The Way to a Healthy Future for National Forest Ecosystems in the West: What Role Can Silviculture and Prescribed Fire Play?

Douglas W. MacCleery[1]

Abstract.—The 1994 wildfires in the U.S. West have highlighted a problem of forest health and fuel buildups that has been increasing for decades. In many Western forest ecosystems, forest biomass per acre has risen substantially since the 1940s and many forests have dense, fire-prone understories. If current trends continue, there will be: 1) increasing risks to National Forest ecosystems from insects, disease, and conflagration events, 2) a rising toll of loss and degradation of watershed values and wildlife habitats from abnormally intense wildfires, as well as continued losses in the biological diversity of vegetation types that were historically characterized by frequent, low intensity, fires, 3) increased risks to the human communities located in forested areas and to the fire fighters sent in to protect them, and 4) significant and increasing losses to taxpayers in fire suppression costs and resource values

Major barriers to taking the management actions needed to effectively address forest ecosystem health include: 1) erroneous public perceptions about the nature of American forests prior to European settlement, 2) piecemeal and uncoordinated implementation of federal environmental laws, 3) focusing on the short-term environmental impacts of projects, while ignoring the long-term risks of failure to take the actions necessary to restore forest health, and 4) lack of consistent, reliable information on the specific extent of forest health problems, and on the treatment measures needed to address them.

INTRODUCTION

The catastrophic Western fires of 1994 have spotlighted a problem that has been building for decades—the growing susceptibility of many Western forest areas to insects, disease, and catastrophic wildfire. Ironically, the cause of this problem is a century of reduced presence of fire in these ecosystems.

[1]Assistant Director of Timber Management for Inventory, Planning, and Silviculture, National Forest System, U.S. Department of Agriculture, Forest Service, Washington, D.C.

Decades of fire exclusion has been a major contributor to poor forest health and forest management problems. On August 29, 1994, Forest Service Chief Jack Ward Thomas discussed these problems in testimony before the Senate Subcommittee on Agricultural Research, Conservation, Forestry, and General Legislation Committee on Agriculture:

> *This year's wildfires have brought to the public's attention a forest health problem that had its beginnings over 100 years ago. In Idaho, and in much of the West, the health of National Forests,*

other federal lands and private and State lands is closely related to changes in the historic role of fire on those lands. . . . The same problems will be with us next summer and each summer in the future unless we recognize that some actions are necessary to return fire to the environment in a way that achieves desired outcomes, to improve forest health and reduce the risk that fire will damage site productivity or destroy human life and property (Thomas 1994).

The twin problems of fuel build-ups and declining forest health, and their effect on ecosystem diversity and sustainability, are likely to be the single most significant environmental challenge facing National Forest managers over the next two decades. The challenge will be great physically and biologically because such problems are extensive on federal forest lands (Sampson et al. 1993, Thomas 1994, USDA/FS 1993b).

The challenge will also be significant intellectually and emotionally because effective solutions will require the public and National Forest managers to rethink some strongly held assumptions about the nature of forests prior to European contact and on the role that natural and human induced processes played in those forests.

It will require the Forest Service and the forest conservation community to come to grips with the often divisive issue of whether and how humans should intervene in natural forest ecosystems. While other forms of intervention, such as timber harvesting, have been a primary focus of public attention, the reduction in ecosystem fire in the West has been one of the most profound and significant human interventions of any that has occurred over the last century.

ORIGIN AND HISTORY OF FOREST HEALTH PROBLEMS IN THE WEST

The assertion is often made that today's Western forest health problems are the result of the aggressive fire suppression activities initiated by the Forest Service and other federal agencies in the 1930s, coupled with the extensive harvest of Western pine forests after World War II. While there is some truth to these assertions, they tell only a partial story.

