Wildfires and Forest Resilience: the case for ecological forestry in the Sierra Nevada

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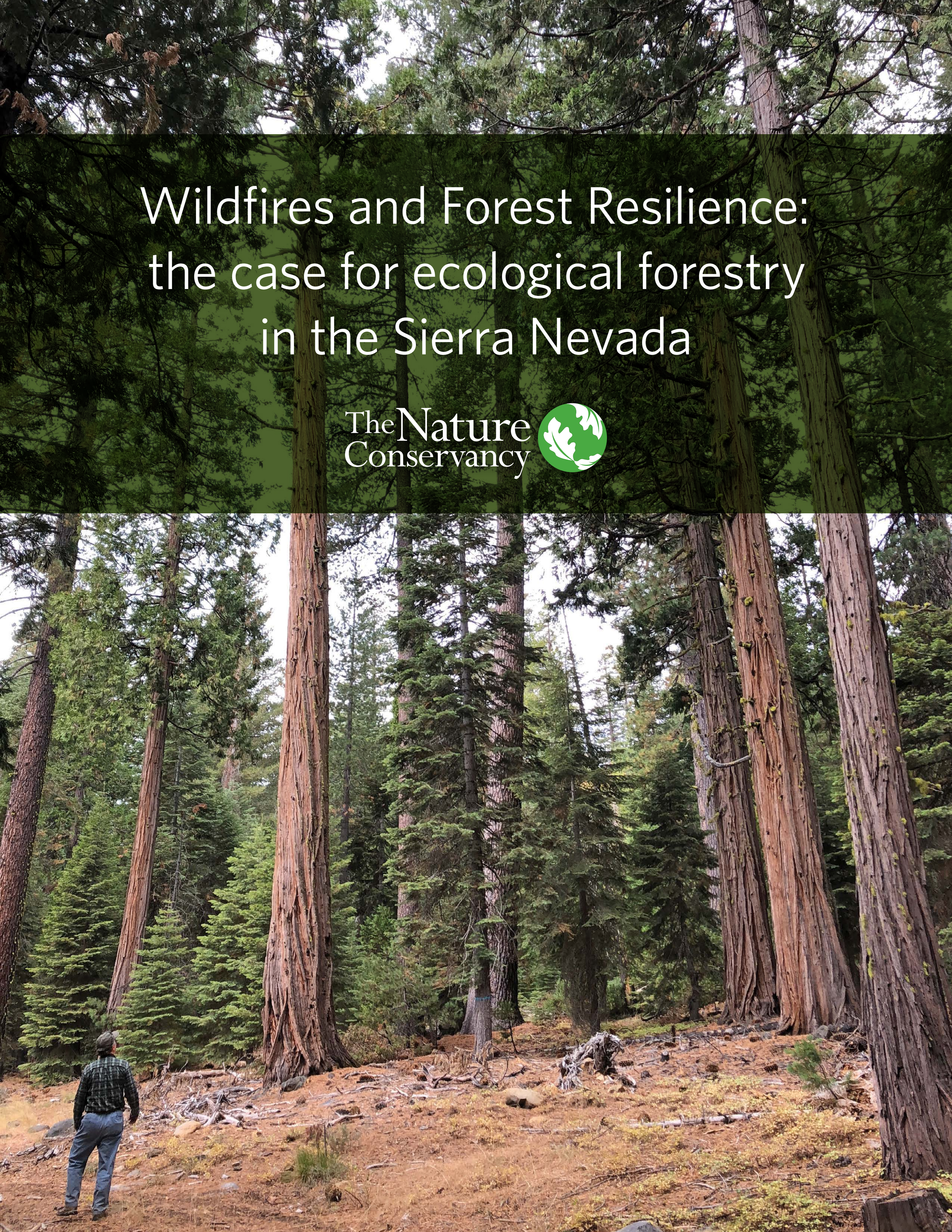

