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# Forest Sustainability: An Approach to Definition and Assessment at the Landscape Level

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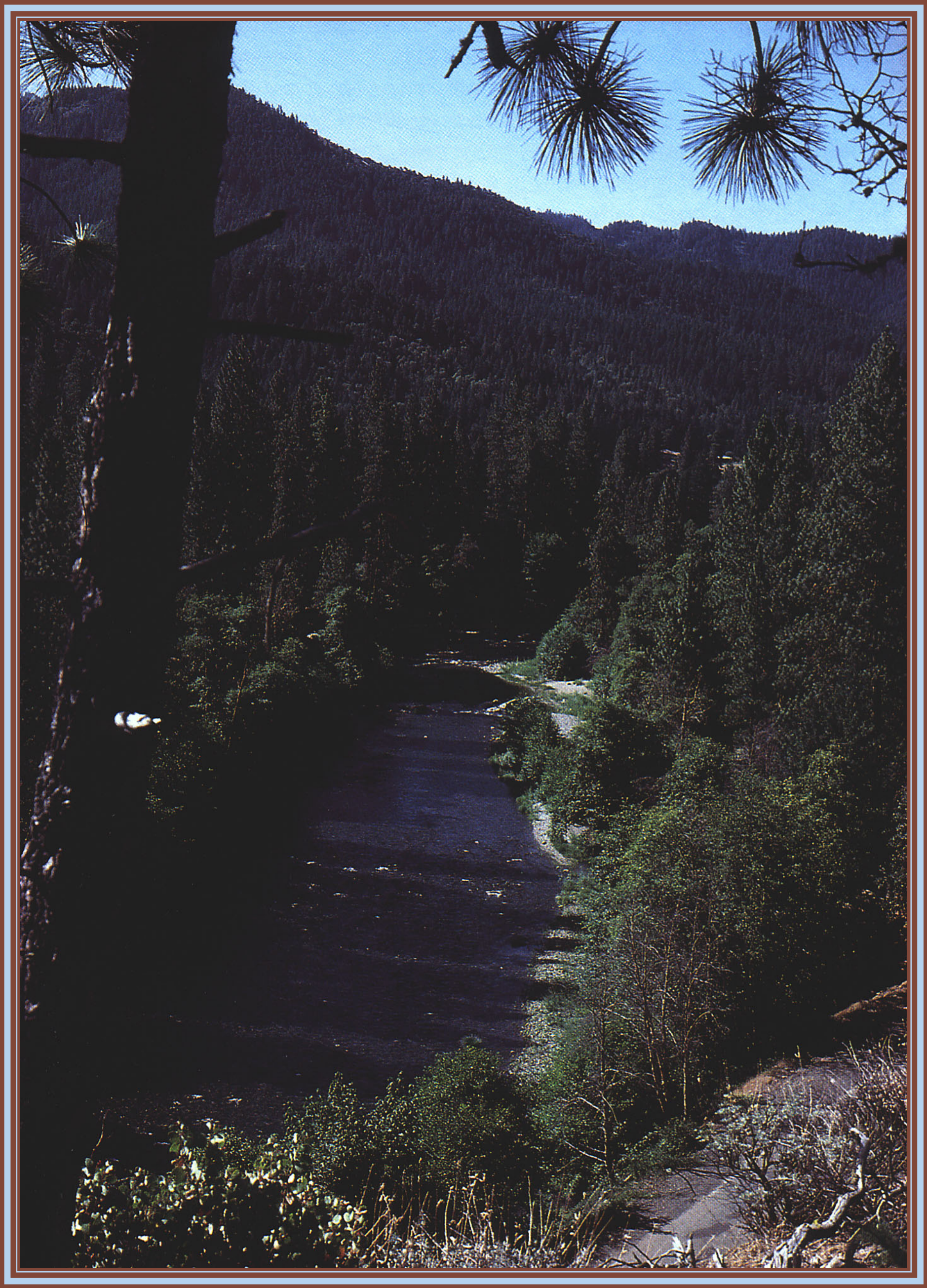