A substantial reduction in ecosystem fire had already occurred over much of the West by the late 1880s or even before. It coincided with the disintegration of the cultures of native peoples in the area, virtually all of whom actively used fire as a major land management tool (Anderson 1990, Arno 1985, Boyd 1986, Bowden 1992, Cronon 1985, Gruell 1985, Pyne 1982, Williams 1989, Williams 1994). Reduced ecosystem fire was associated with the elimination of Indian burning, with the settlement of western valley areas, and, especially, with increased livestock grazing, which broke up fuel continuity (Sampson et al. 1993).

Even in the absence of timber harvesting, exclusion of fire will eventually result in the elimination of ponderosa pine, aspen, and other forest types characteristic of frequent fire regimes. This transition can clearly be seen occurring in National Parks and Wilderness areas and in other areas that have never been logged. Many forests in these "protected" areas are now being replaced by dense stands of fire and insect susceptible fir and mixed conifer species (Sampson et al. 1993).

FOREST ECOSYSTEMS HAVE CHANGED PROFOUNDLY

A number of studies have been made which use repeat photography comparing late 19th century landscape photographs to those recently taken from the same photo points (Gruell 1980, Gruell 1983, MacCleery 1994, Progulske 1974, USDA/FS 1993c, Wyoming State Historical Society 1976). These studies universally demonstrate the profound ecological changes that have occurred over the last century in Western forest landscapes. These photos record dramatic increases in the understory density and overstory biomass volume of forest vegetation over the last century, and a decrease or complete elimination of both the aspen component and in the herbaceous understory in conifer stands. In addition, grasslands have become woodlands and open woodlands have become dense forests. Other non-photographic studies strongly corroborate the existence of such changes (Covington and Moore 1994, Sampson et al. 1993).

The reduction in fire is not just causing forests to become more dense. The overstory trees of many forests are also older on the average than they would have been without this change. An example is the Flathead National Forest in Montana (where the Bob Marshall Wilderness is located). A reconnaissance survey done in 1899 estimated that about 18 percent of the forest area of the Flathead was in a mature forest condition, and 6 percent was old-growth; but by 1990 the area of mature forest had increased to 33 percent, and the area of old-growth to 20 percent (USDA/FS 1992).

ECOLOGICAL EFFECTS—LOSS OF BIODIVERSITY, DETERIORATING FOREST HEALTH, MORE INTENSE WILDFIRES

Biological diversity has already been profoundly affected by these changes, even before the potential ecological effect of an increase in intense wildfire is considered. A recent Forest Service study shows a substantial loss in the aspen component in the forests of the Southwest. Based on forest inventory data, it found that between 1962 and 1986, the area of aspen forests had dropped by 46 percent. The study predicts that if these trends continue, in less than three decades aspen will cease to exist as a distinct forest type in the Southwestern region (USDA/FS 1993a). This same study found that the area of the forest type that is the beneficiary of reduced fire occurrence, the mixed conifer type, increased by 81 percent.

The ecological effects of reduced ecosystem fire depend on the nature of the forest. In warm, dry forest ecosystems which historically were characterized by frequent, low-intensity fires, elimination of fire leads rapidly to the development of a dense, multi-storied forest structure—subject to increasing mortality from drought, other forest health problems, and stand-replacing conflagrations, which seldom occurred in the past (USDA/FS 1993b). These low intensity fire adapted forest types, which are estimated to comprise more than half of the forest area in the Interior West, typically occupy lower elevations (USDA/FS 1993b). Because of their accessibility, such lands often have been rather extensively roaded.

In higher elevation forests, which tend to be cooler and moister, the ecological effects of fire exclusion are typically less profound than in lower elevation forests, at least over the short term. Many cool, moist forest ecosystems were historically subject to infrequent, stand-replacing fires. But even in these forests, reduction in historic fire has had substantial ecological effects in some areas. The aspen component has been substantially reduced, many meadows and openings have diminished in size or disappeared altogether, and existing forest stands have overstory trees which are older on-the-average than historically. The ecological diversity and "patchy-ness" of the forest landscape has been reduced. Such forests will be subject to increased insect epidemics and to larger and more intense stand-replacing conflagrations than typically would have occurred in the past.

