THE ROLE OF TECHNOLOGY IN CONSERVATION AND SUSTAINABILITY[1]

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ABSTRACT

Forests play a vital role in the environmental and economic health of North America. However, pressures on these forests have never been greater. Although progress has been made in understanding and addressing many questions pertaining to sustainability, the dilemma of how to best achieve a balance of environmental and economic goals continues to set the broad context for resource management issues. Sustainability of forestry is clearly influenced by several interrelated trends: (1) international expectations, (2) increasing demand for forest usage, (3) a changing forest resource, and (4) increasing environmental concerns. Demand for all uses of forests will increase because of a growing economy and population. People need products and services from forests, they want jobs, and they expect a clean environment. This puts us on a collision course between resource capacity and people's needs. Aside from population controls or much more stringent consumption controls (both of which appear unlikely), conservation will play a strong role in fostering sustainability. Technology aimed at conservation, although no panacea, is a rational choice for mitigating environmental impacts in the near term and, properly focused, will be a vital part of long-term solutions. Whether technology is used to protect or merely exploit the natural environment will be one of the most challenging policy choices of the 21 st century. Recognizing this distinction is the key to the appropriate development and application of technology.

INTRODUCTION

Forests play a vital role in the environmental and economic health of North America. However, pressures on these forests have never been greater. Population continues to grow with an associated increase in demand for paper and wood products. At the same time, there is increased recognition of the importance of noncommodity forest values such as air quality, water purity, recreation opportunities, carbon sequestration, wildlife habitat, and even spiritual values, that directly impact the quality of life for all people.

Many of these forest benefits are complementary, but some are not, which leads to increased competition and conflict. In the United States, competing uses of forests continue to be debated. This same debate is also taking place on a global scale beginning with the United Nations Conference on Environment and Development (UNCED) in 1992. Discussions at UNCED led to the recognition of sustainability as the overarching issue facing the world, and the recognition that environmental, economic, and social issues cannot be separated. Further, global prosperity and long-term sustainability are dependent on our ability to address all three issues.

Although progress has been made in understanding and addressing many questions pertaining to sustainability, the dilemma of how to best achieve a balance of environmental and economic goals continues to set the broad context for resource management issues. In this paper, we examine some of the driving forces that are affecting resource

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debates, discuss the interrelationships among them, and discuss the ways they are being addressed from a technology standpoint in the United States.

DRIVING FORCES

The forces that are affecting natural resource issues arise locally, nationally, and globally. International issues such as trade barriers among countries, national issues such as population demographics and shifts in political ideology, and regional issues such as water scarcity and forest health in the western United States are intertwined to create unpredictable situations. Understanding the trends in these forces is a start to understanding the overall complexity of true sustainability.

International Linkages and Expectations

Sustainable Development took center stage in many international forums as a result of the Earth Summit (UNCED) held in Rio de Janeiro, Brazil, in 1992. At the Summit, 120 nations agreed on an outline to sustain global development, a plan known as *Agenda 21*. The plan is based on the understanding that global economies, ecosystems, and human needs are inextricably linked.

In addition, UNCED participants agreed to a set of forest principles, they promoted conventions on climate change and biodiversity, and they established the United Nations Commission on Sustainable Development. These have become forums for international dialogue on forests and the role of forests in today's global society. The discussions from these forums, as well as increased interest and concern about environmental issues, have turned U.S. domestic dialogue towards sustainability as well. And, in 1993, the United States announced its intent to achieve sustainable forest management by the year 2000.

Increasing Demand

The demand for renewable resources is driven largely by population, economic activity, and income [1]. Although global population growth rates have declined during the past couple of decades, the actual number of people added to the world every year is about 90 million, the equivalent of another United States every 2 1/2 years [2]. In the United States, we are anticipating an additional 70 million people by the year 2040 [3]

Perhaps more significant, from the standpoint of the demand on our forests, is the fact that the total world economy is growing faster than population growth. The World Bank estimates that within the next 30 years, the average per capita income worldwide could reach the level of the richest one-fifth of the world in 1990. Although exact numbers may be arguable, it is apparent that world markets will grow, economies will grow, and the conflicts about economic growth and maintaining the highest quality living environment will increase [2].

