

Summary and Synthesis

V. Alaric Sample

President, Pinchot Institute
for Conservation, Washington,
DC

Christopher Topik

Director, Restoring America's
Forests, The Nature
Conservancy, Arlington, VA

Abstract: America's forests are undergoing changes unlike any seen before in human history. The concept of the Anthropocene Era, a new geologic epoch characterized by anthropogenic dominance over the Earth's systems, has become an important framework for thinking about the processes and consequences of worldwide environmental change, particularly global climate change, widespread species extinctions, mega-forest fires, and the erosion of the Earth's life support systems. If humanity is now in an epoch where large-scale ecological functions and relationships are outside the historic range of variability, then new and interdisciplinary approaches to forest conservation are required. The people and organizations charged with the conservation and sustainable management of the world's forests and their associated renewable natural resources are at the forefront of efforts to understand and address these challenges. This summary and synthesis is from presentations and discussion at the conference on Forest Conservation in the Anthropocene, convened by the Pinchot Institute for Conservation in Washington, DC, September 17-18, 2013.

INTRODUCTION

As the distinguished authors in the preceding chapters have shown, America's forests are undergoing changes unlike any seen before in human history. With each passing year, new precedents are being set for the extent and impacts of wildfires. Record areas of forests stand dead or dying, not just from exotic insects and diseases, but also from species that have been native to these forests for eons. More subtle but potentially more profound changes are taking place each day as native plant and animal species quietly disappear from their historic home ranges, perhaps to reappear at the frontiers of some other more poleward ecosystem. Scientists and forest managers puzzle over new arrivals, trying to decide whether to define them as invasive species to be eradicated, or as climate change refugees that should be nurtured as they continue their exodus toward destinations unknown even to them.

In the midst of this time of unprecedented change and new uncertainties, the stewards of America's forests, both public and private, must decide how they will act differently if they are to sustain the forests themselves



and the array of economic, environmental, and societal values and services forests provide—water, wildlife, biodiversity, wood, renewable energy, carbon sequestration. Side by side with some of the best climate and resource scientists, forest resource managers are striving to understand, prepare for, and adapt to the effects of climate change. As they do their best to anticipate a ‘no analog future’ in which the lessons of the past can offer little guidance, they must assess the risks associated with several alternative courses of action, and then manage those risks through intensified monitoring and continuous readjustments aimed at preserving as many options as possible for future resource managers.

A sort of triage has developed for forest resource managers and the ecological communities themselves. One can try to *resist* the effects of climate change, taking advantage of niches here and there where survival may be possible. One can try to be more *resilient* to the impacts of new patterns of disturbance, with strategies to survive the periodic and perhaps intensifying shocks and still have the ability to recover afterwards. Or one can accept that the magnitude of the changes is just too large and the momentum too great for either of these approaches to work, and that the only practical strategy is to *readjust* one’s future expectations, continuously monitor the changes taking place on the ground, and modify management actions in order to simply sustain key values or ecosystem services.

WILDLIFE AND BIODIVERSITY CONSERVATION

Traditional wildlife and biodiversity conservation strategies have relied heavily on the establishment of reserves and other protected areas to conserve habitat, but as climate changes, optimal habitat zones shift to different places on the landscape as well. So a basic question that has arisen for conservation biologists is whether protected areas that are fixed and static on the landscape can still play a useful role in protecting plant and animal species that are in the process of relocating. What is developing in biodiversity conservation is a portfolio approach that still relies upon protected areas, but within a larger and more dynamic context, and utilizes all three of the resistance, resilience, and readjustment approaches to climate change adaptation.

As Gary Tabor and his co-authors describe, landscape-scale habitat conservation strategies originally developed to address the issue of habitat fragmentation are now being pressed into service as climate adaptation strategies. Corridors and linkages that can connect habitat across several degrees of latitude are becoming critically important to facilitate the emigration of some plant and animal species and the immigration of others. Schmitz and Trainor point out that, because some species within a given ecological community are more mobile than others, some are able to migrate and others are left behind, disassembling existing communities of interdependent species. At the same time, a region will experience the immigration of mobile species from elsewhere, developing species assemblages that may never have existed before. How to regard these “novel ecosystems” is a topic of considerable ongoing debate among conservation biologists. From one perspective, many of these novel ecosystems are highly biologically productive and may also exhibit a high level of species diversity, so they may represent a significant biodiversity resource in themselves. In any case, they are inevitable and will develop with or without biologists’ consent. From another perspective, this tendency increases the importance of large protected areas with well-buffered interior regions that are more resistant to immigration by species from distant locales.

This still leaves the question of whether something can be done to minimize the emigration of species from such reserves, and the dismantling of the existing ecological community. Anderson and Johnson describe characteristics that can help scientists define both biological and geological characteristics that allow the identification of ‘resilient sites’ that tend to resist the influence of climate change and hold their ecological communities intact. These sites tend to have certain characteristics of geology, soils, and topography. Identifying, mapping, and then protecting a sufficient number of these resilient sites across large landscapes can be an important component in a comprehensive, portfolio approach to adapting biodiversity conservation to the effects of climate change.

There are significant additional challenges associated with actually implementing such a strategy on large landscapes predominantly characterized by private ownership and comprised of many small tracts. These tracts are typically managed for objectives as diverse as the private owners themselves, who may or may not understand or share a commitment to biodiversity conservation. Once again, large landscape conservation strategies originally developed for other purposes can be repurposed to help achieve biodiversity conservation objectives in regions characterized by mixed public-private or predominantly private ownerships.

McCauley describes an innovative approach successfully pioneered by the U.S. Fish & Wildlife Service (FWS) on the Silvio O. Conte National Fish and Wildlife Refuge following its designation by special legislation in 1991. Unlike traditional wildlife refuges at the time, the Silvio Conte encompassed large areas of land that were not directly owned or managed by the FWS—in fact, the entire 7.1 million (2.87 million ha) in the Connecticut River watershed, across four states. The model was motivated by the understanding that the important wildlife and aquatic species in this watershed could never be adequately protected by the FWS working only on the agency’s small reserves. It was a model based on outreach to other landowners in the region, facilitating local meetings in which the FWS provided spatial information about key habitat that had mapped throughout the watershed, and about land management practices that could maintain or enhance these habitat values. Landowner actions were voluntary, not done as a matter of law or regulation, and a large number of landowners stepped forward to learn more about how they could protect habitat values that happened to occur on their land.

Wildlife refuges in other regions have now adopted this watershed-based large landscape conservation model, and the concept is at the heart of the FWS strategy for wildlife and fish habitat conservation in response to climate change. As climate adaptation strategies such as the identification and mapping of ‘resilient sites’ are developed, especially in eastern regions of the United States where forests are primarily in private ownership, outreach models such as that developed on the Silvio Conte Refuge could become critically important to translating the knowledge about where resilient sites are located to actually achieving their conservation and protection, through actions that can only be taken through communication, collaboration, and cooperation with the individuals who actually own the land.

WATER RESOURCE MANAGEMENT

The relationship between climate change, water, and forests is complex, involving direct, indirect, and induced effects. Regions that experience prolonged drought and elevated temperatures will obviously face challenges resulting from lower precipitation and higher evapotranspiration,

and areas that depend upon high elevation snowpack to maintain late-season flows will more often find themselves in extreme water emergencies. This will be a major issue for aquatic habitat, especially when combined with higher water temperatures and lower dissolved oxygen levels. Cold-water species such as West Slope cutthroat trout and Dolly Varden (bull trout) may face particular environmental stress, and localized populations unable to migrate to more suitable habitat may die out.

Intact forests can mitigate all of these influences on water supply, quality, and temperature, but as forests themselves begin to show the effects of climate change their ability to do so will be sharply reduced. Forests are remarkably efficient at absorbing precipitation, storing it, and gradually releasing it as streamflow. Forests in higher elevations can be managed for optimal snow interception by maintaining crown cover that is open enough to not intercept too much snow, where it will sublimate back into the atmosphere, but closed enough to provide shade to the snow that does penetrate to the ground, slowing spring snowmelt and helping to maintain late-season flows. Climate-induced environmental stress that results in tree mortality from drought, insects, or disease diminishes each of these functions.