Of course, there are many gradations between warm/dry and cool/moist forest ecosystems. Many forests were subject both to relatively frequent low intensity fires, as well as occasional stand-replacing conflagrations when weather and forest conditions were right. When viewed from a spatial and temporal scale, the picture can be quite complex. Within the same general vegetation community, there are significant variations in fire frequency and effects over time, depending on periodic drought cycles, topography, and human influences. And within the same general landscape, there can be major variations in vegetation communities and fire behavior depending on soil characteristics, aspect, slope and related factors, eg. north vs. south slopes. Brown (1994) has proposed a classification scheme for fire regimes that should assist in improving understanding and awareness of the complex processes involved.

These complexities make it difficult to simply characterize the vegetation changes that are occurring as the result of fire exclusion. Much of the debate on the forest health issue is focused on these differences and opposing interpretations as to their relevance. While more research into the ecological effects of these changes is certainly needed, a general pattern does emerge. Due to changes in forest density, understory composition, and the kinds of tree species that are emerging to replace the existing forest canopy, the forests that are now developing will be decidedly more susceptible to insects, disease, drought, and catastrophic fire than those of the past. When fires do occur in such forests (as they inevitably will), they will tend to be intense, stand replacing, soil damaging fires, beyond that which would have been typical in the past.

Even high elevation forests, where stand replacing fires were the norm in the past, will likely be subject to larger and more intense fires than in the past due to increased structural homogeneity and reduced patchy-ness (Barrett et al. 1991). This will likely lead to reduced biological diversity over time.

There are also immediate watershed effects of the denser forests as well. It has long been known that the density of forest vegetation affects hydrologic functioning, particularly streamflows during the dry season. It is a common observation in the forests of the Interior West that streamflow rates often increase after stand replacing fires destroy most vegetation. Today, many streams in Western forest areas which were perennial streams a century ago now do not flow year around, and low flows in many others are lower than they used to be. Low flow rates affect water temperature and are a critical factor for fish and other aquatic life.

BIOMASS CHANGES ON NFS LANDS—HOW EXTENSIVE?

Today the volume of net forest growth on the National Forest System as a whole is more than twice the volume of removals. Net forest growth is total forest growth reduced by losses due to mortality, rot, etc.

It is estimated that total (gross) forest growth on National Forest System (NFS) lands is about 22.5 billion board feet (BBF) per year, or 4.5 billion cubic feet (BCF). Forest mortality is estimated at about 6 BBF or 1.2 BCF, and timber harvest in FY 1994 was 5.0 BBF or about 1.0 BCF, about half of which was salvage of mortality. This means that the- net addition- of live forest biomass on NFS lands was—almost 14 billion board feet—or about 2.8 BCF, just in FY 1994 alone (USDA/FS 1993d).

Because net forest growth has substantially exceeded removals since at least the 1950s (and likely decades before that), average forest biomass per acre on NFS lands has risen substantially over the last century. There are major regional differences, however, in where this biomass is being added. Since 1952, average net NFS forest biomass per acre in the East and South has doubled; in the Interior West (Regions 1, 2, 3, and 4), it has increased by 44 percent; and on the Pacific Coast it has dropped by 14 percent (USDA/FS 1993d).

The significant increase in NFS forest biomass in the East and South is understandable and positive because these forests were heavily cutover and burned in the late 1800s and early 1900s prior to acquisition by the Forest Service. The reduction in forest biomass on NFS lands in the Pacific Coast is also understandable since the post World War II period marked the beginning of major timber harvesting activities on NFS lands in the West. While average NFS forest biomass on the Pacific Coast has dropped by 14 percent since 1952, it still is more than twice that of NFS lands in the eastern U.S. (3812 cubic feet/acre vs. 1528 cubic feet/acre in Eastern NFs) (USDA/FS 1993d).

