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Director
Policy Office
United States Forest Service
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July 19, 2023

Re: Public comment on conservation and management of national forests

This letter responds to the United States Forest Service's Advance Notice of Proposed Rulemaking (ANPR),[1] requesting public comment on how the agency should protect, conserve, and manage the national forests and grasslands for climate resilience. Thank you for the opportunity to provide input on a series of important issues raised by the request. Our organizations and their members care deeply about the condition and future of national forests. These lands are indispensable sources and repositories of critical natural and public values including mitigation of global warming, supplies of clean water, habitat for imperiled and other species, repositories of biological diversity, locations of great cultural and practical importance to Tribes, areas for increasingly in-demand outdoor recreation, venues for spiritual renewal, and generators of huge direct and indirect economic benefits for the American people. The Forest Service's proposal to make rules for better securing these qualities is highly significant in its own right and additionally represents a major step towards implementing both an Executive Order (EO) of President Biden[2] and a Secretarial Memo of Agriculture Secretary Vilsack.[3]

SUMMARY

We appreciate the great challenges faced by the United States Forest Service (USFS or Forest Service) and other land management agencies associated with altered ecological conditions and processes in federal forests, including fire—notably fire threats to homes, communities, and infrastructure—in an era of worsening climate change. We applaud the agency's constructive candor identifying past and ongoing management choices as contributing to these challenges. We also admire your commitment to broad public outreach, especially to Indigenous and other disempowered communities as you seek to develop responsive polices and other directives.

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[1] U.S. Forest Service. "Advance Notice of Proposed Rulemaking and Request for Comments." 88 *Fed. Reg*. 24,497 (April 21, 2023).

[2] Biden, J. "Executive Order 14072: Strengthening the Nation's Forests, Communities, and Local Economies." 87 *Fed. Reg.* 24851 (April 27, 2022). https://www.federalregister.gov/documents/2022/04/27/2022-09138/strengthening-the-nations-forests-communities-and-local-economies.

[3] Vilsack, T. "Secretary's Memorandum 1077-004: Climate Resilience and Carbon Stewardship of America's National Forests and Grasslands." *U.S. Department of Agriculture* (June 23, 2022). https://www.usda.gov/directives/sm-1077-004.

Below, we provide perspective and information on both the overarching questions posed by the ANPR and several of the more specific and detailed topics raised in it. Throughout, we emphasize the important values of mature and old growth (MOG) trees and stands and the need for management aimed at improving ecological resilience to preserve and recover them across the national forest system. These trees and stands (considered here as those older than 80 years) contain the majority (two-thirds) of above-ground carbon stores on USFS forested lands while only occupying one-third of the total forested area. MOG trees and stands also provide myriad critical biodiversity, hydrological, social, economic, and cultural benefits outlined below. Protecting MOG trees and stands from logging is a paramount way the USFS can help ensure that we as a Nation are not leaving significant means of mitigating the climate change and biodiversity crises untapped, nor missing a critical chance to lead internationally on vitally important measures that other countries can and must adopt, themselves.

A. OVERARCHING QUESTIONS:

1. "How should the Forest Service adapt current policies and develop new policies and actions to conserve and manage the national forests and grasslands for climate resilience, so that the Agency can provide for ecological integrity and support social and economic sustainability over time?"

In the ANPR, USFS undertakes the critical task of grappling with the implications of climate change for the resilience and management of U.S. national forests. The task is complex not only because of the varied and unpredictable ways that climate change will affect forests, but also because national forests—and especially the mature and old growth trees and stands within them—are vital for mitigating climate change. In addition to exhibiting natural resilience and both storing and sequestering enormous quantities of carbon, MOG provides climate refugia for imperiled species, stabilizes hydrological cycles, and provides other ecosystem services that will only become more important as climate change accelerates.

a. Protecting MOG is an essential component of enhancing climate resilience.

As USFS observes, national forests have endured an evolving array of threats over the decades, including wildfire, disease, drought, and logging—and now climate change, which exacerbates many of the longstanding threats. Against this shifting backdrop, the agency is appropriately evaluating the various threats and considering how to strengthen the resilience of national forests. No single management response can adequately address all the threats that national forests face. Meeting this moment will require a multifaceted response comprising strategies that work together in complementary ways. Some circumstances may call for an active management strategy, while others will call for allowing natural systems to recover, strengthen, and adapt on their own.

For one piece of that resilience puzzle, scientific evidence and policy imperatives strongly lead to a clear management direction: promulgating a rule that substantively protects mature and old-growth forests and trees from logging. MOG forests and trees are naturally resilient to many of the threats facing the National Forest System, including fire. Big trees tend to have thicker bark, pruned lower branches, comparatively high moisture content,[4] and dense tall canopies that favorably modify the local microclimate and near surface fuel conditions. As a result, these trees are more likely to survive when exposed to fire.[5] Thus, their presence enhances the resilience of biodiversity across the ecosystem. Their continued existence helps to mitigate the impacts of climate change that are threatening national forests and other ecosystems around the world.

Protecting MOG from logging is an effective, immediately available way to make progress. Unlike most other threats to national forests, the logging of MOG is entirely within the agency's control, and the practice can be addressed with a single rulemaking. Such a rule would not interfere with—and would in many ways support—the agency's continued efforts to address other threats, including fire.

b. MOG is a key ally for both mitigating and adapting to climate change.

