BENEFITS OF FOREST RESTORATION
LITERATURE REVIEW

COALITION FOR THE UPPER SOUTH PLATTE
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Research in Review

Forest Thinning for Forest Restoration

Introduction

Photo courtesy of USDA Forest Service

Extensive research has been done about the ways in which forest thinning and restoration mitigate the severity of wildland fires. Many organizations are also researching the ecological effects of forest treatments on other aspects of the forest environment. This document reviews reports and journal articles that focus on the other environmental and social effects of treatments, and that pull the pieces together.

Forest management has evolved from large-scale timber cutting to the current landscape-scale efforts to restore forests to more vigorous, healthy conditions. While fire prevention provided part of the original motivation to begin this shift in approaches, the driving forces behind this move toward forest restoration have been watershed management and the escalating costs of catastrophic fire, both in financial terms and in the loss of natural resources.

The costs of wildfire suppression today are unprecedented. Each season brings larger, more damaging, and more expensive fires. (Lynn, K., 2003). The social concerns associated with both wildfire and prescribed fire use are well documented. While prescribed fire is not a new tool in forest management, it remains controversial. At the planning level, public input will have a key role in identifying socially acceptable levels of prescribed fire (Weldon, 1996). The investments in mitigation practices, including prescribed fire, are essential, but these activities must be coupled with sound science that takes a broader view of the resulting ecological and social effects.

Forest restoration, the more recent approach to forest management, has many aspects. To name just a few of the factors involved, it requires attention to vegetation, wildlife, air quality, soil conditions, watershed effects, and fire mitigation. Environmental research examining these segments has been ongoing for more than thirty years and continues in forested areas around the world. A wide variety of scientific disciplines are looking closely at the overall changes that follow these forest treatments and are finding that many positive results can be achieved through management coupled with the use of low-intensity prescribed fire. Even though the research is ongoing, action must be taken now in order to counteract declining forest conditions and to lessen damage from the looming dangers of insect and disease outbreaks and of catastrophic fire. Scientists are making recommendations for Best Management Practices (BMPs) by combining this forest restoration research with current climate shift projections.

There is a consensus among forest professionals that a century of aggressive fire suppression and insufficient funding for extensive management of the resources has resulted in unhealthy forest conditions throughout the West. Overstocked, stunted, and stressed trees are competing for limited water, nutrients, and sunlight. Changing climate conditions are being verified. Catastrophes such as insect and disease epidemics and high intensity wildfires are more prevalent. Wildlife habitats are declining and, as a result of poor forest conditions, so are wildlife populations.

In order to have a sustainable forest and all it entails for the future, every effort must be made to use the best science available to slow and reverse the forest decline. One of the existing opportunities is prescribed thinning of ponderosa and mixed conifer forests, which is focus of this review. Thinning obviously reduces the risk and severity of wildfires yet has influence on other aspects of the forest environment as well. The many other results of thinning are interconnected, with each influencing the rest.

This document covers only a sampling of the extensive research on the topic of thinning and its benefits. For more information on any of the references, please see the bibliography at the end.

Forest restoration benefits the whole ecosystem

First we'll look at some of the aspects of the environment that are affected by forest restoration. They include, but are not limited to, air quality, water quality and use, tree health, soils and the understory, and wildlife habitats and populations.

As with any best practices, when planning forest management, it is critical to manage for long-range objectives, not just immediate results, and to take into account non-market and external benefits and costs, such as watershed and habitat protection, biodiversity, and carbon mitigation. Far-sighted forest management, combined with restoration, can play a large part in improving future forests (Viers, 2005).

Air

For more than a decade, carbon sequestration and carbon effects on climate and temperature have been in the spotlight. Improved forest management can make a difference in carbon efficiencies and capacity.

Carbon is stored in vegetation, soils, oceans, the atmosphere, and fossilized remains of carbon-based organisms (forming fossil fuels) (Viers, 2005). Carbon dioxide (CO_2) is the most abundant of the "greenhouse" gases, which have acquired that name because they trap heat instead of allowing it to escape into the upper levels of the atmosphere. Research indicates that accumulation of these gases close to the earth's surface is increasing global temperatures.

A significant percentage of the earth's carbon is stored in forests, particularly rainforests and old-growth forests. Simply put, as trees grow, they take in carbon, and as they die they release it. Carbon release is typically a long-term cyclical process, but it can be accelerated by the deterioration of forests through fire, disease, or pest infestation. One strategy to increase the amount of carbon that forestland can absorb or sequester is restoring the forests to healthier conditions. Optimum forestry practices can shape forest structure; influence forest growth rates, and increases carbon up-take and storage efficiencies.

