in the woods.

Secondary transport requirements must also be considered in selecting a forest operation. Chipping systems are restricted to areas with higher standard roads that can carry highway chip vans. The high woodflow associated with most chipping systems is often achieved by keeping extraction distance down. This translates into a higher road density. Forwarding systems, on the other hand, are less sensitive to extraction distance costs and may be preferred when road density is relatively low.

The selection of a harvest system for a given management prescription depends on many factors and a large number of alternatives are available. It is important to remember site-specific factors such as transport distance or local market conditions in addition to operating system characteristics in making a system selection. Unique combinations of existing equipment and modifications to methods can provide management with flexibility in addressing prescription requirements.

Alternative Operations in the South

The traditional objective of resource management has been commodity production. This is especially true in the southern United States where private forest

Table 3—Soil disturbance caused by alternative forest operations

System	Disturbance Classification (% total area)			
	Undisturbed	Slightly disturbed	Mineral soil exposed	Deeply disturbed
Manual-forwarder	44	53	3	0
Manual-horse-forwarder	50	45	5	0
Feller/buncher-manual-forwarder	56	41	4	1
Drive-to-tree harvester-forwarder	29	58	11	1
Swing-to-tree harvester-forwarder	40	56	3	0

landholdings represent nearly 75 percent of the forest landbase. Conventional forest operations in the South have been developed to minimize production cost. However, even in private ownerships, there is growing concern about the sustainability, public perception, ecological effects of current management practice. Drive-to-tree feller-bunchers and grapple skidders can be used effectively with acceptable environmental impacts in clearcut operations. In selective cutting systems, however, the effectiveness of a drive-to-tree tree-length system is reduced. More extensive use of uneven-aged management, natural regeneration, and selection cutting will require alternatives to the conventional operations.

Cut-to-length (CTL) technology was examined as an alternative to skidder systems in a study on the Tuskegee National Forest in Alabama. Five variations of CTL operations were tested in four types of selective cutting prescriptions. The forest operations included: manual felling with forwarder extraction; manual felling with horse prebunching and forwarder extraction; feller-buncher with manual processing and forwarder extraction; a 3-wheeled harvester with forwarder; and a 4-wheeled swing-to-tree harvester with forwarder.

The prescriptions varied in removal intensity, removal openings size, and tree size. Conventional time and motion studies were conducted to determine production and costs. Soil disturbance was assessed on transects through the stands. Damage to residual trees was documented on sample plots.

Seixas et al. (1995) summarized the comparison of soil disturbance. There was no significant difference in soil disturbance level due to the different types of silvicultural prescriptions. However, there was a significant difference in soil disturbance due to the type of system employed (Table 3). The feller-buncher/forwarder system had the least amount of disturbance and the 3-wheeled harvester system produced the most disturbance.

In general, the soil disturbance was a result of either machine movement (soil-tire interaction) or piece movement (positioning felled trees or parts of trees). Variations in soil disturbance could be explained by the different methods each system used in felling, processing, and transporting. While system differences were apparent, overall the CTL systems produced significant disturbance in less than 10 percent of the stand.

Productivity data from the study is being incorporated into a harvesting simulation study (Wang and Greene 1996). The harvesting simulation is based on stand maps generated by computer. Images of harvesting machines are maneuvered through the stand by the simulation operator. Combining distance and tree information with the production equations from field studies provides an estimate of production and cost. The primary advantage of the harvesting simulation approach is that it permits modeling different systems operating in identical stands. It also permits the same stand to be treated with a range of prescriptions. Currently, the simulation has been used to investigate the relative impact of removal intensity on feller-buncher productivity.

Concluding Remarks

Management is fundamentally about translating prescription into practice. In this translation, the manager seeks tools that achieve the required ecological manipulations, minimize undesirable side effects, and are economically acceptable. Ecosystem management is altering this entire decision process. Ecological goals are becoming more complex, there is new sensitivity to the ecological impacts of forest operations, and the costs must be minimized while placing values on many non-traditional outputs.

Successfully implementing ecosystem management will require the development of new management tools (forest operations) and the adaptation of conventional practices. Just as the debate over the scientific principles of ecosystem management has been developed and refined over a period of years, forest operations will have to be developed and refined.

Forest operations research is beginning to develop the knowledge needed to make appropriate selection of forest operations. What systems can be utilized to achieve certain silvicultural goals? How do mechanical factors such as equipment specifications affect ecological parameters? What requirements of ecosystem management are not fully met by existing methods of working in the forest? These questions are being prompted by the evolution of the ecosystem approach to forest management. Successful implementation of ecosystem management requires an ongoing research effort to provide reasonable answers.

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Linking Log Quality With Product Performance

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Abstract

In the United States, log grading procedures use visual assessment of defects, in relation to the log scaling diameter, to estimate the yield of lumber that maybe expected from the log. This procedure was satisfactory when structural grades were based only on defect size and location. In recent years, however, structural products have increasingly been graded using a combination of visual estimation of defects, coupled with nondestructive evaluation of other parameters, to obtain a more precise estimate of product properties. Today, the most commonly used nondestructive evaluation parameter is modulus of elasticity (MOE). This paper summarizes the results of three studies that used longitudinal stress wave techniques to determine the MOE of logs prior to processing into lumber. The MOE of lumber was then determined by transverse vibration. A good relationship was generally observed between the MOE of logs and the average MOE of the lumber cut from an individual log. These results indicate that improved sorting of logs for structural products might be achieved using a combination of visual assessment and determination of the MOE of the logs using longitudinal stress wave techniques. Future research will quantify the improvement in log sorting efficiency relative to other nondestructive testing options.

Keywords: Log grade, longitudinal stress wave, modulus of elasticity, lumber, spruce, balsam fir, Douglas-fir, western hemlock, Southern Pine.

Introduction

Considerable savings in material and processing might be achieved if a better relationship could be established between log quality and the quality of products cut from the log. The capability to improve log sorting becomes especially important as the wood industry adapts to a resource base that includes more plantation-grown softwoods, nontraditional species, and small-diameter trees (Skog et al. 1995).

Log grades are used to relate log size and quality to the yield of products that can be cut from the log. Since the 1940s, the Forest Service and industry researchers have been developing log grades to estimate lumber yield (Gregory and Person 1946; Southern and Southeastern Forest Experiment Station 1953; Campbell 1964; Ostrander and Brisbin 1971). These log grading systems are based on visual estimation of the number, size, and type of knots and other defects in relation to log scaling diameter. The visual log grading systems generally work satisfactorily for estimating the yield of visually graded structural lumber that may be expected from a log (Gregory and Person 1946, Lane et al. 1973; Woodfin and Snellgrove 1976; McDonald et al. 1993).

Structural lumber, visually graded by standardized procedures, has been available in the United States since at least the early 1920s (Newlin and Johnson 1923). In the early 1960s, mechanically graded structural lumber also became commercially available. This lumber is graded by a combination of visual assessment of knots and other lumber characteristics and nondestructive evaluation of the relationship between lumber modulus of elasticity (MOE) and modulus of rupture (MOR). Nondestructive evaluation of MOE, along with visual assessment of surface characteristics and defects, is also used for sorting lumber for the production of glued-laminated beams (AITC 1993), structural lumber from hardwood species (Green et al. 1994), and laminated veneer lumber (Sharp 1985). Green et al. (1996) recently proposed that nondestructive evaluation of MOE be used to grade heavy timbers. Despite the increasing importance of grading structural wood products by a combination of visual and mechanical means, the relationship between log and lumber stiffness has generally not been investigated for U.S. species.

In a limited study with six Douglas-fir logs, Galligan et al. (1967) were able to rank lumber obtained from the logs with reasonable accuracy, using only the longitudinal vibration characteristics of the logs. Recently, studies in other countries have begun to evaluate the relationship between log and lumber stiffness. For example, Arima et al. (1990) found a 0.83 coefficient of determination between log MOE and the average MOE of lumber from individual Sugi *(Crypotomeria japonica)* logs using longitudinal stress wave techniques. Aratake et al. (1992) reported coefficient of determination values of 0.82 between log MOE and the average MOE of the lumber from a log for green lumber. The coefficient of determination value was 0.71 between log MOE and average lumber MOE for dry lumber without the pith present and 0.58 with the pith present. Sandoz and Lorin (1994) reported coefficient of determination values of 0.44 between log MOE and lumber MOR cut from 12 spruce logs.

In 1992, we proposed to evaluate the relationship between log and product properties for a range of species and products. The goal of our research is to access improved procedures for sorting logs, and eventually trees, for production of products graded by mechanical means. This paper summarizes some of the results from three of these studies.

Materials and Methods

The first study evaluated the relationship between log and lumber MOE using randomly selected eastern spruce and balsam fir logs (Ross et al. 1997). The second study evaluated the log MOE–lumber MOE relationship for Southern Pine sampled from both natural and plantation forests (Green et al. [in progress A]). The third study utilized Douglas-fir and western hemlock logs 660 mm (26 in.) and less in diameter (Green et al. [in progress B]). The procedures followed in all three studies were similar (Fig. 1).

In each study, logs were selected at a mill and measurements were made of log length, scaling diameters, and visual grade. For each log, longitudinal speed-of-sound stress wave transmission was determined using accelerometers fixed to the ends of the logs. A stress wave was introduced into the specimen through a hammer impact on one end and the signal obtained from the opposite end. The stress wave signal was recorded on an oscilloscope to obtain the transit time from the distance between signal peaks (Ross et al. 1994). Although a preliminary study indicated that equivalent measurements could be obtained with stacked logs, all stress wave measurements were taken with the logs removed from the stack (Fig. 2) (Ross et al. 1997). The logs were then sawn into lumber, with

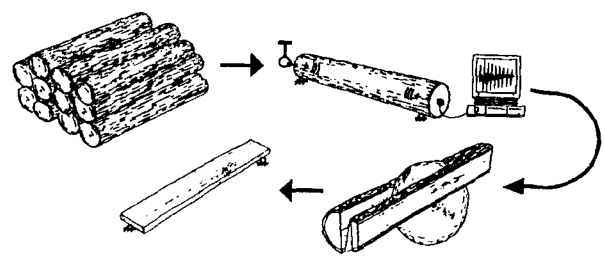

Figure 1—Flow chart of log–lumber correlation studies.

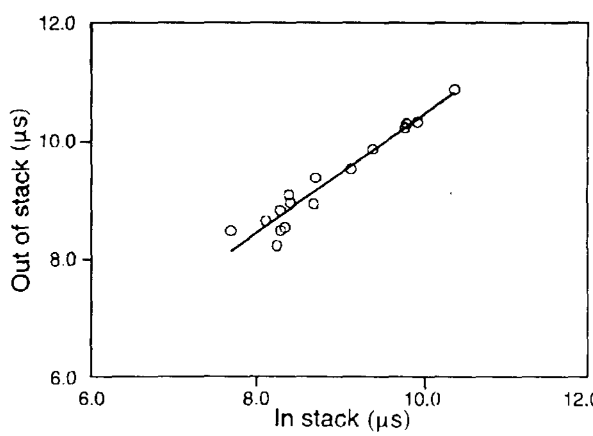

Figure 2—Results obtained from stress wave transmission measurements made in logs in and out of the stack for eastern spruce and balsam fir (Ross et al. 1997).

special care taken to ensure that individual lumber specimens could be traced to the log from which they were sawn. Flatwise MOE was determined for each lumber specimen using transverse vibration techniques (Ross et al. 1991).

Results and Discussion

Linear regression was used to evaluate the relationship between the lumber MOE values and the MOE of the logs (Table 1). The log–lumber MOE relationship was evaluated two ways. First, the correlation was determined between log MOE measured by stress wave techniques and the MOE of each individual board in the logs measured by transverse vibration (called "individual boards" in Table 1). Second, the correlation was established between the log MOE and the average MOE of all boards obtained from a given log (called "average of boards" in Table 1). In general, a good correlation was found between log MOE and the average MOE of the lumber cut from a log for eastern spruce, Southern Pine, and Douglas-fir (Figs. 3–5). For these three species, coefficients of determination ranged from 0.50 to 0.82. Significant, but lower, correlations were found with balsam fir and western hemlock (0.33 and 0.13, respectively). The low coefficient of determination for western hemlock was probably a result of having a limited range in log MOE values in the sample selected. The range in MOE values was about half that expected from tests of dimension lumber. The western hemlock was sampled primarily from trees growing at lower elevations (Green et al. [in progress A]). When combined with Douglas-fir, the log MOE–average lumber MOE correlations were excellent. The reason for the low correlation between log and lumber MOE for balsam fir could be similar to that for western hemlock (Ross et al. 1997). However, the low correlation could also be a result of the frequent occurrence of bacterially infected wood in balsam fir (Ward and Pong 1980). Additional research on western hemlock and balsam fir is needed to clarify the relationship.

The log MOE–average lumber MOE correlation is one indication of the potential of using log MOE values as an additional factor to incorporate into a log grading rule to improve the prediction of the yield of mechanically graded lumber. Another indicator is the log MOE–individual board MOE correlation. If the variability in MOE of individual boards within a log is too large, this might negate the benefit of sorting the logs by MOE. As would be expected, the correlation of log MOE and individual board MOE is less than that between log MOE and the average MOE of the boards (Table 1). As shown in Figure 6, there appears to be

Table 1—Summary of log–lumber correlations between log MOE and the MOE of lumber cut from individual logs

Species	Number of logs	Coefficient of determination (R^2): Individual boards	Coefficient of determination (R^2): Average of boards from a log
Eastern spruce	98	0.50	0.82
Balsam fir	95	0.17	0.33
Combined	193	0.30	0.55
Southern Pine	98	0.31	0.63
Douglas-fir	100	0.30	0.50
Western hemlock	100	0.13	0.34
Combined	200	0.54	0.74

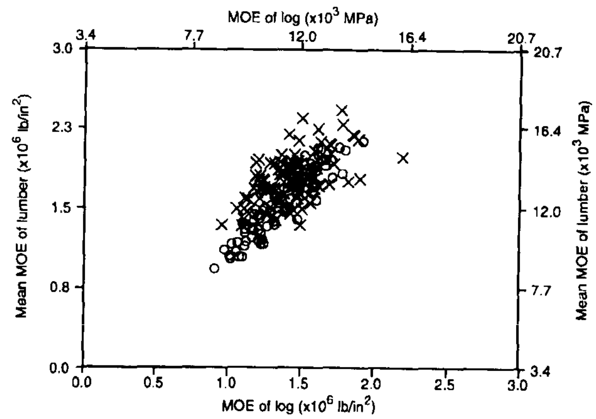

Figure 3—Average MOE of lumber from a log as a function of MOE of logs for eastern spruce and balsam fir (0 = eastern spruce; X = balsam fir) (Ross et al. 1997).

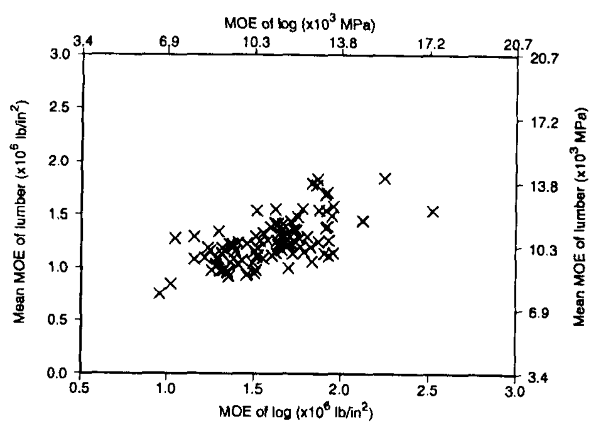

Figure 4—Average MOE of lumber from a log as a function of MOE of logs for Southern Pine (Green et al. [in progress A]).

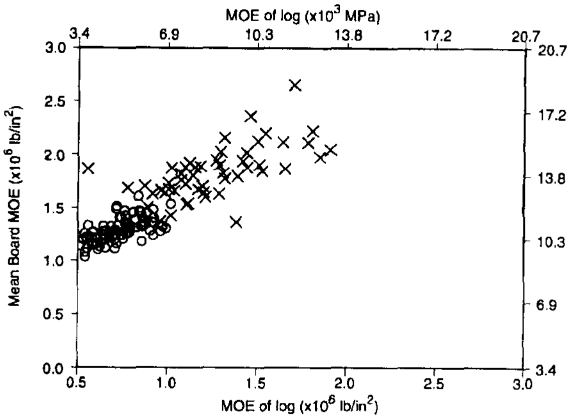

Figure 5—Average MOE of lumber from a log as a function of MOE of logs for Douglas-fir and western hemlock (X = Douglas-fir; 0 = western hemlock) (Green et al. [in progress B]).