The most extreme effects are from wildfire, of course. Extensive crown fires in Colorado's Front Range in 1996 and 2002 caused major damage to the Strontia Springs and Cheesman Reservoirs, threatening the municipal water supply for Denver and communities up and down the Front Range. A decade later, local water authorities were still spending millions of dollars annually for additional water treatment and the removal of tons of sediment and debris from check dams installed upstream from these reservoirs after the fires. Unprecedented flash floods that caused millions of dollars in property damage in Colorado in the summer of 2013 were exacerbated by recent massive wildfires that left slopes barren of trees and other vegetation, and vulnerable to storms.

The decisive steps that Denver took to reduce the likelihood of wildfire damage to its other reservoirs provide a model that other cities and communities are taking up, especially as the changing climate is raising the stakes. Denver Water and several water authorities serving other Front Range communities sought and received permission to add a small surcharge to customers' regular water bills, creating a fund that was used to accomplish hazardous fuels treatments and forest health thinnings on forest lands upstream from municipal reservoirs. Most of these lands are National Forests, and Denver Water and the U.S. Forest Service subsequently entered a cooperative agreement in which each party would contribute more than \$16 million to accelerate treatments on thousands of acres of forest.

The lessons learned in Denver were not lost on other western communities, themselves surrounded by fire-prone forests which, should a wildfire occur, would cause substantial damage to the local water supply. Laura McCarthy's paper describes an analysis conducted by The Nature Conservancy for the city of Santa Fe, New Mexico estimated the economic losses should a major fire occur in the city's primary watershed on the Santa Fe National Forest. The study also demonstrated that the probability of such a fire could be significantly reduced through hazardous fuels treatments and forest health thinnings whose cost would be a fraction of the projected damages. The city council approved a modest surcharge on local water customers, and used this to create a water fund that is used to carry out the necessary forest management activities. The Nature Conservancy is currently working to create a similar water fund on the middle Rio

Grande, where cities like Albuquerque—seeing the results of recent New Mexico fires such as the Las Conchas and the Cochita—are becoming convinced that it is worth it to them to invest in fuels treatments in headwaters forests more than a hundred miles north.

In regions of the country where the changing climate is expected to bring higher levels of precipitation and more of it in the form of extreme storm events, intact forests are becoming a high-value asset. Hurricane Irene in 2011 dumped an extraordinary volume of rain on the Mid-Atlantic States and New England in a very short period, and satellite photos from a few days after the storm showed the Susquehanna River in full flood stage, choked with sediment and debris, which was flushing into the Chesapeake Bay and turning its northern portion an opaque brown. Municipal water supplies were interrupted in Harrisburg, Pennsylvania and other communities drawing their drinking water from the Susquehanna for nearly two weeks, and power plants drawing cooling water from the river were either shut down or operating at reduced output.

In the same satellite photo, the next major watershed to the east, the Delaware River, can be seen running clear and blue, sparkling in the sunlight. One major reason for this is the fact that the headwaters of the Delaware River are roughly 80 percent forested, whereas forest cover has been reduced to less than 40 percent in the headwaters of the Susquehanna. There is a major effort now under way to restore thousands of acres of riparian forest in the upper Susquehanna watershed—a valuable initiative but one that will take years to begin having a meaningful effect.

Meanwhile the upper Delaware River watershed continues to lose forest cover at an average of more than 100 acres (40 ha) a week. The Pennsylvania, New York, and New Jersey counties that come together in the upper Delaware are the fastest developing counties in their respective states. Will Price and Susan Beecher describe the effort to create the Common Waters Fund, an innovative mechanism developed to give private forestland owners a financial incentive to conserve their forest, and to manage it in ways that will enhance its watershed protection capabilities.

But most of the communities and businesses downstream on the Delaware have yet to be convinced that it is in their interest to invest in keeping the forested headwaters intact, rather than waiting for there to be a problem requiring emergency restoration actions such as on the Susquehanna. Water supply and water quality have been good recently, and many water users seem willing to take a chance that the continued loss of forest cover to development will not have any significant impact on them. The growing prospect of more extreme storm events like Hurricanes Irene and Sandy may be changing that benefit/cost ratio. The economic impacts of a severe flood event on the Delaware would be enormous, and the forested headwaters play an important role in flood mitigation and buffering the effects of extreme storm events. Unlike the Rio Grande or the Susquehanna, whose headwaters forests are in need of costly restoration, the headwaters forests of the Delaware simply need to be maintained as they are. Currently there are more private forestland owners in the upper Delaware waiting to participate than there is money in the Common Waters Fund to enlist them—and the development pressure continues. As the effects of climate change become more pronounced, it will be clear that what the headwaters forests provide in terms of water supply, water quality, flood mitigation, and buffering extreme storm events exceeds the modest investment needed to keep them intact.

WOOD PRODUCTION

For the wood products industry, certain high value hardwood species are likely to become more susceptible to exotic pests and pathogens such as the emerald ash borer (*Agrilus planipennis*), Asian long-horned beetle (*Anoplophora glabripennis*), and Sudden Oak Death (*Phytophthora ramorum*). Hopefully this will not have the impacts that the chestnut blight (*Cryphonectria parasitica*) has had on the American chestnut (*Castanea dentata*) that once dominated the eastern hardwood forests, but it is not something that even the best scientists are able to predict with confidence.

In the dry conifer forests of the Southwest and central Rockies, native forests have already been fundamentally altered by widespread mortality from the mountain pine beetle (*Dendroctonus ponderosae*) and other naturally endemic species, the result of a ‘perfect storm’ in which warmer winters have fostered the survival of extraordinarily high populations of bark beetles and other agents, and drought stress has drastically reduced the ability of trees to resist and survive insect attacks. Even in fire-adapted forest types such as Ponderosa pine (*Pinus ponderosa*), the unnatural and all-consuming crown fires that often follow leave vast areas of forests with no means to regenerate and restore themselves. Many areas, especially in the American Southwest, will not return to forest within the foreseeable future and are even now in the process of converting from forest ecosystems to grassland or shrubland ecosystems. As noted by Craig Allen, Anthony Westerling, and others, this is profoundly changing water regimes, wildlife habitat, and biodiversity across immense areas of forests, challenging local communities as well as resource managers to quickly develop new strategies for resistance, resilience, or the readjustment of their future expectations in light of climate change.

In the intensively managed forests in regions such as the U.S. South and Pacific Northwest, there seems to be a sense that the short rotations typical of commercial plantation forests will allow forest managers to stay ahead of the accelerating pace of climate change. Research is producing more drought-resistant varieties of important commercial tree species, which presumably will replace existing forests as they are harvested. Genetic modification may offer opportunities to attune certain tree species to new and evolving climate characteristics, but the acceptance of widespread use of such techniques is far from certain. A strategy based simply on more frequent opportunities to replace existing trees may not fully account for other climate-related effects such as more intense storms, which as seen with Hurricanes Katrina and Hugo, can destroy millions of acres of forest very quickly. Prolonged drought and elevated temperatures also reduce resistance to pests such as bark beetles, which can still kill large expanses of forest in a relatively short time. All of these factors contribute to increases in wildfire activity, a trend that is already being documented even in the South (Vose and others 2012).

FOREST MANAGEMENT ADAPTATION TO CLIMATE CHANGE AS PART OF A CARBON MITIGATION STRATEGY

There is an important duality in the relationship between forests and climate change, and this may become a central consideration in the development of forest management adaptation strategies. Forests both affect and are affected by climate change in major ways. Fortunately, the strategies and techniques that will enhance the role of forests in mitigating climate change,

through carbon sequestration and reducing net carbon emissions, are largely consistent with the techniques that can best support adaptation strategies.