Watersheds and water supplies

Supplies of water, one of the essentials of life, can be enhanced in many ways by forest restoration. Monitoring the effects of the water cycle within arid and semi-arid regions is most critical, because limited supplies have widespread and serious repercussions. Most city dwellers don't think to trace the fact that they can turn on a faucet and have clean water pour out back to how the forest promotes, or inhibits, the accumulation of a deep snowpack during the winter.

This is where thinning can play an important role. At the most basic level, snow that piles up in branches above the ground provides little moisture to the tree or the soil. In climates of low humidity, the suspended snow sublimates, or evaporates into the air, instead of seeping into the soil. In contrast, snowpack on the ground slowly releases moisture that enters the ground and surface water systems. Thinning the forest to provide more space between tree crowns allows for development of a deeper snowpack. This ultimately increases the soil moisture, because it increases the opportunity for water to be absorbed by the soil and by reduces surface evaporation.

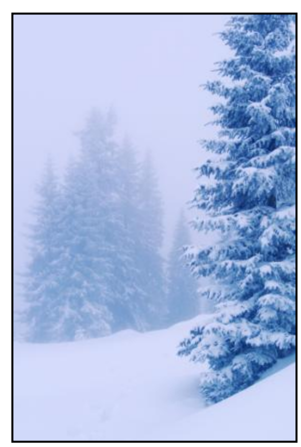


Image by Royalty Free/Corbis

In addition, the deeper the snowpack, the longer it provides water during the spring melt. In 2011, results were released of a study in the Sierra Nevada regarding watershed enhancement as a result of forest treatments (Bales et al.,). According to this report, preliminary estimates, based on average climate information, suggest that reducing forest cover by 40% across watersheds in the Sierra Nevada could increase water yields by about 9%

and extend snow storage—that is, delay snowmelt—by days or even weeks. This study cautions that results are very site-specific; slope, aspect and, elevation are major contributing factors to snowpack moisture content and longevity. Going beyond the obvious positive effects of increased water supplies, the authors observe, “Snowpack storage of water is a valuable ecosystem service and surface water in this region has a significant value downstream to generate carbon-free hydroelectric power with economic revenue. With the probable increase in the value placed on carbon-free energy, the relative value of water runoff may increase substantially.” The report goes on to suggest that this increased revenue could help offset the cost of forest management.

Many other water-related issues are under review. These include topics related to society’s interaction and use of water, such as maintaining current water supplies, sedimentation rates and water-quality issues, and predicting peak flows as related to flood control and erosion (Anderson, Hoover, & Reinhart, 1976). According to the 2008 Pinchot Institute Report (Pinchot Institute for Conservation), the greatest threat to water supplies along Colorado’s Front Range is high-severity wildfire, which can also seriously impact the Front Range economy. The report states that a serious wildfire can impose a heavy toll on water infrastructures that are expensive to repair, such as conveyances and storage reservoirs. This report acknowledges that changing climate and the current drought cycle are contributing factors that put Front Range watersheds, and the 2.9 million residents that rely on the water they provide, at risk.

The plants’ water use

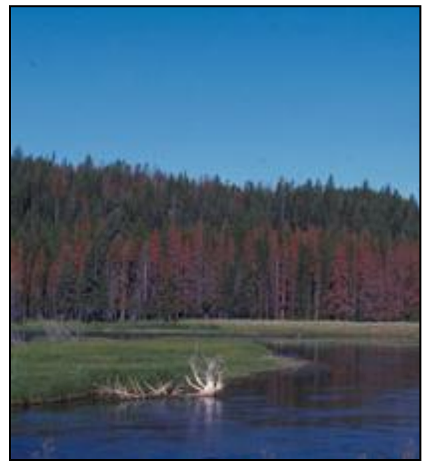
Tree roots draw in soil moisture and release it through the tree crown by evapo-transpiration (Kolb, 2009). Restoring ponderosa and mixed conifer forests by thinning them to historic conditions (Abella & Denton, 2009), followed by prescribed fire, not only allows surface snowpack to develop and water to be absorbed by the soil. It also makes more water available to the remaining vegetation (North, Oakley, Fiegener, Gray, & Barbour, 2005).