Supporting this thesis, Jaakko Poyry forecasts that consumer demand for pulp and paper products in developing countries will grow as a function of increasing population, literacy rates, and standard of living [4]. In the United States, long-range projections indicate modest growth in annual per capita consumption from 270 kg/person in 1973 to more than 400 kg/person by the year 2040 [3].

The expanding population and world economy are not only influencing increased demand for pulp and paper products but also housing. One-tenth of the global economy is derived from constructing homes and offices, Globally, housing construction accounts for more than a quarter of the world's demand for solid wood in products [5].

Residential construction is the dominant market for the solid wood sector in the United States. Although anticipated demand for housing starts in the United States is projected to be relatively stable for the second half of this decade, the size of houses is changing. During the past 40 years, the average size of single-family housing units has nearly doubled, offsetting any trend of declining wood used per square meter of floor area [6].

In addition to wood and fiber products, forests provide other direct-use benefits. Forest-based recreation, for example, continues to increase, with more than 295 million recreation visitor days of use on National Forests in 1993 [7]. Recreation demands are projected to increase almost 65% by 2040 [8]. Direct uses are also broadening in scope to include commercial use of forests for specialty products, ranging from mushrooms and greenery to aromatics and medicinals [9].

More attention is also being placed on the indirect benefits of forests. Increasingly, forests are recognized as "environmental capital", which includes watershed protection, nutrient cycling, a moderating influence on global climate, and a repository for biological and genetic diversity. Many see these indirect values as the foundation for sustainability that will in turn provide the basis for a wide spectrum of resource benefits.

Changing Resource Base

Forest conditions in the United States have changed over time in response to changing human demands, resource management, and environmental laws. These influences have resulted in substantial shifts in the type, location, and quality of timber, but forests have proven to be both dynamic and resilient. Forested areas in the United States have remained relatively constant since about the 1900s, and the total timber supplies have actually increased during that same period [10].

The growth-to-removal ratios for the United States are positive for all species (1.33), for softwoods (1.09) and for hardwoods (1.80) indicating more growth than removal. The ratios in the North are very high, indicating continued substantial increases in growing stock volume. The softwood ratio for the South, which was 0.88 in 1991, has been declining. This is the first time since 1952, when data was first collected, that removals exceeded growth in the South. The growth/removals ratio in the Rocky Mountains exceeds 2.00, and for the Pacific Coast, it is 1.14 [1]. The types of trees included in these growth figures have changed; they are generally smaller and of lower quality, and there are more hardwoods then the traditional mix of timber that has been available for wood and fiber products.

Available timber from Federal lands, particularly in the Pacific Northwest, has decreased in the past decade due to the endangered species act and other legal and administrative requirements. The volume of timber sold by the USDA Forest Service declined from 9.25 billion board feet in 1990 to 2.8 billion in 1995 (billion = 10^9). This resulted in a decrease in short-term timber supply of about 10%. This decline will have an even larger impact on softwood lumber production since much of the timber from public lands is manufactured into lumber [11].

There is increasing concern regarding the health of forests in the United States. Although growth continues to exceed harvests, total forest growth on timberland declined about 2% between 1986 and 1991. The entire decline was attributable to softwoods, but this was the first forest decline since data have been compiled [3].

Many second-growth stands in the western United States, where tire has been excluded for many decades, now contain dense overstocked understories. Stress from prolonged drought in the west combined with infestations by insects and pests have left some stands with significant amounts of dead and dying material, which has caused a tremendous buildup of fuel. Between 1986 and 1991, timber mortality increased almost 25% [12]. Improving the composition of these stands will require reducing some of this understory material through prescribed fire or removal.

The maturing hardwood forests in the East provide an opportunity to help offset the harvest reductions in the West and to reduce the pressure of heavy harvesting in the South. These stands are, however, a challenge for managers. Many of them are in need of silvicultural treatment, but there are limited markets and low demand for the small, poor quality material that needs to be removed.