The increase in NFS forest biomass in the Interior West is another story, however. This increase comes on forests which were not heavily cutover during the settlement period, and occurred even in the face of timber harvesting that averaged more than 2 billion board feet per year between 1960 and 1990. This biomass increase largely represents the legacy of fire exclusion in the Interior West. Biomass buildups have occurred largely in the smaller diameter classes. The volume of trees in diameter classes less than 17 inches increased by 52 percent between 1952–92; and today such trees comprise two-thirds of total stand volume on all lands in the Interior West. The volume of trees greater than 17 inches has been stable since 1952 (USDA/FS 1993d).

The above figures include live biomass only. There has also been a significant, but undetermined, increase in dead biomass in the Interior West. In many western forest ecosystem, biomass recycles primarily through fire, rather than decay.

The large forest biomass increases in the Interior West cannot continue indefinitely. If humans do not make purposeful adjustments, nature most certainly will, as last year's wildfires graphically demonstrated.

CHALLENGES AND BARRIERS TO ECOSYSTEM MANAGEMENT: THE "NATURAL" FOREST PARADOX

One of the most significant barriers to addressing the forest health issue is not physical or biological—neither is it related to a lack of scientific or technical knowledge. Rather it lies in public perceptions as to the nature of pre-European forests.

Today, we have some strongly held popular images of what American forests were like prior to European contact. One of these is the image of the "forest primeval," the idea that pre-European contact forests were dominated by a "blanket of ancient forest." This image is one of continuous, closed-canopy, structurally complex, all-aged "climax" forests which nature maintained for long periods in a steady-state, equilibrium balance with the environment. We have a corollary image of a pre-contact native peoples who lived in the forests and on the plains, but really didn't do much to change either (Bowden 1992). There is overwhelming physical, biological, as well as anthropological evidence that both of these images are incorrect (Arno 1985, Butzer 1990, Covington and Moore 1994, Denevan 1992, Kay 1995, Pyne 1982, Teensma 1991).

Both natural and human caused fires were major factors maintaining the open nature of vast areas of western forests (Pyne 1982). But Indian burning did much more than just add a supplemental ignition source to that of lightning. Because of its frequency and timing, in many areas aboriginal burning created entirely different vegetation mosaics and plant communities than would have existed without it (Blackburn & Anderson 1993, Boyd 1986, Kay 1995, White 1975). Most Indian fires were set in the spring and fall (when lightning is uncommon) and tended to create vegetation communities adapted to frequent, low intensity fires. In the absence of Indian burning, natural lightning fires in many forested landscapes would have been both less frequent, and more intense than Indian fires. Indeed, vegetation modification by native American burning likely tended to reduce the numbers of high intensity fires caused by lightning that otherwise would have occurred (Pyne 1982).

Erroneous images of the nature of forests prior to European contact exist not only in the public's mind. They are also strongly held by many of the managers and employees of the Forest Service and other federal and state agencies. These images continue to profoundly effect public policy today.

Today we are faced with a paradox: The dense stands that now exist in many National Parks, Wilderness areas and other "undisturbed" areas, which many in the public perceive as the "natural" forest condition, are the result of decades of human intervention in the form of fire control. But many of the open, park-like stands encountered by Euro-American settlers were themselves, to a significant extent, a product of thousands of years of intervention by native peoples. Reintroduction of natural sources of fire alone, such as lightning, will not likely restore these systems to what they were.

Under ecosystem management, the concept of "range of natural variation" has emerged—now often called the "range of historic variation" to recognize the influence of native peoples. While this is a useful concept, some people are opposed to any active human intervention in forested ecosystems, even if its purpose is to return them to their historic range. This ignores the fact that: 1) "passive" intervention in those systems in the form of fire exclusion has (and continues to) profoundly changed them; and that 2) active intervention by native peoples often helped create a number plant and animal communities that are relatively rare today.

One thing is clear: If a significant increase in forest mortality and catastrophic wildfire is considered socially and environmentally unacceptable, the current situation is unsustainable without some form of active human intervention. In the face of the profound ecological changes now occurring in many forests, human action will be necessary to achieve over the long term whatever "desired future condition" is likely to come out of National Forest planning. Active management will be required to maintain them, if such a decision is made, in an approximation of their pre-European condition. A paper addressing these problems was prepared last year by the Fire and Aviation Staff in the Washington Office (USDA/FS 1993b).