These paired forest-restoration treatments influence many environmental variables of the understory: in addition to soil moisture, shifts are noted in litter depth, bare ground, and understory light. Following treatment, more soil moisture and nutrients are available to the trees, shrubs, and ground vegetation, and understory diversity increases (Wayman & North, 2007). Changes in the understory need to be taken into account during the planning process, because other research shows that increased understory shrubs might eventually consume more soil moisture than conifers (Royce & Barbour, 2001). The comprehensive plan needs to consider understory management so that the long-term outcomes of treatments produce the intended results.

The Arizona Water Institute (Kolb, 2009) supported a study to measure water loss by tree foliage following restoration-thinning treatments to reduced tree density and fire risk in ponderosa pine. Reducing tree basal area by 35% reduced evapo-transpiration by 17% the first year after thinning, and by 15% the following year (Kolb, 2009). Measurements of soil water storage were consistently greater starting the first spring after thinning, indicating that tree density reduction resulted in increased available soil moisture. This increase soil moisture has a direct effect on understory growth and regeneration.

Tree health and vigor

A combination of climatic influences (increasing temperatures and expanding drought conditions) and environmental pressures (competition for water and nutrients, excessive tree density, and the absence of fire) is contributing to a decline in the general overall vigor of our forests. This decline in vigor is associated with many forest health complications.



Jerald E. Dewey, USDA Forest Service

One of the indicators of reduced tree vigor is the insect epidemics are readily visible in many forested locations throughout the Rocky Mountains from Mexico north through Canada. Endemic (low-level) damage from insects and disease is common and natural in the forest. However, epidemic outbreaks involve larger areas, and result in more extensive decline, and the widespread death of trees. A great deal of research is underway on the current insect activity—for example, of bark-beetle infestations. Yet little can be done to stop a bark-beetle outbreak that is in progress. Colorado alone has seen 3.5 million acres (5468 square miles) affected by Mountain Pine Beetle as of 2011, according to the Colorado State Forest Service (2011 Forest Health Aerial Survey Results, CSFS). The problem is widespread. The British Columbia Ministry of Forests and Range estimates that as of 2009 the cumulative area of provincial Crown forest affected with bark beetle to some degree was about 16.3 million hectares—over 40 million acres or nearly 63 thousand square miles, an area slightly smaller than the state of Wisconsin[1].

Utah State University is researching the resistance of conifers to bark-beetle infestation as related to tree health (Christiansen, Warning, & Berryman, 1987). Coniferous trees have two major defense mechanisms against bark-beetle attacks. Several genera (such as *Pinus, Picea* and *Larix)* have a system of resin ducts within the phloem and the xylem (which, respectively, carry food downward, from needles to roots, or carry water and dissolved minerals upward, from roots to needles). If adequate amounts of stored resin are exuded from these ducts, intruding beetles may be repelled or "pitched out." A conifer's ability to resist or repel a beetle attack is directly related to the amount of resin produced by the individual tree, and the tree's ability to exude resin depends on the storage capacity of the duct system and the viscosity (thickness) of the oleoresin, which seems related to tree vigor. Resin production and viscosity are reduced in stressed forest conditions, such as drought and overstocking.

If the resin flow fails to stop the beetles, the insects infect the host tissues with a variety of microorganisms, (such as fungi, bacteria or viruses) among which are usually the wood-staining

[1] www.for.gov.bc.ca/hfp/mountain_pine_beetle/faq.htm

fungi. These fungi can kill healthy trees by penetrating their sapwood and blocking the flow of fluids within the tree. Most plants respond to an infection produced by microorganisms with a hypersensitive reaction and form a necrotic area (a scar of dead wood) around the point of infection to deprive the invader of living tissue and to thus restrict its growth. In conifers, this scar is also impregnated with resinous and phenolic compounds that are highly toxic to bark-beetle eggs and larvae and that inhibit fungal growth. This wound reaction defends against the attack.

Results of a northern Arizona ponderosa study indicated old pre-settlement trees (established before 1880's) exhibited improved condition and vigor following a restoration thinning treatment (Wallin, Kolb, Skov, & Wagner, 2008). There were measurable increases in canopy growth and uptake of water, nitrogen and carbon, a current environmental concern (Kolb, 2009; Tang, Qi, Misson, & Goldstein, 2005). Another study showed that, in turn, with improved vigor these pre-settlement trees recovered their healthy resistance to insects and disease (Stone, Kolb, & Covington, 1999).