Increasing Environmental Concerns

People expect a wide variety of wood and fiber products for daily uses, but they also want clean air and water, unspoiled lands, and healthy forests. The public, however, continues to link environmental degradation with production and use of wood and fiber products. The typical concerns of the public in North America include the loss

of wildlife and fish habitat, aesthetic impacts, forest fragmentation, loss of biological and genetic diversity, and replacement of natural forests by plantations. In an independent study recently conducted for the World Business Council for Sustainable Development, nongovernmental organizations and environmental groups shared these same concerns about the production and use of paper [13].

With more than 80% of the U.S. streams having problems with water quantity or quality [1], protection of watersheds from nonpoint sources of pollution continues to be a concern. There are many nonpoint sources, but sedimentation resulting from forest roads and harvesting is frequently identified as a key problem. Since the passage of the *1972 Clean Water Act,* point sources of water pollution have been reduced dramatically. Water scarcity, although not generally attributable to forestry, remains a key issue affecting management decisions throughout the Intermountain West.

Air quality, though less linked to forestry and forest products than water quality, also continues to be an issue. Environmental concerns related to SO, emissions during kraft pulping have precipitated a shift towards regulations that add costly pollution abatement procedures.

The *1992 Clean Air Act* in the United States placed great emphasis on eliminating ozone and other noxious gas components, such as volatile organic compounds (VOCs). The forest products industry is one of the largest manufacturing sectors contributing to the emission of VOCs, primarily through drying of wood and chips (Fig. 1). In addition to these manufacturing issues, concerns about emissions from nonformaldehyde-related VOCs have been increasing for the past two decades. In newer, energy-efficient buildings, air exchange rates are low, permitting VOC concentrations to increase to potentially unhealthy levels. Adverse health affects, generically referred to as "sick building syndrome", have been associated with the increased levels of VOCs.

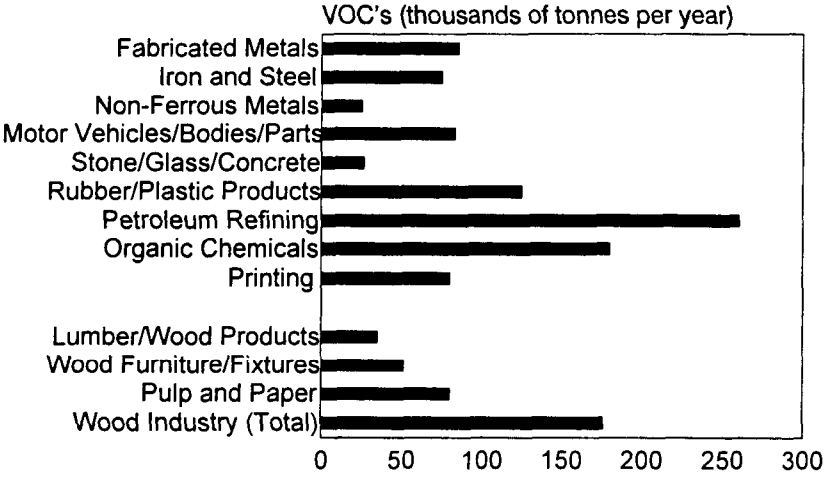

Figure 1. *The forest products sector continues to be a major contributor to VOCs*

Aesthetic impacts have a major effect on public attitudes toward forest management and directly impact the types of silvicultural prescriptions that will be available in the future. Sometimes, these aesthetic issues are interrelated with ecosystem functions or wildlife or fish habitat issues, but often they are solely issues of visual quality.

RESPONDING TO THE DRIVING FORCES

People need products and services from forests, they want jobs, and they expect a quality environment. The pressure for technology, management, and policy direction is framed in this socio-economic context. These factors are intertwined, affecting policy and management decisions and technological innovation that, in turn, reshape the driving forces.

International Linkages and Expectations

A part of the international forestry discussions has been the question of how to define sustainable forestry and measure progress towards achieving this goal. Various countries have joined together to develop sets of criteria and indicators to help characterize and measure sustainable forestry. The United States and Canada are part of the Montreal Process group, which includes 10 other temperate and boreal forested countries, while the Helsinki Process involves European nations, and the Tarapoto Agreements involve Amazonian countries. The Montreal Process criteria and indicators were agreed to in the Santiago Declaration of February 1995. Technology is directly involved in measuring sustainable forest management [14].