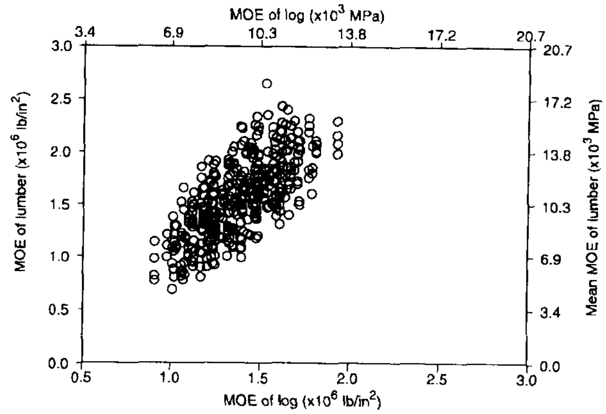

Figure 6—MOE of individual pieces of lumber from a log as a function of MOE of log for eastern spruce (Ross et al. 1997).

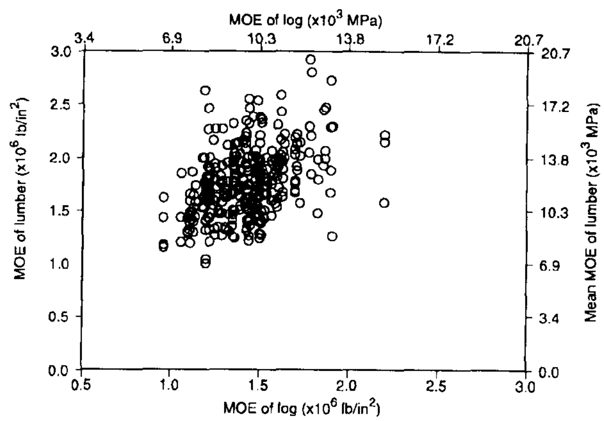

Figure 7—MOE of individual pieces of lumber from a log as a function of MOE of log for balsam fir (Ross et al. 1997).

good potential for sorting eastern spruce logs using this approach. With other species, such as the balsam fir shown in Figure 7, the potential is questionable. As discussed previously, additional work is needed before deciding to abandon this approach with balsam fir and western hemlock.

A detailed discussion of the log MOE-lumber MOE correlations for the species discussed in this paper will be given in the full reports (Ross et al. 1997, Green et al. [in progress A and B]). In addition to the three studies previously noted, several studies are nearing completion that evaluate the correlation between log and lumber properties for other species. Also nearing completion are studies that relate the MOE of logs to the MOE of veneer cut from those logs. Future studies will develop alternatives, using the stress wave based approach, to incorporate log properties into log grading rules and compare these results with existing rules based solely on visual assessment or density.

Concluding Remarks

Based on the results to date, we conclude the following:

- There is a good correlation between log MOE and the average MOE of the lumber cut from an individual log for eastern spruce, Southern Pine, and Douglas-fir. Correlations are not as good for balsam fir and western hemlock. However, a limited range of MOE values in our samples may have reduced the correlations for the latter two species.

- With eastern spruce, Southern Pine, and Douglas-fir, the correlation between log MOE and the MOE of individual boards cut from the log appears to be high enough so that within log variability would not negate the benefits of sorting logs by log stiffness. Additional work is needed to quantify this assumption.

- Results indicate that improvements in log sorting capability may be possible for predicting the yield of structural products that use MOE as part of the grading criteria.

- Additional research is needed to establish the log–product MOE relationship for other species and products and to evaluate the incorporation of log MOE values in log grading rules.

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Potential of Small Dimensioned, Low Quality Round Wood of Scots Pine for the Production of Valuable Timber

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Abstract

The aim of this study is to select end uses for Scots pine timber produced out of low dimensioned round wood with high value and to define its specific quality requests. In general two product groups are possible: timber for furniture, floors etc. and construction timber. 120 test trees from two different growth regions from the southwest of Germany were included. The sawn products are characterized by high contents of juvenil wood near the pith. The first optically orientated product group shows an unexpected high percentage of 54% of grading class A according to the strict grading rule “Nordic Timber”. The bending and tension strength values are similar with such from older Scots pines and Douglas firs. Also the grading result using the DIN 4074 gives very good output of highest grading classes.

Keywords: Scots pine, sawn timber, quality, visual grading, machine grading, Nordic Timber, DIN 4074, mechanical properties.

Introduction and Aim

The European market for small dimensioned round wood of Scots pine, shows actually nearly no acceptance for the production of high quality timber. Only traditional market potentials with low round wood prices in the particle board and pulp industry are used (Becker, 1989; Becker und Niepagen, 1990).
The economic meaning of this fact is given by 1.3 Mio hectares commercial forests in Germany covered with Scots pine. Additionally Scots pine is one of the most important softwoods in Europe in general

The aim of a complex research project as a common challenge of the forest enterprises in the southwest of Germany, the involved local timber industry and the wood research was to select future-orientated timber products with concrete end uses which could be produced out of the resource small dimensioned round wood of Scots pine. Further, to define quality limits under realistic market conditions resp. consumer demands and to test the sawn timber in relation to these quality definitions on its potential for high valuable timber.

The research concept was devided into two tasks related to the product groups:
I. optically orientated sawn products
II. structural solid timber and laminated structural timber for construction purposes.

The first group of end products contents boards for floors, lamellas for laminated boards for the furniture production and endless studs without high requests on the load-carrying capacity.
The second product group includes structural timber only for construction purposes with high demands at construction security.

The timber resource for the project was sawn out of 120 Scots pine trees from five different stands. The construction timber was traditionally sawn, whereas two sizes of studs were choosen with cross-sections of 60 by 120 mm and 38 by 100 mm as well as one board cross-section of 35 by 120 mm.

The optically orientated sawn products were produced in a modem saw mill with automatical output optimization. Timber sizes in this case were boards with 29 mm thickness and different width and one stud cross-section of 58 by 105 mm.

In both cases, it was consciously accepted to include juvenile wood near the pith. After conditioning and surface finishing the timber was graded according to different grading standards adapted to defined end uses. For example the new strong standard from Scandinavia for "Nordic Timber" was used for optically orientated products and the actual version of "DIN 4074" for visual and machine grading of construction timber.

Results

Timber Quality in Consideration of Optically Orientated Sawn Products

The optical classification of sawn product surfaces is mainly determined by esthetic appearance. In this meaning the number, size and condition (green or dead) of knots are dominant criterions.

In Figure 1 is shown the relation of dead knots to healthy grown in green knots. There is a clear increasing trend with the height of the tree for the number of knots. The absolute dimension of biggest knots along the total stem surface of every tree lies in average at 23.4 mm.

The included sawn timber of this study shows only few presence of resin pockets and nearly no resinous wood, which is often a serious problem of Scots pine timber from northern European regions.

The most negative factor for the grading result was besides the knots (85%) the grade of warp which is much more obvious in the collective of studs than for thin boards. There are a lot more criterions to consider according to the "Nordic Timber" grading rules. For example the content of resin, grown in bark, coulour, surface roughness. But all these criterions are nearly without effect on the grading result in this case. A serious problem seems to be the extent of warp in sawn products from the centre part of the stem with high content of juvenil wood. The effect increases with the thickness of the sawn timber.

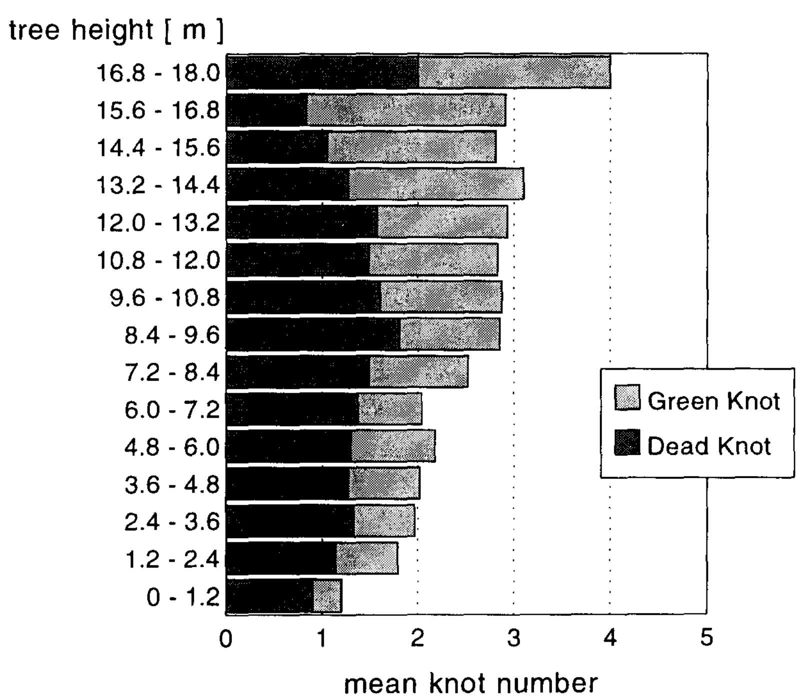


Figure 1 —Mean number of green and dead knots in different stem heights, measured on the sapwood side of sawn timber

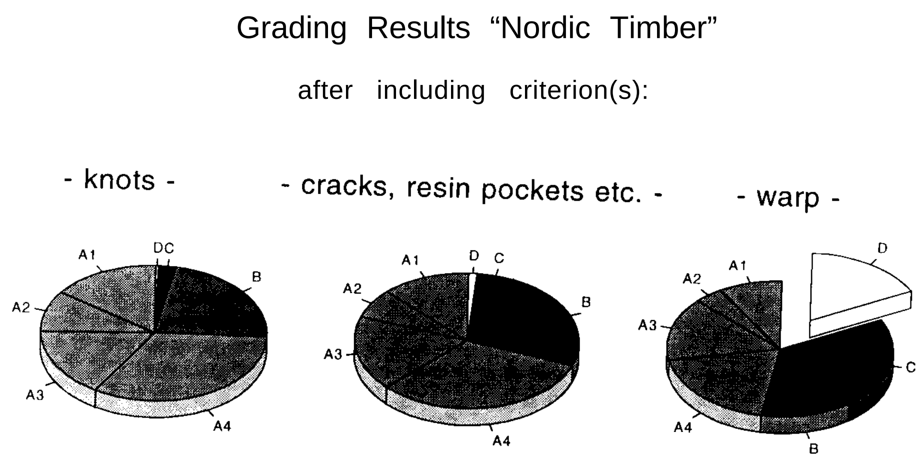


Figure 2—Influence of different grading criterions of grading standard "Nordic Timber"; besides knots the extent of warp is responsible for declassing boards and especially studs from grading class A to B resp. C and D (Sauter, 1996)

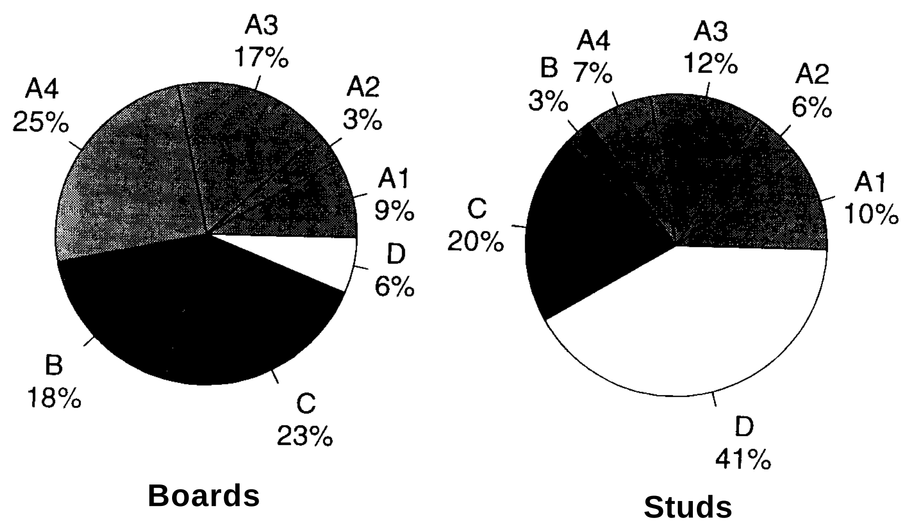


Figure 3—Comparison of grading results in total for boards and studs (Sauter, 1996)

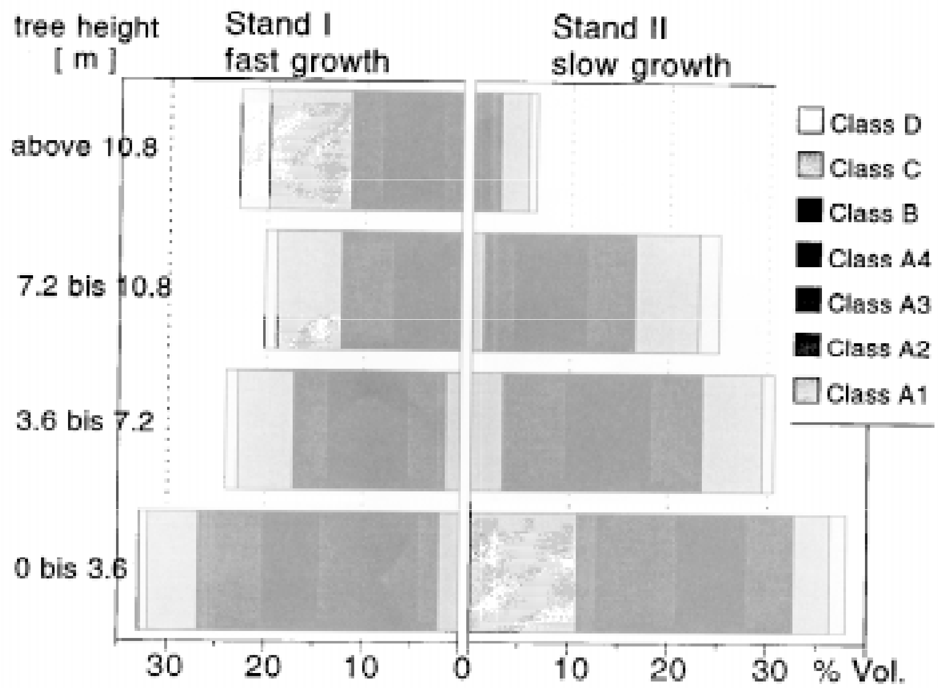


Figure 4—Grading results expressed in percent of the total output of sawn timber volume for boards with sizes 85,105,125 by 29 mm and 1200 mm length in different stem heights for the two included growth regions Rhine Valley (Hagenbach) and Pfaelzer Wald (Dahn)

The boards and studs for non construction purposes show an unexpected big percentage of high quality timber of class A, which is related to most valuable end products. The reasons for that are the small knots with a resonable percentage of dead knots and few resin pockets caused by a very slow growth in dense stands, which are typical growing conditions for Scots pine in middle Europe.

A second result of practical importance is that the percentage of high classified timber produced out of small dimensioned round wood decreases above the stem height of about 10 m dramatically, so that there should be a height limit for high valuable timber.

Timber Quality of Studs and Boards for Construction Purposes

In the case of timber for construction purposes the density level is one of the most critical factors for the resulting mechanical properties. The average density ranged between 0.54 to 0.61 g/cm^3 with a maximum density for one single stud, beam or board with 0.72 g/cm^3. These values show a high density level, despite that all timber pieces were located in the centre of the stem section and at least 4070 includes the pith.

Table 1—Mean wood density r_{12} in the near of the break for strength tested studs and boards

timber dimension		wood density r_{12} near the break [g/cm^3]					
		n	mean	s.d.	min	max	cv%
studs	60 by 120 mm	286	0.560	0.061	0.411	0.724	10.9
	38 by 100 mm	98	0.605	0.052	0.454	0.710	8.7
boards	35 by 120 mm	260	0.538	0.046	0.416	0.657	8.5

Table 2—Mean and 5%-fractile of bending strength and static MOE for studs (60 by 120 mm and 38 by 100 mm) divided by grading classes according to DIN 4074 (excluded have been 6 resp. 2% studs 60 by 120 mm and 4 resp. 4% studs 38 by 100 mm)

		bending properties of studs graded according to DIN 4074								
		visual grading class S 13			visual grading class S 10			visual grading class S 7		
var	size mm	n	mean N/mm²	5%-fract. N/mm²	n	mean N/mm²	5%-fract. N/mm²	n	mean N/mm²	5%-fract. N/mm²
σ_B	60/120	46	71.4	42.7	150	48.6	27.9	84	36.1	18.7
	38/100	20	68.7	41.2	38	49.3	29.6	35	41.8	20.4
MOE	60/120		18,202	12,942		14,201	9,659		11,726	7,425
	38/100		18,290	13,754		14,946	8,751		13,400	8,142

The density values represent despite the position of the timber from the centre part of the stem with high percentage of juvenil wood high level, this not only in comparison to other studies about the same tree species but also in comparison to Douglas fir timber. Reasons are small ring width of the test material with 1.6 to 2 mm and following low early wood percentages resp. dominating late wood in the growth ring. Nevertheless there is a large range of density values to recognize.

A similar positive result were recognized for the knots measured according to the grading rules for timber with structural sizes DIN 4074. Even the biggest knots show seldom a diameter greater than 40 mm. These results give an idea about the fully different wood stucture of Scots pine in comparison to wood from home grown Douglas fir (Fischer, 1994; Sauter, 1992).