THE GROWING WILDLAND/URBAN INTERFACE PROBLEM

Since the 1970s, there has been a major increase in residential development in wildland vegetation types next to National Forest lands. This has vastly complicated National forest management. Among other things, the increased flammability of forests increases the risks to those communities. In the last decade, conflagration events have destroyed hundreds of homes and killed dozens of people. In addition, protecting residential developments has increasingly tied up fire resources traditionally devoted to suppression of fires on National Forest lands. In September 1994, Undersecretary James Lyons estimated that during the 1994 fire season, as much as 75 percent of federal fire suppression resources were tied up protecting structures and residential communities (Lyons 1994). The presence of these communities also makes it more difficult to initiate a program of mechanical treatment and prescribed fire on adjacent federal lands.

In a major strategic evaluation of Forest Service fire management, a team recently recommended major changes in current approaches (USDA/FS 1995). Among other things, the team recommended that: 1) Fire ecology and fire effects considerations be integrated fully into National Forest ecosystem management planning and implementation at all levels, 2) the use of mechanical treatment and prescribed fire be increased dramatically to help restore ecosystem health, 3) the Forest Service reduce direct attack suppression responsibilities in residential wildland areas, 4) public education and local regulation be expanded to ensure fire safe building design and location in the wildland/urban interface, and 5) fuel management areas or zones be established on NFS lands located next to residential areas.

The fuel management zones were considered necessary for two reasons: 1) to allow for more use of prescribed ecosystem fire on NFS lands without jeopardizing adjacent human communities, and 2) to reduce the level of fire suppression resources required to protect communities during fire emergencies.

THE ROLE OF SILVICULTURE AS A TOOL IN ADDRESSING FOREST HEALTH

While exclusion of fire from forested ecosystems is an underlying cause of the forest health problems we face today, returning fire alone, even on a carefully controlled basis, simply is not feasible in many situations. The use of silviculture, in conjunction with increased use of prescribed fire, will be essential in maintaining ecosystem health.

The silvicultural practices designed to maintain forest health will be different than those used to produce timber as a primary objective. Smaller material will be removed. There will be more use of thinnings, salvage, and other silvicultural treatments that involve removal of only a portion of the trees on a site. Wood product values will be lower and logging costs higher.

The potential exists for the use of silvicultural operations in support of forest health objectives to become win/win situations. The equipment and technology already exists to "tread lightly" and to carry out the silvicultural activities needed to maintain forest health. Many of these operations (but not all) will yield positive economic returns, particularly at recent timber price levels. And even when they do not, capturing of timber values can significantly reduce the total cost of the projects. These projects can reduce the substantial economic losses for wildfire suppression and site rehabilitation after severe wildfires. Last year the Forest Service spent almost one billion dollars on wildfire suppression.

Silvicultural treatments involving the sale of merchantable material can substantially reduce total treatment costs, reduce the risk of escaped prescribed fires, support local community economies, reduce the intensity of heat and fire (thus protecting soil and watershed values), increase dry season streamflow rates, and substantially reduce the amount of smoke that would otherwise be released. Going back to the levels of ecosystem fire and smoke that existed in pre-settlement times is simply not legally or politically feasible. Even with pretreatment, dealing with existing smoke management guidelines will be a major challenge.

It is not a question of whether these ecosystems will burn, but when and with what environmental and economic consequences. With respect to smoke, Chief Thomas has said that we must decide whether we want a little in the air a lot of the time, or a lot all at once. That is certainly true, but mechanical treatment and removal of biomass is one way to reduce the total amount of smoke that otherwise would go into the air.

FOREST SERVICE LEADERSHIP AND EFFECTIVE PUBLIC COMMUNICATIONS IS KEY

Introduction of silviculture and prescribed fire for forest health will not be without controversy. Strong Forest Service leadership will be a key factor in successfully forging such a social consensus. Substantial federal and state financial assets will also need to be devoted to forest health issues.