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Introduction

Forests of the Sierra Nevada and across the western U.S. are experiencing an unprecedented increase in the size and severity of wildfires[1–6] along with widespread tree mortality due to drought and insect outbreaks.[7–9] Over the last six years alone, five separate wildfires in the Sierra Nevada have burned 100,000 acres or more with unusually large patches of forest burned at high-severity (where most trees are killed). The fire behavior observed during some of these fires is unlike any experienced in recorded memory, uncharacteristic of the way that forest fires burned in these forests before Euro-American arrival in California, and detrimental to forest sustainability as the climate continues to warm.[10–13 a] These developments not only threaten lives and communities but also seriously compromise forest health and resilience, degrading many important benefits forests provide to people more broadly. The forested watersheds of the Sierra Nevada provide clean water for over 25 million people[14], support rural economies and tourism[15], and play a critical role in carbon storage and climate control.[16–18] Sierra forests are also home to abundant and diverse wildlife, with over 500 vertebrate species (24 of which occur nowhere else) and 3,500 plant species (400 which occur nowhere else).[19]

We know how to manage forests so they are less prone to large, severe wildfires and drought and to decrease likelihood of large tree mortality events from insect and disease outbreaks.[9,10,20,21] Through use of targeted ecological thinning, prescribed fire, and managed wildfire we can reduce the accumulated high fuel loads, promote healthier, more resilient forests, reduce the risk of high-severity wildfire at large spatial scales, and protect sensitive species. Unfortunately, the pace and scale of these activities is inadequate given the widespread scope and long-term consequences of the problem.

Canopy fire during the King Fire of 2014. Canopy fires occur when there are lots of ladder fuels that allow the fire to travel into the canopy. Canopy fires can be extremely hot and lead to widespread tree mortality. © USFS

An important obstacle to increasing the pace and scale of forest management in the Sierra Nevada is misunderstanding about the relative roles of thinning trees to reduce fuels and increasing the natural role of fire as a restorative process. In this briefing paper, we explain how our forests became overgrown and at risk from uncharacteristic, high-severity wildfire and tree mortality. Then, we make the scientific case for ecological forestry—a combination of strategic thinning, prescribed fire, and managed wildfire—as the best solution to the challenges our forests face.

A legacy of logging and fire suppression has created forests prone to severe wildfires

What has changed and why are fires different now? One critical factor is that, despite the large and destructive wildfires of recent years, many of the forests of the Sierra Nevada are fire-starved. There is far less fire now than there was before Euro-American settlement of California, even though there have been major increases in area burned recently. Prior to the 20th century, wildfires frequently roamed over large areas every year in the Sierra Nevada.[22–25] These were both naturally caused by lightning and intentionally set by Native Americans for the diversity of benefits fire can create. On average 400,000 to 500,000 acres burned each year prior to European settlement just in forests that are now National Forest lands in the Sierra Nevada.[3,26] Most of these fires were dominated by low and moderate severity effects, with patches of high severity that created openings in the forest.[13,23,27] This patchy mosaic created the diversity of forest conditions—from open, shrubby patches and pocket meadows to shady stands of large, fire-resistant trees[27–32]—that maintained the health and resilience of the forest and the biota that depend on it. Frequent fire in some forests was also the process that reduced the likelihood of large, severe wildfires by removing surface fuels and keeping shrubs and understory trees that fuel intense fires in check.[27,29–33]

This lack of ecologically appropriate fire is the result of aggressive fire-exclusion. Eliminating most fire from these landscapes began in the mid 19th century when Native American burning was drastically reduced. This was followed by widespread fire suppression in the

Large areas of high-severity fire, where most of the trees are killed, significantly degrade the many values that healthy forests provide for people and nature. © daveynin/Flickr

20th century, based on the well-intentioned but now disproved assumption that all fire is bad.[13,34–38] Another critical factor contributing to the current situation is historical logging practices. Extensive logging beginning in the mid-1800s removed most of the old-growth forests dominated by large, fire-resistant trees that provide habitat for sensitive species like the California spotted owl. Even-aged management of forests for timber production also favored uniform, single-species "plantations" that reduced the overall diversity and resilience of the forests.