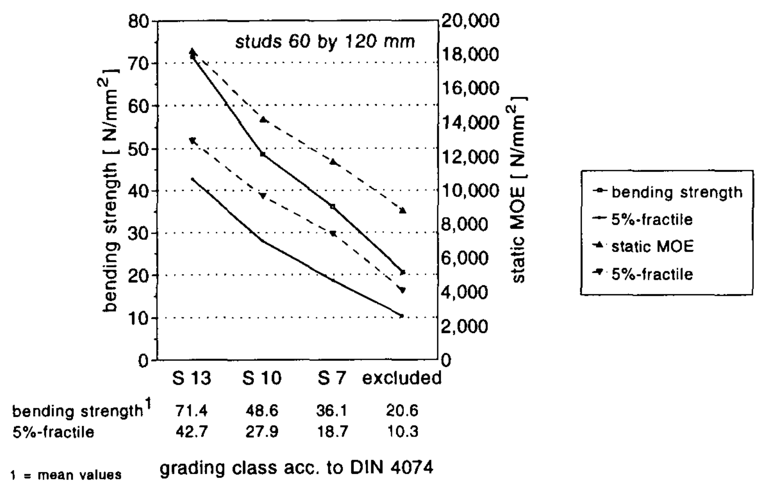


Figure 5—Change of Bending Properties with visual grading class according to DIN 4074 for studs

Table 3— Comparison with other authors: bending strength for studs divided by grading classes according to DIN 4074 or comparable grading rules

author	tree spec.	size	bending strength for studs [N/mm²]					
			S 13 / SS		S 10 / No.2		S 7 / No.3	
		mm	n	mean	n	mean	n	mean
SAUTER 1996	Scots pine	60/120	46	71.4	150	48.6	84	36.1
		38/100	20	68.7	38	49.3	35	41.8
GLOS et al. 1986	Scots pine	60/140 70/150	38	64.2	58	49.9	35	42.1
SAUTER 1992	Douglas fir	60/120	48	72.8	81	44.2	63	33.8
		80/160	55	65.0	107	42.1	39	34.0
FISCHER 1994	Douglas fir	80/160	17	59.0	240	46.6	158	39.4
BARRETT/ KELLOGG 1994	Douglas fir	38/89	153	63.1[1]	80	45.8[2]	31	40.7[3]

Grading classes [1] SS [2] No. 2 [3] No. 3 acc. NLGA Standard Grading Rules f. Canadian Lumber 1980

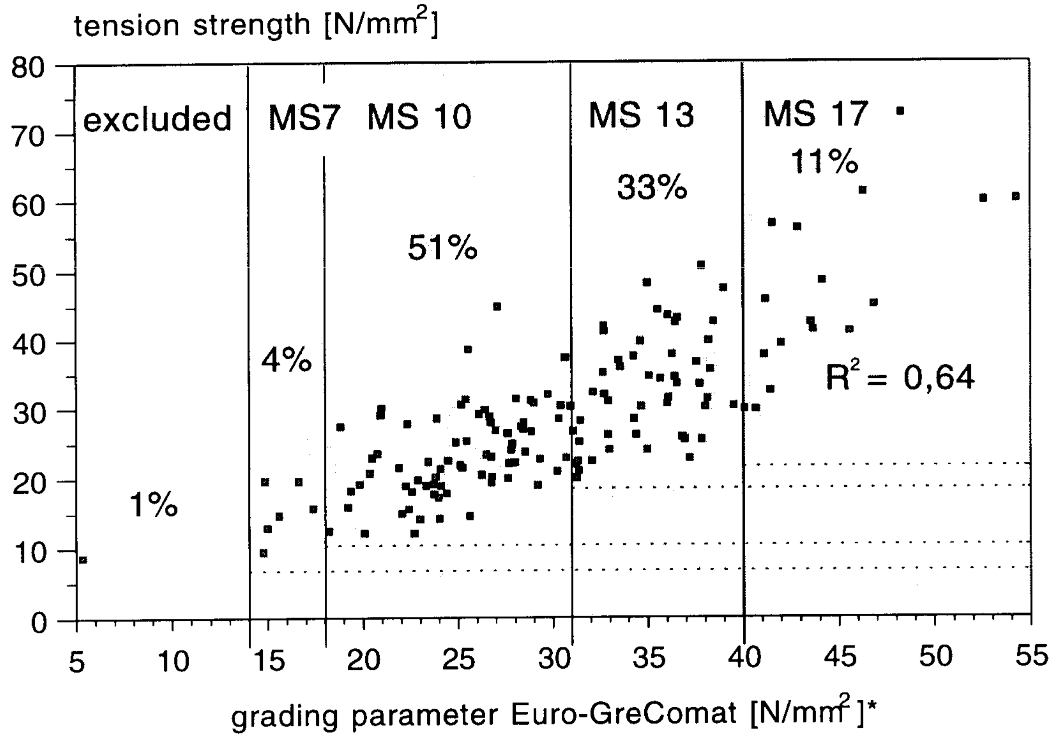
The strength tested in bending for beams and studs with small cross sections reflecting the small dimensioned round wood resource, is related to grading classes of the DIN 4074 not different to tested construction timber from German Scots pine and Douglas fir. Arround two thirds of the total timber output of the test trees have sufficient load-carrying capacity for high quality construction timber (Table 2).

The high strength values of class S13 (Table 2 and Figure 5) may interpreted as clear reference to considerable unused strength potentials of the construction timber resource. The only way of better using this potential requests machine grading including MOE as most valuable criterion (Glos and Diebold, 1994; Sauter and Glos, 1995).

Table 3 allows the comparison of bending strength values with studies from other authors and tree species. Glos et al. (1986) showed quite similar strength and stiffness values for beams in two dimensions from German Scots pine round wood. This comparison indicates that there is no mentionable difference between mechanical properties of timber sawn out from outer parts of the stem section and the material from this study sawn from the centre part of each stem.

For the production of laminated beams solid boards of high quality are used. The main loading direction of every board in a laminated beam is parallel to the fibre and the critical strength is the tension strength. For this reason the tension strength and also the MOE in tension have been tested for the Scots pine boards. The strength level of the tested boards show sufficient values regarding the request of the new European standard EN 338 for construction timber.

In a first step after sawing, drying and planing the test material was visual graded according to DIN 4074. It is known that the visual grading process includes a high portion of insecurity. This is pointed out in a relatively low coefficient of determination for the relation between grading parameters and the strength of the timber, in this case the tension strength. When the most efficient visual grading factor knotiness is used the regression results a coefficient of determination of R^2=0.37. In the opposite it is possible to do the grading of sawn timber for construction purposes with new grading machines. One of such a machine is the Euro-GreComat, produced in Germany, which includes into the multiple regression model the wood density, knotiness and MOE in bending. The grading results are very stabil and give a high practical security for the user of construction timber.



*) grading parameter calculated using multiple regression model of Euro-GreComat

Figure 6—Relation between tension strength and grading parameter of the Euro-GreComat; included are machine grading class limits with grading output as percentage of the total sample with 150 boards

Figure 6 shows the result of the machine grading process for the 150 Scots pine boards. The multiple regression model gives a satisfying fit with a coefficient of determination of R^2=0.64 which is much more better than we could reach for visual grading parameters. Nearly all boards with its individual mechanical properties are right related to the grading resp. strength classes. Even the boards with high strength potential have been clear detected.

In the case of the tested Scots pine boards the output of valuable timber with highest load-carrying capacity could be increased by machine grading using the Euro-GreComat in comparison to visual grading from 19% (visual grading class S13) to 44% (machine grading class MS13 and MS17).

In general the machine grading will be improve the security of wood constructions and support the competitive position of the building material wood in the future.

Conclusions

As conclusion it is to remark that the small dimensioned round wood from Scots pine grown in the southwest of Germany contents the potential for the production of high valuable timber. There are reasonable differences between material from the region Pfaelzer Wald with slow growing, dense stands and the Rhine Valley with better growing conditions and more or less rough material with lower quality in general.

For optically orientated end uses the surfaces of the sawn products graded according to the strict grading rule from Scandinavia "Nordic Timber" show with more than 50% A-classed timber an unexpected high percentage of best quality. For typical stands in middle Europe a height limit of about 10 m stem height is to recomend for the practical use.

The Scots pine timber sawn out of small dimensioned round wood performs to more than two thirds higher requests for construction purposes. In the case of boards as basis for the production of laminated beams it could be proved that the output of timber with high load-carrying capacity is extremly increasing by using machine grading.

For the transformation of these results into practical use a project group works on plans for concrete investments for an industrial timber production.

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Objectives and Study Design of the Colville Study: Silviculture, Ecology, Utilization, and Economics of Small-Diameter Densely Stocked Stands

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and Kenneth Skog, USDA Forest Service, Forest Products Laboratory.

Abstract

Public land managers in the United States are increasingly interested in managing forests to provide a range of ecological and social outputs in addition to timber. These outputs might include healthy riparian areas, connected blocks of late-successional forests, habitat for threatened and endangered species, and high-quality recreational opportunities. On National Forests in the Inter-mountain West, millions of acres of densely stocked small-diameter stands create large, structurally uniform areas. These areas present opportunities to improve biological diversity and ecosystem health through thinning and other silvicultural treatments. The purpose of the Colville Study was to help National Forest land managers understand when forest operations are a cost effective way to accomplish ecological objectives. The study was composed of four technical focus areas: silviculture and ecology, forest operations, timber conversion, and economic analysis. Results will help timber staffs and forest planners evaluate different kinds of treatments in a variety of stand types to understand their relative merchantability. The analyses considers silvicultural prescriptions, harvesting costs, distance to the mill, and the products manufactured. The procedures developed will help forest staff and local industry to communicate about each other's needs while providing a detailed picture of the expected timber outputs from a forest over time. Cooperators included the Colville, Idaho Panhandle, and Ochoco National Forests; Boise Cascade Corp.; Riley Creek Lumber; Vaagen Brothers Lumber; Oregon State University; the University of Idaho; the University of Washington; Washington State University; the USDA Forest Service, Forest Products Laboratory and Pacific Northwest Research Station.

Keywords: Small-diameter wood, silviculture, ecology, forest operations, wood products,

Introduction

Under the umbrella of ecosystem management, the USDA Forest Service emphasizes sustaining healthy forest ecosystems and restoring damaged ecosystems to health. Land management plans are being developed to combine both preservation and manipulation to promote resiliency through diversity of future composition, structure, and function that will also provide a variety of benefits from our public lands (Thomas, 1994). To accomplish this, ecosystem assessments are typically made at the landscape level (Haynes et al., 1996; Iverson, 1996; Quigley et al., 1996; USDA and USDI, 1994). As landscape level assessments and watershed analyses are completed, forest managers are given mandates to accomplish general themes. They receive strategic instructions about how the landscape should appear on some temporal and spatial scale and are expected to make the tactical decisions about where and when to practice active management or use a hands-off approach.

In the past, we changed the composition and structure of landscapes through activities such as fire suppression and the way we selected stands for harvest. In the first instance, by choosing to limit disturbance, we created many densely stocked stands with a high proportion of small-diameter stems. In the second, we tended to select the stands with the best economic return and often ignored those with many small stems. When combined, these activities resulted in the development of millions of acres of small-diameter, densely stocked stands throughout the Western United States.

A recurring theme in western landscape management is to alter the developmental trajectories of some of these densely stocked stands. Many of these stands have marginal economic value and may be at risk for insect attack, disease, and stand replacement fires that can perpetuate these conditions. In other places, they simply occupy a part of the landscape where it might be desirable to have stands with a different structure and composition. These concepts are illustrated in figure 1.

When stand manipulation is the tactic, forest managers must choose between many alternatives. Should fire be used to reduce stocking density or is harvesting a better choice? Should fire and harvesting be combined? Does a specific thinning operation require helicopters or can a ground based logging system meet the ecological objectives for the site? Is a specified silvicultural prescription likely to result in the desired change in a stand's developmental trajectory? Can a desired stand condition even be developed on a given site in a specific time frame?

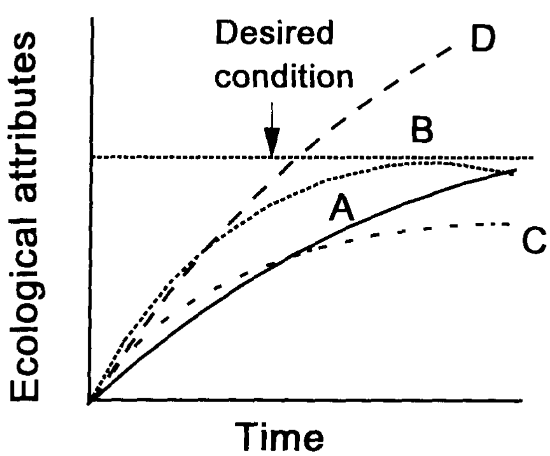

Figure 1–Alteration of stand developmental trajectory: (A) original trajectory no manipulation or (B, C, D) with stand manipulation, (B) stand reaches desired condition sooner and stays there longer, (C) and (D) stand reaches an altogether different condition.

The Colville Study was designed to help managers and planners answer these and related tactical questions. Often their questions will be fiscal in nature. Budgets are limited. Federal managers currently have few alternatives to timber sales for funding of treatments designed to accomplish ecological objectives. As a result, they want to be able to quickly and inexpensively identify places where timber sales are not a feasible method. It is better to reject timber sales early in the process than to expend the funds necessary to plan them only to discover there are no interested bidders.

The Colville Study also was intended to help National Forest level planners understand the kinds, quality, and quantities of commodities or alternative wood products that might be produced over the long term under different planning scenarios. This information will help local community and business leaders in making investment decisions and in discussing those decisions with National Forest staff.

The study centered on the Rocky II Timber Sale area of the Colville National Forest, in northeastern Washington. This sale involved a range of silvicultural treatments that, if successful, are likely to be used in many other situations (Colville NF, 1994). The types of stands included in this sale were economically marginal at best (Barbour et al., 1995, 1997) but represented conditions where stand manipulation may provide an opportunity to develop late-successional structural characteristics more rapidly than is possible through either natural processes or clearcutting and replanting (Ryland, 1996; Ryland et al., in prep.).

An Integrated Team Approach

The Colville Study was organized by a team of researchers and forest managers (the authors of this note) representing expertise in each of the study's four technical focus areas: (1) silviculture and ecology, (2) forest operations, (3) timber conversion, and (4) economics. Information generated in each technical focus area flows to the others (figure 2). Developing information and providing answers to specific questions is expected to be adaptive, and thus figure 2 includes a provision for iteration through the process.

The activities under each technical focus area were developed collaboratively within the Colville Study team and through interactions with National Forest

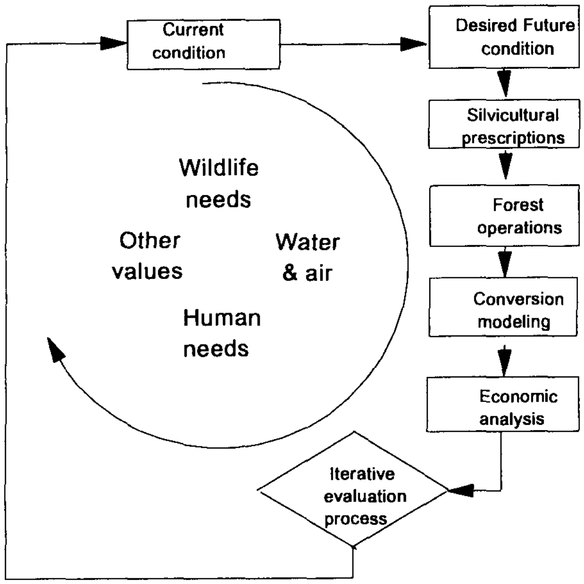

Figure 2–Organizational structure and information flow of the Colville Study.

staffs, industry representatives, members of environmental groups, and the general public. Four information meetings were held at the Colville and Ochoco National Forests during the planning stage for the projects, and over 100 people participated in discussions about the design of the study and possible formats and uses for outputs.

Silviculture and Ecology

Results of work in this technical focus area are reported elsewhere (Ryland, 1996; Ryland et al., in prep.; Willits et al., 1996). Analyses used the forest vegetation simulator or FVS (Wycoff et al., 1982) to simulate stand development patterns associated with various timing and intensities of silvicultural treatments. There was no intention to establish long-term monitoring plots. Several scenarios, including no entry (i.e., natural stand development), thinnings, and treatments promoting regeneration, were modeled. The resulting species composition, diameter distributions, growth rates, etc., were evaluated by comparing them with desired future conditions. They are (1) *increase structural diversity,* by increasing the number of large trees and snags, and developing a reverse J-shaped diameter distribution; (2) *decrease, forest health risk,* by increasing stand vigor; (3) *improve wildlife habitat,* by increasing habitat for cavity nesting birds while maintaining winter range for White-tail deer; and (4) *improve stand aesthetics* by encouraging development of large western larch.