Also driving the issue of sustainable forest management is the worldwide increase in public demand for assurances that wood products such as logs, lumber, paper, and finished products have been produced from sustainably managed forests. The idea of certification is affecting every region of the world and is precipitating analysis of the potential implications on policy and trade.

Increased Demand

Development and implementation of cost-effective conservation technologies through research continues to be a sound strategy to achieve the goals of meeting the needs of people for wood and fiber while avoiding undue pressures on forests. Specific examples include research that improves utilization, increases recycling, and increases durability of products.

Improvements in wood utilization, including harvesting and processing, have demonstrated significant savings in forest resources. Since the turn of the century, the ratio of product output to resource input (Fig. 2) has been increasing [15]. Because of previous successes, continuing to reduce material losses will become more difficult; but the lag between the development and implementation of technology will probably allow the trend to continue for some time. The greatest opportunity for research to contribute great benefits will probably come in improved design and engineering of wood products that will allow more efficient structural applications.

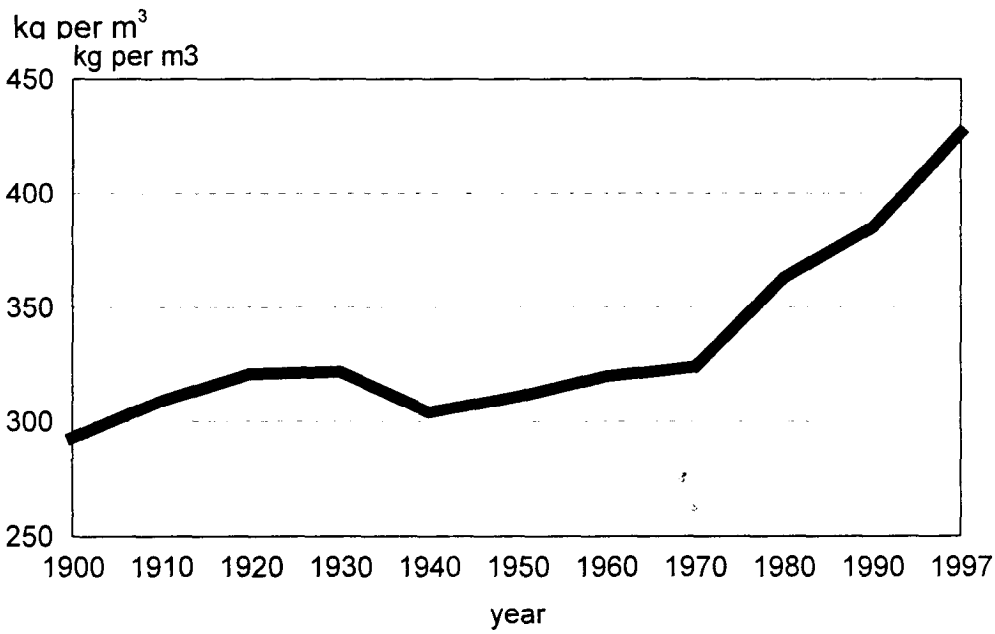

Figure 2. *Ratio of product output to resource input has increased since the turn of the century. A major challenge facing scientists is continuing to find new ways of extending our resources*

Today, engineered wood products and composites contribute to effective and efficient use of the forest resource by reducing material losses during primary processing and allowing use of a more diverse fiber base. Strength properties of engineered and composite wood products are also less variable. Therefore, products do not have to be overdesigned to account for the effects of variability. The use of engineered wood and composite products is expected to grow in the areas of laminated veneer lumber, oriented strandboard, and medium-density fiberboard (Fig. 3) [16].

Recycling has had a profound impact on extending the forest resource. In 1986, 28% of the paper and paperboard consumed in the United States was recovered for recycling. The rate of paper and paperboard recovery for recycling is projected to reach almost 50% by 2000 and almost 60% by 2040. These increases in paper recycling indicate that recycling could offset projected increases in pulpwood consumption [17]. Housing offers a large potential market for recycled products, but technological barriers exist that impede their use in housing components. Before these recycled products are accepted for use in housing, for example, material and engineering properties need to be defined. Products must meet performance specifications, and we must ensure that codes and standards are in place to assure safety.