As early as 2020, U.S. forests are projected to switch from being a key mechanism for storing carbon to being themselves a significant net source of greenhouse gas emissions. Today, U.S. forests store enough carbon to absorb roughly 14 percent of total U.S. greenhouse gas emissions. By 2020, this very significant carbon offset is expected to drop to zero. And by 2030, the nation's forests are expected to become significant net sources of carbon emissions themselves (USDA Forest Service 2012a). This is largely due to two factors: (1) the increasing size, frequency, and intensity of wildfires, as most of the western United States continues on a trend of elevated temperatures and extended drought, and (2) the continuing loss of private forests for development.

Conceivably, it is still possible to avoid or at least mitigate this projected future, but it will require decisive actions and a substantial strengthening of current conservation and sustainable forest management efforts to change the trajectory U.S. forests are now following. These actions include (Vose and others 2012):

1. Increase afforestation and decrease deforestation:

- Stem the conversion of forests to development and other land uses; the loss of forests and open space to development was recently estimated at approximately 6,000 acres (2,400 ha) per day—roughly 4 acres (1.6 ha) per minute.
- Increase the resistance and resilience of dry forests in the western United States to minimize the conversion to grassland ecosystems in the wake of major insect or disease outbreaks and wildfires.

2. Increase substitution of wood for fossil fuels in energy production, and for other building materials to maximize long-term carbon storage:

- Increased biomass energy from the current 2 percent of U.S. energy use to 10 percent would prevent the release of 130-190 million metric tons/year of carbon from fossil fuels (Perlack and others 2005; Zerbe 2006); commitment to conservation and reforestation of harvested sites is critically important to this net gain.
- Use of 1 metric ton of carbon in wood materials in construction in place of steel or concrete can result in 2 metric tons in lower carbon emissions, due to lower emissions associated with production processes (Sathre and O'Connor 2008; Schlamadinger and Marland 1996). Using wood from fast-growing forests can be more effective in lowering atmospheric carbon than storing carbon in the forest, where increased wood production is sustainable (Baral and Guha 2004; Marland and Marland 1992; Marland and others 1997).

3. Manage carbon stocks in existing forests:

- Increase forest carbon stocks through longer harvest intervals and protect forests with high biomass.
- Manage forest carbon with fuel treatments: carbon emissions from wildland fires in the coterminous United States have averaged 67 million metric tons/year since 1990 (USEPA 2009, 2010); stand treatments to reduce fire intensity, especially crown fires that result in near-total tree mortality, have the potential to significantly reduce carbon emissions.

POLICY OPTIONS

A careful consideration of the foregoing information and insights from distinguished scientists and experienced natural resource managers, and from the vigorous discussions that took place among the diversity of interests represented at the conference, leads to several overarching conclusions:

1. *A better integrated approach* is needed to understand, prepare for, and adapt to the effects of climate change on natural resources. Scientists and natural resource specialists in wildlife habitat management, biodiversity conservation, water resource protection, and other disciplines are all working to develop effective climate change adaptation strategies, but there is still a strong tendency to focus within rather than across disciplines. Land and resource management requires an integrated approach of course, but there is an added concern that strategies developed independently to optimize one set of objectives, e.g., carbon management, may dictate management activities that run counter to strategies oriented to other objectives, such as biodiversity conservation.
2. *Wildfire management and policy is central* to adaptation strategies across all resources. There is much more to climate change adaptation than managing the increasingly damaging effects of wildfires, but how these risks are managed will have a profound influence on biodiversity, wildlife, water, carbon and virtually every other aspect of any climate change adaptation strategy. The development and *effective implementation* of policies to limit the ecological, economic, and social impacts of wildfires are not the only consideration, but they are an essential consideration.
3. *A more dynamic policy framework* is necessary to enable natural resource management that can adapt to climate change. To the extent that the existing institutional, legal, and policy framework for natural resource management is based on science, it must continue to evolve just as science itself evolves. The most important lesson is not that the existing policy framework should be replaced by a new one, but that policies themselves must be dynamic enough to accommodate rapidly changing environmental conditions. Statutes and regulations that provide a broad enabling framework may be more effective than prescriptive laws, and rules that reflect theories and approaches that are highly changeable can continue to evolve with new scientific knowledge.

To the extent that there currently is a strategy for forest management adaptation to climate change, it is more of an amalgam of several different strategies being developed largely independent of one another. As the papers in this volume demonstrate, considerable scientific research and management resources have been devoted to developing new adaptive strategies for biodiversity conservation, as geographic shifting of habitat zones raises questions about the long-term effectiveness of traditional protected-area approaches. The extraordinary increase in the size, frequency, and extent of wildfires in forest watersheds has prompted urgent development of strategies to protect municipal water supplies and water quality. This increase in the number of ‘megafires,’ and the immense volume of greenhouse gases emitted during both the fire event itself and the often lengthy recovery period afterwards, have become a new and significant factor in the nation’s climate change mitigation policy. Because of the impact that megafires have on

these and other resource values and environmental services from forests, wildfire policy itself is undergoing a thorough re-examination in light of the projected influences of climate change.

The downward trajectory in U.S. forest conditions is negatively affecting all of these resource areas, with environmental, economic, and societal impacts that are likely to increase in the absence of coherent, cohesive policies, and integrated, results-oriented strategies. To a large extent, the actions needed to prepare for and adapt to climate change effects on these resources are similar to one another, and a more explicitly integrated approach to climate change adaptation could increase the likelihood that these actions will be timely and effective.

Correcting this downward trajectory in forest conditions and reinforcing their resiliency to the effects of climate change is a daunting challenge, requiring ecosystem restoration on an estimated 152 million acres (61.5 millions ha) of federal, state, tribal, and private forest land in the United States (USDA Forest Service 2013b). Ecosystem restoration in this context is focused on restoring ecosystem functions and processes, and strengthening the capacity to recover from significant, large-scale natural disturbances. It is not about attempting to restore forests to some earlier evolutionary state, in climate conditions that are already quite different from those of today, and which are unlikely to return any time in the foreseeable future.

Substantial improvements may be needed to the current institutional, legal, and policy framework for the management of forests and their associated values and services, including at the federal level. Encouraging policies and practices increase community engagement and local involvement could develop common visions for forest management and facilitate the work being implemented. Nowhere is this truer than wildfire policy and management. Not only are there major direct impacts of wildfire on multiple resources discussed above; there are also important indirect effects, as well as the burgeoning costs of emergency wildfire suppression that have drained away much of the public funding available for the management and protection of other resources.

Climate change is exacerbating the wildfire problem, as forests are becoming warmer, dryer and subject to both more extreme weather events and longer fire seasons. Acres burned by wildfires during 2012 were the third most of any year since 1960, with 9.3 million acres (3.76 million ha) burned, and the Forest Service is estimating 20 million acres (80.9 million ha) will burn annually by 2050. The Forest Service itself expects severe fires to double by 2050 (Finley 2013). These impacts are already evident: the Four Corners region has documented temperature increases of 1.5-2.0 degrees Fahrenheit over the last 60 years (Robles and Enquist 2010).

The societal, environmental, and fiscal costs of fire in the nation's forests continue their precipitous climb. Federal expenditures for emergency wildland fire suppression during 2012 alone were \$1.9 billion, in addition to the nearly \$1.5 billion required to maintain, staff, and equip federal fire programs. The cost of wildfire management currently consumes more than 40 percent of the U.S. Forest Service budget, leaving an ever smaller pool of funds to support hazardous fuels reduction, timber management, wildlife habitat improvement, recreational access, watershed protection, and the wide variety of other important services that the American people value and expect.

The full economic and social impacts of this extraordinary increase in wildfires are far greater, but thus far have been difficult to quantify. A study by the International Association of Fire Chiefs (2013) estimated that direct public expenditures for emergency wildfire suppression are averaging around \$4.7 billion annually—\$2.5 billion from federal agencies, \$1.2 billion from state agencies, and about \$1 billion from local governments. But even this is only a fraction of the total economic and social costs of these wildfires. An analysis of six recent wildfires by the Western Forestry Leadership Coalition (2010) showed that fire suppression expenditures may be as little as 3-5 percent of the total economic impact of these fires. Current federal wildfire policy and funding priorities are focused on strategies to limit direct emergency wildfire suppression costs. A more comprehensive approach based on reducing the overall environmental, economic, and social impacts of wildfires may better inform federal wildfire policies to optimize spending on emergency wildfire suppression, versus wildfire prevention through forest restoration actions that reduce wildfire risks.