The tools and technologies currently exist to address the growing forest health problem in the West. Unfortunately, there is a lack of consistent, reliable information on the specific extent of forest health problems, and on the treatment measures needed to address them. In spite of these shortcomings, the biggest barrier is social—that is, forging the social consensus on the actions needed to manage NFS lands to maintain ecosystem health.

In a major strategic vision document, "The Forest Service Ethics and Course to the Future," Chief Jack Ward Thomas lays a solid foundation for addressing forest health issues (USDA/FS 1994a). Two major focus areas identified in this publication include ecosystem protection and ecosystem restoration. Actions called for under these focus areas include: "Understanding the roles of fires, insects and disease, and drought cycles in shaping ecosystems, and bringing that understanding to bear in management" (Ecosystem Protection); and "Promoting the use of prescribed fires in ecosystems that evolved with a fire regime . . . (Ecosystem Restoration).

The Forest Service's Western Forest Health Initiative, kicked off last fall, is a good start in putting this vision into action (USDA/FS 1994b). But continued strong Forest leadership and follow-through will be the key to ultimate success.

The Western Forest Health Initiative illustrates the barriers that will be encountered. It is clear that public trust is a significant problem. Some people will oppose any direct human intervention in forest ecosystems (although humans have been doing so for millennia). They will view use of commercial timber harvesting, even in support of ecosystem restoration objectives, as "business as usual." Controversy is likely to be particularly intense if NFS roadless areas are involved. People will also be opposed to seeing smoke in the air on a regular basis.

On a positive note, many of the areas that have been the most profoundly affected by fire exclusion are lower elevation areas that are already roaded. Many have relatively moderate topography, which will greatly facilitate use of logging equipment and prescribed fire. The Forest Service should begin in these areas to demonstrate what the end result will look like and try to build a reservoir of public trust.

But long term staying power will be needed. Forest health problems were decades in the making will not be solved overnight. If the Forest Service does not enter the forest health arena recognizing the long term nature of the issue, but instead treats it as an "on again, off again" issue, it risks losing considerable agency credibility.

LEGAL AND ADMINISTRATIVE BARRIERS TO ACHIEVING FOREST HEALTH OBJECTIVES

It is not the purpose of this paper to explore in depth the legal and administrative barriers to implementing forest health goals. These have been documented elsewhere (Sampson et al. 1993; USDA/FS 1993b; USDA/FS 1995). Briefly, however, they include:

1) Agency aversion to risk and controversy. Public aversion to smoke and the aversion to the risk of escaped prescribed fire by Forest Service managers discourages National Forest managers in their use of prescribed fire, even when projects are approved and funded.
2) Piecemeal and uncoordinated implementation of federal environmental laws. The Endangered Species Act, Clean Air and Clean Water Acts, and other federal environmental laws by their nature tend to encourage a piecemeal and ad hoc approach to federal land management. Unfortunately, agency regulations and bureaucracies act to compound this tendency. The bureaucracies of the lead agencies for these laws tend to focus on the short-term impacts of projects, while ignoring the long-term risks of failure to take the actions necessary to restore forest health. An example are the guidelines for the protection of the Mexi-

can spotted owl, which mandate the maintenance of large areas of Southwestern forests as multi-storied types. Such conditions are highly conducive to conflagration events which seldom occurred under pre-European conditions. They are certain to be unsustainable over the long term.
In addition to their short-term bias, the analysis processes established pursuant to these laws are very costly, time consuming, and provide considerable opportunity for interest groups to intervene to block proposed actions.