Younger trees that had grown under intense competition caused by tree density showed even greater beneficial effects, in terms of increased growth rates, when restoration thinning and prescribed burning altered their environment. A study published by the Society of American Foresters (Skov, Kolb, & Wallin, 2003) found that old-growth, pre-settlement ponderosa trees (trees between 150 and 450 years old) showed less response to restoration thinning and broadcast burning than post-settlement ponderosa (those approximately 80 years old). Based on bole radial growth, the growth rates of the older trees were not significantly affected by treatment, perhaps because these trees had reached their peaks, with growth rates stabilized or declining. The average growth of the younger post-settlement trees was significantly higher in the heavily thinned plot. Measurements taken one and two years after treatment indicated that the restoration measures implemented in this study (thinning followed by low-intensity prescribed burn) had larger positive effects on the photosynthesis of younger post-settlement trees than on old-growth pre-settlement trees. These beneficial effects were most pronounced during periods of drought.

Soils and the understory

Forest treatment of thinning or burning alone did not significantly increase the richness or cover in the understory of a ponderosa pine plantation, according to research reported in the *Journal of Tree Physiology* (Wayman & North, 2007). Species that increased significantly in cover were associated with conditions that combined thinning and burning. Thinning increased light and soil moisture. Burning reduced litter, slash, and shrub cover. Prescribed fire was most effective for increasing understory diversity and reducing shrub cover when it was applied off-season. The additional fuels provided by mechanical thinning increased the burn area and intensity, reducing litter and slash and increasing herb richness and abundance.

Soil moisture, litter depth, and diffuse light were the most significant environmental gradients influencing understory plant distribution. Herb cover and regeneration was most strongly influenced by increased soil moisture. Shrub cover, on the other hand, is associated with more diffuse light, less direct light, and sites with lower soil moisture. Herb richness is most affected by conditions that influence soil moisture. Richness is positively correlated with litter depth, and negatively correlated with direct light and shrub cover (North, Oakley, Fiegener, Gray, & Barbour, 2005).

The greatest changes in species composition reportedly occur in the first year after treatment, with smaller but still substantial changes each year thereafter. If care is taken to maintain those understory species that rely on undisturbed forest patches and to prevent exotic invasion, combined thinning and fire treatments may enhance the richness and cover of native plants in the understory community (Wayman & North, 2007). This ground vegetation continues other segments of the restoration cycle by inhibiting erosion and providing new and renewed food sources to wildlife.

<u>Wildlife populations and habitats</u>

Photo courtesy of US Forest Service

The food sources available to wildlife are very limited in areas where tree crowns touch, producing overwhelming shade on the forest floor. Historic fires provided forest openings where a variety of types of vegetation thrived, and so did birds and wildlife. Thinning followed by low-intensity prescribed fire can recreate these openings. Native plants return quickly, particularly to the bare soil (Wayman & North, 2007). Increased understory light and reduced litter, slash, and shrub cover were most associated with increases in species richness and herb cover.

Populations of most bird species associated with grassland, shrub-scrub habitats and with disturbed areas in forested habitats (referred to as *disturbance-dependent species*) have declined sharply (Hunter, Buehler, Canterbury, Confer, & Hamel, 2001). Many of these disturbance-dependent species are now extinct, rare, threatened, or endangered. This raises a question of balance between conservation efforts for birds dependent on disturbance and birds more closely associated with mature forests.

A study undertaken by the Institute for Bird Populations (2002) evaluated the ecological effects of thinning on breeding-bird populations in stands of Sierran mixed conifer forest. Bird counts demonstrated that populations of many species expanded dramatically in thinned areas. Shrub-nesting species were more abundant on the thinned plots, while species that are generally considered to be resident in forest interiors were detected in similar densities on both thinned and unthinned plots. The overwhelming majority of nests were located in the thinned plots and nest success rates (fledglings) were nearly equivalent in both plot types.

Concern for the spotted owl, an endangered species, has played prominently in forest-management decisions in the western United States, including Colorado. According to research completed by the US Forest Service, Pacific Southwest Research Station, modest fuel treatments in the Sierra Nevada would not be expected to reduce canopy cover enough to have measurable effects on owl occupation and reproduction (Lee & Irwin, 2005). This research indicated that habitat needs for the spotted owl can be incorporated in developing fire- and fuels-management strategies in ways that also lessen the chances of extreme wildfire.