The following near-term policy recommendations are aimed at providing some practical methods that might be considered in order to enhance forest and fire management in the United States and create more resilient forests and forest-dependent communities.

Recommendation 1. Strengthen the institutional framework for long-term investment in forest restoration and sustainable management

a. Hazardous fuels reduction

Congress and the Administration could increase federal investments to reduce fire risk in a manner that make forests more resilient and resistant to fire and other stressors. This could be based on a broadly supported long-term strategy so that, with respect to the annual process by which federal budgets and appropriations are determined, steady progress can be made toward overarching goals for resource protection and long-term sustainability. Strategic, proactive hazardous fuels treatments have proven to be a safe and cost-effective way to reduce risks to communities and forests by removing overgrown brush and trees, leaving forests in a more natural condition resilient to wildfires. A recent meta-analysis of 32 fuels treatment effectiveness studies confirmed that when implemented strategically, fuels treatments make a crucial difference in the size, spread and severity of wildfires (Martinson and Omi 2013). These treatments can improve the safety and effectiveness of firefighters and provide protection for a community or essential watershed that might otherwise see extensive loss.

Federal investments in maintaining the capacity and skills for hazardous fuels treatments have been shown to improve firefighter safety and reduce property losses, while also providing jobs and other economic benefits to rural communities. There is a growing body of literature documenting the many instances in which hazardous fuels treatments have modified wildfire behavior, thereby allowing firefighters to safely engage in protecting infrastructure and landscapes (Ecological Restoration Institute 2013). A recent economic assessment of forest restoration in eastern Oregon by the Federal Forest Advisory Committee (2012) revealed “an investment in forest health restoration has the potential to save millions of dollars in state and federal funds by avoiding costs associated with fire suppression, social service programs and unemployment benefits.” It is estimated that for every \$1 million invested in hazardous fuels treatments, approximately 16 full-time equivalent jobs are created or maintained, representing more than a

half million dollars in wages and over \$2 million in overall economic activity (Nielsen-Incus and Moseley 2010). Nevertheless, recent federal budgets have cut funding the Hazardous Fuels Reduction programs at both the U.S. Forest Service and the Department of the Interior.

Strategic mechanical fuels reduction in wildlands, combined with controlled burning to reduce fuels across large areas, can significantly reduce the chance that megafires will adversely impact the water supply, utility infrastructure, recreational areas, and rural economic opportunities on which communities depend.

There has been an ongoing discussion of whether hazardous fuels projects should be done primarily to protect structures nearly to the exclusion of natural areas that support life and livelihood. Community protection buffer zones can limit the damage from wildfire. Fighting fires will remain costly until such buffers are in place and people feel safe. But shifting too much funding away from undeveloped forest areas where fires have been excluded for a century, and where conditions remain overly dense and susceptible to unnaturally damaging wildfire, will have a long-term negative impact on forest health and resiliency. A careful science-based evaluation system to inform a balanced allocation of funding between treatments in wildland and developed areas could be developed. Strategic mechanical fuels reduction in wildlands, combined with controlled burning to reduce fuels across large areas, can significantly reduce the chance that megafires will adversely impact the water supply, utility infrastructure, recreational areas, and rural economic opportunities on which communities depend.

b. Strengthen results-based cooperation on forest restoration through initiatives such as the Collaborative Forest Landscape Restoration (CFLR) Program

The active involvement of local communities and stakeholders plays an essential role in the management of public lands, but the challenges of forest restoration will likely require an unprecedented level of cooperation among federal land managers, stakeholders, and organizations that provide the local economic infrastructure for carrying out resource protection and restoration activities in the field. The Collaborative Forest Landscape Restoration (CFLR) Program is an new mechanism aimed at enhancing community involvement in forest restoration and management. It is being used to test a wide variety of approaches, bringing science and local needs together in forming collaborative visions for future forest management.

Through these projects, the CFLR Program is demonstrating that collaboratively-developed forest restoration plans can be implemented at a large scale with benefits for people and the forests. From fiscal year 2010 through fiscal year 2012, the cumulative outputs generated by the funded projects already total: 94.1 million cubic feet of timber; 7,949 jobs created or maintained; \$290 million in labor income; 383,000 acres (155,00 ha) of hazardous fuels reduction to protect communities; 229,000 acres (92,600 ha); and 6,000 miles of improved road conditions to reduce sediment in waterways (CFLR Steering Committee 2012).

The scale and complexity of the situation facing the nation's forests and communities means that we must find ways to forge agreement among diverse interests about the 'where, when, and how' of forest management and then focus resources on those landscapes that are poised for success. Collaboration once considered 'innovative' and 'new', has often become an essential tool to reduce wildfire risks, increase forest restoration, and contribute to the sustainability of

local economies. By bringing together county commissioners, local mill owners, water and utility managers, fire protection officials, conservation groups, scientists, and others, collaborative groups can identify mutually beneficial solutions to forest health challenges and, sometimes by enduring a few bumps and bruises, pave the way for smooth and successful projects on the ground. Equally important is the long-term commitment these projects have fostered to both community sustainability and forest resilience (Butler 2013). Various funding sources, and even the state of Oregon, are providing funds that support the community collaborative capacity to enhance implementation of the CFLR program.

The CFLR Program can be a test of administrative and operational processes, as well as the project planning and preparation activities that facilitate implementation success, if allowed to continue over the ten-year life span of the projects. Future expansion could be considered. Applying lessons learned through the CFLR Program may improve National Forest management throughout the system as collaborative, large-scale projects are created and new land management plans are developed under the new forest planning rule.

c. Maintain capacity for multi-resource management and protection through increased administrative and budgetary efficiencies

Given the scope of the wildfire management challenge on federal lands, it is likely that other resource programs will continue to be funded at levels below projected needs for resource protection and stewardship. One way of addressing this challenge may be to consider more efficient and better integrated approaches to budgeting and accomplishing multi-resource management on federal forests. Both the U.S. Forest Service and BLM have in the past considered budget reforms aimed at facilitating a more integrated approach to implementing land and resource management plans developed under the National Forest Management Act (P.L. 94-588; 16 U.S.C. §§ 1600-1614) and the Federal Land Management and Policy Act (P.L. 94-579; 43 USC 1701-2, 1711-23, 1732-37, 1740-42, 1744, 1746-48, 1751-53, 1761-71, 1781-82) (Sample 1990). These early pilot studies of consolidated budgeting, planning, and accomplishment reporting demonstrated significant cost savings, increased performance accomplishment, and improved accountability in many instances.

Finding budgetary and administrative efficiencies that allow the U.S. Forest Service and BLM to accomplish multi-resource management and protection priorities at lower funding levels will be an essential component in these agencies' strategies for wildfire management and broader adaptation to climate change. Among the key lessons learned from the earlier efforts at USFS and BLM budget reform is that Congressional and Administration support is essential. This more integrated approach to planning, budgeting, and accomplishment reporting may require significant modification to the existing budget structure. To the extent that these modifications result in changes to existing Congressional and Administration processes for budget development and appropriations, these efforts have met with resistance, particularly at the President's Office of Management and Budget (OMB), and among members of Congress with a strong personal or constituent interest in specific resource programs (Sample and Tipple 2001).

The increasing proportion of the U.S. Forest Service and BLM budgets being directed to emergency wildfire suppression, in addition to the more general budget reductions, means that other resource programs are struggling to accomplish management objectives with a smaller and

smaller piece of a steadily shrinking budgetary pie. The efficiencies discovered in previous attempts at budget reform suggest that it may be time to consider this once again, in ways that will be acceptable to Congress and OMB. The U.S. Forest Service is currently experimenting with Integrated Resource Restoration (IRR), a budgetary tool that attempts to increase efficiency by blending funding sources for a variety of forest, watershed, and wildlife habitat programs. The IRR is being employed in three regions on a pilot basis (Northern, Southwest, and Intermountain).