3) An overly narrow focus and short term perspective taken by some Forest Service assessments and studies. Despite the profound effects that increasing forest density has on hydrological functioning (e.g., dry season low flow rates and their critical importance to fish and other aquatic life), this factor has been virtually ignored by many Forest Service regional, forest, and watershed level assessments of fish habitat. The historic role of aboriginal fire in shaping Western forest ecosystems similarly has been largely ignored. Such assessments often result in delaying management action while more information is gathered, even though some actions could be taken to address forest health, such as some salvage and thinning in already roaded areas, with very modest adverse short-term environmental consequences.
4) Lack of consistent, reliable information on the extent of forest health problems and on the treatment measures that will be needed to address them. The Forest Health Monitoring grid has not yet been established in the West, although work to do so is beginning. Forest Inventory and Analysis (FIA) provides reasonably good forest trend information on nonfederal lands in the West. Unfortunately, NFS forest-level data is often not consistent with FIA data (and is very often inconsistent with data of adjacent National Forests). There currently exists little data on reserved forestlands, such as Wilderness and National Parks, or on forestlands of low productivity. Reserved and low productivity forestlands comprise 45 percent of all NFS forestlands in the West. Information on treatment needs for forest health is also poor, and currently provides little basis for prioritizing federal expenditures at a national level.

The net collective effect of all of these barriers has been a strong bias in favor of delay, even in the face of strong Agency public statements on the need for prompt action. Such statements are well placed on this issue. The reality is that time is running out for taking effective action to address Western forest health problems. The time to act is now.

SUMMARY AND CONCLUSION

The forest health and fuel buildup problem is likely to be the most challenging resource issue to face the Forest Service over the next two decades. It will be challenging intellectually because it will cause the Agency and public to rethink some long standing images of forests and the role of humans in shaping them. It will require the Forest Service and the forest conservation community to come to grips with the often divisive issue of human intervention in natural forest ecosystems.

It will also be challenging physically, economically, and organizationally. Key to success will be Forest Service leadership—its persistence and effectiveness—in carrying through on a long-term public communications effort and on the necessary actions in the field to "walk the talk." A good groundwork has been laid in Chief Thomas' "Course to the Future" and the Western Forest Health Initiative. However, some actions of the Forest Service and other federal agencies run counter to the stated objective of aggressively addressing forest health problems. Failure to act in a positive and coordinated way to deal with this issue is likely to have serious long-term effects on both National Forest ecosystems and to the Forest Service's own credibility.

LITERATURE CITED

Anderson, R.C. 1990. The historic role of fire in the North American grassland. In Fire in North American tallgrass prairies, ed. S.L.Collins and L.L.Wallace, pp.8–18. Norman. University of Oklahoma Press.

Arno, S.F. 1985. Ecological effects and management implications of Indian fires. In Proceedings: Symposium and workshop on wilderness fire. November 15–18, 1983.

Missoula, MT. Intermountain Forest and Range Experiment Station, General Technical Report INT-182, USDA/Forest Service. Ogden, Utah.

Barrett, S.W., S. Arno, and C.H. Key. 1991. Fire Regimes of western larch—lodgepole pine forests in Glacier National Park, Montana. Can. J. For. Res. 21: 1711–1720.

Blackburn, T.C., & K. Anderson, eds. 1993. Before the wilderness: Environmental management by native Californians. Ballena Press, Menlo Park.

Bowden, M.J. 1992. The invention of American tradition. Journal of Historical Geography, Vol.18, No.1, pp.3–26.

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. Canadian Journal of Anthropology, No. 5.

Brown, J.K. 1994. Fire Regimes and their relevance to ecosystem management. Presented at the Society of American Foresters/Canadian Institute of Forestry Convention, Sept. 18–22, 1994, Anchorage, Alaska.

Butzer, K.W. 1990. The Indian legacy in the American Landscape. In The Making of the American Landscape, ed. Micheal P. Conzen, pp. 27–50. Boston. Unwin Hyman.

Cronon, W. 1985. Changes in the land: Indians, colonists, and the ecology of New England. Hill and Wang. New York, N.Y.

Covington, W.W., & M.M. Moore 1994. Southwestern ponderosa pine forest structure: Changes since Euro-American settlement. Journal of Forestry 2:73–76.

Denevan, W.M. 1992. The pristine myth: the landscape of the Americas in 1492. Annals of the Association of American Geographers. Vol. 82, No. 3.