Some of the considerations used in selecting areas for stand manipulation and the types of treatments selected are as follows: (1) *uniform, dense stands provide insufficient space, for individual trees to attain large diameters.* When diameter-growth is slow it may take a very long time for trees to reach dimensions adequate for the large-diameter snags required by cavity-nesting species. Under some conditions, trees of suitable size might never develop. (2) *Individual tree vigor may be poor in very dense stands when stagnation occurs and crown class differentiation is susceptible to insect- and disease-related mortality.* Although such processes can be considered natural, the results of these events may or may not move stands towards the desired composition and structure. (3) *Thinning may have to be approached with caution in some situations.* Opening up dense stands may leave residual stems susceptible to snow breakage, windthrow, or sunscalding. Site-specific evaluations will be important when identifying appropriate silvicultural strategies. (4) *Thinning may alter, forest, floor microsites.* Development of shrubs or herbaceous plants desirable for some habitat objectives may benefit from increased light and moisture levels prevailing after thinning. (5) *Mortality associated with competition between trees for additional resources or as a result of insects and disease will lead to increasing fuel loads and fire hazard in these stands over time.* Thinning operations that remove stems likely to die will minimize fuel buildup and provide opportunities to control the composition, spacing, and distribution of remaining trees.

Forest Operations

Preliminary results from this technical focus area have been published or reported elsewhere (Barbour et al., 1995, Schroder and Johnson, 1996) and a detailed report on the productivity of the harvester-forwarder system used on the Rocky II timber sale area is being developed (McNeel and Barbour, in prep.). Schroder and Johnson (1996) summarized the challenges of operating in small-diameter densely stocked stands as follows: *"Implementation of forest management activities that facilitate the goals of "ecosystem management will probably involve the harvesting of smaller trees with decreased road density. The location of the processing step may also be shifted to the woods to allow the retention of the nutrients in the limbs and tops on site. These constraints present significant challenges for conventional logging systems. Expressed on the basis of dollars per unit of volume, small trees are expensive to handle and process. Larger skidding or forwarding distances add to the economic challenge, since the economic haul distance of the transport equipment is generally a, function of machine capacity and speed.*

A partial solution may lie in prebunching material to a skid or, forwarder trail for movement over larger distances with larger capacity, forwarding machines, This would allow smaller equipment to work in the forest stands moving material from the point of harvest to the forwarding trail. ”

Research was linked to the silvicultural options established in the silviculture and ecology section. Results available so far (Barbour et al., 1995; McNeel and Barbour, in prep.; Willits et al., 1996) suggest that costs associated with both the harvesting and forwarding steps of harvester-forwarder systems increase rapidly in stands with average tree sizes of less than 10 inches (25 cm).

The analysis of the study results and information from the literature are being used to evaluate the effectiveness of using a range of harvesting systems to attain specified post treatment conditions. Effectiveness is defined as a combination of ecosystem benefits, technical feasibility of using a specific system, and costs associated with each system. The greatest emphasis was placed on harvester-forwarder systems because that was the system used on the Rocky II Timber Sale. This system was chosen because it (1) has less impact on the site than conventional systems, (2) leaves slash in the trails thus reducing nutrient losses, and (3) improves recovery of the limited saw-log resource. A study of small tractor logging systems has yet to be completed. Information on production costs from this technical focus area will provide input data for the financial analysis model being developed under the economics technical focus area (figure 2).

Timber Conversion

Preliminary results from this work are presented by Olson (1996), Willits et al. (1996); Barbour et al. (1997); Fight (1997); Myers et al. (1997a, 1997b); and Will its et al. (1997). Technical evaluations were conducted for several different conversion options, including lumber, veneer, pulp, and composite products. Manufacturing cost estimates for use in the economic sensitivity analysis were developed for each conversion process (Spelter et al., 1996). Lumber and veneer production were evaluated in mill settings. Field-level trials of nondestructive testing technology for logs were incorporated into the mill level recovery studies to investigate the possibility of selecting the logs with the highest value for lumber and veneer. Pilot-scale trials on chip, kraft pulps, mechanical pulps, and composite products were conducted to evaluate the quality of these products. The purpose of these studies was to identify the unique properties of small, slow-grown stems that may hold previously unrecognized value; e.g., tight-grain, small knots, and possibly superior mechanical properties.

Results so far suggest that the quality of wood products manufactured from trees removed from small-diameter densely stocked stands is generally as good or better than the quality of products manufactured from the traditional resource (typically stands with average breast-height diameters of 12 inches [30 cm] or greater). The costs associated with manufacturing products from small-diameter trees is higher because more small stems must be processed to recover the a given volume. As with forest operations, the production relations developed under this technical focus area provide input for the financial analysis model (figure 2).

Economics

An initial analysis evaluated economic return to timber that could be obtained by manufacturing various products: oriented strandboard (OSB), stud lumber, random-length dimension lumber, machine stress rated (MSR) lumber, laminated veneer lumber (LVL), and bleached chemithermomechanical pulp (BCTMP). The products providing the highest return to wood were (highest first) LVL, BCTMP, OSB, and MSR lumber (Spelter et al., 1996).

Manufacturing costs developed during the initial analysis were used in a simulation tool being developed by Fight (1997) to conduct financial analyses for the viability of forest operations in the types of stands expected to be treated under ecosystem management prescriptions in the U.S. interior West. This tool is called FEEMA for financial evaluation of ecosystem management activities. It integrates the costs associated with specific treatments by using different forest operation and manufacturing options. It has the flexibility to consider a wide array of stand conditions, harvesting systems, and product options in determining the net cost or revenue from a specific treatment regime. It emphasizes identification of the conditions where forest operations assist in achieving ecological objectives. FEEMA allows the rapid evaluation of many silvicultural prescriptions for a given set of stand conditions and ecosystem objectives.

FEEMA was not intended for use in designing individual timber sales. Other tools, such as TSPAS (Schuster et al., 1995), are already available for that purpose. Rather FEEMA is intended to help managers evaluate the types of silvicultural prescriptions and equipment combinations that might be economically feasible under a range of prevailing economic conditions, given the manufacturing facilities located within a reasonable haul distance from the forest.

Conclusions

A major assumption of the Colville Study is that forest managers want to balance the costs and revenues associated with management activities in stands where there are compelling ecological reasons to manipulate stand conditions, but forest operations yield marginal or negative returns. At the present time, Federal land managers have few ways to finance ecosystem restoration or forest health improvement treatments. Timber sales currently are the most frequently used funding mechanism. Even if new authorities are created, it is unlikely that appropriated funds will be sufficient, and timber sales will probably remain an important way to fund forest operations.

Federal land managers also are presented with more complex silvicultural prescriptions, an array of new and unfamiliar harvesting systems, an increasing list of restrictions on activities, and a resource composed of a different mix of species and sizes than they are accustomed to. National Forest staffs must determine how to allocate limited funds and personnel to accomplish important objectives. They want to know which activities truly need to be subsidized and which can carry their own costs. The results from each of the Colville Study's technical focus areas provide stand alone information to answer some of the questions Facing land managers. Together with FEEMA, the results of the Colville Study provide a powerful tool that can help managers understand some of the complex interactions that make activities profitable or result in a loss.

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Lumber and Veneer Yields From Small-Diameter Trees

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Abstract
Forest management activities since the start of the 20th century have created vast acreages of densely stocked small-diameter stands throughout the intermountain West. Current management goals include reducing the stocking of these stands to increase their resistance to insect and disease attacks, to reduce the risk of catastrophic wildfires, to create diverse mosaics of wildlife habitat, and to provide economic benefits to the public. One of the economic benefits of active management of these stands is to use the material being removed from the forest to produce wood products. To efficiently use the small-diameter material, information about the volume and quality of products that can be produced is necessary. A recent series of mill recovery studies was conducted on small-diameter Douglas-fir, western larch, lodgepole pine, ponderosa pine, and white fir trees from eastern Washington, northern Idaho, and southwestern Oregon. Results of the lumber study showed that the volume recovery is as high or higher than previously experienced from timber of this size. Lumber grade recovery was also good, with 50 percent of the lumber from the lodgepole pine sample and 65 percent of the Douglas-fir sample graded as Construction or better. Veneer volume recovery also compared favorably with previous studies with the exception of the ponderosa pine sample, which had fairly low recovery.

Keywords: Densely-stocked small-diameter stands, Douglas-fir, ponderosa pine, lodgepole pine, larch, lumber recovery, veneer recovery.

Introduction
Forest management activities since the start of the 20th century have created vast acreages of densely stocked small-diameter stands throughout the intermountain West. Current management goals include reducing the stocking of these stands to increase their resistance to insect and disease attacks, to reduce the risk of catastrophic wildfires, to create diverse mosaics of wildlife habitat, and to provide economic benefits to the public. Once the overall goals for ecosystem management or ecosystem restoration have been established; key decisions will be made on the vegetation management treatments are necessary to change stand trajectories within the National Forests. Questions of what, when, where, why, and how to implement treatments must be addressed at the landscape, watershed, and stand levels. The answers to these questions require a balance of information on current forest conditions; growth and yield projections; insect, disease, and fire risk; species diversity and

Table 1–Sampled trees by species in 2-inch diameter classes

	Southwestern Oregon			Northeastern Washington		Northern Idaho		
Diameter class	Douglas-fir	Ponderosa pine	White fir	Douglas-fir	Larch	Douglas-fir	Larch	Lodgepole pine
8	6	4	3	4	2	3	5	4
10	6	8	9	6	5	6	4	5
12	7	6	7	3	7	6	7	8
14	6	6	3	2	5	7	4	2
Total	25	24	22	15	19	21	24	19

aesthetics; water supply and quality; soil conditions; and economics. Areas considered to have high priority for treatment include densely stocked stands of small-diameter trees that have become stagnant or are not developing structural diversifying at fast enough rates.

Management of these stands will likely require removal of small-diameter trees of mixed species, unlike the removal from traditional harvest. For wood products, a large part of the economic question is related to the cost of removing the material from the site, but an equally important issue is the value of the products that can be manufactured from the raw material. This paper presents the results of recent studies on the quality and quantity of lumber and veneer products that can be manufactured from trees removed from densely-stocked stands with average ages of 60 to 90 years and diameter at breast height (dbh) ranges from 8 to 14 inches. Species included in the studies were Douglas-fir *(Pseudotsuga menzriesii* (Mirb.) Franco), lodgepole pine *(Pinus contorta* Dougl. ex Loud.), western larch *(Lark occidentalis* Nutt.), white fir *(Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.), and ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.).

Much of the existing information on these species was developed in the 1970s when the resource was primarily older and larger and the products were Construction grade solid lumber (Fahey and others 1986, Snellgrove and Ernst 1983, Plank 1979). Just as changes have occurred within forest management, changes in the manufacturing sector have been substantial. Technological changes have allowed mills to decrease sawkerfs and decrease the target green sizes, thus increasing the volume of wood that ends up in finished product. Technology and economics combined have created opportunities to capitalize on the specific properties of wood with products such as machine stress rated (MSR) lumber and laminated veneer lumber (LVL), The main objective of the recent set of studies was to evaluate the potential of the small-diameter resource for producing traditional solid wood products as well as for producing engineered wood products.

Methods

Two veneer studies and one lumber study were conducted on small-diameter timber. Samples came from three geographically different areas having similar stands conditions; the Applegate Adaptive Management Area in southwestern Oregon and northern California, the Colville National Forest (NF) in northeastern Washington, and the Idaho Panhandle NF in northern Idaho. All the stands were between 60 and 90 years old, had slow growth rates (10 growth rings or more per inch), and were considered typical of stands that would need treatment in the near future. Trees were selected across a range of diameter classes (from 8 to 14 inches at dbh) and locations within the study areas. Sample were selected to cover the range of diameters and not represent a "normal" distribution of logs processed by the mills. Table 1 summarizes sampled trees by area, species, and diameter class.

Trees were felled and bucked and logs tagged with a number identifying which tree it came from and its position within the tree. Felled trees were bucked to normal industry standards; log lengths were in multiples of 8.5 feet for veneer and 12 to 20 feet for lumber to a minimum top diameter of 6 inches. Logs were hauled to the mill sites for log scaling and non-destructive testing of stiffness. Each log was then bucked into either 8.5-foot blocks or sawmill-length logs and remeasured and nondestructively tested for stiffness (Ross and others 1997).

Veneer

Veneer blocks were conditioned in a hot water bath and then peeled into veneer (l/10-inch thickness for the southwestern Oregon sample and 1/1 5-inch thickness for the northeastern Washington sample). All the veneer from each block was sprayed with dye so that its identity could be maintained through the veneer dryer. The veneer was clipped primarily into fill sheets (54-inches wide by 102-inches long). Blocks were peeled down to a 3-inch core diameter. Veneer was dried and graded only for grade C or D. The dried veneer was tested for stiffness with a Metriguard testing machine.

Lumber

Mill-length logs ranged from 12 to 20 feet in 2-foot multiples and were sawn into primarily 2-inch dimension lumber (89 percent) and the rest as 1-inch boards. Each board was labeled with a number corresponding to the log from which it was sawn. With this level of detail, the volume and value of sawn material from each log could be calculated. Lumber was kiln-dried, surfaced four sides, and graded by a Western Wood Products Association (WWPA) grade inspector according to WWPA grading rules (WWPA 1995). Lumber was non-destructively tested with an E-computer for estimating modulus of elasticity (MOE) and establishing a MSR lumber grade level.

Analysis

Lumber and veneer volume recovery were estimated from cubic volumes. Gross cubic-foot volume of green veneer or rough-green lumber was used as the dependent variable and cubic-foot volume of log was the independent variable. Covariance analysis was used to test for differences among species and mills.

Because the veneer was not graded visually, only the proportion of veneer that would meet the stiffness criteria for LVL is reported. Lumber was graded both visually and by using a combination of visual and mechanical testing data. Average lumber value is estimated by multiplying the percent grade recovery by the current $/MBF for each lumber grade.

Results and Discussion

Veneer

Results indicated that for some species there is a fairly strong relation between cubic-foot veneer volume recovered and block volume. Regression analysis of combined Douglas-fir and larch data gave the strongest relation ($R^2 = 0.82$). Differences in recovery results of Douglas-fir and larch were found to be insignificant therefore the data were combined for analysis. For these species, as block volume increases more veneer is recovered (Figure 1). White fir gave results similar to Douglas-fir and larch. Analysis of the ponderosa pine data suggests a somewhat weaker relation between veneer volume recovered and block volume ($R^2 = 0.15$) and lower overall veneer recovery. Blocks that had no veneer recovery were not included in the analysis.

Table 2–Percent cubic-foot volume recovered by species in full sheets, random width strip, and fishtails

Veneer type	Douglas -fir	Larch	White fir	Ponderosa pine
Full sheet	72	71	69	48
Strip	21	26	19	44
Fishtail	7	3	12	8

To evaluate the potential of producing a significant quantity of veneer from small-diameter trees, percent veneer recovered in full sheets was assessed by species. Results indicate that, in general, small-diameter Douglas-fir trees produce high recovery rates of till-sheet veneer (about 70 percent) and that recovery is constant across diameters sampled. Analysis of white fir and larch indicated the same general recoveries as with Douglas-fir. Ponderosa pine produced the lowest full sheet recovery and had the greatest proportion of blocks which produced no fill sheets (29 percent). By comparison, 2 percent of Douglas-fir, 11 percent of white fir, and 4 percent of larch blocks produced no fill sheets. Table 2 gives percent volume recovered by species in full sheets, random width strip, and fishtails.

Findings indicated that recovery compares favorably in volume with other studies. The combined Douglas-fir and larch veneer recovery was compared with a study of second-growth Douglas-fir from the Coast and Cascade Ranges of Oregon and Washington (Fahey and Willits 1991) and a study of Douglas-fro and larch from Montana (unpublished data on file). Volume recovery was found to average about 20 percent greater than either of the previous studies. Differences in recovery among studies are due mainly to a difference in core diameter, 3 inches in these studies versus 5 inches for Fahey and Willits and 5.25 inches for Montana.