Recommendation 2. Create and fund a new federal fire suppression funding mechanism to free up resources for proactive management referenced above

Policy action may be needed to guarantee adequate resources for wildland fire first responders, but to do so in a way that allows needed investments in the up-front risk reduction programs discussed above. Even with a robust, proactive approach to land management, federal fire preparedness and suppression resources will still need to be maintained at an effective level to protect life, property, and natural resources. Emergency preparedness and response resources may need to be provided through a new mechanism that does not compromise the viability of the forest management activities that can actually serve to reduce risks to life and property and mitigate the demand for emergency response in the future. The current system of funding fire preparedness and suppression, at the expense of hazardous fuels and other key programs threatens to undermine the other management and conservation purposes for which the USDA Forest Service and Department of the Interior bureaus were established.

The dramatic increase in the number of homes near federal lands that are prone to frequent and unnaturally damaging fire has added significantly to the cost of fire suppression. In the past, paying for this tremendous cost often resulted in ‘borrowing’ of funding from other resource management and stewardship programs into fire suppression accounts. Fire borrowing, and the threat of fire borrowing, severely impacts even the most basic level of resource management planning, reducing non-fire related agency personnel, and undermines efforts to retain skilled contractors in local communities to carry out land management and stewardship activities. Studies by GAO have documented the tremendous adverse impacts of this fire borrowing (GAO 2004). Congress subsequently passed the Federal Land Assistance, Management, and Enhancement (FLAME) Act of 2009 (43 USC § 1748a) as part of a bipartisan effort to change the funding mechanism for wildfire suppression by establishing two emergency wildfire accounts funded above annual suppression. These FLAME reserve accounts are intended to serve as a safeguard against harmful fire borrowing and should have represented an important change in the funding mechanism for wildfire suppression.

Unfortunately, the implementation of the FLAME Act has not proceeded as intended. Due to several factors, during both 2012 and 2013 the Administration had to again transfer hundreds of millions of dollars from the agencies’ non-suppression programs into emergency response accounts (Taylor 2013).

A new, separate federal funding source could be established so vital fire suppression activities are funded distinct from ongoing land management requirements. One option is the establishment of a ‘Wildland Fire Suppression Disaster Prevention Fund’ that could be utilized to support federal fire suppression actions during emergencies, just as the Disaster Relief Fund is utilized to help communities recover after disasters. Fire suppression is different from other natural

disasters, since the federal response is needed most acutely during the actual event. Such support could complement prevention and risk reduction activities discussed earlier, and post-fire recovery and restoration actions. It may also be wise and appropriate to enhance state participation in such a fund. This wildland fire suppression disaster prevention fund could be established through the Congressional appropriations process and could be supported using declarations in subsequent annual appropriations bills. In addition, Congress could increase the ability of the Federal Emergency Management Agency to provide states impacted by wildfire with additional resources for fuel hazard mitigation. Broadening and diversifying the investments in proactive management and mitigation activities may be far more cost-effective than continuing to focus tremendous resources on emergency response.

Recommendation 3. Accelerate implementation of cooperative stewardship authorities

Stewardship contracts and agreements are among the most valuable effective tools the U.S. Forest Service and BLM have to carry out ecosystem restoration actions, including hazardous fuels treatments, on federal forests (Hausbeck 2007). This statutory authority was first granted by Congress on a pilot basis, to allow the U.S. Forest Service to carry out critically important land stewardship and resource protection activities, many of which had been carried out previously through National Forest timber sales. The success and effectiveness of these pilot studies led Congress to expand the program to authorize both the U.S. Forest Service and BLM to utilize stewardship contracts anywhere on the federal forests under their management (16 U.S.C. § 2104). The authorization was temporary, however, covering only a ten-year period in order to give Congress a chance to evaluate its effectiveness through multi-party monitoring (Pinchot Institute 2006). Permanent statutory authority for stewardship contracts and agreements was provided within the Agricultural Act of 2014 (Public Law 113-79; 2.7.14).

Over the past decade, stewardship contracting has proven to be an innovative and flexible tool that allows the U.S. Forest Service and Bureau of Land Management to implement projects that restore and maintain healthy forest ecosystems, foster collaboration, and provide local employment through sustainable community economic development (Pinchot Institute 2012). Stewardship contracts are the only administrative tool that can provide certainty to local contractors for up to ten years, a critically important consideration for small businesses in local communities securing financing to purchase equipment, expand facilities, or increase their skilled workforce to carry out the land management activities specified in the stewardship contract. Continued strong public and Congressional support may be needed to enable the U.S. Forest Service and DOI Bureau of Land Management (BLM) to move forward rapidly to expand forest restoration, forest management and fire risk reduction activities utilizing the new permanent authority for stewardship contracting and agreements provided in the Agricultural Act of 2014 (P. L. 113-79).

The following specific could be taken to achieve two objectives: (1) expedite agency-level policy direction on Stewardship Contracting to resource managers in the field at both the U.S. Forest Service and BLM, and (2) immediately initiate the agency-level process for enhancing the implementation of stewardship contracting in the field.

- Release updated guidance to agency field staff related to the permanent authorization of stewardship contracting, and how the authorities can be used to accelerate the pace and scale of

restoration of our federal lands. The Forest Service and BLM operate under different policy frameworks, but that should not prohibit interagency coordination. Agency and Department communications related to the Farm Bill should include consistent messaging and communications.

- Develop a forum or communications process for interested stakeholders to remain current. Provide guidebooks to help with industry, tribal and citizen outreach on the use of stewardship contracts and agreements.
- Evaluate opportunities to use the recently expanded Good Neighbor authority to work with stewardship contracts and agreements (Public Law 113-79).
- Expedite the release of an updated Forest Service stewardship contracting handbook.
- Consider the recommendations from the FY 2012 Stewardship Contracting Programmatic Monitoring report (http://www.pinchot.org/gp/Stewardship_Contracting), and the recommendations from the Stewardship Contracting Roundtable and regional partners.

Recommendation 4. Increase capacity of states and communities to become fire adapted

Programs such as State and Volunteer Fire Assistance and Forest Health Protection provide important resources to help states and local communities develop and sustain community wildfire protection capacity. These programs foster the development of fire-adapted communities. Policy makers could seek opportunities to allocate other federal resources in a way that rewards communities for proactive actions that collectively result in national benefit.

Relatively small federal and state investments in community capacity can have substantial results for lowering wildfire risk. Building local community capacity to learn to live with fire is the most cost-effective way of reducing harmful impacts to society, while also allowing for enhanced, safe, and controlled use of fire to restore wildlands as appropriate.

Given the potential for devastating increases in both values lost and public expense, a diverse range of agencies and organizations (including The Nature Conservancy) have begun promoting the concept of ‘fire-adapted communities.’ The U.S. Forest Service defines a fire-adapted community as a knowledgeable and engaged community in which the awareness and actions of residents regarding infrastructure, buildings, landscaping, and the surrounding ecosystem lessen the need for extensive protection actions and enables the community to safely accept fire as a part of the surrounding landscape.

The U.S. Forest Service and other members of the Fire Adapted Communities Coalition are working to get communities the information and resources they need to successfully live with fire. The web site www.fireadapted.org provides access to a wide variety of educational materials and tools in support of community wildfire protection planning and action. Coalition members are also working to develop local, grassroots leaders and partnerships. These partnerships are essential for engaging all relevant stakeholders to assess and continually mitigate a community’s wildfire risk.

Recommendation 5. Seek policy adjustments that foster innovation and improvement in National Environmental Policy Act (NEPA) implementation, thereby increasing the scale and quality of resulting projects and plans

The Administration has established a goal of increasing the pace of restoration and job creation on the National Forests (USDA Forest Service 2012b). The Forest Service acknowledges that the pace and scale of restoration must dramatically increase in order to get ahead of the growing threats facing America's forest ecosystems, watersheds, and forest-dependent communities. To facilitate this accelerated rate of treatment, effective use must be made of all available management tools and the Forest Service must explore opportunities to increase the efficiency of planning and implementation processes.