Increasing the durability of wood and fiber products through preservation, finishes, and proper construction practices has also been effective at extending the forest resource. New preservative techniques are being developed that increase the service life of wood and fiber products under a variety of exposure conditions and improve the resistance of wood-based materials to moisture. Recent advances in nondestructive technology have allowed the evaluation of on-site wood members for decay and residual strength, avoiding unnecessary removal of wood members.

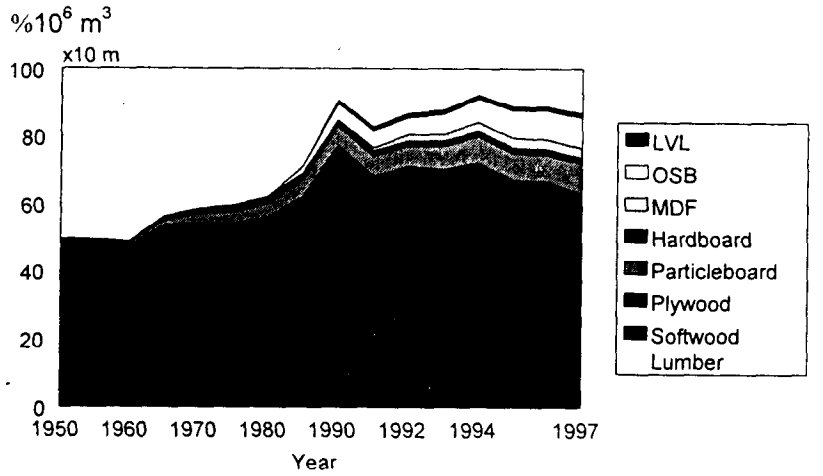

Figure 3. *U.S. Lumber and Wood Composite Production (LVL is at the top, and the progression downward matches that* ***of*** *the legend).*

Changing Timber Resource Base

Resource managers are faced with a changing resource, a variety of forest health issues, and some indication of less productivity. Recent inventory statistics indicate that mills producing wood and fiber products will have to adjust to a resource based on fewer softwoods, more hardwoods, and material that will generally be smaller and of lower quality than the traditional resource.

The proportion of hardwoods available to mills will increase, but much of this material is of lower than usual quality. To effectively use this material in structural applications, grading rules similar to those for softwoods are

needed. Advances in science and technology have allowed development of new products, such as oriented lumber composites and wood-plastic composites, that are more adaptable to being made from a diverse hardwood supply.

Changes are anticipated in the type of wood products that will be used for housing [18]. Much of the increased demand in the United States will occur in the structural and nonstructural panel markets. Oriented strandboard and waferboard are increasingly being substituted for softwood plywood. Science and technology helps assure that these products are more flexible in using a diverse raw material base. The structural and nonstructural panel market is expected to increase, while the traditional lumber market will be stable or maintain slight growth. The use of engineered wood products is increasing dramatically. The market for laminated veneer lumber, patented in 1970, has steadily increased to about 1 million m^3 in capacity and continues to grow. Although these products are able to use a diverse resource with some low quality material, they also require a proportion of high quality material.

Restoration of forest health is a nationwide resource issue and a priority for the USDA Forest Service, particularly in the western United States. Many western forests have been altered over time by fire suppression, infestations of pests, and severe droughts. These conditions have led to tremendous volumes of dead material. In stands with dense, small-diameter suppressed understory as well as dead and dying material, forest restoration will require reduction of woody biomass. Technology is needed to effectively convert this previously unused material into products. If the material can be used effectively, a portion of the cost of restoring these ecosystems can be offset.

The use of this small and low quality material for energy generation has proven to be effective in a number of locations in the West. Several National Forests in California have employed various types of contracts to reduce risk of severe fires and help defray costs of management while accomplishing “nontimber” objectives. The material is currently used for direct combustion, but research continues to develop alternative fuels such as ethanol [19].

