Received: 19 January 2023 | Revised: 21 March 2023 | Accepted: 30 March 2023
DOI: 10.1111/csp2.12935

PERSPECTIVE

Conservation Science and Practice
A Journal of the Society for Conservation Biology
Open Access
WILEY

The importance of natural forest stewardship in adaptation planning in the United States

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Abstract

Forests are critical to the planetary operational system and evolved without human management for millions of years in North America. Actively managing forests to help them adapt to a changing climate and disturbance regime has become a major focus in the United States. Aside from a subset of forests wherein wood production, human safety, and experimental research are primary goals, we argue that expensive management interventions are often unnecessary, have uncertain benefits, or are detrimental to many forest attributes such as resilience, carbon accumulation, structural complexity, and genetic and biological diversity. Natural forests (i.e., those protected and largely free from human management) tend to develop greater complexity, carbon storage, and tree diversity over time than forests that are actively managed; and natural forests often become less susceptible to future insect attacks and fire following these disturbances. Natural forest stewardship is therefore a critical and cost effective strategy in forest climate adaptation.

KEYWORDS

adaptation, biodiversity, carbon, climate change, fire, management, natural forest, protected areas, resilience

Forests, along with oceans, are the most significant ecosystems that regulate the planetary operational system. They determine global temperatures, climate and weather, provide oxygen, and remove carbon dioxide. Forests require a high degree of integrity, complexity and diversity to be at their most functional, and when they lose these attributes they become less resilient and effective in their role in planetary dynamics (Grantham et al., 2020; Millenium Ecosystem Assessment, 2005; Parmesan et al., 2022).

North America's temperate forests evolved continuously in response to natural disturbances and changes in climate over the past 65 million years (Askins, 2014). Only in the past 10–15,000 years did humans arrive and manage forests with fire and tree removal for subsistence and safety near their settlements (Roos, 2020; Roos et al., 2021), and only in the past two centuries did humans manage forests intensively (including the suppression of natural disturbances like fire) for industry and other values at the regional scale (Williams, 1992).

Today, tree mortality is on the rise due to fire, insects, wind, drought and other natural disturbances that are increasing in frequency and intensity with anthropogenic

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This article is designed for forest and land managers, conservation biologists, conservation organizations, and other forest landowners.

climate change (Parmesan et al., 2022). In response to these impacts, intensified efforts to manage forests proactively to help them adapt to future changes has become a major priority among forest managers and many public and private conservation agencies in the United States (Prichard et al., 2021; Swanston et al., 2016). For instance, California pledged to actively manage at least 1 million acres of forestland per year over the next 20 years; the state spent 1.5 billion dollars in 2021 alone on "wildfire resilience" (Office of Governor Gavin Newsome, 2020). Additionally, a recent USDA Forest Service grant promotes active management on 15 million acres of eastern forest land owned by small private landowners. "Improving forest health" is one of the primary goals of this project (Purdue University, 2023).

Forest health and resilience are important tenets of adaptation. Yet definitions of forest health focus on the ability of forests to provide direct resources and services to people (Millar & Stephenson, 2015), rather than the ability of ecosystems to persist and adapt per se in the face of changing disturbances. Hence, forest adaptation projects are portrayed as necessary for protecting forest ecosystems from climate change, when these initiatives are often more about resisting and directing change to promote a particular set of natural resource values and objectives, including economic gain.

Recently, many natural resource managers have embraced the RAD framework for stewarding ecosystems undergoing rapid change (e.g., Schuurman et al., 2022). RAD stands for resist, accept, or direct change, with active management and intervention inherent in "resist" and "direct" and a passive, hands off approach characterizing "accept." Although relatively few forests are harvested each year (e.g., 2.6% of forest area across the northern United States; Thompson et al., 2017)—which gives a snapshot impression that a hands off approach ("accept") is the dominant management approach—this rate of harvest scales up to >50% of forest area cut in 20 years, suggesting that management is pervasive over a decadal time scale. In contrast, only 3% of land in the continental United States is currently protected under natural stewardship (i.e., Gap 1—managing forests largely free of human disturbance to allow natural disturbances to operate without interference; Peterken, 1996; USGS, 2022). Here we argue that a resist and direct approach to managing forests (e.g., mechanical thinning, prescribed burns, species selection, pre- and post-disturbance salvage/planting, and other fire suppression tactics) is appropriate in some forests intended for resource production, experiments, and human safety in the "wildland–urban interface." However, accepting the capacity of natural systems to adapt and be self-sustaining with natural stewardship is a critical and cost-effective approach in other forest contexts.