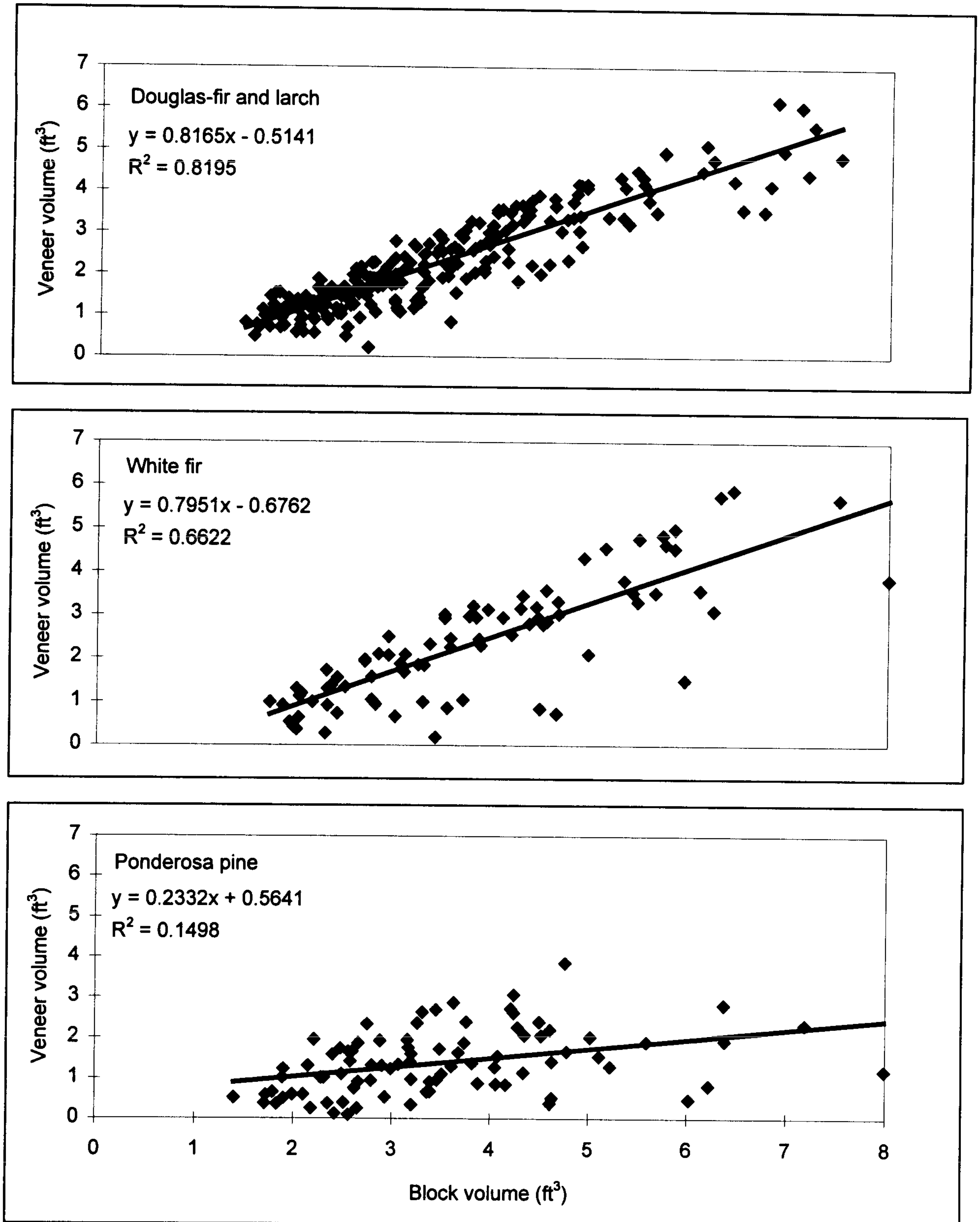

Figure 1–Veneer volume vs block volume by species

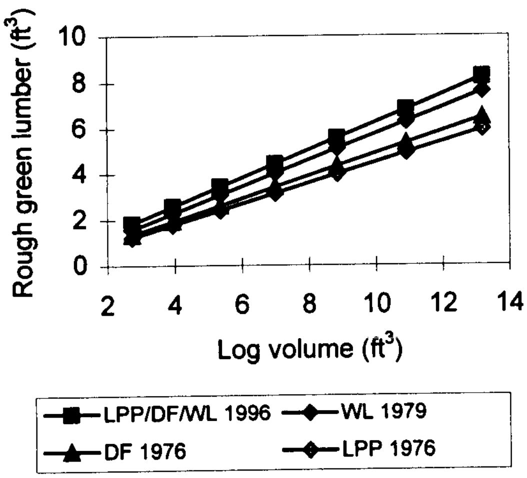

Figure 2— Lumber volume recovery has increased over time with changes in technology and mill efficiency. Lodgepole pine (LPP), Douglas-fir (DF), and western larch (WL) recoveries from the current study (1996) and past research (1976 and 1979).

There also was a difference in full sheet recovery in comparison with the Fahey and Willits (1991) study because of the end products being produced. Veneer from the earlier study was used for plywood with clipping priority being on producing high-grade veneer not full sheets as done in the present study; therefore the proportion of full sheets was only half that of the current study. Analysis of grade recovery results found no difference in visual grades, all sheets were C or D grade veneer.

Lumber

Volume recovery results were not different among the three species (lodgepole pine, Douglas-fir, and western larch) processed at the sawmill. Lumber recovery was strongly correlated with log volume ($R^2 = 0.90$), with 60 percent of the cubic log volume recovered as green lumber. A comparison of the volume recovery to previous studies (Fahey and others 1986 and unpublished data on file) of dimension lumber recovery from inland mills showed the effect of changes in technology, rough-green target sizes, and quality control overtime (Figure 2). Differences in these studies conducted over the last 20 years include a reduction in sawkerf from 0.250 inches to 0.115 inches and in green target size from 1.81 inches to 1.645 inches for a 2-inch thickness. These changes allow for the recovery of more boards from a given size log.

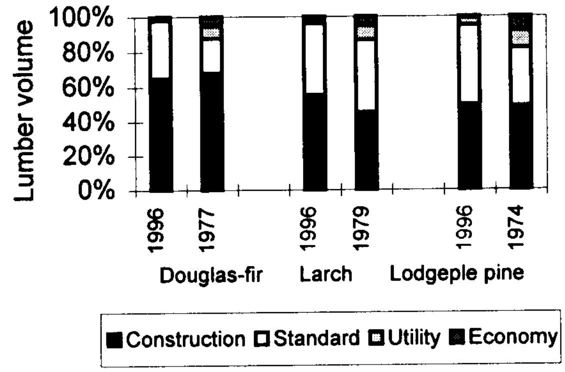

Figure 3—Grade recovery from the current study is not different from earlier studies with the exception of an increase in the production of Standard lumber and a corresponding decrease in Utility and Economy lumber.

Lumber grade recovery also is important for determining the value of the small-diameter resource. Lumber grades were combined into four categories corresponding to differences in market prices. The Construction grade group includes Select structural, Construction, and No. 2 Common boards and is priced at $500/MBF. Standard grade group includes Standard, Stud grade, and No. 3 Common with a price of $425/MBF. Utility is priced at $300/MBF, and Economy at $200/MBF. Figure 3 shows the average grade recovery for each species and a comparison with studies run in the 1970s. The overall results show an increase in the percentage of Standard grade lumber with a corresponding decrease in Utility and Economy lumber. Differences in average value of the lumber range from a 3-percent increase for lodgepole pine to a 5-percent increase for Douglas-fir. This increase in grade recovery is reflective of increased quality control and a change in the resource from tops of old-growth trees with large limbs and greater amounts of defect, to the densely stocked resource with smaller knots and little or no defect.

Engineered Products

A summary of nondestructive testing of veneer by species is given in Table 3. Based on the summary analysis, the combined Douglas-fir and larch from northeastern Washington had the greatest mean stiffness, as indicated by the lowest mean Metriguard reading. A Metriguard reading of 450 or less was used to measure the volume of veneer suitable for LVL. The proportion ranged from as low as 39 percent for ponderosa pine to as high as 87 percent for Douglas-fir

Table 3– Summary of Metriguard output for veneer full sheets by study location and species.

Metriguard reading	Southwestern Oregon			Northeastern Washington
	Douglas-fir	White fir	Ponderosa pine	Douglas-fir and larch
Maximum	621	644	642	492
Minimum	372	380	405	384
Average	445	474	486	428
%<450	59	45	39	87

Table 4–Percent MSR lumber grade level by species

MSR Level	Douglas-fir	Larch	Lodgepole pine	Young-growth Douglas-fir[1]
2100f	60	41	1	19
1650f	26	39	12	42
1450f	3	15	45	17
900f or No. 3	1	3	31	13
Economy	10	2	11	9

[1]Estimated from Fahey and others 1991. Juvenile wood percent=30 and largest limb average diameter=1.0 inches

and larch combined. This indicates that Douglas-fir and larch have better quality characteristics over other species sampled for products such as LVL. In comparison, a study of plantation grown Douglas-fir (Kretschmann and others 1993) found only 20 percent of the veneer produced tested at the 450 level and below. Amount of juvenile wood and average width of the growth rings are critical factors in producing high stiffness veneer, and here again, the small-diameter resource from densely stocked stands produced a higher quality product.

The MSR lumber recovery results also are favorable for the small-diameter resource. Table 4 shows the percentage of lumber by MSR grade level for each species. Grade level 2100f is the most valuable with a value of $560/MBF. A comparison to second-growth Douglas-fir in western Oregon and Washington (Fahey and others 1991) shows that for low amounts of juvenile wood (30 percent) and an average knot size of 1-inch, the recovery of higher quality MSR lumber was much lower in the earlier study than that in current study.

Conclusion

We found that this small-diameter resource had volume and grade recoveries similar to those found in larger trees. Comparison to previous studies indicated that technological improvements have slightly increased the volume that can be recovered from a given size log and that visual grade recovery is very consistent. Using nondestructive techniques to measure the quality of the resource for engineered wood products shows some economic benefit. When comparisons were made to fast grown Douglas-fir trees of the same size class, the small-diarneter trees from densely stocked stands produced significantly higher quantities of the higher grade products.

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Pulp Quality from Small-Diameter Trees

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Abstract

Kraft and thermomechanical (TMP) pulps were prepared and evaluated from lodgepole pine and mixed Douglas-fir/western larch sawmill residue chips; lodgepole pine, Douglas-fir, and western larch submerchantable logs; and lodgepole pine, Douglas-fir, and western larch small trees and tops. Kraft pulp from small trees and tops was identical to that from submerchantable logs, except for Douglas-fir submerchantable logs. Lodgepole pine showed higher yield than western larch at the same target kappa levels. The handsheet properties of western larch from different raw material sources were the same. However, there were differences in tensile and tear indexes for lodgepole pine from different raw material sources. Douglas-fir submerchantable logs produced higher burst index than the small trees and tops. Thermomechanical pulp prepared from Douglas-fir and lodgepole pine small trees and tops had equal or better paper properties than pulp from sawmill residue chips of the same species. Thermomechanical pulp prepared from Douglas-fir, western larch, and lodgepole pine submerchantable logs and western larch small trees and tops had lower paper properties than pulp from sawmill residue chips of the same species. Thermomechanical pulp prepared from lodgepole pine submerchantable logs and western larch small trees and tops had the poorest properties of the eight raw materials evaluated. The results indicate that submerchantable logs and small trees and tops are suitable for pulping.

Keywords: Nontraditional wood species, forests, pulp and paper, ecosystem management, mechanical pulping, thermomechanical pulp, chemical pulping, kraft pulping, pulp properties, paper properties, handsheet properties

Introduction

Various silviculture methods will be applied by forest managers to alter the growth trajectory of stands and increase ecosystem diversity in many U.S. forests. Thinning is one such method, but it can draw public opposition, be expensive, and generate a large volume of small-diameter woody material with only marginal economic value. Another silviculture tool is cutting large tracts of timber that have been killed by insect or disease outbreaks. This type of treatment has proven to be even more controversial. At the same time, doing nothing might make additional forest resources vulnerable to insect and disease outbreaks, increase fuel load on the ground, and set the stage for stand replacement fires.

Thinning will probably be applied in two entirely different situations. Many young plantations and second-growth stands require thinning to maintain vigorous growth. Without thinning, competition between trees will slow growth and mortality will increase. In the Interior West, millions of acres of forests are composed of mature trees with small diameters in densely spaced stands. Development of these stands is slow, and the stands may never reach desired structural conditions.

These two situations yield entirely different types of wood, which will affect their end-use possibilities.

Trees from a young, vigorously growing forest usually contain a large proportion of juvenile wood. Saucier (1987) reported that the percentage of juvenile wood can be controlled by rotation length, ranging from 20 percent in a 40-year rotation to 50 percent in a 22-year rotation. Juvenile wood has several features that make it different from mature wood, such as low specific gravity, thin-walled cells, shorter tracheids, high lignin and hemicellulose content, and low cellulose content (Zobel and van Buijtenen 1989). Juvenile wood occupies the center of a tree stem, varying from 5 to 20 growth rings in size, and the transition from juvenile to mature wood is gradual. This juvenile wood core extends the full tree height, to the uppermost tip.

Low-yield chemical pulp quality is affected when juvenile wood is more than 20 percent of the chip supply (Zobel and van Buijtenen 1989). For the same chemical pulping conditions, pulp yield for juvenile wood is about 25 percent less than pulp yield for mature wood. Paper made from juvenile wood chemical pulp has low tearing and tensile strength values. However, Carpenter (1984) reported that southern pine juvenile wood is desirable in the preparation of stone groundwood and refiner mechanical pulp for newsprint.

The other type of forest mentioned consists of densely spaced, small-diameter, mature trees. Structural diversity in this type of forest is often low, and late successional structures develop slowly. These trees might also contain a high proportion of compression wood (Timell 1986).

Compared with normal wood, compression wood has greater density and slightly more extractives. Compression wood tracheids are shorter with thicker cell walls, have 30 to 40 percent more lignin, 20 to 25 percent less cellulose, about the same amount of xylan, and twice the galactoglucomman of normal conifer wood (Timell 1986).

Compression wood is inferior to normal wood for the manufacture of pulp and paper (Timell 1986). Compression wood does not chemical pulp as well as normal wood. Identical kraft cooking conditions will produce a lower yield compression wood pulp that has stiffer fibers with a higher lignin content compared with a normal wood pulp. Papers made from kraft compression wood pulp are weaker than those obtained from normal wood. Stone grinding compression wood breaks the thick-walled tracheids into fiber fragments that produce weak paper. Compression wood fibers also do not respond as well to mechanical refining, probably as a result of their short length, thick walls, and high lignin content.

Many forests growing on the eastern side of the Pacific Northwest Cascade Mountains consist of densely stocked, small-diameter trees. These forests resulted from large stand replacement fires and tend to be uniform. They consist of tree types that are abundant in the landscape, but in some cases, these forests could develop structural characteristics that are relatively scarce, such as large widely spaced green trees and snags. These features are desirable in providing habitat for certain wildlife species and developing a high level of diversity on the landscape. However, management of these stand types is costly and will probably generate large volumes of low value raw material. These materials might find a market in the Pacific Northwest pulp and paper mills, returning revenue to the national forests to help offset the high management costs. Therefore, the objective of this study was to establish the suitability of nontraditional woody materials for kraft pulping at the University of Washington (UW), Seattle, WA, and high yield mechanical pulping at the Forest Products Laboratory (FPL), Madison, WI.

Experimental

Raw Materials

All raw materials used in this study were obtained from the Colville National Forest (eastern Washington) or the Idaho Panhandle National Forest (western Idaho). The species selected were Douglas-fir *[Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco], lodgepole pine *(Pinus contorta* Doug]. ex Loud,), and western larch *(Larix occidentalis* Nutt.). A Douglas-fir/western larch mixture and lodgepole pine sawmill residue chips (SRC) were obtained from Vaagen Bros. Lumber, Colville, WA. Identical samples of SRC were shipped to the UW and FPL. The UW screened their SRC to remove chips <2 and >10 mm thick. The submerchantable logs (SML) had a <89-mm end diameter and were the top logs cut from the trees. The small-diameter trees and tops (STT) had a <127-mm diameter at breast height, and tops had large end diameters <89 mm. The STT were the entire tree. All logs were shipped to FPL where they were hand peeled to remove all bark and chipped to a 19-mm length in a four-knife commercialized chipper. Chipped logs and FPL’s SRC were screened to remove all particles >38 and <6 mm long. Screened chips were thoroughly mixed in a large V-mixer. To assure that FPL and UW were researching the same SML and STT, ~100 kg of chips from each raw material were shipped to U W for experimentation. The UW air dried all of their chips and stored them at room temperature in polyethylene bags until pulping. The FPL divided their green chips into 4-or 5-kg sample sizes, placed them in polyethylene bags, and stored them at 4°C until pulping.

In this study, SRC are the controls, representing raw materials currently used for pulping. The SML and

STT are considered an alternative, or nontraditional, raw material that might be suitable for pulp and paper.

Kraft Pulp Preparation

The pulping experiments were carried out in 10-L dual vessel Aurora digesters. White liquor of 30.38 g/L (expressed as sodium monoxide) and 25 percent sulfidity was prepared using sodium hydroxide and sodium sulfide. Chips were placed in one of the 10-L vessels and impregnated by applying a vacuum for 5 rein, using the vacuum to flood the chips with room temperature white liquor (17.5 percent effective alkali on ovendry wood). The 6:1 liquor-to-wood chip mixture was heated to 170°C for 120 min, with three to four ventings to prevent buildup of noncondensibles. Temperature was held at 170°C until five H-factor levels between 900 and 1700 were achieved. At the conclusion of the cook, the spent liquor was drained from the digester and cooked chips were removed and disintegrated in a 2-L laboratory blender at medium speed for 2 min. The pulp was screened, dewatered in a centrifuge, fluffed, and placed in polyethylene bags for refrigerated storage. Based on the kinetics obtained in the initial pulping experiments, chips from all eight raw materials were cooked to produce 30 kappa number pulp. These unbleached kraft pulps were beaten in a PFI (Norwegian Pulp and Paper Research Institute) mill across the range of 0 to 10,000 revolutions.