The result is that many forests in the Sierra Nevada are now highly homogenous and overly dense with small trees and shrubs. They are dominated by fire-intolerant species with few large fire-resistant trees, continuous canopy cover and heavy understory fuel loading from litter and woody debris.[13,31,36,37,39–43] Many private timberlands are characterized by relatively homogenous, even-aged stands of trees. Overall, these uncharacteristically uniform, dense and young forests are more prone to high-severity fire. As a consequence, while fire frequency overall remains lower than prior to fire suppression, in recent decades we have experienced a rapid increase in burned area and fire size,[5,44] with strong evidence for an increase in severity of fires, as measured by trends in fire-driven tree mortality and the minimum area of high severity burns.[1,3,11,34,45,46] At high elevations, where fire was historically infrequent, the number of fires burning and the annual area burned also appear to be increasing over time.[3,47] Of particular concern is the potential for more of the largest, most severe fires ("megafires"), like several experienced just within the last 5 years.[48]

One recent example is the 2014 King Fire, in which 50% of the burned area was high-severity, mostly occurring as one very large contiguous patch. Over the last hundred years the forests in this area have changed dramatically[49] and, based on the best available evidence on historical fire regimes, high severity burn areas would have been lower overall and distributed across many smaller patches.[2,3,27] The King Fire burned 30 spotted owl territories. An average of 53% of each territory burned at high-severity and 14 of these territories had an average of 89% high-severity burn area (Gavin Jones, personal communication). The result was sevenfold higher abandonment of territories compared to unburned and low-severity burned territories.[50] The intensity of the King Fire also precipitated massive erosion events that caused millions of dollars in damage and maintenance costs for Placer County Water Agency. It can take decades if not hundreds of years for large patches of severely burned forests to recover; some of the forests may be permanently converted to shrub fields if the sizes of high severity patches are very large (like in the King Fire) or if they repeatedly burn during the warmest, driest periods of subsequent years.[51–54]

Even more concerning are the observed and potential long-term effects of a warming climate. California is on track to exceed 2°C increase in average temperature by 2050 and to experience more intense droughts.[44,55,56] This may push many forests into a climate regime they have not experienced for millenia or ever[57] and intensify already observed fire and tree mortality trends in Sierra forests.[10,12]

Increasingly early snowmelt is likely to increase fire frequency and lengthen the fire season.[5] Overall burned area is expected to increase with a drier and warmer future, with a predicted 50% increase by the end of the century in the frequency of extreme wildfires burning more than 25,000 acres.[58,59] Dense and young forests are also more prone to the impacts of drought.[60,61] Dense forests are more susceptible to water stress, insect outbreaks and some diseases that can lead to large-scale tree die offs and conversion to non-forest vegetation.[9,20,21,62–65] During the 2012-2016 drought an estimated 130 million trees died in the Sierra, including up to 50% of pines in lower and middle elevation watersheds in the central and southern Sierra.[66,67] These conditions can lead to high intensity fires that could be dangerous to human communities and forests.[21]

Current forest conditions are bad for people and nature

The effects of increasing fire size and severity, as well as the recent drought, are having significant, negative impacts on people and nature. Not only do severe fires near communities threaten lives and properties, they can lead to damaging erosion and mudslides that affect homes and water supplies.[68–71] The effects of severe wildfires also go well beyond the forest. Large, intense wildfires degrade air quality around the state and even across the country.[72–74] This increases the duration of smoke exposure[75] with acute and chronic human health impacts, such as increased asthma-related hospital visits, respiratory disease, and cardiovascular disease.[76–78] Forests are also a significant source of carbon storage in terrestrial ecosystems, but the value of Sierra Nevada forests as a vital carbon sink is in jeopardy.[12,16,18] Further, the many imperiled species that depend on older, closed canopy forests and suffer from the legacy of past logging—like California spotted owls[79]—are increasingly threatened by the impact severe fires can have on the little remaining old forest they occupy.[50,80–83]

California spotted owl parent and chick newly out of the nest. Spotted owl populations have declined following early logging that removed most of the large, old tree habitat they need for nesting. Now, those that remain are increasingly threatened by high severity fires that can remove or significantly degrade their remaining habitat. © Danny Hofstadter

Finally, we have many more homes and people living in the forest now than we did a century ago. This has intensified the potential impact and challenges to managing fire, especially at the wildland–urban interface where people live.[84] At the same time, eliminating wildfire is neither a practical, affordable, or ecologically desirable solution. As recent events have demonstrated, it is also impossible.