Although improved resilience and protection of biodiversity are goals of proposed adaptation management, active management may, in some cases, have little effect on future stand resistance (Morris et al., 2022), is often unnecessary for natural forest resilience (e.g., Cansler et al., 2022; Hart et al., 2015) and biodiversity (Thom & Seidl, 2016; Viljur et al., 2022), and is generally counterproductive to carbon storage, structural complexity, tree diversity, and resistance to invasive species. (Donato et al., 2013; Miller et al., 2018; Patton et al., 2022; Schwilk et al., 2009; Young et al., 2017; Table 1). Moreover, conservation evidence for the effectiveness of management interventions is often lacking or has mixed results (Sutherland et al., 2021), resources for interventions are limited, and management incurs substantial financial and other costs to society (Houtman et al., 2013). Depending on local considerations, and based on multiple values, natural or near natural forest stewardship is an effective approach to developing and sustaining forest complexity, diversity, and functionality and traditional/aesthetic values (Franklin et al. 2002; Miller et al., 2016; Miller et al., 2018; Sze et al., 2022; Waller & Reo, 2018). It is also an insurance policy as we face an uncertain future.

Human safety is a major consideration with respect to fire risk within communities and especially to individual homes. Depending on the region and climate risks, adaptation management and suppression efforts to protect the immediate area around residential homes (e.g., removal of combustible plants and debris, forest clearing, and forest thinning) in fire-prone areas is beneficial for safety (J. Cohen, 2008; Roos et al., 2021). Clearing this "home ignition zone" (i.e., trees and shrubs in a 30–60 meter buffer area around a house) and preventative fireproofing itself (i.e., metal roof, fire-resistant doors and windows, secured pet doors and attic vents) is primarily what reduces the ignition potential of a home (J. D. Cohen, 2001; J. Cohen, 2008).

In forests managed for resource production, some adaptation management efforts to maintain forest cover, species composition, and tree regeneration can be beneficial in some regions (Foster & Orwig, 2006; Sutherland et al., 2021). For instance, in western coniferous forests (e.g., *Pinus ponderosa* and *Pseudotsuga menziesii)* thinning and prescribed burns can, in some cases, reduce fire severity (Cansler et al., 2022; Yocom-Kent et al., 2015), increase densities of desirable conifer regeneration (Shive et al., 2013), and mitigate transformation of forest into non-forest vegetation following fire (Walker et al., 2018). However, the conservation evidence to date suggests that while mechanical thinning alone can be beneficial for forest understories and young trees (Sutherland et al., 2021), it can also

TABLE 1 Forest management objectives and outcomes from pre- and post-disturbance management relative to natural stewardship.

	Management strategy and outcome (+ positive; − negative; ? unknown)			
Forest management objective	**Pre-emptive stand management (thinning, prescribed fire)**	**Natural stewardship (little to no management)**	**Post-disturbance management (salvage logging, tree planting, herbicide, site preparation)**	**References**
Procure timber products	+	−	+	Foster & Orwig, 2006; Donato et al., 2013
Reduce fuels near homes and building	+	−	+	J. D. Cohen, 2001; J. Cohen, 2008
Increase empirical understanding of adaptation management with experiments	+	+	+	Powers et al., 2010; Morris et al., 2022
Increase forest carbon storage	−	+	−	Bradford et al., 2012; Donato et al., 2013; Yocom-Kent et al., 2015; Moomaw et al., 2019; Patton et al., 2022
Increase forest structural complexity	+/−	+/−	−	Schwilk et al., 2009, Donato et al., 2013; Miller et al., 2016; Young et al., 2017; Stiers et al., 2018, Shell et al., 2021; Patton et al., 2022
Increase adult tree diversity	−	+	?	Stapanian et al., 1997; Zlonis & Niemi, 2014; Young et al., 2017; Miller et al., 2018; Morris et al., 2022; Patton et al., 2022
Reduce invasive plants	−	+	−	McIver & Starr, 2001; Schwilk et al., 2009; Willms et al., 2017; Fornwalt et al., 2018; Riitters et al., 2018
Reduce insect outbreaks and associated tree mortality	+/−	+/−	+	Foster et al., 2006; Youngblood et al., 2009; Stark et al., 2013; Hood et al., 2016; Knapp et al., 2021; Morris et al., 2022; Leverkus et al., 2021
Reduce impacts from windstorms to structure and composition	−	+	?	Valinger & Fridman, 2011; Sharma et al., 2021; Fortuin et al., 2023
Reduce fire severity and impacts in forests	+/−	+/−	+/−	Raymond and Peterson, 2005; Youngblood et al., 2009; Fraver et al., 2011; Thompson et al., 2007; Yocom-Kent et al., 2015; Bradley et al., 2016; Cansler et al., 2022
Maintain existing tree species composition	+/−	+/−	?	Hood et al., 2016; Knapp et al., 2021; Morris et al., 2022; Sharma et al., 2021
Promote density of tree regeneration	+/−	+/−	+/−	Donato et al., 2006; Schwilk et al., 2009; Donato et al., 2012; Royo et al., 2016; Santoro and