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## Abstract

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Forest sustainability is a concept for the desired condition of forest ecosystems all over the world. The essential aspects of sustainable forests differ tremendously, however, among peoples of the world. Parks and wilderness areas, wildlife preserves, watershed protection areas, multiple-use forestry, and short-rotation tree farming all are sustainable, from some viewpoints, when inflows and outflows balance over time. Sustainability needs to be defined to minimize conflict, confusion, and mistrust. For what, where, whom, and how long are forest values being sustained? One recommended approach is to assess sustainability at the landscape level and define the processes, structures, and resources needed to meet many of society's objectives. A landscape-level example in the 200 000-hectare Applegate watershed in southwest Oregon uses four criteria as a measure of sustainability. With these criteria, management objectives, activities, and monitoring measures can be implemented across the watershed. Managers and policymakers must recognize that modern forest practices have a short history and there is little documentation of long-term effects. Increased efforts are needed for well-designed, long-term, and integrated approaches for monitoring forest sustainability.

Keywords: Applegate watershed, landscape level, forest management, social values, spatial and temporal scales, sustainability.

# Contents

## Introduction

Forest sustainability is a concept for the desired condition of forest ecosystems all over the world. Although the term "sustainable forestry" is used frequently, it is seldom defined. The essential aspects of sustainable forests differ tremendously among and within peoples of the world. Parks and wilderness areas, wildlife preserves, watershed protection areas, multiple-use forestry, and short-rotation tree farming all are sustainable, from some viewpoints, when inflows and outflows balance over time. Individual views of forest sustainability differ widely and depend on various ecosystem perspectives, uses, and spatial and temporal scales. For what, where, whom, and how long are forest values being sustained? Once specific definitions are made, management objectives, activities, and monitoring measures can be implemented.

## Sustainability of What?

Although people want to sustain forests, differences and misunderstandings often arise about what features should be sustained. Sustainability can range from commodity outputs to spiritual values, from individual mushrooms to whole forest ecosystems (fig. 1). The features used as a measure of sustainability reflect the needs and backgrounds of the people involved: fiber production may be the feature most important to the industrial landowner, but a forester working in a wilderness area on public lands may place a higher value on biodiversity. Regional and national differences can be great: an artist in New York City may value visual quality, whereas a cabinet maker in Oregon may place a high value on wood quality. Villagers from the mountains of Nepal may value coppiced fuelwood, fodder, and green manure for their fields, but a rural resident in the mountains of California may value the recreation industry associated with old-growth forests.

Utilitarian perspectives often dictate what is to be sustained (Monnig and Byler 1992). For example, insect- and fungus-related disturbance and mortality are integral parts of how forests normally function, with many species dependent on and adapted to forest senescence, decay, and disturbance (Bormann and Likens 1979). Yet most groups would consider these organisms to be destroying forests rather than sustaining them. Far from being negatives, these organisms tend to renew and diversify forest stands and landscapes, if their disturbance-related activities do not become too severe or occur too frequently (fig. 2) (Perry and others 1989).

What practices are sustainable? Sustainable forestry practices often include a "tool kit" of actions with which people modify the forest to perpetuate desired features. Throughout the Western United States, forest thinning and other density-management projects are often considered sustainable forestry practices. Although density management can be an excellent tool to increase the vigor of an existing stand and reduce susceptibility to bark beetle attack, thinning is not synonymous with forest sustainability. A commercial thinning project may do little for the sustainability of organisms that thrive at high basal areas or high canopy closure, or rely on inputs of dead trees (fig. 3). Similarly, commercial thinning and other vegetation removal can reduce fuel loadings, continuity, and fire risk but do little for organisms that rely on high levels of forest structure and canopy or are shade intolerant (FEMAT 1993, Thomas and others 1993). Prescribed underburning is another forestry practice perceived as "sustainable" throughout much of the Western United States. Although burning can be an effective tool to reduce fuel levels and thin forest stands, loss of coarse woody debris due to fire can impact populations of small mammals (Harmon and others 1986). In addition,

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Figure 1—Sustainability measures differ widely, from commodity to aesthetic and other values: (A) Forest harvest in Gifford Pinchot National Forest, southwest Washington (photo by Jim White); (B) admiring old-growth redwood tree in Redwood National Park, northwest California