Given that our fire-adapted forests need more of the right kind of fire, but existing conditions and a warming climate make it unsafe for people and nature to allow all fires to burn under unmanaged conditions, what is the solution?

The solution: ecological forestry

Forests are diverse and complex, as are the changes they have experienced. There is not a one-size-fits-all answer to restoring their resilience, diversity, and safety.[85–88] An essential part of the answer will be taking a landscape-scale and ecologically-based approach to forest management. The good news is that we largely know what needs to be done and it is based on a robust body of science showing what the trends are, what the forests used to look like, and how to balance the trade-offs between reducing high-severity fire risk and protecting the natural diversity and function of these forests in a changing climate.

Many low and mid-elevation forests of the Sierra Nevada need to be restored to a more open, patchy and diverse structure with more frequent low and moderate severity fire in order to make them more resilient to drought and a warming climate.[87,89] This will require increasing the scale of ***ecological forestry*** across large areas. It will also require fire-hardening human communities and reducing development in fire prone areas. All three solutions will be necessary, and none of them will be sufficient on its own.

Ecological forestry has two main ingredients: careful and targeted removal of forest fuels—thinning of smaller trees and shrubs in strategic, accessible areas where it is needed most and will have the least negative impact on sensitive species—plus implementation of prescribed fire and managed wildfire as a natural process where it is safe to do so. Prescribed fires are intentionally planned, ignited and managed fires targeted to specific places and often preceded by thinning where needed. Managed wildfires are those that are unintentionally started (either by natural causes like lightning or human caused) but then allowed to burn where weather conditions permit and managed for resource benefits and human safety. Managed wildfires take advanced planning so that when fires start the appropriate measures can be taken to manage them.

Ecological forestry will also need to include proactive measures that will ensure the resilience and adaptive capacity of the forests in a changing environment over the long-term. This may include active replanting of seeds from drought tolerant populations or facilitating the expansion of tree and shrub genotypes that are better-adapted to future climates and disturbance regimes.[90,91]

Ecological Thinning

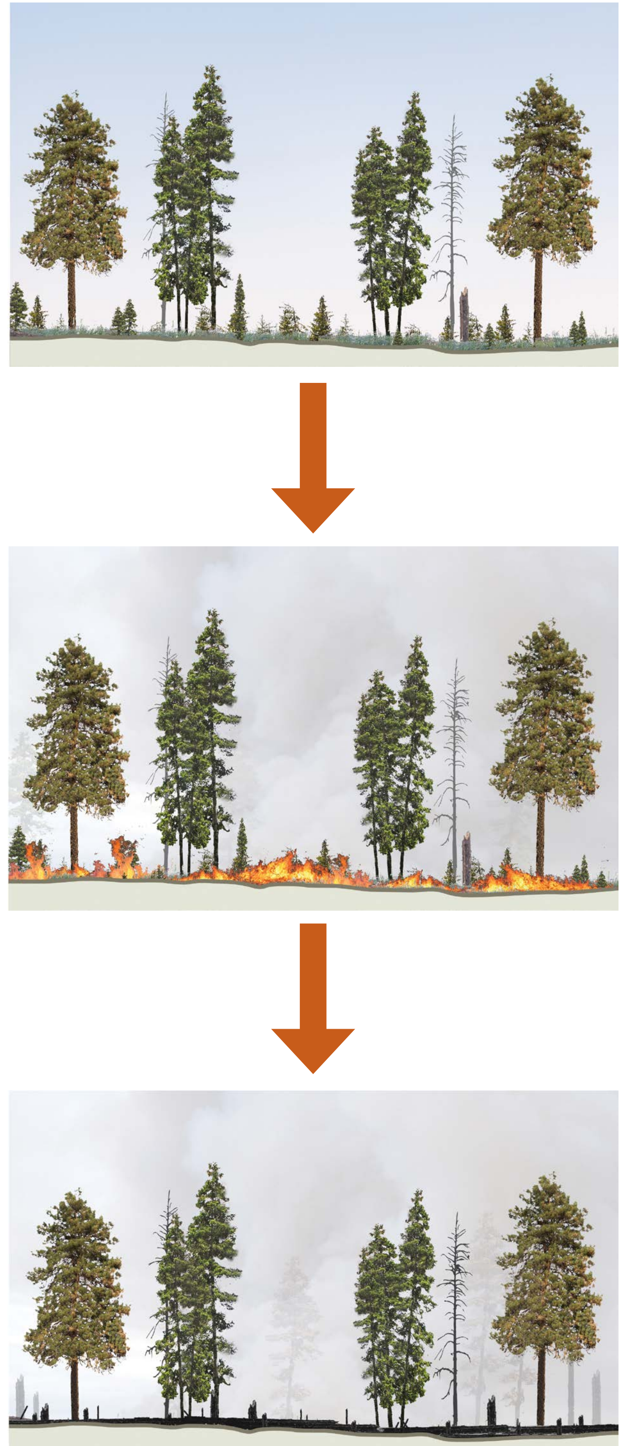
As counter-intuitive as it may seem given that historical logging created some of the challenges our forests face, cutting some trees out of our forests is now a necessary part of the solution.[28,92–96] Given current conditions, healthy fire cannot be safely re-introduced to some forested areas without some preliminary fuels reduction. This is particularly important in areas that are closest to homes and communities and in areas that can transport high intensity fire to the wildland-urban interface, as happened in the 2018 Camp Fire. Targeted and ecologically based thinning in accessible areas is needed to open up the forest where it is unnaturally dense. Done well, this kind of thinning can recreate a diverse forest structure that protects wildlife and plant diversity and facilitates the reintroduction of fire where it would currently be unsafe to do so.[95–97]