(Continues)

TABLE 1 (Continued)

Forest management objective	Management strategy and outcome (+ positive; − negative; ? unknown) Pre-emptive stand management (thinning, prescribed fire)	Natural stewardship (little to no management)	Post-disturbance management (salvage logging, tree planting, herbicide, site preparation)	References
				D'Amato, 2019; Sutherland et al., 2021
Promote vertebrate diversity	+/−	+/−	−	Thorn et al., 2018; Sutherland et al., 2021
Promote invertebrate diversity	+	+/−	+/−	McIver et al., 2012; Campbell et al., 2018; Thorn et al., 2018; Bladon et al., 2022
Promote understory plant diversity	+/−	+/−	+/−	McIver & Starr, 2001; Lain et al., 2008; Abella & Springer, 2015; Thorn et al., 2018; Santoro & D'Amato, 2019; Sutherland et al., 2021

increase subsequent fire risk and vulnerability to severe wind damage from hurricanes (Fortuin et al., 2023; Raymond and Peterson, 2005). Additionally, "no evidence was found" to assess the effectiveness of mechanically removing understory vegetation for reducing wildfires (Sutherland et al., 2021).

A scarcity of empirical evidence is a notable problem of adaptation management strategies. A recent review article found that "most of the inference about intervention options has been drawn from theory rather than empiricism" (Prober et al., 2019); and according to the latest IPCC report, there is almost no evaluation of the success of adaptation approaches in the scientific literature (Parmesan et al., 2022). Establishing more long-term experiments with adaptation treatments and unmanaged controls (e.g., Morris et al., 2022) would provide much-needed information on this topic.

From an ecological perspective, it is questionable whether it is even desirable or necessary to reduce the frequency and intensity of fire and other disturbances away from human settlements and forests managed for sustained wood production (e.g., Bradley et al., 2016; Kulakowski, 2016). Even moderate to severe natural disturbances promote structural heterogeneity, create biological legacies and unique habitats, and can increase biodiversity (Carbone et al., 2019; Klaus et al., 2010; Santoro & D'Amato, 2019; Shive et al., 2013; Swanson et al., 2011). And while mechanical thinning may mimic some of the habitat benefits of low to moderate severity fires, it does not emulate the important habitat characteristics of high severity fires (Stephens et al., 2012).

1 | REEXAMINING LOSSES FROM NATURAL DISTURBANCE AND ADAPTATION MANAGEMENT

A common rationale for forest adaptation management is preventing future tree mortality, species compositional shifts, and carbon loss from natural disturbances. In some cases, thinning has been shown to reduce subsequent tree death from insects and drought compared to untreated areas, thereby promoting stand resistance and maintaining an existing species composition, while procuring sound timber (Hood et al., 2016; Knapp et al., 2021). However, in other cases prescribed burn treatments increased subsequent tree mortality (Knapp et al., 2021; Stark et al., 2013; Youngblood et al., 2009), and thinning and burn treatments generally promote the spread of invasive plants relative to controls (Schwilk et al., 2009; Willms et al., 2017). Additionally, loss of tree basal area and carbon storage from thinning and prescribed burning is often equal to or considerably greater than tree mortality and carbon loss from the disturbances themselves (Campbell et al., 2012; Hood et al., 2016; Knapp et al., 2021; Powers et al., 2010; Yocom-Kent et al., 2015). As a result, treated stands are not objectively more resistant or resilient to tree mortality or carbon loss—and in many cases are less so—if losses from the management itself are taken into account. Not surprisingly, natural forests in strictly protected areas store greater amounts of carbon, on average, than managed and unprotected areas (Collins & Mitchard, 2017; Moomaw et al., 2019).