In the big picture, changing forest conditions and availability of wildlife habitat will increase the diversity of plants, birds, and wildlife to maintain healthy populations in larger areas. Small mammals also thrive in thinned forests and quickly repopulate newly created openings (Converse, Block, & White, 2006). However, a decrease in shrub cover and slash was negatively associated with some small mammal species. No two wildlife species are affected by habitat changes in the same way or to the same degree. Enhancement of habitat for all species within a given area is not always practical or possible. Key wildlife species must be identified and projects designed and implemented to meet the needs of those key species. Overall, productive wildlife habitat depends on diversity in space, cover, food, and water (Stevens, 2004).

Forest Restoration in Action

According to current research, the most successful restoration treatments involve carefully planned thinning of specific areas to the pre-settlement (1880s) number of trees, followed by prescribed fire to reduce the litter and fuels on the forest floor (needles and small branches), which also releases the nutrients necessary for recovery. In terms of timing, these treatments appear to be most beneficial after the herbs and grasses die back or senesce for the winter and before the spring resurgence (Wayman & North, 2007). Prescribed fire during this period produces the least damage in terms of soil, vegetation, and wildlife disturbance and offers the quickest recovery.

Need and economics

In a roundtable project that took place in 2006, the Front Range Fuel Treatment Partnership identified approximately 1.5 million forested acres within the 14 counties of Colorado's Front Range that require treatment to protect communities or restore forest health, which the Roundtable refers to as *fire-risk mitigation* (700,000 acres) and *ecological restoration* (800,000 acres) (Living with Fire: Protecting Communities and Restoring Forests: Findings and Recommendations of the Front Range Roundtable, May 2006). At current treatment costs, achieving these goals could cost approximately $15 million annually over a 40-year period, a sum that vastly exceeds the approximately $6 million currently available each year for forest treatments.

> "A new economic approach that prioritizes investment in our ecological infrastructure is gaining increasing attention, giving real substance to that often vague and misleading phrase the 'Green Economy'. Investing in our ecological infrastructure is a cost-effective strategy for achieving national and global objectives, such as increased resilience to climate change, reduced risk from natural disaster and improved food and water security—all of which contribute directly to poverty alleviation, sustainable livelihoods and job creation" (Nellemann & Corcoran, 2010).

Of course, it is less expensive to maintain, conserve, and sustainably use biological diversity and naturally functioning ecosystems than to restore them. However, given the present state of ecosystem degradation, restoration is now an imperative. Ecosystem restoration activities can significantly increase job opportunities and improve livelihoods in rural areas. A 2010 study by Northern Arizona University demonstrated that federal spending for ecological restoration treatments could generate a substantial economic stimulus in northern Arizona (Ecological Restoration Institute, 2009).

Additional benefits also result from restoration treatments. Restoration reduces the risk that lives and property will be lost to wildfires, and also decreases the amount of money needed to fight fires. Estimated minimum net benefits range from $600 per acre, for moderate-risk forests, to $1400 per acre, in high-risk forests. (Ecological Restoration Institute, 2009)

Ecological restoration is a sound economic development strategy. It improves the quality of the natural environment. It provides greater and more diverse employment opportunities. It reduces the enormous costs associated with wildfire.

Conservation vs. Restoration

A recurring controversy in the research and articles reviewed concerned the different approaches taken by forest restoration proponents and conservation biologists. In general, forest restoration focuses on preventing landscape-scale catastrophes caused by fire or by insect or disease epidemics by manipulating the structures of forests that have centuries-long life spans. Conservation biology, on the other hand, focuses on existing and future conditions for flora and fauna that have shorter lifespans (on the order of a season, a year, or decade) and that are present in geographically smaller environments that may be scattered throughout the landscape of a forest. Where these two viewpoints reach consensus is in the observation that post-settlement human impacts have resulted in unhealthy and dangerous forest conditions and declining habitats that require human intervention to slow or reverse further degradation.

Looking at the documentation does not give us a clear understanding of the effects of forest restoration of ponderosa pine. Although there is plenty of research about the prevention of catastrophic fires, changes in tree health and vigor, and shifts in the condition of soil and water are not always in agreement. There is no doubt that historical (pre-settlement) data have immense value in improving the way humans understand ecosystem responses to environmental changes and in helping them set management goals (Millar, Stephenson, & Stephens, 2007). However, many forest managers assume that restoring and maintaining historical conditions will maximize the chances of maintaining ecosystems sustainably into the future (i.e., that goods, services, amenity values, and biodiversity will benefit most from aiming to replicate the past). While restoration to pre-settlement forest stand conditions is a widespread treatment method, some research suggests this might not achieve the desired results in the long term (Schoennagle, Sherriff, & Veblen, 2011) (Skov, Kolb, & Wallin, 2003). Mixed-conifer forest response is being studied, but the effects are not consistent or clearly defined.