Not only do mature and old-growth trees and forests draw greenhouse gases out of the atmosphere and store carbon long-term, but they also support conditions that will help humans and other species adapt to a changing world. As we explain more fully below, they are pillars of carbon sequestration and storage. Across forest types, the proportion of carbon stored in MOG far exceeds the proportion of acres that they occupy. Not only do older trees hold more carbon than younger trees, but their annual rate of carbon sequestration increases as they age.[6] After a forest stand enters maturity, it continues to accumulate carbon at a high rate, and dead big trees can continue to store carbon for centuries as they slowly decompose when left as snags or coarse woody debris (CWD).[7] That is true even for older, larger trees affected by wildfire—a sharp

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[4] Agee, J.K. "Fire Ecology of Pacific Northwest Forests.*" Island Press* (1993) 121–124; Brown, P.M. et al. "Identifying old trees to inform ecological restoration in montane forests of the central Rocky Mountains, USA." *Tree Ring Research* (2019) 75(1): 34–48. https://doi.org/10.3959/1536-1098-75.1.34.

[5] Stevens, J.T. "Fire resistance trait data for 29 western North American conifer species." *U.S. Geological Survey data release* (2020). https://doi.org/10.5066/P97F5P7L; Habeck, R.J. "Fire Effects Information System (FEIS): Sequoiadendron giganteum." *U.S. Forest Service* (1992). https://www.fs.usda.gov/database/feis/plants/tree/seqgig/all.html (last visited June 13, 2023).

[6] Mildrexler, D.J. et al. "Large Trees Dominate Carbon Storage in Forests East of the Cascade Crest in the United States Pacific Northwest." *Frontiers in Forests and Global Change* (2020) 3:594274. https://doi.org/10.3389/ffgc.2020.594274; Lutz, J.A. et al. "Global importance of large-diameter trees." *Global Ecology and Biogeography* (2018) 27(7): 849–864. https://doi.org/10.1111/geb.12747; Brown, S.A. et al. "Spatial distribution of biomass in forests of the eastern USA." *Forest Ecology and Management* (1999) 123(1): 81–90. https://doi.org/10.1016/S0378-1127(99)00017-1; Stephenson, N.L. et al. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* (2014) 507: 90–93. https://doi.org/10.1038/nature12914.

[7] He, L. et al. "Relationships between net primary productivity and forest stand age in U.S. forests." *Global Biogeochemical Cycles* (2012) 26(3). https://doi.org/10.1029/2010GB003942; Law, B.E. et al. "Changes in carbon storage and fluxes in a chronosequence of ponderosa pine." *Global Change Biology* (2003) 9(4): 510–524. https://doi.org/10.1046/j.1365-2486.2003.00624.x; Keeton, W.S. et al. "Late-Successional Biomass Development in Northern Hardwood-Conifer Forests of the Northeastern United States." *Forest Science* (2011) 57(6): 489–505. https://academic.oup.com/forestscience/article/57/6/489/4604514.

contrast to the fate of carbon in trees that are logged.[8] In fact, logging releases more greenhouse gas pollution than wildfire, both on a per-acre basis and nationally; for example, U.S. Geological Survey data from 2005-2014 found logging on Federal lands in the conterminous United States emitted 43 million metric tons of CO_2 equivalent per year (MMT CO_2 eq./year) due to logging, compared to 21 MMT CO_2 eq./year from fire.[9] Federal forests are one of the most effective, immediately available natural climate solutions, and MOG is the carbon storage stronghold within the system.

While MOG would be worth protecting for its carbon storage value alone, MOG forests and trees provide many other irreplaceable benefits. Over extremely long timespans, they develop complex habitats that support significant—and often imperiled—biodiversity. Depending on the forest type, important habitat features might include shady canopies that provide cooler conditions and snags and CWD in which many species take up residence. They also regulate hydrological cycles, often preventing water from quickly evaporating or running off the landscape.[10] Many of these habitats are becoming even more important under changing climatic conditions. Relatively cool, moist areas can serve as climate refugia for species that are sensitive to temperature increases in a warming world.

c. MOG has been depleted across the nation, and USFS must protect and expand upon what remains.

Despite their importance, mature and old-growth forests have been reduced to a fraction of their historical prevalence, and much of the MOG that remains is under threat. Old growth as a proportion of total U.S. forests is far below its pre-colonization level. In the Pacific Northwest, for instance, "the approximated historical extent of old-growth forest . . . was nearly two-thirds of the total land area," but as of 2006, "approximately 72% of the original old-growth conifer forest has been lost to conversion or subjected to intensive forestry practices."[11]

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[8] Campbell, J.L. et al. "Pyrogenic carbon emission from a large wildfire in Oregon, United States." *Journal of Geophysical Research* (2007) 112. https://doi.org/10.1029/2007JG000451; Meigs, G.W. et al. "Forest Fire Impacts on Carbon Uptake, Storage, and Emission: The Role of Burn Severity in the Eastern Cascades, Oregon." *Ecosystems* (2009) 12: 1246–1267. https://doi.org/10.1007/s10021-009-9285-x; Stenzel, J.E. et al. "Fixing a snag in carbon emissions estimates from wildfires." *Global Change Biology* (2019) 25(11): 3985–3994. https://doi.org/10.1111/gcb.14716; Harmon, M.E. et al. "Combustion of aboveground wood from live trees in megafires, CA, USA." *Forests* (2022) 13(3): 391. https://doi.org/10.3390/f13030391.

[9] Harris, N.L. et al. "Attribution of net carbon change by disturbance type across forest lands of the conterminous United States." *Carbon Balance and Management* (2016) 11: 24. https://doi.org/10.1186/s13021-016-0066-5; Merrill, M.D. et al. "Federal lands greenhouse gas emissions and sequestration in the United States: Estimates 2005-14." *U.S. Geological Survey data release* (2018). https://doi.org/10.5066/F7KH0MK4.

[10] Aron, P.G. et al. "Stable water isotopes reveal effects of intermediate disturbance and canopy structure on forest water cycling." Journal of Geophysical Research (2019) 124(10): 2958-2975. https://doi.org/10.1029/2019JG005118; Perry, T.D. and J.A. Jones. "Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA." *Ecohydrology* (2017) 10(2): 1790. https://doi.org/10.1002/eco.1790.