In addition to natural forests, forests managed for longer rotations and larger trees also store more carbon than those that are more intensively managed with shorter rotation intervals (Waller & Reo, 2018). This has occurred, for example, on indigenous tribal lands in Wisconsin on which human population densities are low, the corresponding need for timber relatively small, and where old trees and forests are valued (Trosper, 2007; Waller & Reo, 2018). Protected areas and protected areas that overlap with indigenous lands have been shown to support greater connectivity and carbon stocks and have fewer human modifications and impacts (i.e., greater integrity) than adjacent unprotected areas (Parmesan et al., 2022; Sze et al., 2022).

Certainly, insects, disease, wind, and wildfire account for current and future tree death and carbon losses in forests (Thom & Seidl, 2016); however, in many cases disturbances such as insect outbreaks that target dominant tree species result in increased tree diversity in the post-outbreak stand (Morris et al., 2022). Additionally, carbon losses from fire and insects are often much less than models predict. For instance, Lodgepole pine (*Pinus contorta*) forests killed by mountain pine beetles (*Dendroctonus ponderosae*) in the southwestern United States underwent little net flux in carbon for a decade or more because of a cessation of respiration following tree death (Moore et al., 2013). In the Northeastern United States, eastern hemlock (*Tsuga canadensis*) forests killed by (simulated) Hemlock Woolly Adelgid (*Adelges tsugae)* insects maintained aboveground carbon storage, primarily in dead and downed wood, similar to pre-infestation forests (Raymer et al., 2013). With respect to fire, observations revealed that on average less than 5% of live tree biomass burns in western US wildfires when considered across the full range of fire severities (Stenzel et al., 2019). As a result, these authors reported that carbon models overestimate carbon loss from fires by up to an order of magnitude (i.e., a factor of 10) at local scales and by 59%–78% at the regional scale.

Tree declines from increased disturbances also impact non-tree biodiversity, and the direction of the impact (positive or negative) depends on the species guild or taxonomic group in question (Fleming et al., 2021; Thom & Seidl, 2016; Viljur et al., 2022). However, meta-analyses reveal that overall natural disturbances have either significantly positive or neutral effects on biodiversity (Thom & Seidl, 2016; Viljur et al., 2022). Pollinating insects, tree lichens, birds, reptiles, arachnids, and herbaceous plants tend to increase as a result of disturbance (Carbone et al., 2019; Fleming et al., 2021; Viljur et al., 2022), whereas epigeic lichens, mollusks, and mycorrizhal fungi are more likely to decline. Species diversity, on average, peaked at about 60% of forest area disturbed at the landscape scale (Viljur et al., 2022). To put that figure into perspective, the Yellowstone National Park fires of 1988, among the largest wildfires in the western United States, burned 45% of the Yellowstone landscape (Christensen et al., 1989). Additionally, the percentage of forestland in the United States impacted by natural disturbances at any given time over the past 30 years is well below 5%, peaking at about 8%–9% in the western United States (W. B. Cohen et al., 2016). These numbers suggest that biodiversity is unlikely to be reduced at the landscape scale by very large and severe disturbances and may continue to increase in the foreseeable future as natural disturbances become more intense and frequent.

2 | THE BENEFITS OF NATURAL RECOVERY

While often perceived as catastrophic, severe insect outbreaks can result in a decline in subsequent insect attacks for 60 years and result in a decreased (or lack of increased) risk of subsequent fire (Hart et al., 2015; Meigs et al., 2016). Severe fires can also reduce the susceptibility of forests to severe insect outbreaks for ∼100 years (Kulakowski et al., 2012) and in some cases can reduce future fire severity even when fire weather conditions are extreme (Cansler et al., 2022; Stevens-Rumann et al., 2016). Severely burned forests can reburn at high severity (Taylor et al., 2022; Thompson et al., 2007); however, burned areas that were salvage logged and planted with conifer seedlings experienced more severe reburns than burned areas that were left untreated (Thompson et al., 2007). In other words, natural forests have built-in resilience and adaptation capacities following many disturbances. At broad scales the resilience ("capacity to withstand and recover from environmental perturbations"; Forzieri et al., 2022) of natural forest landscapes typically exceeds that of actively managed forests, in large part because of a generally higher structural complexity and tree species richness in the absence of management (Bradley et al., 2016; Forzieri et al., 2022; Miller et al., 2016; Miller et al., 2018). Leveraging this natural capacity of forests to a greater extent via natural stewardship would result in substantial cost and carbon emissions savings by avoiding or reducing pre-emptive and post-disturbance management (Houtman et al., 2013; M. North et al., 2009), resulting in increased protection against species extinctions (Di Marco et al., 2019).