Gruell, G.L. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming, Vol.I: Photographic record and analysis, INT-252, 207 p. Vol.II: Changes and causes, management implications. INT–252, 35 p. Intermountain Forest & Range Experiment Station, Ogden, Utah.

Gruell, G.E. 1983. Fire and vegetative trends in the northern Rockies: interpretations from 1871–1982 photographs. Intermountain Forest and Range Experiment Station, General Technical Report INT-158, USDA/Forest Service. Ogden, Utah, December 1983.

Gruell, G.E. 1985. Indian fires in the Interior West: a widespread influence. In Proceedings: Symposium and workshop on wilderness fire. November 15–18, 1983. Missoula, MT. Intermountain Forest and Range Experiment Station, General Technical Report INT-182, USDA/Forest Service. Ogden, Utah.

Kay, C.E. 1995. Aboriginal overkill and Native burning: implications for modern ecosystem management. Eight George Wright Conference on Research and Resource Management on Public Lands, Portland, OR. April 17–21, 1995.

Lyons, J.R. 1994. Statement before the Committee of Agriculture, Committee on Natural Resources, concerning fire suppression, fire prevention, and forest health issues and programs. October 4, 1994.

MacCleery, D. 1994. Repeat photography for assessing ecosystem change: A partial listing of references (Unpublished). USDA/Forest Service. Washington, DC.

Progulske, D.R. 1974. Yellow ore, Yellow Hair, yellow pine: a photographic study of a century of forest ecology. South Dakota Agricultural Experiment Station Bulletin 616. 169 p.

Pyne, S.J. 1982. Fire in America: A cultural history of wildland and rural fire. Princeton, NJ. Princeton University Press.

Sampson, R.N. & D.L. Adams ed. 1993. Assessing ecosystem health in the Inland West. Overview papers from an American Forests scientific workshop. November 14–19, 1993, Sun Valley, ID. American Forests, Washington, D.C.

Teensma, P.D., J.T. Rienstra, & M.A. Yeiter. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850 to 1940. Technical Note OR-9. USDI/Bureau of Land Management. Portland, OR. 10/91.

Thomas, J.W. 1994. Statement before the Subcommittee on Agricultural Research, Conservation, Forestry, and General Legislation, Committee on Agriculture, United States Senate, concerning the health and productivity of the fire-adapted forests of the Western United States. August 29, 1994.

USDA/Forest Service, 1992. LRMP Supplemental Monitoring Report, 6/92. Figure 8. Flathead National Forest. Northern Region. Missoula, MT.

USDA/Forest Service, 1993a. Changing conditions in Southwestern forests and implications on land stewardship. Southwestern Region. Albuquerque, NM.

USDA/Forest Service, 1993b. Fire related considerations and strategies in support of ecosystem management. Fire and Aviation Management, Washington Office. Washington, D.C. 30 p.

USDA/Forest Service, 1993c. Snapshot in time: repeat photography on the Boise National Forest, 1870–1992. Boise National Forest, Region 1, 7/93.

USDA/Forest Service, 1993d. Forest resources of the United States, 1992. General Technical Report RM–234, 12/93 (revised 6/94).

USDA/Forest Service, 1994a. The Forest Service ethics and course to the future. FS 567, Washington Office. Washington, D.C., 10/94. 9 p.

USDA/Forest Service, 1994b. Western forest health initiative. Washington Office State and Private Forestry. 67p.

USDA/Forest Service, 1995. Strategic assessment of fire management in the Forest Service. Fire and Aviation Management, Washington Office. Washington, D.C., 1/95.

Williams, J. 1994 (Draft). References on the American Indian use of fire in ecosystems (Unpublished). USDA/Forest Service. Pacific Northwest Region. Portland, OR.

White, R. 1975. Indian land use and environmental change: Island County, Washington: A case study. Arizona and the West 17:327–338.

Wyoming State Historical Society. 1976. Re-discovering the Big Horns; a pictorial study of 75 years of ecological change. Cheyenne, Wyoming.