[11] Strittholt, J.R. et al. "Status of Mature and Old-Growth Forests in the Pacific Northwest." *Conservation Biology* (2006) 20(2): 363–374. https://www.jstor.org/stable/3591344.

As a result of this approach to forest management, federal lands hold most of the few remaining strongholds of mature forests and trees in the United States, but USFS and the Bureau of Land Management continue to allow the logging of mature and old-growth trees and forests.[12] The only way to begin rebuilding the nation's lost old growth and all co-benefits associated with it is by protecting extant mature forests and trees. And the best place to do that—the only part of the United States with significant stretches of these essential forest components—is the federal estate.[13]

d. Protecting MOG will support the agency's goals of managing for climate resilience to provide ecological integrity and support social and economic sustainability over time.

The benefits of MOG are fundamental to ecological integrity and social and economic sustainability. As explained above, MOG enhances climate resilience by sequestering and storing carbon, providing stable ecosystems and habitats—including climate refugia—safeguarding hydrological cycles and drinking water supplies, and increasing resistance to wildfire. The benefits of MOG are described in greater detail further down in these comments.

While the ANPR does not define "climate resilience," it notes that resilience is "essential for ecological integrity and social and economic sustainability" as those terms are defined in the 2012 Planning Rule.[14] The Planning Rule defines "ecological integrity" as

> [t]he quality or condition of an ecosystem when its dominant ecological characteristics (for example, composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence."[15]

The Planning Rule expressly situates resilience with the concept of ecological integrity, anticipating that forest "[p]lans will include plan components to maintain or restore ecological integrity, so that ecosystems can resist change, *are resilient under changing conditions*, and are

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[12] Climate Forests Campaign. "Worth More Standing: 10 Climate-Saving Forests Threatened by Federal Logging." 2022. https://www.climate-forests.org/_files/ugd/73639b_03bdeb627485485392ac3aaf6569f609.pdf; Climate Forests Campaign. "America's Vanishing Climate Forests: How the U.S. is Risking Global Credibility on Forest Conservation." 2022. https://www.climate-forests.org/_files/ugd/ae2fdb_b5a2315e3e8b42498b4c269730c3955a.pdf.

[13] U.S. Forest Service and Bureau of Land Management. "Mature and Old-Growth Forests: Definition, Identification, and Initial Inventory on Lands Managed by the Forest Service and Bureau of Land Management: Fulfillment of Executive Order 14072, Section 2(b)." (2023) FS-1215a. https://www.fs.usda.gov/sites/default/files/mature-and-old-growth-forests-tech.pdf; DellaSala, D.A. et al. "Mature and old-growth forests contribute to large-scale conservation targets in the conterminous United States." *Frontiers in Forests and Global Change* (2022) 5. https://doi.org/10.3389/ffgc.2022.979528.

[14] U.S. Forest Service. "Advance Notice of Proposed Rulemaking and Request for Comments." 88 *Fed. Reg.* 24,498 (April 21, 2023).

[15] U.S. Forest Service. "National Forest System Land Management Planning." 77 *Fed. Reg.* 21,162, 21,271 (Apr. 9, 2012).

able to recover from disturbance."[16] For all of the reasons that MOG is resilient—from resistance to fire and drought, to harboring biodiversity, to the regulation of hydrological systems—protecting MOG from logging advances ecological integrity. Protecting MOG from logging would also help it recover to something more closely resembling its natural range of variation and adapt to future ecological conditions resulting from climate change.

The Planning Rule defines "social sustainability" as "the capability of society to support the network of relationships, traditions, culture, and activities that connect people to the land and to one another, and support vibrant communities."[17] It defines economic sustainability as "the capability of society to produce and consume or otherwise benefit from goods and services including contributions to jobs and market and nonmarket benefits."[18]

MOG contributes to social and economic sustainability by helping to mitigate the catastrophic social disruptions of climate change, including climate-driven forced migration, food shortages, and communities lost to sea-level rise and extreme weather. In many locations, MOG supports social and economic sustainability by providing a stable source of clean drinking water. It preserves traditions and cultures; indeed, the Planning Rule recognizes "cultural and historic resources to be very important for social sustainability as well as important economic contributors."[19] MOG also provides opportunities for recreation, which the Planning Rule describes as "an important contribution to the economic vitality of rural communities" and "a critical part of social sustainability."[20] Allowing MOG to remain standing safeguards these sustainability benefits indefinitely.

2. "How should the Forest Service assess, plan for and prioritize conservation and climate resilience at different organizational levels of planning and management of the National Forest System (e.g., national strategic direction and planning; regional and unit planning, projects and activities)?"

As USFS seeks to enhance the climate resilience of national forests, it is appropriately engaging personnel across the country, from local field offices to national headquarters. The urgency and complexity of the mission demand an all-hands-on-deck approach, and all components of the agency will have an important role in the comprehensive strategy.

For the purpose of protecting MOG from logging, a nationally applicable rulemaking is required. The benefits of mature and old-growth trees and forests—including climate mitigation, biodiversity protection, and hydrological regulation—are common to MOG across the country and across forest types. It is not necessary to conduct site-specific assessments to determine that MOG provides critical benefits, and many of these benefits—most notably, carbon storage—have national or even global significance. The problem we call climate change is caused by cumulative emissions at the global scale and solutions need to be consistently implemented across the broadest possible area. Haphazard or inconsistent conservation of MOG would be

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[16] *Ibid.* p. 21,176 (emphasis added).

[17] *Ibid.* p. 21,259, 21,272.

[18] *Ibid.* p. 21,272.

[19] *Ibid.* p. 21,223.

[20] *Ibid.* p. 21,222.

inconsistent with the very nature of the global climate crisis. Moreover, the national office has advantages in terms of resources, expertise, and authority to swiftly confer these urgently needed protections. Protecting MOG from logging would preserve these benefits for the nation as a whole, not just for the region where a specific forest is located. A national rulemaking is necessary for the agency to protect these nationally significant resources.