Thermomechanical Pulp Preparation

An Andritz Sprout-Bauer Model 12-1CP 305-mm-diameter pressurized refiner, fitted with plate pattern D2B505, was used for fiberization. All raw materials were steamed for 10 to 20 min at 206.8 kPa before fiberization. Fiberized pulp was wet screened through a 0.2- or 0.3-mm-slot flat screen. Screen accepts and rejects were refined separately in a Sprout–Waldron Model 105-A 305-mm-diameter atmospheric refiner, also fitted with plate pattern D2B505. A constant volume of shredded pulp was delivered to the atmospheric refiner inlet by a constant-speed belt conveyor, and dilution water was added to the shredded pulp to adjust refiner consistency to ~20 percent. Multiple passes were necessary to reduce pulp Canadian Standard Freeness (CSF) to ~200 mL, when the accepts and rejects were combined. An additional pass was run on the combined pulp to reduce CSF to <100 mL. Energy consumed during fiberization and refining was measured using an Ohio Semitronic Model WH30-11195 integrating watt-hour meter attached to the power supply of the 44.8-kW electric motor, measuring amperes, volts, and power factor. Energy consumption values for fiberizing and refining were reported as watt-hours per kilogram (ovendry weight basis), with the idling energy subtracted. Latency was removed from the pulp after fiberization and each refining step by soaking the pulp in 90°C water for a minimum of 30 min, with occasional stirring. Four replicates were prepared for each raw material evaluated.

Pulp Testing and Handsheet Formation and Testing

Alkali content of the kraft white liquors were determined by TAPPI Test Method T624. The CSF was measured according to TAPPI Test Method T227. Shive contents of the TMP were determined with a Pulmac shive analyzer, using a disk with 0.10-mm slot openings. Average fiber length, fines content, and fiber coarseness were determined using a Kajaani FS-100 analyzer for the TMP and a Kajaani FS-200 analyzer for the kraft pulps. Handsheets weighing 60 g/m^2 were made according to TAPPI Test Method T205. Burst and tear indexes were measured according to TAPPI Test Methods T403 and T414, respectively. Tensile breaking properties and paper smoothness were measured according to TAPPI Test Methods T494 and T538, respectively. Brightness, printing opacity, and light-scattering coefficient were measured with a Technidyne Corporation Technibrite Model TB-1 diffuse brightness apparatus according to TAPPI Test Method T525.

Statistics

No statistical analysis was performed on the kraft pulps or their handsheet results. Each TMP was processed to freeness levels above and below the 100-mL target, and 10 handsheets were made and tested for each pulp. These results were regressed, and values at 100 CSF were estimated (Tables 1 and 2). Individual test results were used to perform a Dunnett’s multiple comparison procedure, which provided confidence intervals on ratios of the medians of the original data and statistical significance.

Results and Discussion

Kraft Pulping Studies

Kappa Compared with H-Factor – Results for kraft pulping of STT, SML, and SRC are presented in Figure 1. Douglas-fir SML had a distinct pulping response. It produced a higher kappa number pulp compared with other species at the same H-factor level. All other SML and SRC produced pulps with kappa numbers only 2 to 3 units different. All three STT species showed similar pulping response and had higher kappa numbers than SML and SRC at a low H-factor. Pulping a mixture of STT species and SRC in liner board mills (kappa number range 70–100) may produce pulp with significant chemical nonuniformity.

Kappa Number Compared with Yield – The relationships between yield and kappa number for all raw materials are shown in Figure 2. There are several notable differences between all raw materials that can be extracted from this figure.

Table 1—Thermomechanical pulp test results at 100 Canadian Standard Freeness (pulp properties)

Input material[a]	Total energy (watt-hour/ ovendry kg)	Pulmac shive <0.004 mm (%)	Kajaani FS-100 fiber analysis: Length-weighted Average (mm)	Length-weighted Fines (%)	Coarseness (mg/m)
D.-fir/W. larch SRC	3761	0.93	1.15	4.50	0.336
L. pine SRC	5020	0.65	1.17	4.56	0.349
D.-fir SML	4405	0.67	0.86	6.67	0.306
L. pine SML	2314	0.10	0.67	8.52	0.323
W. larch SML	4962	0.82	1.01	5.75	0.389
D.-fir STT	2687	1.06	1.09	4.26	0.318
L. pine STT	2958	0.42	1.05	4.43	0.298
W. larch STT	2256	1.44	0.92	6.29	0.373

[a]SRC, sawmill residue chips; SML, submerchantable logs; STT, small-diameter trees and tops.

Table 2—Thermomechanical pulp test results at 100 Canadian Standard Freeness (paper properties)

Input material[a]	Apparent density (kg/m^3)	Burst index (kPa• m^2/g)	Tear index (mN• m^2/g)	Tensile index (N•m/g)	Stretch (%)	TEA[b] (J/m^2)	Smooth -ness (SU[c])	ISO[d] bright- ness (%)	Printing opacity (%)	Scattering coefficient (m^2/kg)
D.-fir/W. larch SRC	456	1.13	1.97	26.3	1.50	19.04	197	34.4	99.6	61.0
L. pine SRC	461	1.47	2.22	33.3	1.81	27.82	173	46.0	98.8	79.2
D.-fir SML	471	1.04	1.67	25.5	1.47	17.47	200	31.8	99.6	44.0
L. pine SML	416	0.64	0.93	19.3	1.07	9.30	234	45.2	98.4	49.2
W. larch SML	443	1.06	3.37	26.8	1.46	17.98	221	32.6	99.3	41.0
D.-fir STT	456	1.36	4.28	29.9	1.70	23.25	191	37.0	98.9	44.9
L. pine STT	457	1.31	3.61	30.3	1.56	22.24	201	43.8	97.7	45.2
W. larch STT	397	0.78	2.74	20.8	1.27	11.95	287	39.3	98.3	40.9

[a]SRC, sawmill residue chips; SML, submerchantable logs; STT, small-diameter trees and tops.
[b]TEA, tensile energy absorption.
[c]SU, smoothness units.
[d]ISO, International Organization for Standardization.

Douglas-fir SML had a steeper yield to kappa number relationship compared with all other raw materials. That is, for an identical change in the target kappa number, yield loss is higher for the Douglas-fir SML. The yield response is related to a slow pulping rate for the Douglas-fir SML. Douglas-fir STT and Douglas-fir/western larch SRC were nearly identical in their yield response.

Lodgepole pine SML had ~2 percent higher yield for the same target kappa number than lodgepole pine SRC. The increase is large enough that a mill pulping a high proportion of lodgepole pine SML for a long time would realize measurable gains. Lodgepole pine SM kappa to yield response is between the lodgepole pine SML and SRC.

Western larch STT and SML were nearly identical and had the lowest yield for the same target kappa number of all species and raw materials. The Douglas-fir/western larch SRC showed a higher yield than western larch STT and SML because of the Douglas-fir in the raw material. Lower yield for western larch is due to presence of higher amounts of water-soluble arabinogalactans (Adams and Douglas 1963, Fengel and Wegener 1989, p. 124).

All three species of STT yielded pulps with a kappa number within 1 to 3 units of each other (Fig. 1). However, for the same target kappa number, there were differences in yield (Fig. 2). The order of increasing pulp yield is as follows: western larch STT < Douglas-fir STT < lodgepole pine STT. Douglas-fir yield was ~2 percent greater than that for western larch, and yield

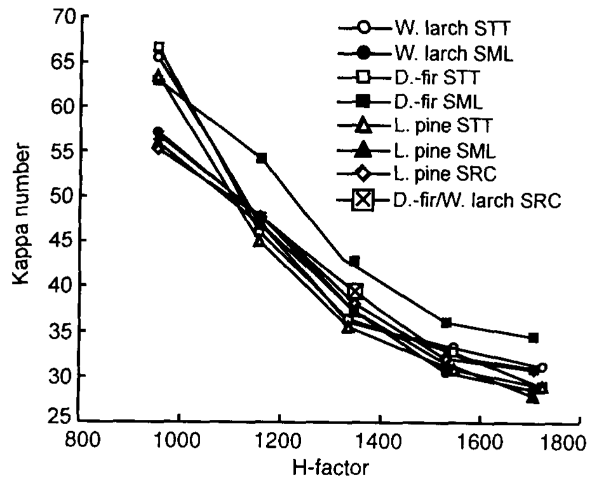

Figure 1—Kappa number as a function of H-factor for different species of STT, SML, and SRC.

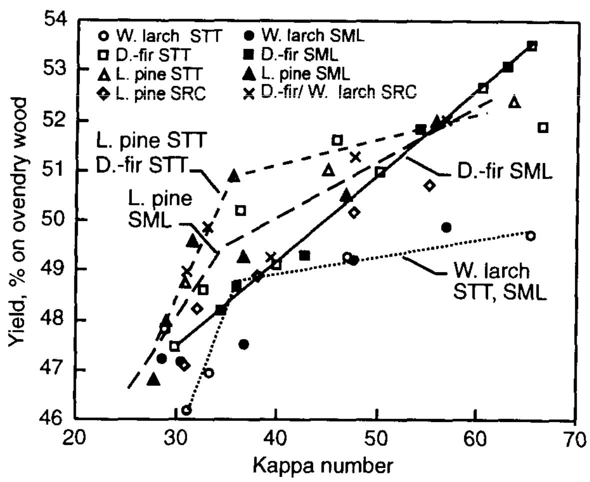

Figure 2—Total pulp yield as a function of kappa number for different species of STT, SML, and SRC species.

for lodgepole pine was ~0.5 percent greater than that for Douglas-fir. There was no consistent trend for any of the three wood sources among species except for higher kappa at low H-factor in the case of STT. The relationships between species, raw materials, H-factor, yield, and kappa are summarized in Table 3.

Kraft Pulp Properties

The weighted-average fiber lengths (WAFL) of the unbleached kraft pulps are shown in Table 4. Average fiber lengths of STT were similar to those of their corresponding SML for each of the three wood species. The SRC produced a moderately higher WAFL value than did STT and SML of any species.

Fiber coarseness values for the unbleached kraft pulps are shown in Table 4. Fiber coarseness did not vary greatly for the different western larch raw materials. Coarseness differences among one species were largest for lodgepole pine. Douglas-fir pulps from different raw materials had a moderate coarseness difference. The coarsest fibers were obtained from SRC raw material.

Kraft Paper Properties

Handsheets from unrefined and PFI-refined unbleached kraft pulp samples were tested for their mechanical properties, and the development of sheet properties was investigated. The analysis did show some differences between raw materials for the three wood species. Some of the differences found in the handsheet study are highlighted in the following sections.

Pulp Freeness as a Function of PFI Revolutions— The freeness values at different beating levels for all raw materials are presented in Table 5. Freeness characteristics were similar for the STT and SML for all three species. The SRC produced pulp with higher freeness values at a given beating level.

Unbleached Kraft Handsheet Properties- The data given in Table 5 quantify the following narrative of differences and similarities between different raw materials for the three wood species.

There were no differences in tensile indexes among the different raw materials of Douglas-fir and western larch. Lodgepole pine STT produced a lower tensile index than lodgepole pine SML. In general, lodgepole pine papers had higher tensile indexes than western larch and Douglas-fir papers. As illustrated in Figure 3, all SML required lower refining energy to produce handsheets of 90 N·m/g tensile index than did all STT and SRC.

There were no differences in burst indexes among the different raw materials of lodgepole pine and western larch. Douglas-fir SML produced higher burst index than did STT. In general, lodgepole pine papers had higher burst indexes than western larch or Douglas-fir papers.

There were no differences in tear indexes among Douglas-fir and western larch raw materials. Lodgepole pine STT produced a lower tear index than did SML. In general, western larch had higher tear indexes than Douglas-fir. Lodgepole pine had the lowest tear indexes.

Tear Index Compared with Tensile Index— The PFI mill revolutions and the tear indexes from different raw materials that had a 90-N·m/g tensile index are presented in Table 4. Lodgepole pine had the lowest and western larch the highest tear indexes (Fig. 4). Tear index trends for Douglas-fir and western larch were similar to coarseness for these species (Fig. 5), with the coarser fibers producing handsheets with higher tearing resistance. Douglas-fir STT and SML did not show a significant difference in tear indexes. The western larch SML had a lower tear index than did STT.

Table 3—Comparison among same species from different raw materials[a]

Species	Kappa compared with H-factor	Yield compared with kappa
L. pine	No difference between SML and SRC. But STT has slightly lower kappa number at same H-factor level.	Yield at same kappa number levels follows this order: SRC < SML < STT
D.-fir	SML has higher kappa number than STT at same H-factor level. STT is equivalent to SRC.	No difference among sources.
W. larch	No difference among sources.	No difference among sources.

[a]SML, submerchantable logs; SRC, sawmill residue chips; STT, small-diameter trees and tops.

Table 4—Weighted-average fiber length (WAFL), fiber coarseness, PFI mill revolutions, and tear indexes of handsheets, from different raw materials, of tensile index 90 N•m/g

Raw material[a]	WAFL (mm)	Coarseness (μg/m)	PFI mill revolutions	Tear index (mN•m^2/g)
L. pine STT	2.857	118	5,875	14.0
L. pine SML	2.877	126	2,250	17.2
L. pine SRC	3.153	155	2,950	17.1
W. larch STT	3.090	155	4,190	20.9
W. larch SML	3.210	148	3,625	18.8
D.-fir/W. larch SRC	3.323	155	5,000	20.9
D.-fir STT	2.660	133	6,250	17.4
D.-fir SML	2.667	114	5,000	17.0

[a]STT, small-diameter trees and tops; SML, submerchantable logs; SRC, sawmill residue chips.

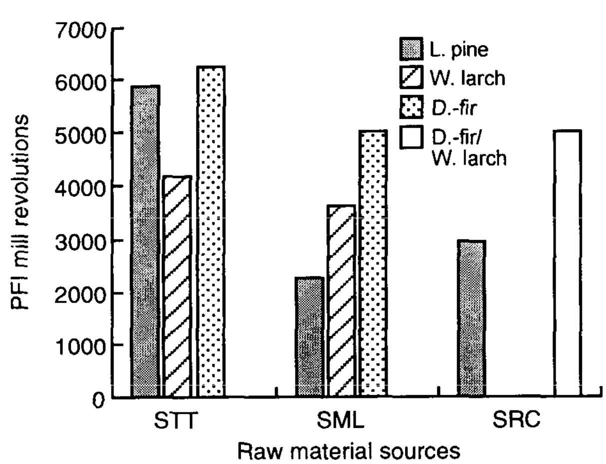

Figure 3—PFI mill revolutions required to produce handsheets of tensile index 90 N•m/g.

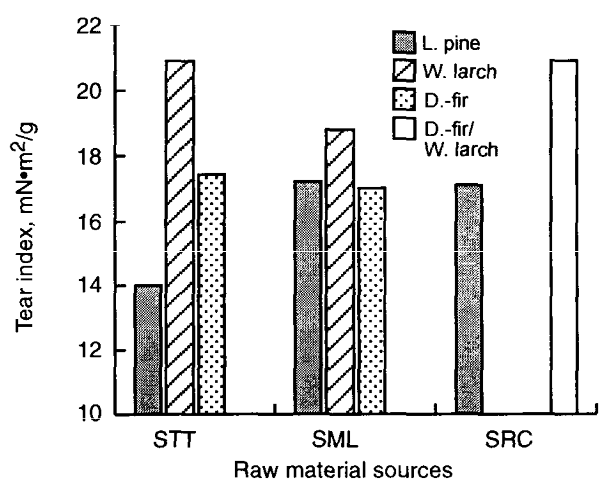

Figure 4—Tear indexes of handsheets of tensile index 90 N•m/g.

Table 5—Mechanical properties of handsheets from eight different raw material sources

Raw material[a]	Property[b]	PFI mill revolutions 0	2,500	5,000	7,500
L. pine STT	Freeness	720	610	460	340
	Tensile index	48.7	88.1	89.5	90.6
	Burst index	3.2	6.7	7.4	7.324
	Tear index	23.06	15.80	14.83	13.05
W. larch STT	Freeness	700	635	440	265
	Tensile index	36.4	81.6	94.0	94.4
	Burst index	1.9	5.1	6.1	6.5
	Tear index	27.78	22.57	20.20	19.58
D.-fir STT	Freeness	700	630	445	265
	Tensile index	44.7	86.9	88.2	91.4
	Burst index	2.3	5.6	6.3	6.3
	Tear index	28.09	20.97	18.35	16.44
W. larch SML	Freeness	730	645	430	270
	Tensile index	36.8	79.0	103.9	86.2
	Burst index	1.9	5.3	6.1	6.4
	Tear index	28.50	22.07	19.86	19.45
D.-fir SML	Freeness	715	630	425	300
	Tensile index	52.4	89.1	90.0	92.7
	Burst index	3.2	6.6	6.7	6.7
	Tear index	28.48	19.83	17.07	16.22
L. pine SML	Freeness	690	610	460	300
	Tensile index	65.0	92.7	113.8	100.1
	Burst index	3.3	6.3	7.0	7.4
	Tear index	24.92	16.62	15.49	15.32
L. pine SRC	Freeness	730	650	510	310
	Tensile index	52.7	88.8	95.5	108.6
	Burst index	3.2	6.2	7.1	7.3
	Tear index	26.90	17.48	15.89	14.75
D.-fir/W. larch SRC	Freeness	695	655	525	350
	Tensile index	40.6	77.1	90.0	92.5
	Burst index	2.1	4.8	5.6	6.1
	Tear index	28.23	24.48	20.86	17.92

[a]STT, small-diameter trees and tops; SML, submerchantable logs; SRC, sawmill residue chips.
[b]Units for freeness and tensile, burst, and tear indexes are Canadian Standard Freeness, N•m/g, kPa•m^2/g, and mN•m^2/g, respectively.