Ecological forestry has little in common with historical logging practices. Ecological thinning does *not* mean clearcutting, old-growth forest logging or extensive salvage logging after fires. It is explicitly focused on protecting the oldest trees and creating a diverse mosaic of natural features that are essential for forest diversity and regeneration.[96,98] To do this, it must be done carefully. Intensive logging can negatively affect sensitive wildlife and the diversity and function of the forests. Thus, ecological thinning must minimize disturbance and balance the trade-offs between potential short-term impacts of treatment with the longer-term benefits from reduced risk of large, high-severity fires. This means prioritizing removal of surface and ladder fuels that contribute most to wildfire hazard[99], while minimizing ground disturbance and impacts to those trees

Fire-suppressed Forest

Forests that have not experienced fire in many decades, that are dense with thickets of young trees and shrubs in the understory, are prone to high-severity fires that travel up into the canopy, burn very hot and can kill most of the trees, even the large, fire-resistant trees. © The Nature Conservancy

Ecologically managed Forest



By carefully thinning the understory of some forests to reduce overall fuel load and open the forest up, we can safely reintroduce fire as a restorative process that will over time maintain healthy forests. © The Nature Conservancy and shrubs that will not be removed. It also means maintaining higher canopy cover in some locations and protecting stands of large trees in high quality and occupied habitat of sensitive species—like the California spotted owl and Pacific fisher.

There remains some uncertainty about the relative impacts to sensitive species from severe wildfire compared to ecological thinning. For example, further research is needed on how spotted owls respond to ecological thinning in their territories relative to how they respond to varying amounts and severities of fire. However, given the degree to which forests have been modified and current fire trends it is clear that some thinning in strategic areas will be needed to reduce the risks that high-severity wildfire poses to these species.[50,101] Otherwise, there is the risk that the benefits of avoiding near-term impacts from ecological thinning will be overwhelmed by the devastating loss of habitat due to high-severity wildfires.[50] Ongoing and future research will build on our understanding of how species respond to forest management and megafires, and we will be able to adapt our forest management strategies in response.

Prescribed Fire and Managed Wildfire

Reintroducing fire to many of our forested watersheds is the other key ingredient in ecological forestry and ultimately will be the most important contributor to restoring forest health and resilience. This means re-establishing more frequent fires of relatively low-severity where this was once the natural regime. This will keep the most flammable fuels in check, protect the larger trees, and recycle nutrients in the forest to develop a healthier canopy and less flammable and more diverse understory. It also means allowing and managing for smaller patches of moderately and severely burned forest where safe and appropriate. The kind of structural diversity and patchiness created by fires with mixed severity moderates the intensity of future fires.[30,103–105] This heterogeneity is also essential for supporting the full diversity of plants and wildlife that are unique to the Sierra Nevada, including those that are adapted to and benefit from severely burned forest patches.[83,102,106–110]