In addition to the reasons that a national rulemaking is the essential mechanism for national MOG protections, dispersing the policymaking among regional or unit offices would not be meaningfully responsive to the climate and biodiversity crises or fulfill the objective of climate resilience for several reasons. First, it would most likely result in inconsistent levels of protection for resources that share many common attributes—and provide similar benefits—across the country. Second, it would waste valuable time and energy, replicating the same process in multiple offices when the objective is to protect MOG for the nation as a whole. Third, it could result in serious ongoing loss of MOG if competing priorities cause protections to be delayed in some regions. Any delay due to administrative inefficiencies would most likely lead to more MOG lost to logging. While regional and unit offices can and should prioritize the protection of MOG, a national rulemaking is necessary to achieve substantive protections that reflect the critical role of MOG and an urgent response to its widespread depletion across the country.

3. “How should Forest Service management, partnerships, and investments consider cross-jurisdictional impacts of stressors to forest and grassland resilience at a landscape scale, including activities in the WUI?”

We strongly favor landscape level assessments of ecological stressors, including anthropogenic ones. Where review under the National Environmental Policy Act is conducted, such assessments may be needed to comply with the regulatory requirement that analyses cover cumulations of ecological effects.[21] As a general matter, such assessments and the implementation of consequent management activities need close coordination among managers and decisionmakers within a given landscape. The Forest Service already invests substantially in cooperation around its efforts to respond at that level to climate change related phenomena, as it does for instance when using prescribed fire. Prime consideration needs to be given in those processes to consultation with adjoining Tribal landowners and nearby Tribal communities, as specifically prioritized by President Biden.[22] We welcome and encourage Forest Service efforts to increase Tribal communication and make consultation more meaningful for and responsive to affected Tribes, as directed by the President.

When designing responses to climate change, the Forest Service also needs to understand and take full account of activities on nearby lands under different ownership. In particular, where other stands in a forested landscape have been heavily affected—and their resilience degraded—by timber harvest, the role of national forests in preserving areas of lower anthropogenic stress

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[21] 40 C.F.R. §§1508.1(g)(3)&(4).

[22] Biden, J. “Memorandum on Tribal Consultation and Strengthening Nation-to-Nation Relationships.” *Whitehouse* (January 26, 2021). https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/26/memorandum-on-tribal-consultation-and-strengthening-nation-to-nation-relationships/ (last visited June 28, 2023).

and the mature and older forest components removed from adjacent parcels, takes on even greater significance.

4. "What are key outcome-based performance measures and indicators that would help the Agency track changing conditions, test assumptions, evaluate effectiveness, and inform continued adaptive management?"

Historically, a forest's ability to produce marketable wood products was used as a primary performance measure. Board feet produced from the national forests is still one of the dominant performance measures for agency performance nationally and at the regional levels.[23] Now, with greater recognition that forests are essential for climate mitigation and biodiversity protection—with MOG making disproportionately high contributions—performance measures should more squarely reflect those outcomes. In recent years, there has been an increase in the scientific literature establishing credible metrics for ecosystem health and forest management practices that support climate adaptation and resilience, biodiversity, carbon sequestration and storage, water storage and water quality enhancement, and more. As the Forest Service considers "key outcome-based performance measures and indicators that would help the Agency track changing conditions, test assumptions, evaluate effectiveness, and inform continued adaptive management," the agency should consider the best available science. Such measures and indicators should include the following in all forest types:

- **In-situ forest carbon storage** (above and belowground). President Biden's EO 14072 explicitly directs the Forest Service to "retain and enhance carbon storage." This is a critical and objectively measurable performance measure and indicator. Progress towards potential ecosystem carbon storage should be estimated according to best available science, such as Keeton et al 2011.[24] Measurements should not only be at a stand level, but at a landscape level to allow for variations of carbon levels over time due to natural disturbance.

- **Forest complexity**. See Thom et al 2019[25] and Faison et al 2023.[26] Measures of forest complexity should include:
    - Number of older trees within stands.
    - Density of large live trees.

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[23] United States Department of Agriculture. "USDA FY 2023 Budget Summary." p. 74. https://www.usda.gov/sites/default/files/documents/2023-usda-budget-summary.pdf; United States Department of Agriculture. "FY 2023 Performance Plan." p. 10. https://www.usda.gov/sites/default/files/documents/usda-fy-2023-performance-plan.pdf.

[24] Keeton, W.S. et al. "Late-successional biomass development in Northern hardwood-conifer forests of the northeastern United States." *Forest Science* (2011) 57(6): 489–505. https://academic.oup.com/forestscience/article/57/6/489/4604514.

[25] Thom, D. et al. "The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal–temperate North America." *Global Change Biology* (2019) 25(7): 2446–2458. https://doi.org/10.1111/gcb.14656.

[26] Faison, E.K. et al. "Adaptation and mitigation capacity of wildland forests in the Northeastern United States." *Forest Ecology and Management* (2023) 554: 121145. https://doi.org/10.1016/j.foreco.2023.121145.

- Density of standing deadwood.
- Presence of coarse woody debris.
- Tree species diversity.
- Understory development.
- Spatial variability, both horizontal and vertical.
- Comparisons of current conditions should be made with pre-colonial estimates.
- Forest function (wildlife habitat, climate regulation, hydrological and nutrient cycling, etc.)

Importantly, these indicators should be used as general targets, not as predicates for intervention. Numerous natural processes are at work to advance development of stands toward complex conditions. These natural processes include wind, snow/ice, insects. disease, fire, physical damage, competition, floods, etc.

B. SPECIFIC TOPICS.

1. Relying on Best Available Science, including Indigenous Knowledge, to Inform Agency Decision-making.

a. Braiding Together Indigenous Knowledge and Western Science.