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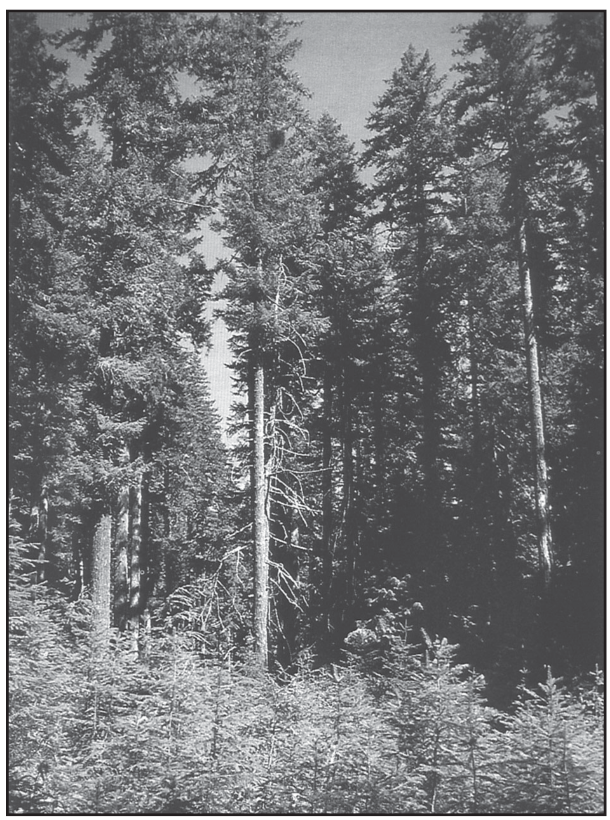

Figure 2—Disease organisms can promote forest structure: (A) *Fomitopsis pinicola* fruiting body and; (B) resulting gap in forest canopy with regenerating trees, Umpqua National Forest, southern Oregon.

burning can result in erosion and increased distribution of nonnative species (Amaranthus and others 1993). Clearly, the selection of sustainable forestry practices depends on what one is trying to sustain.

## Sustainable Where?

The term "forest sustainability" can be applied to stands, landscapes, and regions. Thus, understanding how forests function at different spatial scales is critical to assess the impact of any management activity on sustainability. For the most part, sustainability concepts have developed at the level of individual organisms and have not been applied effectively at the landscape level. For example, insects and pathogens may increase the quality of habitat for organisms requiring high levels of coarse woody debris at the stand scale, but they may create a landscape and regional environment vulnerable to catastrophic fires that could affect the existence of those same organisms when viewed at a larger scale. Many practices can create one condition at the stand scale and a different one at a landscape or regional scale (fig. 4). Protecting excessive levels of forest structure and coarse woody debris may mean healthy habitat for dependent organisms at the stand scale, but when viewed in the landscape scale, it may create an environment that magnifies the spread and intensity of uncontrolled fire.

Site productivity often is used as a criterion for evaluating sustainable forestry. Site productivity emphasizes a stand-level view of sustainability, focusing on the productive capacity of forest sites and most often referring to vegetative production, soil fertility, and other considerations at the stand level. Impacts to sustainability such as soil erosion, nutrient depletion, and compaction also are evaluated at the stand level (Dyck and Mees 1990). By comparison, a regional approach to sustainability emerges in the Northwest Forest Plan covering large areas of California, Oregon, and Washington (Species Analysis Team 1994). Sustainability issues focus on late-successional forest species, especially the northern spotted owl (*Strix occidentalis*) that can be understood only with landscape and regional approaches. Moreover, the Northwest Forest Plan reflects relative national priorities between wood production and preservation of endangered species. This approach, in which massive allocations of public lands are off limits to any logging activity, emphasizes sustainability in terms of certain wildlife species, aesthetics, and water quality. Such a large-scale approach, however, can constrain wood supplies and human needs for shelter and fuel (Koch 1992). Unforeseen consequences can result when forest management and timber supplies are discouraged or constrained at this scale. These include the conversion of private forest land to nonforest uses and increased use of nonrenewable substitutes for wood products (Bowyer 1992).