Directed adaptation strategies following disturbances often involve salvage, planting and other site preparation and management to facilitate forest regeneration (Donato et al., 2013; M. P. North et al., 2019). These types of interventions may make sense in forests prioritized for timber production if the goal is to extract resources and more reliably and rapidly regenerate sites that may be distant from seed sources, in challenging terrain, or exposed to suppression from invasive vegetation and intensive ungulate browsing (M. P. North et al., 2019; Ward et al., 2018). However, the evidence is mixed at best for the effectiveness of these interventions. According to the conservation evidence (Sutherland et al., 2021), thinning following wildfire has "tradeoffs between benefits and harms" on tree saplings and understory plants; and the evidence is limited and therefore the effectiveness "unknown" for removing burned trees and mechanically/chemically removing invasive plants to promote understory vegetation and young trees. Additionally, sowing seeds following wildfire is "likely to be ineffective or harmful," and evidence on the effectiveness of planting trees following wildfire is lacking (Sutherland et al., 2021).

In truth, most forests still regenerate without interventions, even after severe natural disturbances (Donato et al., 2016; Pielou, 1991; Santoro & D'Amato, 2019; Shive et al., 2013). In fact, natural regeneration often exceeds active restoration efforts (Cook-Patton et al., 2020; Donato et al., 2006), provides greater genetic diversity than planted seedlings (Swanson et al., 2011), and greater stand-level carbon storage in coarse woody debris (Donato et al., 2013). Additionally, in areas in which there is a general support for large carnivores such as wolves there is naturally reduced browsing pressures by ungulates and greater tree regeneration and diversity of forest understories (Flagel et al., 2016; Waller & Reo, 2018).

Perceived regeneration failures from severe fire, intensive ungulate browsing, or seed source limitations may, in many cases, be patchy or delayed tree regeneration that has other benefits when seedling densities, growth rates, and particular tree species are not primary concerns. As one example, low density regeneration reduces the severity of reburns, facilitating forest recovery (Cansler et al., 2022; Harvey et al., 2016). Heterogeneity of natural regeneration also avoids structural uniformity that occurs with planting and can extend the duration of early successional patches and gaps, there by accelerating the development of spatial and structural complexity (Donato et al., 2012; Reed et al., 2022; Swanson et al., 2011).

3 | CONCLUSION

In sum, we find the current climate adaptation paradigm that is focused on active management to be appropriate within a limited forest management context. In forests prioritized for experimental research, resource production, or safety within the "home ignition zone" of severely fire-prone areas, resisting and directing change with management can, in some cases, provide helpful solutions and useful knowledge about management. Unprecedented disturbances in these areas may necessitate flexible responses as conditions change (i.e., adaptive management). However, outside of these three contexts, accepting change with natural stewardship and exposure to natural disturbances and processes generally increases structural complexity, carbon storage, and tree species and other diversity. These accruing benefits, in turn, make forests more resistant and resilient to many future natural challenges and provide mitigation against climate change. Given the limited resources for actively managing forests, the mixed evidence of management promoting young trees and reducing fire and other risks, and little evidence that we can actively resist or direct change in unknown future conditions better than nature can, protecting more forests with natural stewardship is a cost effective way to harness the inherent adaptation and mitigation powers in forests and ensure that they are at their most functional to regulate planetary processes.

ACKNOWLEDGMENTS

We thank David Foster, Dave Orwig, Peter Del Tredici, Audrey Barker-Plotkin, and Neil Pederson for helpful discussion and comments on earlier versions of this manuscript. The manuscript also benefitted from the comments of two anonymous reviewers and *Conservation Biology's* editor in chief, Mark Burgman, as well as helpful comments from *Conservation Science and Practice's* associate editor, Mark Schwartz. This article was supported by the Highstead Foundation in Redding, CT, USA.

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How to cite this article: Faison, E. K., Masino, S. A., & Moomaw, W. R. (2023). The importance of natural forest stewardship in adaptation planning in the United States. *Conservation Science and Practice*, e12935. https://doi.org/10.1111/csp2.12935