We applaud and fully support USFS's commitment to engage with Tribal Nations and work to better incorporate Traditional Knowledge into its policy making. To accomplish such incorporation, the agency must pursue meaningful, ongoing engagement with Tribal Nations throughout the pendency of a rulemaking and beyond. That should include building a dialogue with Tribal forest managers who have led the way in maintaining and increasing mature and old-growth forests and trees. This will require the agency to marshal its resources to ensure robust Tribal participation, rather than the pro forma participation that the federal government has too often pursued in prior years.

USFS should also look to the resolutions adopted by the Affiliated Tribes of Northwest Indians and the National Congress of American Indians last year on mature forest and tree protection.[27] These resolutions contain priorities and recommendations that the agency should carefully consider when adopting a final rule. The resolutions requested that the agency initiate a rulemaking to conserve mature and old-growth forests and trees on ancestral land managed by the agency. Both urged protecting mature and old-growth federal forests and trees from avoidable logging, subject to limited exceptions. And both called for rules that respect traditional and customary uses, incorporate Traditional Knowledge, continue meaningful and supported collaboration with Tribal Nations, and do not infringe on Treaty rights.

b. Better Operationalizing Adaptive Management.

As discussed more fully below, we recognize that very substantial uncertainty exists about future conditions in national forests, indeed in forestlands throughout North America and elsewhere.

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[27] Affiliated Tribes of Northwest Indians, Res. #2022-36 (2022); National Congress of American Indians, Res. #SAC-22-012 (2022).

Paired with uncertainty about the effects of various treatment options, the possibility of widespread changes—first in temperature and moisture regimes and then in species ranges and plant communities—argues strongly for conservation of the key ecological building blocks that have the longest replacement times. Strategies that remove these elements, should they ultimately prove unnecessary or counterproductive, will cause irremediable harm, damaging forests and costing us vital functionality in ways that may never be recovered. Pending a fuller understanding of climate change trajectories and demonstrated forest responses to both those changes and to active management, the Forest Service needs to concentrate its efforts on managing the younger, more readily replaced, forest components that most reflect anthropogenic influences and that provide neither scarce habitat and ecological services nor the majority of carbon sequestration and storage. Mature trees and forests, by contrast, are harder to replace and contribute heavily to resilience by serving as climate refugia and harboring genetic diversity that contributes to adaptation in the face of climate change.[28]

2. Adaptation Planning and Practice.

a. Adaptation Planning: Planning and Achieving a Sustainable Road System

Summary

In its ANPR, the agency asks "How might the Forest Service think about complementing unit-level plans with planning at other scales, such as watershed, landscape, regional, ecoregional, or national scales?"[29] The Forest Service explains that the underlying purpose of this question is "to seek input on how we can develop new policies or build on current policies to improve our ability to foster climate resilience, recognizing that impacts are different in different places across the country."[30]

While protecting MOG from logging is the focus of these comments, it is also evident that road management affects the agency's ability to promote climate resilience and meet the purposes of the 2012 Planning Rule as explained in the ANPR.[31] In fact, the Forest Service developed several multi-scale tools that specifically address the harmful environmental consequences of the forest road system. These tools apply across all National Forest System lands and readily integrate with unit-level planning efforts. The following sections provide a brief overview of road impacts, increasing ecological resilience by addressing those impacts, and specific planning tools the agency can utilize during unit-level plan revision with specific recommendations for their integration. These sections are offered as additional considerations responsive to the agency's question—not as alternatives to the urgent need to protect MOG from logging.

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[28] Frey S.J. et al. "Spatial models reveal the microclimatic buffering capacity of old-growth forests." *Science Advances* (2016) 2(4): e1501392. https://doi.org/10.1126/sciadv.1501392; Faison E.K. et al. "The importance of natural forest stewardship in adaptation planning in the United States." *Conservation Science and Practice* (2023) 5(6): e12935. https://doi.org/10.1111/csp2.12935.

[29] U.S. Forest Service. "Advance notice of proposed rulemaking and request for comments." 88 *Fed. Reg.* 24,502 (April 21, 2023).

[30] *Ibid.*

[31] U.S. Forest Service. "Advance notice of proposed rulemaking and request for comments." 88 *Fed. Reg.* 24,499 (April 21, 2023).

Discussion

The Forest Service transportation infrastructure is necessary for the management of national forests and grasslands, yet indisputably it also harms aquatic and terrestrial environments at multiple scales. The construction and presence of forest roads can dramatically change the hydrology and geomorphology of a forest system leading to reductions in the quantity and quality of aquatic habitat.[32] While there are several mechanisms that cause these impacts, most fundamentally, compacted roadbeds reduce rainfall infiltration, intercepting and concentrating water, and providing a ready source of sediment for transport.[33] In fact, roads contribute more sediment to streams than any other land management activities on Forest Service lands.[34] As a result, forest roads can have dramatic and lasting impacts on fish and aquatic habitat. Increased sedimentation in stream beds has been linked to decreased salmonid fry emergence, decreased juvenile fish densities, loss of winter carrying capacity, increased predation of fish, and reductions in macro-invertebrate populations that are a food source to many fish species.[35] Roads close to streams reduce the number of trees available for large wood recruitment, and reduce streamside shade.[36]

In regard to terrestrial impacts, roads and motorized trails impact wildlife through a number of mechanisms including: direct mortality (poaching, hunting/trapping), changes in movement and habitat-use patterns (disturbance/avoidance), as well as indirect impacts including altering adjacent habitat and interference with predator/prey relationships.[37] Some of these impacts result from the road

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[32] Al-Chokhachy, R.T. et al. "Linkages between unpaved forest roads and streambed sediment: why context matters in directing restoration." *Restoration Ecology* (2016) 24(5): 589-598. https://doi.org/10.1111/rec.12365.