Measures of forest sustainability get increasingly more complex as one moves from individual organisms and stands to landscapes (fig. 5). Sustainability of the growth of an individual tree can be evaluated simply by height and diameter measurements and external examination of crown conditions. At the stand or landscape level, sustainability qualities expand to include soil and water protection, wildlife habitat, disturbance effects, and many other features not dependent on the sustained growth of all trees and, in fact, requiring the mortality of individual trees (Bisson and others 1987, Thomas and others 1993). Defining the spatial scale being evaluated reduces opportunities for confusion.

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Figure 3—Throughout the Western United States, forest thinning and other density-management projects are often considered sustainable forestry practices: (A) Recently thinned mixed-conifer stand, Rogue River National Forest, southwest Oregon, increases tree vigor and reduces canopy cover; some organisms in the area, however, such as the (B) California red backed vole (*Clethnonomys occidentalis*), require habitat with dense canopy cover.

B

A

C

Figure 4—Retaining coarse woody debris is considered a sustainable practice at the stand scale but, when viewed at the landscape scale, may create an environment that magnifies the spread and intensity of uncontrolled fire: (A) High levels of coarse woody debris left for wildlife habitat in mixed-conifer stand (B) stand-replacing wildfire; and (C) resulting stand condition following wildfire, Siskiyou National Forest, southwest Oregon.

## Sustainable for Whom?

Sustainability has several meanings and most often reflects the values of those involved. Sustainability depends on what people want and this is often clouded with controversy, because one view often represents one group's particular values at the expense of others (fig. 6 ). Whether a forest practice enhances sustainability depends on the cultural "lens" that influences how people think and the nature of their work. No one version of the sustainable forest is correct. A resource specialist concerned about declining late-successional habitat or salmon habitat may not view prescribed burning as a sustainable forestry practice. A wildlife biologist studying snag-dependent species may view a landscape recently affected by bark-beetle mortality as adding to the sustainability of the forest. A commercial mushroom picker may see decomposing woody material as a moisture source for the sustained production of his favorite fungal species. A fuel specialist may view the same piece of wood as a fire hazard and risk and not sustainable. A villager may see a continual source of fuelwood.

Over time, what people need, want, and can do changes; this is reflected in the forest values they seek to sustain. In the Pacific Northwest United States, the emphasis of National Forest management has shifted over the years from watershed protection to fiber production to conservation of biological diversity. Even at a particular time, human interests often differ depending on ownership and locality of the forest resources (Romm and Washburn 1987). Local, state, and national governments often disagree on how forests should be managed and which resources are important to sustain.

## Sustainable for How Long?

Most modern forest management practices have a short history and little documentation of long-term effects on forest sustainability (Powers and Van Cleve 1991). Much effort has focused on predicting forest responses via models. Few models, however, actually test the sustainability of resources that are not traded in the marketplace or that use comprehensive data sets collected during the period relevant to the predicted outcome (Franklin and others 1989). Knowledge of the long-term effects of forest management practices on basic forest resources, such as soil productivity, water quality and quantity, biodiversity, and wood production, are clearly needed. Forest phenomena can occur on time scales of seasons, decades, and centuries. Short-term results, chronosequence, and retrospective studies may mask the real sustainability of the forest and lead to erroneous conclusions and serious management mistakes (Magnuson 1990).

Forest ecosystems are slow to develop and subject to complexities that confound measures of sustainability. Changes in sustainability thus may not be recognized without long-term measurements. Forest soil formation is slow, requiring many centuries to millenia; coarse woody debris can take several centuries to decompose (Sollins and others 1980). Several rotations may be necessary to determine if the system is losing, gaining, or cycling nutrients and organic matter (Miller and others 1988). Over the long term, cumulative effects can result from the incremental impact of a forestry practice that results in individually minor but collectively significant actions over time (Gosselink and others 1990) For example, loss of soil productivity can result from the continuous removal of the forest floor: these may be individually minor actions but collectively a significant action over a long period (fig. 7). Several tree rotations may be necessary to assess the sustainability of practices.