The conservation of biological diversity has become one of the most important goals of managing forests in an ecologically sustainable way (Lindenmayer, Margules, & Botkin, 2000). Simply protecting special species will no longer assure their survival in the declining forest habitats. It is not always practical or possible to enhance habitat for all species within a given area (Stevens, 2004). Understanding of the complex effects of restoration treatment on flora, fauna, and other aspects of the many types of forest communities is still evolving.

Restore: To bring back, as to use or condition; to give back

Conserve: To prevent injury, decay waste or loss of; to use or maintain wisely

Restoration and conservation practices used in the past may not be applicable in the future. Though the causes of climate change are debated, research demonstrates that climates are changing around the world. New, dynamic strategies are needed to accommodate future, naturally occurring and human-induced, changes in climate that present evidence suggests are inevitable (Hannah et al., 2002). Ecosystems will react to climate changes through both adaptation strategies (actions that help them accommodate changes by adapting) and mitigation strategies (actions that enable them to reduce human influences on global climate). Resource managers will need to consider, and integrate, both of these strategies into overall plans (Millar, Stephenson, & Stephens, 2007).

Biodiversity conservation is a human endeavor. It is initiated by humans, designed by humans, and intended to modify human behavior to achieve a desired objective—that, is the conservation of species, habitats, and ecosystems (Mascia et al., 2003). As forests shrink, fisheries collapse, and species—the charismatic as well as the unknown—wink out around the globe, the conservation community continues to look to biological sciences to inform policy and practice. Ecological problem solving requires a flexible social structure that can incorporate scientific insights, even as they evolve, and can adapt to changing conditions (Flitcroft, Dedrick, Smith, Thieman, & Bolte, 2009). As mentioned earlier, no segment of the environment stands alone, and change to any one component has ripple effects on all.

No one science has the answers. Collaboration and research by multi-disciplinary teams will provide the best opportunity for successful ecological management and the conservation of biodiversity in the many segments of forest environments. A narrow field of vision will not serve us or the forests well. Forest planning must involve, first of all, the setting of goals and priorities that make sense at regional or broader spatial scales (Noss, 1999).

Social effects

Among the ripple effects caused by any change in a forest, whether man-made or naturally occurring, come social considerations. These need to be taken into account when considering forest restoration.

Decision-makers, scientists, and the interested public now recognize that there is an urgent need to restore forest ecosystems. Scientifically credible principles and criteria provide a yardstick with which to evaluate proposed forest-restoration policies and projects. Years of efforts by scientists, forest practitioners, environmentalists, restoration workers, and others have helped develop restoration methods and techniques. We have experience with both good and bad restoration projects—models of what to do and what not to do when restoring forests.

A Citizen's Call for Ecological Forest Restoration outlined a vision of Forest Restoration Principles and Criteria that should be taken into consideration when projects are still in the planning phase (DellaSala et al., 2003). Three of these principles are:

- *Enhance ecological integrity by restoring natural processes and resiliency.*
- *Develop and employ the use of economic incentives that protect or restore ecological integrity.*
- *Restoration must be linked to economic development in a way that prioritizes the long-term interests and benefits of (human) communities.*

By including social criteria, the restoration principles help bridge the gap between what is good for the forest and what is good for communities and workers.

Conclusions

When each scientific discipline is engaged in research on very specific, measurable topics relating to issues of forest restoration, the participants "can't see the forest for the trees." There is a critical need for consistent collaboration among people who are studying all of the aspects of this subject: conservation and ecology, forest health and fire mitigation, water supplies and communities, and many others. When developing forest-restoration best-management practices, we need to discard the narrow views of single topics. Our way of thinking needs to evolve to include broader perspectives that encompass more segments, and we need to identify the many consequences of proposed treatment actions.

Some conditions are out of human control, particularly changes brought about by climate shifts and catastrophic events. No single answer will fit all forests or forest conditions. In both policy and project design, we need to identify priorities with regard to desired conditions for the forest structure, understory, and flora and fauna habitats. People from all the related disciplines agree that the need for action is urgent. The successful forest-restoration projects must be ecologically and environmentally responsible, socially acceptable, and economically feasible and sustainable.

This is a difficult mandate for forest practitioners of today and tomorrow. Yet they must take action to protect our forests and all the lives they encompass and support through collaboration and focus on the broad, long-term view,

Resources

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