[33] Wemple, B.C. et al. "Forest roads and geomorphic process interactions, Cascade Range, Oregon." *Earth Surface Process and Landforms* (2001) 26(2): 191-204. https://doi.org/10.1002/1096-9837(200102)26:2%3C191::AID-ESP175%3E3.0.CO;2-U

[34] Gucinski, H. et al. "Forest roads: a synthesis of scientific information." *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-509. Pacific Northwest Research Station, Portland, OR (2001). https://doi.org/10.2737/PNW-GTR-509.

[35] Endicott, D. "National level assessment of water quality impairments related to forest roads and their prevention by best management practices." *Environmental Protection Agency* Great Lakes Environmental Center Office of Water, Traverse City, MI (2008). https://www.regulations.gov/document/EPA-HQ-OW-2015-0668-0005.

[36] Meredith, C. et al. "Reductions in instream wood in streams near roads in the interior Columbia River Basin." N*orth American Journal of Fisheries Management* (2014) 34(3): 493-506. https://doi.org/10.1080/02755947.2014.882451.

[37] Coffin, A.W. "From roadkill to road ecology: A review of the ecological effects of roads." *Journal of Transport Geography* (2007) 15(5): 396-406. https://doi.org/10.1016/j.jtrangeo.2006.11.006; Fahrig, L. and T. Rytwinski. "Effects of roads on animal abundance: an empirical review and synthesis." *Ecology and Society* (2009) 14(1): 21. http://www.jstor.org/stable/26268057; Robinson, C. et al. "A conceptual framework for understanding, assessing, and mitigating ecological effects of forest roads." *Environmental Reviews* (2010) 18: 61-86. http://dx.doi.org/10.1139/A10-002.

itself, and some result from the uses on and around the roads (access). Ultimately, numerous studies show that roads reduce the abundance, diversity, and distribution of several forest species.[38] Furthermore, it is well documented that, beyond specific road density thresholds,[39] certain species will be negatively affected, and some risk being extirpated.[40] Most studies that explore the relationship between road density and wildlife focus on the impacts to large, endangered carnivores or hunted game species, although high road densities certainly affect other species. Several studies show that higher road densities also impact aquatic habitats and fish, with one finding that:

> 1) no truly "safe" threshold [for] road density exists, but rather negative impacts begin to accrue and be expressed with incursion of the very first road segment; and 2) highly significant impacts (e.g., threat of extirpation of sensitive species) are already apparent at road densities on the order of 0.6 km per square km (1 mile per square mile) or less.[41]

Harmful effects from climate change are exacerbating these impacts. Just as scientists predicted, climate change is responsible for more extreme weather events, leading to increasing flood severity, more frequent landslides, changing hydrographs, and changes in erosion and sedimentation rates and delivery processes.[42] The Forest Service Office of Sustainability and Climate compiled climate change vulnerability assessments for several regions of the Forest Service discussing near-term consequences for managers to consider, including impacts to transportation infrastructure.[43] The agency found that roads and other infrastructure that are near

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[38] Fahrig, L. and T. Rytwinski. "Effects of roads on animal abundance: an empirical review and synthesis." *Ecology and Society* (2009) 14(1): 21. www.ecologyandsociety.org/vol14/iss1/art21/; Benítez-López, A. et al. "The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis." *Biological Conservation* (2010) 143(6): 1307-1316. http://dx.doi.org/10.1016/j.biocon.2010.02.009; Muñoz, P.T. et al. "Effects of roads on insects: a review." *Biodiversity Conservation* (2015) 24: 659-682. http://dx.doi.org/10.1007/s10531-014-0831-2.

[39] We use the term "road density" to refer to the density of all roads within national forests, including system roads, closed roads, non-system roads, temporary roads and motorized trails, and roads administered by other jurisdictions (private, county, state).

[40] Robinson, C. et al. "A conceptual framework for understanding, assessing, and mitigating ecological effects of forest roads." *Environmental Reviews* (2010) 18: 61-86. https://doi.org/10.1139/A10-002.

[41] Carnefix, G. and C.A. Frissell. "Aquatic and other environmental impacts of roads: The case for road density as indicator of human disturbance and road-density reduction as restoration target; A concise review." *Pacific Rivers Council Science Publication* (2009) 09-001.

[42] Schwartz, H.G. et al. "Chapter 5: Transportation." In: "Climate change impacts in the United States: The third national climate assessment." *Global Change Research Program* (2014) 130-149. http://dx.doi.org/10.7930/J06Q1V53.

[43] Halofsky, J.E. and D.L. Peterson. "Climate change vulnerability and adaptation in the Blue Mountains." *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-939. Pacific Northwest Research Station, Portland, OR (2017). https://doi.org/10.2737/PNW-GTR-939; Halofsky, J.E. et al. "Climate change vulnerability and adaptation in the Northern Rocky Mountains [Part 1]." *USDA Forest Service* Gen. Tech. Rep. RMRSGTR-374. Rocky Mountain Research Station, Fort Collins, CO (2018). https://doi.org/10.2737/RMRS-GTR-374PART1; Halofsky, J.E. et al. "Climate change vulnerability and adaptation in the Intermountain Region [Part 2]." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-375. Rocky Mountain Research Station, Fort Collins, CO (2018). https://doi.org/10.2737/RMRS-GTR-375PART2; Halofsky, J. et al. "Climate change vulnerability and adaptation in south-central Oregon."

or beyond their design life are at considerable risk to damage from flooding and geomorphic disturbance (e.g., debris slides). If road damage increases as expected, it will have a profound impact on access to Federal lands and on repair costs.[44] In addition, forests fragmented by roads will likely demonstrate less resistance and resilience to stressors, like those associated with climate change.[45] This is particularly true for migrating wildlife. One of the most well documented impacts of climate change on wildlife is a shift in the ranges of species.[46] As animals migrate, landscape connectivity will be increasingly important, and reducing road densities in key wildlife corridors will increase wildlife resiliency.[47]