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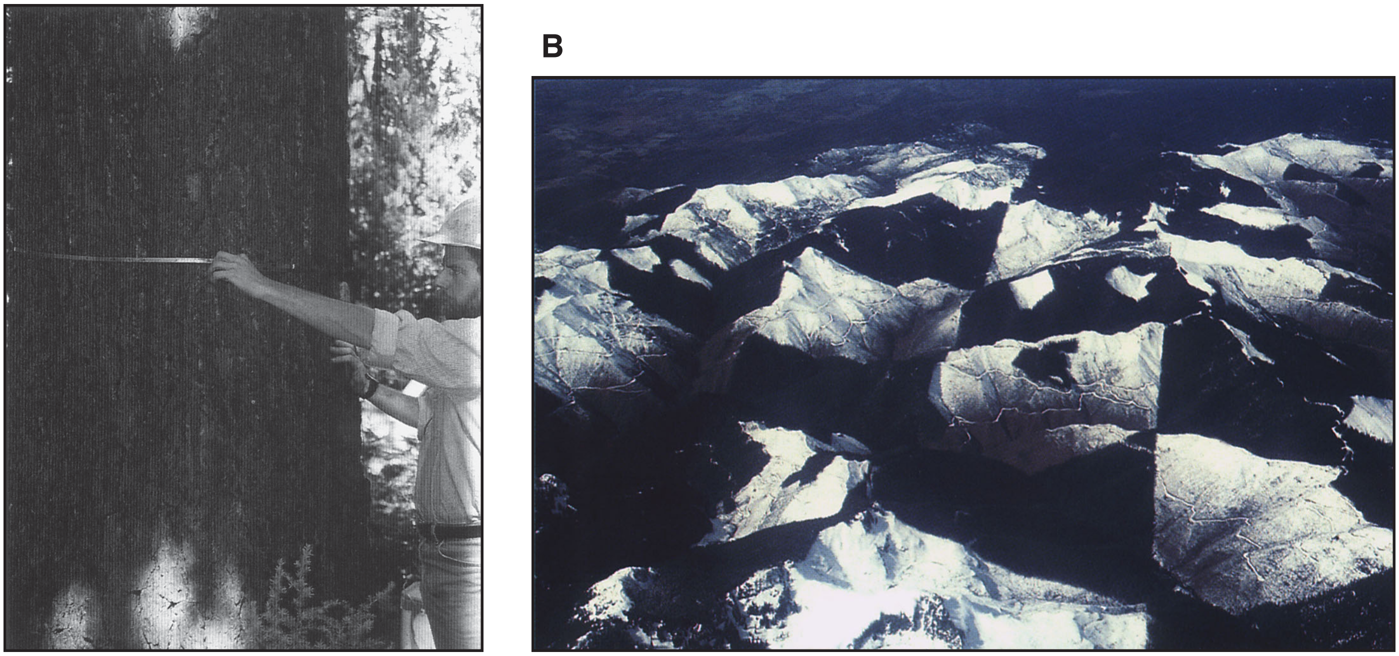

Figure 5—Measures of forest sustainability get increasingly more complex as one moves from individual organisms and stands to landscapes: (A) Evaluating individual tree diameter and (B) landscape view of mix of forest habitats in managed forests of central Cascade Range in Oregon.

Figure 6—Protesting a timber sale at the Siskiyou National Forest headquarters in southwest Oregon (photo by Robert Ettner).

Many processes in forest ecosystems are subject to considerable annual variability, such that systematic long-term monitoring is necessary to determine whether year-to-year variations during these periods are unidirectional, cyclic, time-lag, or episodic, or reflect other trends (Waring and Schlesinger 1985). Observations of sustainability can be confounded by the timing and pattern of disturbance processes, such as insects, windfall, or fires, that are greatly influenced by human activities (Franklin and others 1989). Comparisons of wildfire activity early and late in the 20th century in the Siskiyou National Forest, southern Oregon, illustrate different levels and patterns of disturbance (table 1). The period between 1915 to 1940 had three times more hectares burned annually compared to the 1970-94 period. This probably reflects a high level of arson-related fires during the 1915-40 period and less fire supression capability compared to the 1970-94 period. The 1970-93 period had an episodic pattern of wildfire activity with almost 90 percent of the total hectares burned in just one year. Extreme wildfire years, such as 1987, may result from a combination of factors: the episodic nature of fire weather conditions; decades of effective suppression activities that result in increased fuel levels, fire intensity, and rates of spread when fire suppression capabilities are overwhelmed; interactions of other disturbance agents, such as bark beetles, that increase tree mortality and fuel levels; and landscape vegetative patterns caused by management practices. Failure to assess episotic events with long-term study may limit understanding of factors influencing sustainability. In addition, time-lag effects of previous practices also may influence sustainability measures, such as forest productivity or soil fertility. Native Americans used fire extensively in the period before European settlement, and extensive burning by miners and settlers before 1915 confound current efforts to define baseline estimates of sustainability. How often disturbances occur and how they influence sustainability require long-term studies; foresters, biologists, managers, and policymakers must recognize that sustainability of forests and forest practices depends on a temporal scale seldom considered.