There is broad commitment to the principles of public engagement and environmental review embodied in NEPA. There may be opportunities to significantly increase the efficiency of these processes, while continuing this commitment, through targeted adjustments in policy and implementation. The U.S. Forest Service is currently testing and tracking a variety of innovative NEPA strategies that hold promise for broader application. Adaptive NEPA, for example, is a relatively new approach in which the official record of decision allows sufficient leeway for some variety of subsequent federal actions, thereby greatly streamlining the analysis, allowing for more efficient project implementation, and enabling land managers to more effectively incorporate emerging science. These innovative approaches to NEPA could be expanded and additional opportunities sought for streamlining policies and processes in a way that increases the pace and scale of implementation while holding true to the core values inherent in the Act.

Greater use of the categorical exclusion procedures allowed under NEPA may be possible without diminishing the intent of this key environmental law. Full public participation and transparency in federal decision making, based on science and public discourse, results in better management decisions that in the long run are more effective and efficient. The new National Forest System Land Management Planning Rule and draft Directives (Federal Register 2012) emphasize collaborative, science-based adaptive management. Application of this new framework will guide a new round of forest planning that is intended to be more meaningful *and* more efficient, and set the stage for timely implementation of projects that achieve multiple benefits on the ground. Clear guidance and support for the development and implementation of monitoring strategies will also be essential to the rule's success.

Recommendation 6. Increase shared commitment to and support for forest restoration by states and local governments

Federal agencies alone cannot prevent the loss of homes, infrastructure and other values in the wildland-urban interface (WUI). Individuals and communities living in the WUI must meaningfully invest in preparing for and reducing their own risk from fire. Post-fire studies repeatedly show that using fire resistant building materials and reducing flammable fuels in and around the home ignition zone are the most effective ways to reduce the likelihood that a home will burn (Graham and others 2012). Similarly, community investments in improved ingress and egress routes, clear evacuation strategies, strategic fuel breaks, and increased firefighting capacity can go a long way toward enabling the community to successfully weather a wildfire event.

Community commitment is also necessary to effectively shift the national approach to wildfire from a emphasis on disaster response to a proactive strategy with multiple benefits. Research increasingly shows that rising wildfire suppression costs are directly linked to the growing presence of homes and related infrastructure in the WUI (Stein and others 2013). A corresponding analysis by Headwaters Economics revealed that 84% of the WUI is still undeveloped, so there is tremendous potential for the costs associated with wildfire protection to exponentially increase (Rasker 2013). According to the same study, if just half of the WUI is developed in the future, annual firefighting costs could explode to between \$2.3 and \$4.3 billion. States and communities could examine the ramifications of their planning on the resulting wildfire environment, especially since future decades will no doubt bring more and more severe droughts and wildfire incidents.

Federal public lands and surrounding communities could also foster greater partnerships and multi-lateral cooperation and coordination. There are many opportunities for states and municipalities to directly participate and even help fund beneficial forest management activities on nearby federal forest lands. The Eastern Oregon study cited above (Oregon Department of Forestry 2012) demonstrates that state investments in federal land management can yield great savings to the state in reduced unemployment costs, reduced social services, and increased tax revenue. Elsewhere, such as in Flagstaff, Arizona, communities are contributing directly to restore forest conditions that reduce fire risk in order to protect existing watershed and recreation resources (Flagstaff Watershed Protection Project 2012). There may be additional opportunities for many states and communities to investigate a wide spectrum of innovative funding mechanisms that will support up-front investments that increase the livability of forest dependent communities and reduce fire risk.

Recommendation 7. Enhance participation of additional sectors of society, such as water and power utilities, recreation and tourism, public health, and industrial users of clean water

There are tremendous opportunities for diverse and sustainable sources of non-federal funding to provide an effective complement to federal land management resources, thereby facilitating an overall increase in landscape-scale forest restoration on federal lands. There are a number of efforts underway, including water funds, which produce revenue for upstream forest restoration that benefits downstream water users and water companies while enhancing the restoration and maintenance of federal forests. Other utility and industrial partnerships can be developed.

The Forest Service has been particularly active in Colorado. Since 2009 they have established partnerships with five water utilities (Denver Water, Aurora Water, Colorado Springs Utilities, Northern Water, and Pueblo Water), several major corporations (such as MillerCoors, Vail Resorts, and Coca-Cola), and several philanthropic entities (Brian Ferebee, USDA Forest Service, personal communication 2013). Such efforts, often spearheaded by the National Forest Foundation, are facilitating greater shared responsibility that can reduce wildfire risk while enhancing forest health and enhancing the values those companies and other entities rely on (see National Forest Foundation 2013).

There are additional, important partnerships with forest products industries. Forest products industry investments in new biomass and wood products development can play a substantial role

to facilitate the removal of overstocked trees, while enhancing the condition of the forest and streams following harvest.

The insurance and reinsurance industries are closely involved in wildland fire issues and are important partners in such efforts as the Fire Adapted Communities Coalition (see website Fireadapted.org). There are important opportunities for greater engagement of these industries since they have such direct contact with citizens and they have such a direct involvement and desire to see fire risks reduced (Munich Reinsurance America, Inc. 2013). There may be additional opportunities to bring various compensatory mitigation funds for the support of forest restoration.

Wildfires and even controlled fires can have sizable impacts on public health due to smoke (Knowlton and others 2011; Kochi and others 2012). There is potential need to increase engagement with public health agencies and air agencies concerning impacts of smoke, and analyze the relative merits of massive, uncontrolled smoke events from severe wildfires versus controlled smoke episodes from prescribed burning accomplished to reduce severe wildfire risks.

Recommendation 8. Increase the safe and effective use of wildland fire

The beneficial use of fire as a tool for resource management is another area where greater forest restoration efficiency and effectiveness could be achieved. By increasing the use of both controlled burns and naturally ignited wildland fires to accomplish resource benefit, land managers can accomplish both ecological and community protection goals on a larger scale and at reduced cost. In fact, some states annually reduce fuels on more than 100,000 acres (40,400 ha) in wildlands with fire treatments. Both Congress and the Administration could make it clear that the safe and effective use of fire is a priority for land management agencies, and provide the necessary funding, training, and leadership support needed to foster increased fire use where appropriate.

Many communities across the nation are already deeply engaged in trying to proactively address their role within fire-driven forest ecosystems, but this engagement could be both sustained and increased. For more than 10 years, The Nature Conservancy has worked cooperatively with the U.S. Forest Service and the Department of the Interior to foster the Fire Learning Network (FLN) that brings communities together and helps them to build collaborative, science-based strategies that protect both people and ecosystems (The Nature Conservancy 2013). The FLN supports public-private landscape partnerships that engage in collaborative planning and implementation, and provides a means for sharing the tools and innovations that help them scale up. Locally, the FLN helps federal land managers to: convene collaborative planning efforts; build trust and understanding among stakeholders; improve community capacity to live with fire; access training that helps fire professionals work with local communities; and address climate change and other emerging threats.

Recommendation 9. Increase research on economic, social, and ecological impacts of forest investment

It is essential that the federal government and other sectors invest in monitoring, research, and accountability studies for fuels treatment, wildfire management strategies, and related efforts. This requires relatively small investments, when compared to the costs of fire suppression and

fire damage, but it is essential if scientists are to really learn what works and what does not. Furthermore, new technologies, including remote sensing, LIDAR, and focused social science studies can offer creative new perspectives to increase efficiency of action.

CONCLUSION

The challenges of forest management adaptation to climate change are great, but the opportunities may be even greater. There is a higher level of interest and public concern over the state of the world's forests than at any time in recent history. Forest science is becoming more relevant than ever to sustaining the economic values and environmental services that forest ecosystems provide and that society needs—water resources protection, fiber, biodiversity, renewable energy, and carbon mitigation.