Environmental Concerns

To reduce environmental degradation, we must avoid adverse environmental impacts during the extraction of wood from the forest, during primary processing, and while the product is in use. Pollution abatement currently emphasizes controlling releases and cleaning up pollution that is in existence. In the future, however, emphasis will be on developing technologies that are designed to avoid generating pollutants during the manufacturing process, such as nonchlorine bleaching and nonsulfur pulping.

Eliminating the use of toxic materials to prevent the decay of wood is a major challenge for the wood products industry. Although wood preservatives can extend the durability of wood products, they can also create environmental and health hazards if not handled properly. New environmentally benign treatments are needed to replace toxins such as compounds that contain pentachlorophenol and arsenic. Research is focusing on compounds that interfere with the reproduction and growth of fungi, by inhibiting the metabolic pathways of wood-degrading fungi.

Kraft pulping accounts for more than 80% of the wood-based pulp produced in the United States and is the dominant pulping process worldwide. Kraft pulps are suited for a wide variety of softwood and hardwood species, producing paper and paperboard with high strength. Organic sulfur compounds and mercaptans are produced during the pulping operation, driving a need to find alternatives to kraft pulping. New technologies have been developed that can help solve this problem, such as biopulping, which uses white-rot fungi to partially delignify wood, and nonsulfur-based chemical pulping technologies.

In the United States, more than 30 million tons of bleached or semibleached kraft pulps are produced each year. In addition, a substantial portion of the 29 million tons of recycled paper produced must also be brightened before it can be reused. Technologies are needed to eliminate use of chlorine and chlorine-based chemicals. Technology developments using oxygen, peroxide, and ozone show promise but must be carefully applied because they are not selective for lignin. New technologies using polyoxometalates show promise because they are selective for lignin and are nonchlorine based [20].

In the pulp and paper industry, capital investments have been made to install primary, secondary, and even tertiary water treatments. In addition, the pulp and paper industry is moving to a "closed mill" concept. A key technological obstacle to closed mill systems, however, is chlorinated hydrocarbons from pulp bleaching. Black liquor from the pulping process, along with waste wood, continues to be a source of energy for plants that are conserving resources and reducing pollution. The use of black liquor will be limited in the future by production of paper and solid wood,

Research is helping to overcome the environmental impacts of VOCs attributed to wood and fiber products processing and end-use applications. Analytical procedures are being developed for measuring the types and quantities of VOCs emitted, the effects of processing steps and conditions on VOC emissions are being quantified, and new wood finishes that do not contain VOCs are being developed.

An overarching environmental issue is how to maintain existent ecosystem functions and processes while continuing to produce commodities. One way of addressing this broad issue is through an ecosystem-based approach to resource management, but the role of technology in helping implement ecosystem-based activities is not always obvious, Harvesting activities and roads are two areas most often criticized from the standpoint of environmental impacts. Sedimentation in streams, visual degradation, and loss of stand structure can result from harvesting. New types of equipment, such as cut-to-length systems and "walking" harvesters, are examples that will allow managers to carry out harvesting or other forest operations while minimizing soil compaction and damage to residual trees. Visualization technology, which incorporates geographic information system (GIS) data into computer models, is an important tool for viewing simulated management activities over time.

SUMMARY AND CONCLUSIONS

Some trends seem to be certain and predictable. Demand for all uses of forests, for example, will increase because of a growing economy and population. People need products and services from forests, they want jobs, and they expect a clean environment. This puts us on a collision course between resource capacity and people's needs. As Robert Shapiro of Monsanto Corporation puts it, "Our nation's economic system evolved in an era of cheap energy and careless waste disposal, when limits seemed irrelevant. None of us today whether we're managing a house or running a business, is living in a sustainable way. It's not a question of good guys and bad guys" [21].

Aside from population controls or much more stringent consumption controls (both of which appear unlikely), conservation will play a strong role in fostering sustainability. Technology aimed at conservation, although no panacea, is a rational choice for mitigating environmental impacts in the near term and, properly focused, will be a vital part of long-term solutions.

Whether technology is used to protect or to exploit the natural environment will be one of the most challenging policy choices of the 21 st century. The decision of which path to pursue does not rest in the hands of one government or one sector of society. Rather, the decision lies in the collective actions of individuals throughout the world. Recognizing this distinction is the key to the appropriate development and application of technology [22].

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