## Defining Sustainability

If forest sustainability is to be used as a desired goal for forested lands, it is important to specify what it implies and how it will be evaluated. The World Commission on Environment and Development (1987) considers sustainable forestry as the balancing of ecology and economics to current human needs while protecting the ability of future generations to meet their needs. Unfortunately, this definition lacks the clarity and specificity needed for evaluation. How would such a definition be measured? Are balanced forestry uses the only sustainable forest practices? At what scale is sustainability evaluated? What is meant by human needs? Are current levels of human needs realistic and sustainable?

A useful definition of forest sustainability is presented by Kolb and others (1994); it specifically identifies the products, structures, and resources needed to support healthy forests in the sense of satisfying at least some of the objectives of society. This definition considers a healthy forest to have the following four characteristics that relate to forest sustainability: (1) the physical environment, biotic resources, and trophic networks to support productive forests; (2) resistance to catastrophic change and the ability to recover on the landscape level; (3) a functional equilibrium between supply and demand of essential resources (water, nutrients, light, and growing space) for major portions of the vegetation; and (4) a diversity of seral stages and stand structures that provide habitat for any native species and all essential ecosystem processes.

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Figure 7—Over the long term, cumulative effects can result from the incremental impact of a forestry practice that results in individually minor but collectively significant actions over time: (A) Northern Thailand pine stand with forest floor bare following pine needle removal and (B) bundles of pine needles being hauled to market.

**Table 1—Hectares burned by wildfires, Siskiyou Natonal Forest, 1915-40 and 1960-94**

| Year | Area burned | Year | Area burned |
|---|---|---|---|
| | Hectares | | Hectares |
| 1915 | 4227 | 1970 | 304 |
| 1916 | 5723 | 1971 | 408 |
| 1917 | 42687 | 1972 | 89 |
| 1918 | 18298 | 1973 | 72 |
| 1919 | * | 1974 | 16 |
| 1920 | 314 | 1975 | 204 |
| 1921 | 1376 | 1976 | 10 |
| 1922 | 1854 | 1977 | 15 |
| 1923 | 1014 | 1978 | 15 |
| 1924 | 7795 | 1979 | 49 |
| 1925 | * | 1980 | 39 |
| 1926 | * | 1981 | 2 |
| 1927 | 27 | 1982 | 60 |
| 1928 | * | 1983 | 8 |
| 1930 | 9308 | 1984 | 14 |
| 1931 | 9018 | 1985 | 144 |
| 1932 | 14610 | 1986 | 6 |
| 1933 | 263 | 1987 | 45377 |
| 1934 | 1244 | 1988 | 13 |
| 1935 | 1201 | 1989 | 4 |
| 1936 | 5011 | 1990 | 932 |
| 1937 | 643 | 1991 | 21 |
| 1938 | 20549 | 1992 | 18 |
| 1939 | 5368 | 1993 | 3 |
| 1940 | 837 | 1994 | 3157 |
| Total | 151366 | Total | 50981 |
| Average per year | 6880 | Average per year | 2039 |

* = data not available.

## A Landscape Example

The Applegate watershed in southern Oregon is a 200 000-hectare landscape containing a mix of private, state, and Federal ownerships that range in elevation between 50 and 2000 meters (fig. 8). Applegate forests are occupied by a complex array of conifer and hardwood forests supporting a rich mix of plant and animal species. About 13,000 people live in the watershed, mostly in the lower elevations and near to the forest interface. The four sustainability characteristics in Kolb and others (1994) can be used to assess forest sustainability in the Applegate watershed.