The Anthropocene, this new epoch in which *Homo sapiens* has become the predominant force in the global biosphere, is about more than just a changing climate. The climate has always been in a state of flux, and certain past episodes have been as drastic as what the world is witnessing today. Species and communities have in most instances found ways to adapt and survive, through migration, mutation, or other coping mechanisms. One thing that is different this time is the pace of the change. As Curt Stager notes, climate shifts that in past epochs have taken place over millennia are now happening in just a few decades (Stager 2011). Natural adaptation strategies of the past are of limited success in today's circumstances, heightening the risk of unprecedented ecological disruptions, with consequences no one can predict.

The other major difference this time around is the presence of 7 billion people, with extensive human infrastructure that often interdicts historic migratory pathways and corridors, and limits the ability of species to get where they need to be. Large landscape conservation initiatives like Yellowstone-to-Yukon that were developed to address habitat fragmentation have become essential tools for enabling species to migrate along continental-scale corridors that include roads, towns, and other manifestations of humanity's ubiquity. 'Assisted migration' or 'managed relocation' of species to areas to which they are climatically better suited, or will be in the near future, may be something that works well with a few commercially important tree species. But as suggested by the continuing controversy over these techniques within the conservation biology community, there is still a sense by many that the unintended consequences of humans inserting species into new ecosystems may still outweigh the purported benefits. Forest managers are increasingly seeking guidance as new species arrive on their own—is it an invasive species or an environmental refugee? Should it be killed or cared for? Wildlife managers and conservation biologists are hotly debating whether to emphasize traditional efforts to protect natural landscapes, or focus on more advanced techniques for working in explicitly human-dominated landscapes to sustain both the 'players' and the 'stage' in the evolving theater of life on Earth.

Forest managers with responsibilities for sustaining multiple ecosystem services without interruption or significant decline will be especially challenged. First they must develop the science and management practices to respond to continuously changing conditions. There are numerous valuable examples of scientists working side by side with forest managers to conduct vulnerability assessments and develop strategies that move very quickly from development to implementation on public forest lands. Helping private forestland owners understand how climate change is likely to affect their management objectives is the first step to assisting them in

taking actions that—because two-thirds of the nation’s forests are in private ownership—can collectively have a major impact on how well U.S. forests adapt to, and also mitigate, climate change. The information-based outreach model pioneered by the U.S. Fish and Wildlife Service on the Silvio Conte and other units of the wildlife refuge system is a one example of how knowledge can be quickly translated to action on the ground, even on very large landscapes in mixed public-private or predominantly private ownership.

The second and perhaps greater challenge is to develop the political will to make considerable public investments in sustaining forests and the essential services on which society depends. Ambitious goals have been set for forest restoration aimed at reducing risks and strengthening resilience—only to have these goals missed by wide margins as dedicated funding has been withdrawn and redirected to other purposes, year after year. Efforts could be focused on developing new and alternative budgeting methods for wildfire suppression and mitigation, in addition to making a clear and compelling economic case illustrating avoided costs by investing in proactive forest restoration treatments.

Similarly, public programs aimed at stemming the loss of private forest land to development or conversion are perpetually funded below to the level of interest among private forestland owners who want to utilize these programs for conservation easements and other forms of land protection. Creating and sustaining non-federal funding sources through water funds, biomass, and wood products development, and fire funds for mitigation and risk reduction is a potential complement to a funding portfolio that includes traditional sources of federal funding.

Efforts to increase the use of wood biomass to substitute for fossil fuels in renewable energy production are hampered by difficult economics and public concerns that biomass removal will result in long-term impacts on forest productivity, water regimes, biodiversity, and other values. The economic question could be addressed by a more comprehensive accounting of the benefits of risk reduction and forest restoration, which produce many of the wood biomass byproducts that go into renewable wood bioenergy, as well as the continuing contribution of these activities through job creation, small business development, and environmentally sustainable economic growth in rural communities.

For conservationists, this may be a defining era. Meeting human needs for food, shelter, energy, and especially water will continue to alter landscapes at an expanding scale, with direct, indirect, and induced effects that are far too complex for humans to predict or for other species to anticipate.

The knowledge and the tools to optimize the role of forests in strategies for both mitigating and adapting to climate change are close at hand. Uncertainties around the potential future effects of climate change on forests are high, but there already is enough knowledge to begin managing the risks and taking the first steps in a strategy that incorporates robust monitoring and continuous course corrections. To do so will require continuous improvement in collaborative efforts that expand learning networks and utilize the diversity of expertise and experience among forest managers, interest groups, and local communities.

Most importantly, through decisive actions taken now, there is an opportunity to change the future, and avoid the projected switch in U.S. forests from providing an important carbon sink to

becoming themselves a major net source of carbon emissions. Stemming the loss of private forests to development, restoring public forests to relieve climate-induced environmental stresses, reduce fire risks, and protect essential public values and ecosystem services—these all have substantial environmental, economic, and societal benefits in addition to reducing carbon emissions. Also, these are goals that are already well understood and widely supported by a broad consensus of Americans. The barriers to achieving these goals are eminently surmountable.

REFERENCES

- Baral, A.; Guha, G. 2004. Trees for carbon sequestration or fossil fuel substitution: the issue of cost vs. carbon benefit. *Biomass and Bioenergy*. 27: 41-55.
- Butler, W.H. 2013. Collaboration at Arm's Length: Navigating Agency Engagement in Landscape-Scale Ecological Restoration Collaboratives. *Journal of Forestry*. 111(6): 395-403.
- CFLR Steering Committee. 2012. People Restoring America's Forests: 2012 Report on the Collaborative Forest Landscape Restoration Program. Available at: <http://www.fs.fed.us/restoration/documents/cflrp/CoalitionReports/CFLRP2012AnnualReport20130108.pdf>
- Ecological Restoration Institute. 2013. The Efficacy of Hazardous Fuels Treatments: A Rapid Assessment of the Economic and Ecological Consequences of Alternative Hazardous Fuels Treatments. Northern Arizona University. Available at: <http://library.eri.nau.edu/gsd/collect/erilibra/index/assoc/D2013004.dir/doc.pdf>.
- Federal Forest Advisory Committee. 2012. National Forest Health Restoration: An Economic Assessment of Forest Restoration on Oregon's Eastside National Forests. Prepared for Governor John Kitzhaber and Oregon's Legislative Leaders. Available at: http://www.oregon.gov/odf/BOARD/docs/2013_January/BOFATTCH_20130109_08_03.pdf.
- Federal Register. 2012. Final rule and record of decision. 36 CFR Part 219. Department of Agriculture, Forest Service, National Forest System Land Management Planning. *Federal Register* Vol. 77, No. 68, April 9, 2012.
- Finley, B. 2013. Feds project climate change will double wildfire risk in forests. *Denver Post*, April 3, 2013. http://www.denverpost.com/ci_22943189/feds-project-climate-change-will-double-wildfire-risk#ixzz2mvvPfmIU.
- Flagstaff Watershed Protection Project. 2012. Project Background. Available at: <http://www.flagstaffwatershedprotection.org/about/background/>.
- GAO. 2004. Wildfire Suppression Funding Transfers Cause Project Cancellations and Delays, Strained Relationships, and Management Disruptions GAO-04-612, U.S. General Accountability Office.
- Graham, R.; Finney, M.; McHugh, C. [and others]. 2012. Fourmile Canyon Fire Findings. Gen. Tech. Rep. RMRS-GTR-289. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pages 64-69. Available at: http://www.fs.fed.us/rm/pubs/rmrs_gtr289.pdf.
- Hausbeck, K. 2007. The little engine that could: the success of the Stewardship Contracting authority. *William and Mary Environmental Law and Policy Review*. 32(3): 33-55.
- International Association of Fire Chiefs. 2013. WUI Fact Sheet. Available at: http://www.iawfonline.org/pdf/WUI_Fact_Sheet_08012013.pdf.
- Knowlton, K.; Rotkin-Ellman, M.; Geballe, L. 2011. Six climate change-related events in the United States accounted for about \$14 billion in lost lives and health costs. *Health Affairs*. 30(11): 2167-7216.
- Kochi, I.; Champ, P.A.; Loomis, J.B.; Donovan, G.H. 2012. Valuing mortality impacts of smoke exposure from major southern California wildfires. *Journal of Forest Economics* 18: 61-75.