A Special Note on Roads and Wildfire

Often, the intersection between forest access and human wildfire ignitions receives little attention, yet one study found that humans ignited four times as many fires as lightning. This represented 92% of the fires in the eastern United States and 65% of the fire ignitions in the western U.S.[48] Another study that reviewed 1.5 million fire records over 20 years found human-caused fires were responsible for 84% of wildfires and 44% of the total area burned.[49] Just this year, the Congressional Research Service found that "[m]ost wildfires are human-caused, 89% of the average number of wildfires from 2018 to 2022."[50] These human-caused fires undoubtedly align with access. In fact, forest roads can increase the occurrence of human-caused fires, whether by accident or arson, and road access has been correlated with the number of fire ignitions.[51] In addition to changes in frequency, human-caused fires change the timing of fire

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USDA Forest Service Gen. Tech. Rep. PNW-GTR-974. Pacific Northwest Research Station, Portland, OR (2019). https://doi.org/10.2737/PNW-GTR-974.

[44] Halofsky, J.E. et al. "Climate change vulnerability and adaptation in the Intermountain Region." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-375. Rocky Mountain Research Station, Fort Collins, CO (2018). https://doi.org/10.2737/RMRS-GTR-375PART2.

[45] Noss, R.F. "Beyond Kyoto: Forest management in a time of rapid climate change." *Conservation Biology* (2001) 15(3): 578-590. https://doi.org/10.1046/j.1523-1739.2001.015003578.x.

[46] Parmesan, C. "Ecological and evolutionary responses to recent climate change." *Annual Review of Ecology, Evolution, and Systematics* (2006) 37: 637-669. http://dx.doi.org/10.1146/annurev.ecolsys.37.091305.110100.

[47] Ament, R. et al. "Wildlife connectivity: Fundamentals for conservation action." *The Center for Large Landscape Conservation* (2014) 1-48. https://largelandscapes.org/wp-content/uploads/2019/05/Wildlife-Connectivity-Fundamentals-for-Conservation-Action.pdf (last accessed July 5, 2023).

[48] Nagy, R.C. et al. "Human-related ignitions increase the number of large wildfires across U.S. ecoregions." *Fire* (2018) 1(1): 4. https://doi.org/10.3390/fire1010004.

[49] Balch, J.K. et al. "Human-started wildfires expand the fire niche across the United States." *PNAS* (2017) 114(11): 2946-2951. https://doi.org/10.1073/pnas.1617394114.

[50] "Wildfire statistics" *Congressional Research Service* (2023). https://sgp.fas.org/crs/misc/IF10244.pdf (last accessed, June 12, 2023).

[51] Syphard, A.D. et al. "Human influence on California fire regimes." *Ecological Applications* (2007) 17(5): 1388–1402. http://dx.doi.org/10.1890/06-1128.1; Yang, J. et al. "Spatial patterns of modern period human-caused fire occurrence in the Missouri Ozark Highlands." *Forest Science* (2007) 53(1): 1–15. https://doi.org/10.1093/forestscience/53.1.1; Narayanaraj, G. and M.C. Wimberly. "Influences of forest roads on the spatial pattern of human- and lightning-caused wildfire ignitions." *Applied Geography* (2012) 32(2): 878–888. https://doi.org/10.1016/j.apgeog.2011.09.004

occurring, essentially extending the wildfire season much longer compared to lightning-started fires.[52]

Roaded areas create a distinct fire fuels profile which may influence ignition risk and burn severity.[53] Forest roads create linear gaps with reduced canopy cover, and increased solar radiation, temperature, and wind speed. Invasive weeds and grasses common along roadsides also create fine fuels that can be combustible. These edge effects can change microclimates far into the forest.[54] Also, there is an increase in the prevalence of lightning-caused fires in roaded areas that may be due to roadside edge effects.[55] Furthermore, heavily roaded and intensively managed watersheds leave forests in a condition of high fire vulnerability.[56]

After a forest fire, roads that were previously well vegetated often burn or have been bladed for fire suppression access or firebreaks leaving them highly susceptible to erosion and weed invasion. Roads are a source of chronic erosion following a fire, and pulses of hillslope sediment and large woody debris can result in culvert failures.[57] Fine sediment is frequently delivered to streams and reduces the quality of aquatic habitat. Further, non-native invasive plant species often propagate on many forest roads, and post-fire invasion can be facilitated through suppression efforts.[58]

While the Forest Service focuses its resources on wildfire suppression and reducing wildfire risk in priority “firesheds,” these and other studies suggest controlling access and reducing the road network could be an effective management strategy for reducing human-caused wildfires. Further, the Forest Service should recognize that road improvement and access carry substantial risks of human-caused wildfires, which must be equally weighted with any management benefits.

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[52] Nagy, R.C. et al. “Human-related ignitions increase the number of large wildfires across U.S. ecoregions.” *Fire* (2018) 1(1): 4. https://doi.org/10.3390/fire1010004.

[53] Narayanaraj, G. and M.C. Wimberly. “Influences of forest roads on the spatial pattern of human- and lightning-caused wildfire ignitions.” *Applied Geography* (2012) 32(2): 878–888. https://doi.org/10.1016/j.apgeog.2011.09.004.

[54] Narayanaraj, G. and M.C. Wimberly. “Influences of forest roads on the spatial pattern of human- and lightning-caused wildfire ignitions.” *Applied Geography* (2012) 32(2): 878–888. https://doi.org/10.1016/j.apgeog.2011.09.004; Ricotta, C. et al. “Assessing the Influence of Roads on Fire Ignition: Does Land Cover Matter?” *Fire* (2018) 1(2): 24. https://doi.org/10.3390/fire1020024.

[55] Arienti, M.C. et al. “Road network density correlated with increased lightning fire incidence in the Canadian western boreal forest.” *International Journal of Wildland Fire* (2009) 18(8): 970–982. https://doi.org/10.1071/WF08011; Narayanaraj, G. and M.C. Wimberly. “Influences of forest roads on the spatial pattern of human- and lightning-caused wildfire ignitions.” *Applied Geography* (2012) 32(2): 878–888. https://doi.org/10.1016/j.apgeog.2011.09.004.