Lodgepole pine STT produced a lower tear index than did SML. This maybe due to weakening of fiber strength because lodgepole pine STT required more beating (Fig. 3) to produce a 90-N·m/g tensile index. In well-bonded paper, tearing resistance depends more on fiber strength than on fiber length (Seth and Page 1988).

Thermomechanical Pulp Results

A minimum of four replicates were run for each of the eight raw materials, the results for each raw material were regressed, and a value was predicted for 100-mL CSF. These predicted values are presented in Tables 1 and 2 for the eight raw materials.

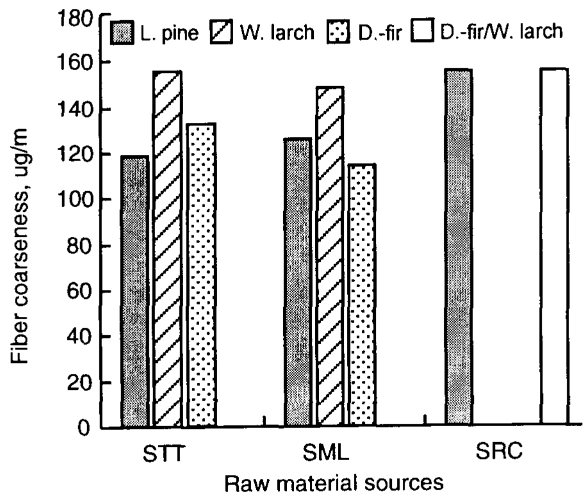

Figure 5—Coarseness of fibers in handsheets of tensile index 90 N•m/g.

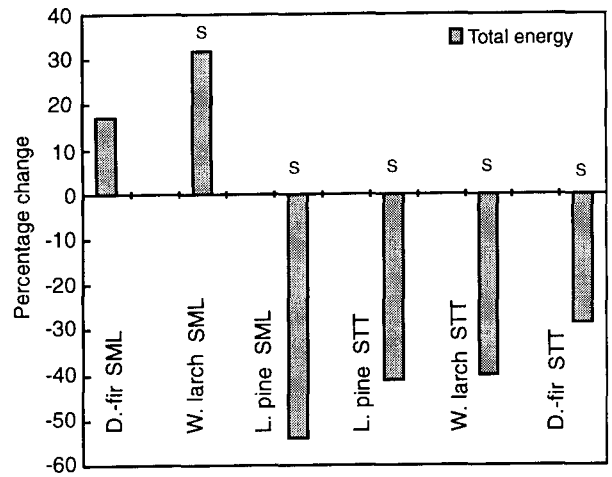

Figure 6—Percentage change from sawmill residues (S means that amount of energy was significantly different than the sawmill residues).

Making comparisons between raw materials was accomplished by computing the percentage of change from the controls (SRC), as shown in Figures 6 through 9. The results of a statistical analysis were also added to Figures 6 through 9, and the presence of a capital S indicates that a specific property was significantly different than the SRC.

Thermomechanical Pulp Preparation and Properties

Energy consumption is traditionally high in preparing mechanical pulp; therefore, any new raw material that reduces energy consumption is desirable. All raw materials in this study used less electrical energy than SRC during pulp preparation, except for the Douglas-fir and western larch SML (Fig. 6). All the differences in energy use compared with the SRC were statistically significant, except for the Douglas-fir SML.

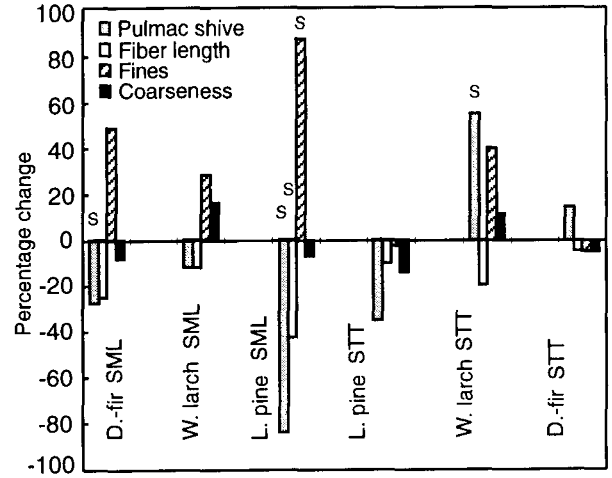

Figure 7—Percentage change from sawmill residues (S means that property was significantly different than the sawmill residues).

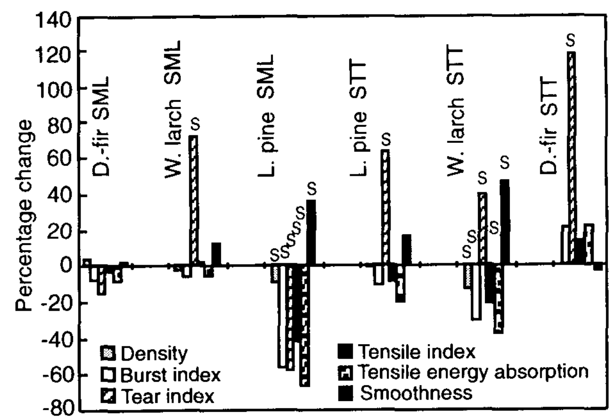

Figure 8—Percentage change from sawmill residues (S means that property was significantly different than sawmill residues).

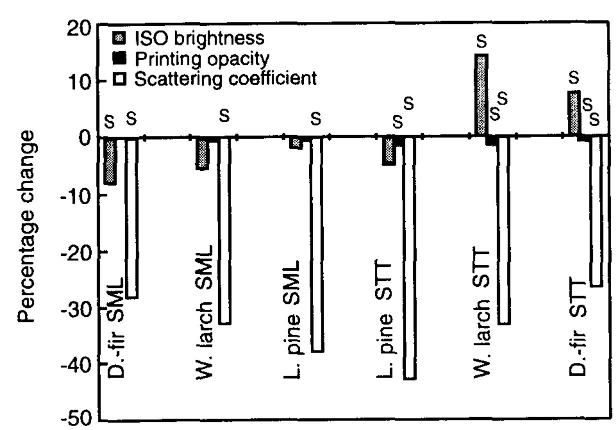

Figure 9—Percentage change from sawmill residues (S means that property was significantly different than sawmill residues).

Pulmac shive declined for all but the western larch and Douglas-fir STT, which showed an increase (Fig. 7). The changes in Douglas-fir SML and western larch STT were significantly different. This implies a more complete fiber-to-fiber separation for the nontraditional raw materials. Fiber length was expected to be shorter, based upon the literature (Zobel and van Buijtenen 1989), for all the nontraditional raw materials (Fig. 7). The fiber length decline for lodgepole pine SML was significant. A reduced fines content is always desirable, but the fines content increased for all nontraditional raw materials other than lodgepole pine and Douglas-fir STT (Fig. 7). The frees might have been generated from fiber breakage and shortening or materials being removed from the fiber surface. Coarseness also decreased for everything except the western larch SML and STT (Fig. 7). Because most western softwood species are rather coarse fibered, a reduction in coarseness might be desirable.

Examination of the combined energy consumption and pulp properties showed that several of the nontraditional raw materials (lodgepole pine and Douglas-fir STT and lodgepole pine and western larch SML) were equal or higher quality than the traditional SRC.

Thermomechanical Pulp Paper Strength Properties

Handsheet density differed <5 percent from SRC for all but the lodgepole pine SML and western larch STT (Fig. 8), which had significant reductions. Most strength properties are density dependent; therefore, this decline could affect the strength properties. Burst index values decreased compared with SRC for all nontraditional raw materials except Douglas-fir STT, and the decreases were significant for lodgepole pine SML and western larch STT (Fig. 8). The most spectacular differences occurred in tear index. Tear index had four large and statistically significant increases and two decreases. The lodgepole pine SML had a large and significant decrease in tear index (Fig. 8). Tensile index and tensile energy absorption (TEA), for the most part, followed the general trend of burst index. The Douglas-fir STT was the only nontraditional raw material to show an increase in all strength properties. Surface smoothness increased for all nontraditional raw materials except the Douglas-fir STT, which had a small decrease.

Based on strength properties alone, the Douglas-fro and lodgepole pine STT appear to be stronger than their corresponding SRC. The remaining nontraditional raw materials were not as strong as their corresponding SRC.

Thermomechanical Pulp Paper Optical Properties

High opacity and light scattering properties are important for mechanical pulps, which are heavily used to produce various printing and writing papers. In general, except for two instances, none of the nontraditional raw materials improved the optical properties of the final paper compared with paper from their corresponding SRC. Brightness decreased for all nontraditional raw materials except western larch and Douglas-fir STT (Fig. 9). Printing opacity was high for all nontraditional raw materials, and even though several changes compared with SRC were significant, the actual changes were very small. Scattering coefficient had some large and significant decreases for all the nontraditional raw materials (Fig. 9). Scattering coefficient is affected by change in fiber length, fines content and characteristics, and fiber-to-fiber bonding.

Conclusions

The principal conclusions for kraft pulp follow:

- The results of this study indicate that STT and SML can be exploited as potential raw material sources in kraft mills. These wood sources produce pulps that have a kappa number comparable with SRC, except for Douglas-fir SML. Pulping Douglas-fir SML together in large quantities with SRC will produce pulp with inherent chemical nonuniformity. The STT species pulped together with SRC in liner board mills (70–100 kappa number range) may produce pulp with significant chemical nonuniformity. Western larch appears to be a poor raw material source due to its low kraft pulp yield.
- The WAFL of unbleached kraft pulps from STT and SML were similar. The SRC produced fibers with moderately higher WAFL and coarseness values than those obtained from STT and SML raw materials. Coarser fibers produced sheets with higher tearing resistance for Douglas-fir and western larch.
- In general, lodgepole pine sheets had higher burst and tensile indexes but lower tear indexes compared with western larch.

The principal conclusions for TMP follow:

- Lodgepole pine and Douglas-fir STT were equal or higher quality than the TMP prepared from their corresponding SRC.
- Douglas-fir and western larch SML produced TMP and paper that were slightly lower quality than their corresponding SRC.
- TMP and paper with the lowest property values were made from lodgepole pine SML and western larch STT.

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Acknowledgments

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Financial Analysis of Ecosystem Management Activities in Stands Dominated by Small-diameter Trees

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Abstract

Cost should be considered in the design of ecosystem management activities requiring the removal of trees, to avoid the cost of preparing plans that cannot be implemented and timber sales that will not sell. This can be minimized by an awareness of the types of treatments, stands, conditions, and harvesting requirements that are likely to result in positive versus negative contribution to the net value of a timber sale. The primary intended purpose of software being developed is to provide a tool to do such an analysis at a stage of planning prior to the preparation of specific timber sales. A tool that makes it easy to do that analysis also would make it easier for planning teams to recognize and carefully consider the tradeoffs made when management objectives are set.

Keywords: financial analysis, sotfware, ecosystem management, planning

Introduction

In National Forests of the U.S. Intermountain West, attainment of ecosystem management objectives often call for removal of small-diameter trees from stands that may or may not include larger trees. Prudent stewardship of taxpayers' financial resources requires that commercial use of these trees be considered as a means to accomplish the management objectives, when it is appropriate and the least costly way to achieve the objectives. Attempts to accomplish these treatments through timber sales have sometimes been unsuccessfull for lack of bidders. Prudent stewardship of taxpayers' money also requires that managers try to anticipate the circumstances that will lead to a lack of interested bidders to avoid the expense of preparing timber sales that do not sell. The purpose of this paper is to describe requirements for an analysis tool that will help foresters and managers determine under what circumstances various stands and proposed treatments are likely to make a positive contribution to a timber sale from the perspective of a potential bidder. This model is being developed as part of the Colville Study (Barbour et al. 1997).

Criteria for an Analysis Tool

A well-designed analysis tool will provide information relevant to the issue, use data that is reasonably available at the stage of planning where it is intended to be used, use terminology and concepts appropriate for the intended users, and provide flexibility in fitting the level of detail to the user. The analysis tool we are developing, Financial Evaluation of Ecosystem Management Activities (FEEMA), was designed with these criteria as guiding principles.

Planning Stage

Planning and analysis tools already exist that are intended to be used in a production mode to prepare every timber sale (Schuster et al. 1995). These tools focus on how to combine stands into timber sales. They use the regional timber sales transactions database as their starting point. They do not easily deal with the effect of product options and product grade mix on revenue potential. They also do not easily provide descriptive information on how stand attributes, silvicultural prescriptions, and harvesting systems interact to affect harvesting costs. My focus is on an earlier stage in the planning process, and the intent is to provide a tool to help managers examine the financial viability of a range of forest operations in various stand types. A better understanding of the potential profitability of stands should make the timber sale planning process more efficient and cost effective.

Criteria

The potential profitability of stands is viewed from the perspective of a timber purchaser. It is affected by the things that affect the potential revenue from products made from timber and the things that affect the costs of harvesting and processing the timber. Important factors for potential revenue include the type of products that can be made from the timber, the tree attributes affecting the volume and grade recovery of products, and the market conditions affecting product prices. Important factors for harvesting costs include tree size, volume of timber per hectare, the type of harvesting system required, and the accompanying activities required by the sale contract, such as erosion control measures and deposits for future activities. Important factors for manufacturing costs include the product produced, the mix of log sizes, and mill performance characteristics. A useful indicator of profitability of a stand is the projected net return to a purchaser from a timber sale composed of identical stands under specified assumptions about harvesting methods, sale requirements, and market conditions.

Data requirements

Ecosystem management objectives and desired future conditions for large areas are considered in a planning step typically done by an interdisciplinary team. At that stage of planning, the data available on many forest stands will be plot data from stand examinations that include an estimate of the number of trees by species and diameter with a small sample of tree heights. That constitutes the minimum stand data requirements for use of FEEMA. Missing heights will be estimated with a regression equation developed from the data provided for that stand. If there are no measured heights or an inadequate number of measured heights for some species, the user can specify that the trees of that species be combined with another species for which there are sufficient measured heights to develop the regression equation. Other variables that may be useful in predicting product volume and grade recovery are provided for, but their use is optional (fig. 1).

Level of detail in results

It is expected that developing an understanding of the relative profitability of different types of stands would be done through analysis of representative stands rather than analysis of every stand. The analysis might be done under different assumptions about mill product mix and market conditions. The simplest level of product detail would be to buck the trees into logs and price by species and log diameter, if desired. If product information is desired, the user will be able to specify the allocation of logs to product types or allow the program to allocate logs to the product having the highest net return. If pricing is by product, it is necessary to estimate manufacturing costs. Manufacturing cost tables will be provided with the program but also can be entered by the user. Manufacturing cost is entered by species and product type and can differ with log size if desired (fig. 2). The simplest level of harvesting cost is to specify a cost per hectare or a cost per unit of cubic log volume. If more detail is desired, harvest cost tables that differ with tree size and volume per acre can be used (fig. 3). Various other cost components can be specified individually by unit of area or unit of volume (fig. 4). Once the level of detail in harvesting costs and products is set, various levels of detail are available in program output. The most basic summary is a listing of various cost and revenue components with an estimated net value for stumpage (fig. 5). Other available output includes tables of gross value or volume for trees by species and diameter class (fig. 6), tables of net value or volume for logs by species and product type (fig. 7), and tables of gross value or volume of products by species and product by grade (not shown). It is anticipated that most users will find sufficient detail in the standardized tables. If users want some combination of information not in the standardized tables, they have access to the files from which the summary data was drawn. Those files can be read into a spreadsheet or a database for further analysis or manipulation.