**1. The physical environment, biotic resources, and trophic networks to support productive forests.**

Over most of the Applegate watershed, the physical, biotic, and tropic networks are intact to support the forest ecosystem. There are some exceptions at the stand level: highly eroded or steep raveling areas, aggraded stream reaches, and high-elevation, old, nonreforested clearcuts. These areas, however, occupy less than 3 percent of the entire watershed. Based on this criterion, the forests of the Applegate watershed are probably in a sustainable condition.

**2. Resistance to catastrophic change and the ability to recover on the landscape level.**

A significant threat of catastrophic disturbance exists within the Applegate watershed that could dramatically alter plant and animal structure and composition. Bark beetle hazard is high across large portions of the watershed with risk extreme in many areas (fig. 9). These insects are known to reach outbreak levels when stand density exceeds the carrying capacity of sites across large areas. In addition, high levels of fuels, stand density, increasing mortality, and urban encroachment have increased the risk of intense wildfire over the next several decades. Natural rates of fire frequency indicate that much of the area has missed two to five fire cycles. In its current state, the Applegate landscape will magnify rather than resist the catastrophic effects of disturbance. Suburban encroachment, forest clearing, and changes in land use within the watershed have reduced the ability of the area to recover. Based on the second criterion, the forests of the Applegate watershed are probably not in a sustainable condition.

**3. A functional equilibrium between supply and demand of essential resources.**

Stagnant, overstocked stands of low vigor are characteristic across the Applegate watershed. Nutrient cycling is low because of fire-suppression activities. Larger, older trees are rapidly dying because of intense competition with dense understory vegetation. Streamflows have declined across the landscape owing to increased evapotranspirational demand upslope and water withdrawals. These factors indicate a major imbalance between demand and supply of water, nutrients, and growing space for some important vegetative components (fig. 10). Based on the third criterion, the forests of the Applegate watershed are probably not in a sustainable condition.

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Figure 9—Recent bark beetle mortality in the Applegate watershed.

Figure 8—A landscape view of the Applegate watershed (photo by Robert Ettner).

Figure 10—Dense, stagnant 120-year-old Douglas-fir stand in the Applegate watershed.

**4. A diversity of seral stages and stand structures that provide habitat for any native species and all essential ecosystem processes.**

The Applegate watershed contains a diversity of seral stages and stand structures. Logging and especially fire exclusion have led to an abundance of younger, smaller trees and increases in stand-structure complexity and canopy coverage. Habitats for some native species have been promoted by fire suppression and bark beetle mortality, which have increased stand-structure diversity and the numbers of snags across much of the watershed. Other species that require fire have probably been adversely affected. Open savannas of pine (*Pinus* spp.) and oak (*Quercus* spp.) sustained by fire have been lost. Heavy grazing and introduction of exotic plant species in some areas have adversely affected rates and types of ecosystem processes and plant succession. Based on this fourth criterion, the forests of the Applegate watershed are only marginally in a sustainable condition, and more data are needed to accurately assess the current situation.

Having evaluated these criteria, what can be done to bring the Applegate watershed into a sustainable condition? This evaluation permits managers to devise specific approaches. Although the physical and biological resources and networks to support productive forest are still in place, the watershed has lost resistance to catastrophic change and the equlibrium between supply and demand of essential resources. A strategy to reduce the potential catastrophic effects of fire and insects and address major imbalances among the vegetative demands for water, nutrients, and growing space will require a large, long-term, cooperative effort among ownerships. Because the needs have been specifically identified, however, a measureable strategy can be implemented.

## Conclusions

The growing use of the terms “sustainable forests” and “sustainable forestry practices” demands that natural resource users and managers understand the many different perspectives embodied in them. Individual views of sustainability differ widely and depend on various ecosystem perspectives, uses, and spatial and temporal scales. To minimize conflict, confusion, and mistrust, sustainability needs to be defined. Clarity is needed on what, where, for whom, and for how long forest values are being sustained and assessed. Once specific definitions are in place, management objectives, activities, and monitoring measures can be implemented. One recommended approach is to assess sustainability at the landscape level and define the processes, structures, and resources needed to meet many of the objectives of society. In the Applegate watershed in southwest Oregon, this approach allows for specific needs to be identified and strategies for sustainable forests to be implemented.

## Acknowledgments

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Keywords: Applegate watershed, landscape level, forest management, social values, spatial and temporal scales, sustainability.



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