- Marland, G.; Marland, S. 1992. Should we store carbon in trees? *Water, Air and Soil Pollution*. 64: 181-195.
- Marland, G.; Schlamadinger, B.; Lieby, P. 1997. Forest/biomass-based mitigation strategies: does the timing of carbon reductions matter? *Critical Reviews in Environmental Science and Technology*. 27: S213-S226.
- Martinson, E.J.; Omi, P.N. 2013. Fuel treatments and fire severity: A meta-analysis. Res. Pap. RMRS-RP-103WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Munich Reinsurance America. 2013. Focus on Wildfire Firefighting. Available at: <http://www.munichreamerica.com/mram/en/publications-expertise/research-spotlight/wildfire-firefighters/index.html>.
- Nielsen-Pincus, M.; Moseley, C. 2010. The Employment and Economic Impacts of Forest and Watershed Restoration in Oregon. Institute for Sustainable Environment, University of Oregon.
- Oregon Department of Forestry. 2012. National Forest Health Restoration: An Economic Assessment of Forest Restoration on Oregon's Eastside National Forests. Prepared for Governor John Kitzhaber and Oregon's Legislative Leaders. November 26, 2012. 94 p. available at: http://www.oregon.gov/odf/BOARD/docs/2013_January/BOFATTCH_20130109_08_03.pdf.
- Perlack, R.; Wright, L.; Turholow, A. [and others]. 2005. Biomass as Feedstock for Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply. Oak Ridge, Tennessee: U.S. Department of Energy, Oak Ridge National Laboratory. 60 p.
- Personal communication Nov. 1, 2013, Brian Ferebee of USDA Forest Service R2
- Pinchot Institute. 2006. Stewardship Contracting: A Summary of Lessons Learned from the Pilot Experience. Policy Report 01-06. Washington, DC: Pinchot Institute for Conservation. Available at: http://www.pinchot.org/gp/Stewardship_Contracting.
- Pinchot Institute. 2012. The Role of Communities in Stewardship Contracting: Programmatic Monitoring Report to the US Forest Service for Fiscal Year 2011. Washington, DC: Pinchot Institute for Conservation. Available at: http://www.pinchot.org/gp/Stewardship_Contracting.
- Rasker, R. 2013. Wildfire Costs, New Development, and Rising Temperatures. *Headwaters Economics*. Available at: <http://headwaterseconomics.org/wildfire/fire-research-summary>.
- Robles, M.D.; Enquist, E. 2010. Managing Changing Landscapes in the Southwestern United States. The Nature Conservancy. Tucson, Arizona. 26 p.
- Sample, V.A. 1990. The Impact of the Federal Budget Process on National Forest Planning. Greenwood Press, 250 p.
- Sample, V.; Tipple, T. 2001. Improving Performance and Accountability at the Forest Service: Overcoming the Politics of the Budgetary Process and Improving Budget Execution. *Journal of Public Budgeting, Accounting, and Financial Management*. 13(2).
- Sample, V.A.; Anderson, S., eds. 2008. Common Goals for Sustainable Forest Management: The Divergence and Reconvergence of American and European Forestry. Durham, NC: Forest History Society. 399 p.
- Sathre, R.; O'Connor, J. 2008. A Synthesis of Research on Wood Products and Greenhouse Gas Impacts. Technical Report TR-19. Vancouver, BC: FPInnovations, Forintek Division.
- Schlamadinger, B.; Marland, G. 1996. The role of forest bioenergy strategies in the global carbon cycle. *Biomass and Bioenergy*. 10: 275-300.
- Stager, C. 2001. Deep Future: The Next 100,000 Years of Life on Earth. New York: St. Martin's Press. 284 p.

- Stein, S.M.; Menakis, J.; Carr, M.A. [and others]. 2013. Wildfire, Wildlands, and People: Understanding and Preparing for Wildfire in the Wildland-Urban Interface. Gen. Tech. Rep. RMRS-GTR-299. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. http://www.fs.fed.us/rm/pubs/rmrs_gtr299.pdf.
- Taylor, P. 2013. 'It's just nuts' as wildfires drain budget yet again. Greenwire, October 30, 2013. Available at: <http://www.eenews.net/greenwire/stories/1059989688>.
- The Nature Conservancy. 2011. Managing Changing Landscapes in the Southwestern United States. Center for Science and Public Policy. http://azconservation.org/downloads/category/southwest_regional
- Topik, C. 2013 Investments in Forest Restoration Represents a Responsible Investment for People and Nature. Testimony before the United States Senate Committee on Agriculture, Nutrition and Forestry. Available at : http://www.ag.senate.gov/hearings/shortchanging-our-forests_how-tight-budgets-and-management-decisions-can-increase-the-risk-of-wildfire
- U.S. Climate Change Science Program. 2007. The North American Carbon Budget and Implications for the Global Carbon Cycle: A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Asheville, NC: National Oceanic and Atmospheric Administration, National Climatic Data Center. 242 pp.
- U.S. Congress. 2009. Federal Land Assistance, Management and Enhancement Act of 2009. Title V of Division A of 123 STAT. 2904, Public Law 111–88—Oct. 30, 2009.
- U.S. Congress. 2013a. Appropriations for Interior, Environment, and Related Agencies for Fiscal Year 2014. Full Committee print [see page 41 for DOI and page 73 for USDA-FS] House Interior and Environment Appropriations Subcommittee. Available at: <http://appropriations.house.gov/uploadedfiles/bills-113hr-fc-ap-fy2014-ap00-interior.pdf>.
- U.S. Congress. 2013b. Appropriations for Interior, Environment, and Related Agencies for Fiscal Year 2014. Senate Interior and Environment Appropriations Subcommittee. Available at <http://www.appropriations.senate.gov/news.cfm?method=news.view&id=b3e22f9d-a060-45eb-90ef-1225244125a7> see page 144.
- U.S. Congress. 2013c. P.L. 113-46 Division A, Sec 135 and Sec 136 of Continuing Appropriations Act, 2014.
- USDA Forest Service. 2012a. Future of America's Forest and Rangelands: Forest Service 2010 Resources Planning Act Assessment. Gen. Tech. Rep. WO-87. Washington, DC. 198 pp.
- USDA Forest Service. 2012b. Increasing the Pace of Restoration and Job Creation on Our National Forests. Available at: <http://www.fs.fed.us/publications/restoration/restoration.pdf>.
- USDA Forest Service. 2013. Fire-adapted Communities Are Prepared for Wildland Fire. Prevention & Education Newsletter. http://www.fs.fed.us/fire/prev_ed/index.html.
- U.S. EPA. 2005. Greenhouse Gas Mitigation Potential in US Forestry and Agriculture. EPA 430-R-05-006. Washington, DC: US Environmental Protection Agency, Office of Atmospheric Programs. 157 p.
- U.S. EPA. 2009. Land Use, Land Use Change and Forestry: Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2007. Washington, DC: US Environmental Protection Agency, Office of Atmospheric Programs.
- U.S. EPA. 2010. Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2008. EPA 430-R-09-006. Washington, DC: U.S. Environmental Protection Agency, Office of Atmospheric Programs.

Vose, J.; Peterson, D.; Patel-Weynand, T., eds. 2012. Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the US Forest Sector. General Technical Report PNW-GTR-870. Portland, Oregon: U.S. Forest Service, Pacific Northwest Research Station. 265 p.

Western Forestry Leadership Coalition. 2010. The True Cost of Wildfire in the Western U.S. Available at: http://www.wflccenter.org/news_pdf/324_pdf.pdf

Zerbe, J. 2006. Thermal energy, electricity, and transportation fuels from wood. Forest Products Journal. 56: 6-14.

This paper received peer technical review. The content of the paper reflects the views of the authors, who are responsible for the facts and accuracy of the information herein.