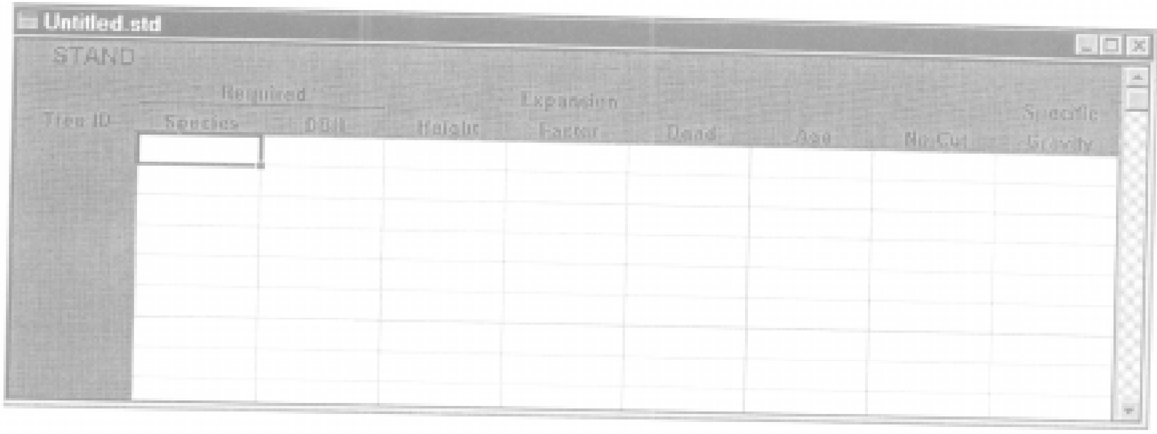

Figure 1—input form for stand data. Only species and diameter breast height (DBH) are required for all trees.

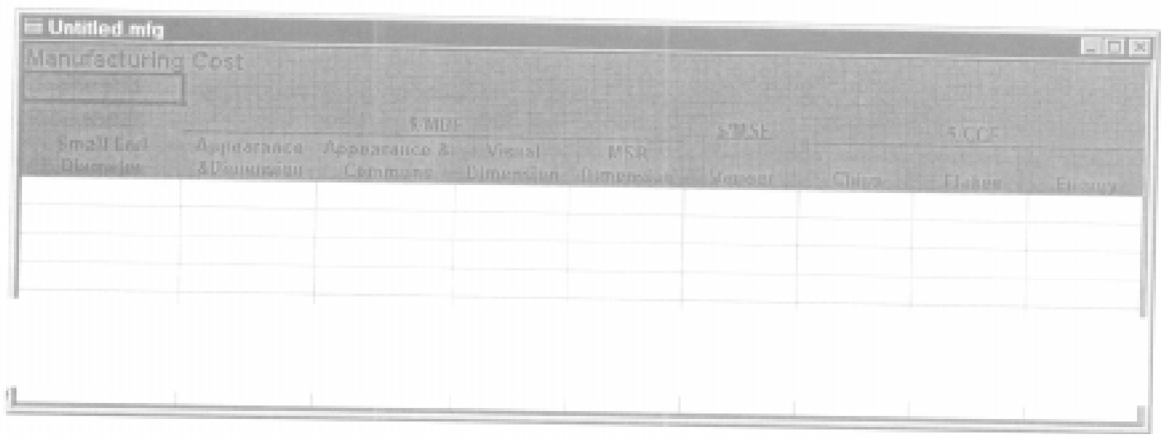

Figure 2—Input form for manufacturing costs. Costs can differ with small-end diameter of logs.

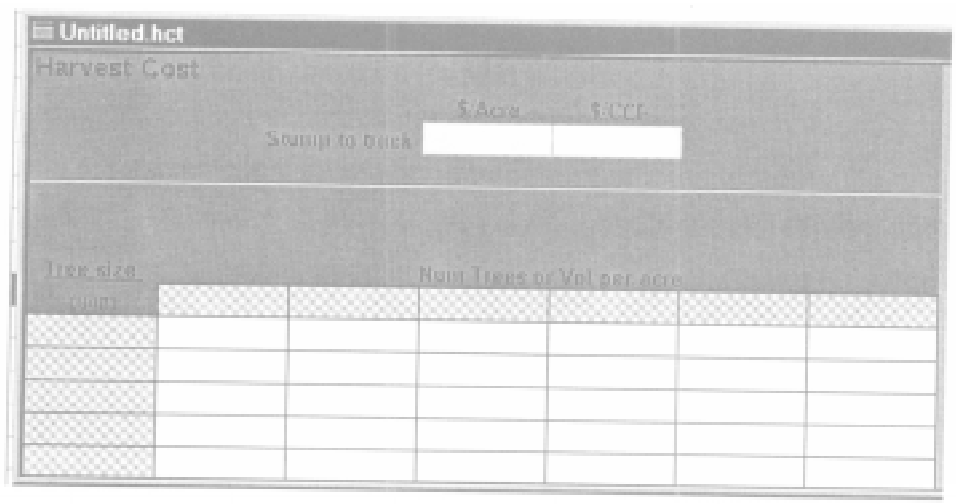

Figure 3—Input form for stump-to-truck harvesting cost. Cost can be entered as a unit cost (top of form) or as a table by tree size and per-acre quantity (bottom of form).

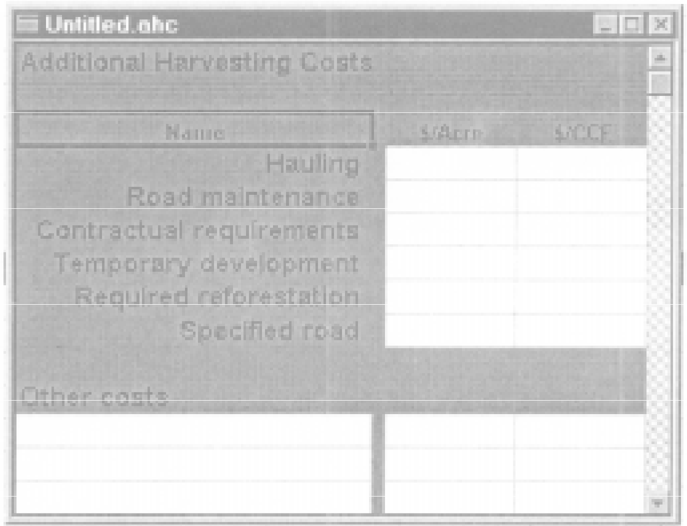

Figure 4-Input form for additional harvesting costs. Costs not specifically listed on the form can be added in the blank lines at the bottom of the form.

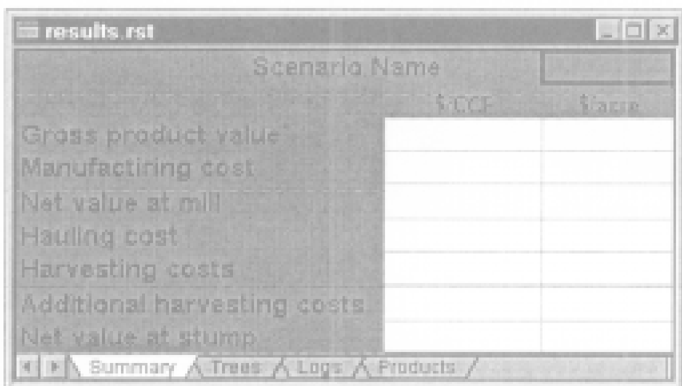

Figure 5-Format for table of summary results.

Conclusions

Although FEEMA calculates residual values for stands and can allocate logs to products based on highest net return, it is neither an appraisal nor a merchandising tool. The level of resolution is keyed to the needs of planners who are trying to make decisions about silvicultural prescriptions for stands dominated by small-diameter trees. If it proves useful to planners in determining the relative profitability of stands under predefined silvicultural prescriptions, it may also prove useful in thinking about the tradeoffs involved in modifying prescriptions to increase the financial feasibility of creating the desired future conditions.

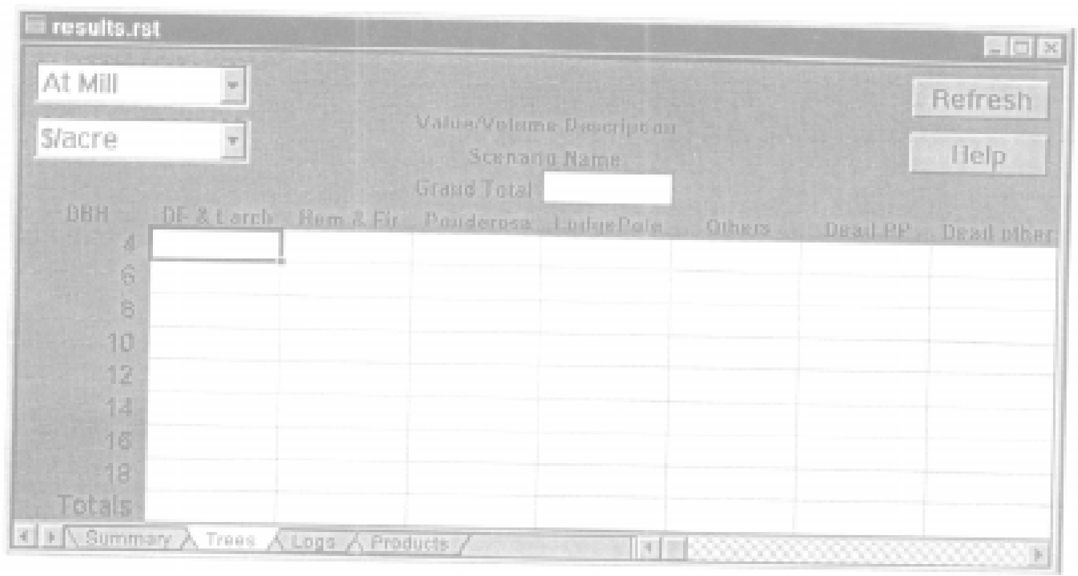

Figure 6—Format for table of volumes or values of trees by species and DBH

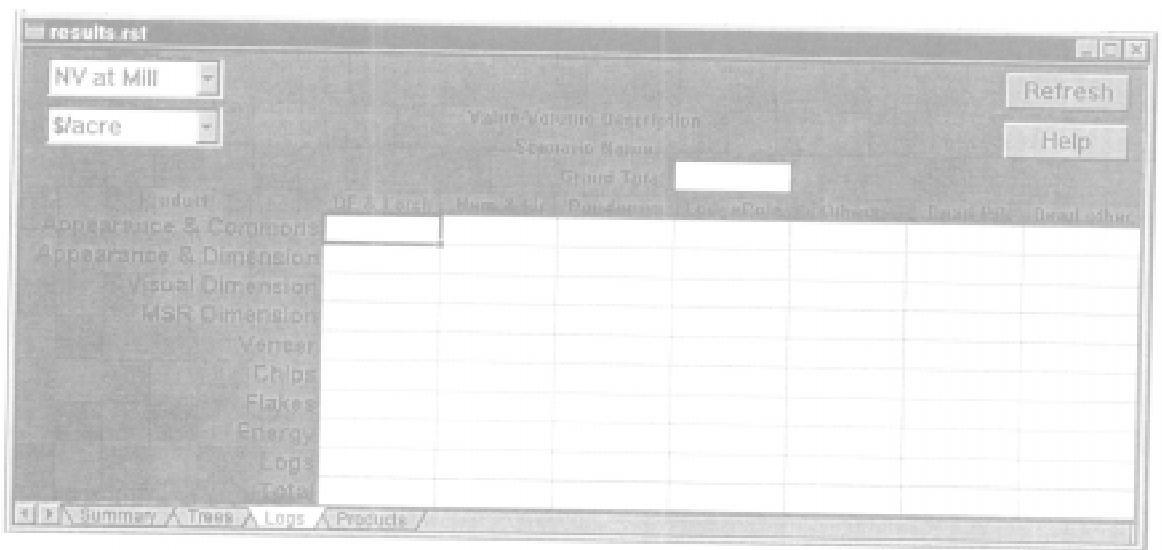

Figure 7—Format for table of volumes or values of logs by product and species.

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Strategies for Sustainable Wood Supplies in the Changing Indian Scenario

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Abstract

Indian forests produce nearly 12 million m^3 of industrial wood against an annual country requirement of over 25 million m^3 Although timber yielding species number 400-500 making India biologically rich. Timber species available on commercial scale number over 150. This large variety available in mixed form makes their utilization difficult due to identification and processing' problems. Deficit in wood supplies is met by imports and other forest and non forest resources like bamboos, palms, canes and plantation woods like robber wood, eucalyptus, babul, poplar, etc.

Wood prices are relatively lower in the country, which has been responsible for inefficient and unscientific use of wood. Significant losses occur in various stages of handling/storage transportation/processing, manufacture and utilization. Scientific practices can cut down residues and proven technologies can reduce wasteful use making available resources to the tune of 8,5 million m^3 annually. Additional resources exceeding nearly 4.4 million m^3 can be generated by adopting wood preservation treatments alone. The total timber so saved (12.9 million m^3) can thus augment supplies by nearly 50 percent and release pressure on forest.

Key Words: India, wood preservation, waste reduction, supply enhancement

Sustainable Forestry and People's Participation: A Case Study of India

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Abstract

India's existing systems of forest management are failing to sustain natural forest ecosystems. Lands at imagery indicates that India's remaining natural forests are being rapidly degraded. As forest resources are depleted, communities dependent upon them are impoverished. As forests are lost, hundreds of millions of rural people loose sources of fuel, fodder, food saw materials for village industry, medicines and shelter. As the vegetative cover is removed, soil and water are lost, leaving the land drier and less fertile. The importance of India's natural forests in meeting the needs of her vast rural population is immense. If the government has to pay for this support it would no doubt cost hundreds, even thousands of cases of rupees. Deforestation and the poverty, displacement and disruption it causes can also result in economic and political instability.

This paper indicates that forest department efforts to establish participatory management system have been most successful in areas with committed field staff who receive strong encouragement from their senior officers. The state forest departments have begun to encourage the spread of strategies like joint forest management. Participating communities and foresters agree that while the joint management of reserved and protected forests offers a new hope. It is important that forest departments and communities have commitment and flexibility to work cooperatively to evolve effective management system.

"The Green Certification": Chances and Challenges for Central European Forest Industries

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Abstract

Similar to the process in the U.S. in Central Europe forest industry, trade, unions, buyers and environmental groups have a common commitment to the principle of sustainability, driven by the responsibility for the environment as well as a justified degree of self-interest (protection of resources).

The certification of sustainable managed forests (sfm) and the labeling of timber and timber products, originating from these forests, is a market-orientated incentive, combining two functions: (1) a steering function for encouraging ecologically, economically and socially sfm, and (2) a marketing function, to be utilized for competitive advantage of non-certified products in the interest of sfm.

Induced by issues of the rapid deforestation in the tropics some 5 years ago especially in Germany strong conflicts existed between forest industry and calls for boycott and abandonment of wood consumption. Today the idea of certification is developing faster in Europe than in the USA, partially due to the influence of consumers organized by environmental groups like WWF. The crucial question in Central Europe is no longer whether but how to put certification and labeling into practice.

While U.S. forest products industry has largely chosen the second-party certification scheme, the European stakeholders are mainly orientated to operate under a third-party certification scheme like FSC or ISO provide, which they feel is the more credible way.

Questions to be answered are in the field of national forest policy (willingness for international harmonization, sponsoring), in the area of technical implementation (verification of "chain of custody"), in research (definition of regional and local standards of sfm; how to cover audit costs / license fees?), in stakeholder groups (joint cooperation of small scale forestry?). Further more questions due to the structure of Central European timber industry (small to medium sized business with a high degree of specialization) are in marketing (would high audit costs scare off small forest owners and businesses? Certified products for a broad market or for niche markets only?). These questions have to be solved as the system is put into practice and resolved through adjustments to the system.

Key Words: certification, labeling, sustainability, marketing

Collins Pine Company—57 Years of Sustainable Forest Management

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Abstract

Collins Pine Company has managed the 94,000 acre Collins Almanor Forest since 1941. The land is located about 20 miles south of Mount Lassen National Park, in northeastern California. This forest produces a sustainable harvest of about 30 million board feet or one-half the annual log requirements for its mill located in Chester, population 1,700. At 4,500 feet, Chester boarders the 34 square mile Lake Almanor, with the surrounding forest land ranging from 3,800 to 6,000 feet in elevation. The forest is managed in two blocks, because they had very different stand structures at the time of purchase by Collins Pine Company. The 77,000 acre Chester block was purchased around 1900, in pristine condition, with timber harvesting beginning in 1941. The Wolf Creek block, around 17,000 acres, was purchased in 1946 in a cut over condition, with most trees over 20 inches in diameter at breast height (DBH) having been logged. Management will eventually bring both blocks to a similar stand structure. An unevenaged silviculture system and natural regeneration has been used for 57 years to manage the mostly Sierran Mixed Conifer vegetation on the forest, with average stand volume of 18,500 board feet per acre, and over 150 square feet of basal area. Sugar pine is about 26 percent of the stand volume, with ponderosa pine at 19 percent and white fir around 40 percent. Douglas-fir and incense cedar make up the remainder of the volume. Tree sizes range from one to over 50 inches DBH and tree ages from one to 400 years. Merchantable trees are over 80 years old and at least 11 inches in DBH. For sustainable wildlife populations, the forest has more than adequate numbers of small snags under 24 inches DBH, large woody material over 24 inches large end diameter, and complete coverage of litter on the forest floor. A short term management goal is to slightly increase the number of large snags, over 24 inches DBH. Most of the forest is in mid to late seral structural condition, though the horizontal and vertical structural diversity is high within stands.