Ecologically-based thinning and fire need to be combined as part of increasing the pace and scale of forest restoration for several reasons. First, we know that the combination of thinning followed by prescribed fire works best to restore Sierra Nevada forests. Treated areas are more species diverse and the reduction in potential fire severity lasts longer than if thinning or fire are implemented alone.[11,26,28,89,113–117] In fact, following thinning with fire may be essential in many areas to avoid increased fire severity following a single thinning treatment.[99,116–119] Second, as a practical matter given the scope of the problem and many constraints on applying prescribed and managed wildfire, ecological thinning will be an important part of the solution at least in the near to mid-term. The fact is that less than 1% of Forest Service lands are currently being managed with fire each year,[26] which likely reflects the scale across other federal and state lands. It will take some years to build the capacity and social will to manage fire for resource benefits at large scales. Also, management guidelines for federal and state lands often require or encourage wildfire suppression regardless of potential to safely manage them for resource benefits. In addition, some areas (e.g. near communities) may never be suitable for fire even in the long-term.

Ecological thinning removes dense thickets of small trees and shrubs in the understory, leaving medium and large trees . © David Edelson

Ecological forestry will provide many benefits

While it is a daunting challenge, implementing ecological forestry broadly across Sierra Nevada forests where both human and natural communities are at the greatest risk will provide many benefits. Ecological forestry will help ensure we are able to protect the natural diversity and beauty of California's fire-prone forests. Done thoughtfully, it will protect habitat for and mitigate high-severity fire risks to the imperiled species that have been pushed to the brink. Ecological management of our forests will also be an important part of protecting California's largest supply of clean water[120–125] and making forests more resilient to drought.[10,60,126,127] Further, protecting our forests from the most extreme fire and tree mortality events will protect the forests against more extreme losses of carbon storage that would come with widespread and severe wildfires, as well as help stabilize carbon stores in these forests over the long-term.[44,128–132] Importantly, managing for these diverse benefits will require planning for and managing the Sierra Nevada forests at landscape and regional scales to balance the trade-offs between fire risk, habitat, carbon storage and water supplies.

Taking a large-scale and ecologically-based approach to forest management is also important for human safety. Focusing all of California's forest investments only on defensible space around communities and fire-hardening homes may not be enough. These defenses could be overwhelmed by an intense and fast-moving fire coming out of the forest. As recent fires like the 2018 Camp fire have demonstrated, late season fires of that intensity driven by large fuel loads, dry weather, and high winds—conditions that will become more frequent in California—can quickly move out of the wildlands and send embers flying miles to land on homes in the middle of densely populated communities. Instances like these are forcing the state to rethink how it maps fire hazard zones.

There could also be important indirect benefits of ecological forestry to people other than safety. Lower severity fires (including prescribed fires and managed wildfires) can have lower emissions per fire event and thus may reduce the potential human health impacts and costs over time compared to unplanned megafires.[72,75] Given the scale of forest management needed and the inadequate capacity to implement at the required scales, there is also the potential for California to lead in the development of a forest restoration economy. California's current capacity to implement ecological forestry at the scale needed is far short of what is required. There are few innovative uses for the small wood material that will be removed (e.g. cross-laminated timber) and not enough facilities to process the material. There are also far too few trained personnel in ecological thinning and the application of prescribed fire. Those that are trained can barely keep up with managing the dangerous wildfires that need to be contained. Ramping up investments and training could supply jobs in ecological forestry, bio-energy, and small diameter wood products that could revitalize struggling rural communities.[133]

Crew working to implement a prescribed fire at The Nature Conservancy's Independence Lake Preserve following ecological thinning. © Ed Smith/The Nature Conservancy

California's fire-prone forests are unhealthy and at serious risk of uncharacteristic, high-severity wildfire, drought, and insect outbreaks. There is compelling evidence that ecological forestry—ecological thinning, prescribed burning, and managed wildfire—can reduce these risks and promote healthier, more resilient forest conditions. We urge policymakers to maintain and increase funding for ecological thinning and prescribed fire and to take steps to address the policy and practical barriers to implementing ecological forestry at a scale and pace appropriate to the challenge at hand.

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