[56] Hessburg, P.F. and J.K. Agee. “An environmental narrative of inland Northwest United States forests, 1800-2000.” *Forest Ecology and Management* (2003) 178(1-2): 23-59. http://dx.doi.org/10.1016/S0378-1127(03)00052-5.

[57] Bisson, P.A. et al. “Fire and aquatic ecosystems of the western USA: current knowledge and key questions.” *Forest Ecology and Management* (2003) 178(1-2): 213-229. https://doi.org/10.1016/S0378-1127(03)00063-X.

[58] Birdsall, J.L. et al. “Roads impact the distribution of noxious weeds more than restoration treatments in a lodgepole pine forest in Montana, U.S.A.” *Restoration Ecology* (2012) 20(4): 517-523. http://dx.doi.org/10.1111/j.1526-100X.2011.00781.x

Benefits of Addressing Road Impacts

The ecological benefits, especially increased watershed resilience, from reducing the forest road system and performing critical maintenance are widely accepted. Reconnecting fragmented forests has been shown to benefit native species.[59] Decommissioning and upgrading roads can reduce fragmentation of both aquatic and terrestrial systems. For example, reducing the amount of road-generated fine sediment deposited on salmonid nests can increase the likelihood of egg survival and spawning success.[60]

Strategically removing or mitigating barriers such as culverts has been shown to restore aquatic connectivity and expand habitat.[61] Decommissioning roads in riparian areas may provide further benefits to salmon and other aquatic organisms by permitting reestablishment of streamside vegetation, which provides shade and maintains a cooler, more moderated microclimate over the stream.[62] Further, controlling access management has been important for reducing elk disturbance and improving connectivity.[63] Similarly, restricting motorized recreation increased grizzly bear population density by 50 percent in one study.[64] In addition, road decommissioning restores wildlife habitat by providing security and food such as grasses, forbs, and fruiting shrubs.[65]

Recently, researchers have been exploring the relationship between road restoration and carbon. There is the potential for large amounts of carbon to be sequestered by restoring roads to a more natural state. Upon road decompaction, vegetation and soils can develop more rapidly and

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[59] Damschen, E.I. et al. "Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment." *Science* (2019) 365(6460): 1478-1480. https://doi.org/10.1126/science.aax8992.

[60] Switalski, T.A. et al. "Benefits and impacts of road removal." *Frontiers in Ecology and the Environment* (2004) 2(1): 21-28. https://doi.org/10.1890/1540-9295(2004)002[0021:BAIORR]2.0.CO;2; McCaffery M. et al. "Effects of road decommissioning on stream habitat characteristics in the South Fork Flathead River, Montana." *Transactions of the American Fisheries Society* (2011) 136(3): 553-561. http://dx.doi.org/10.1577/T06-134.1.

[61] Erkinaro, J. et al. "Road culvert restoration expands the habitat connectivity and production area of juvenile Atlantic salmon in a large subarctic river system." *Fisheries Management and Ecology* (2017) 24(1): 73-81. http://dx.doi.org/10.1111/fme.12203.

[62] Battin J. et al. "Projected impacts of climate change on salmon habitat restoration." *Proceedings of the National Academy of Sciences* (2007) 104(16): 6720–6725. https://doi.org/10.1073/pnas.0701685104; Meredith, C.B. et al. "Reductions in instream wood and streams near roads in the Interior Columbia River Basin." *North American Journal of Fisheries Management* (2014) 34(3): 493-506. http://dx.doi.org/10.1080/02755947.2014.882451.

[63] Paton, D.G. et al. "Hunting exacerbates the response to human disturbance in large herbivores while migrating through a road network." *Ecosphere* (2017) 8(6): e01841. https://doi.org/10.1002/ecs2.1841.

[64] Lamb, C.T. et al. "Effects of habitat quality and access management on the density of a recovering grizzly bear population." *Journal of Applied Ecology* (2018) 55(3): 1406–1417. https://doi.org/10.1111/1365-2664.13056.

[65] Switalski, T.A. and C.R. Nelson. "Efficacy of road removal for restoring wildlife habitat: Black bear in the Northern Rocky Mountains, USA." *Biological Conservation* (2011) 144(11): 2666-2673. https://doi.org/10.1016/j.biocon.2011.07.026; Tarvainen, O. and A. Tolvanen. "Healing the wounds in the landscape—reclaiming gravel roads in conservation areas." *Environmental Science and Pollution Research* (2016) 23: 13732–13744. https://doi.org/10.1007/s11356-015-5341-6.

sequester large amounts of carbon. Research on the Clearwater National Forest in Idaho estimated total soil carbon storage increased 6-fold compared to untreated abandoned roads.[66] Another study concluded that reclaiming 425 km (264 miles) of logging roads over the last 30 years in Redwood National Park in Northern California resulted in net carbon savings of 49,000 megagrams (54,013 tons) of carbon.[67] A further analysis found that recontouring roads had higher soil organic carbon storage outcomes than ripping (decompacting) the roads.[68] Finally, a recent study in Colorado found that adding mulch or biochar to decommissioned roads can increase the amount of carbon stored in soil.[69]

Achieving a Sustainable Minimum Road System on National Forest Lands

Undoubtedly, there are numerous benefits from reducing the forest road system and controlling motorized access. And there are several underutilized tools that the Forest Service should consider for realizing these benefits and enhancing forest resilience and ecosystem integrity. Using these tools would enable the agency to base planning decisions on a more rigorous assessment of roads' impacts. To get the most benefit, the agency should deploy these tools in a coordinated manner through the planning process, and the ANPR provides an opportunity to establish a framework for doing so.

Specifically, the agency should consider how its Transportation Resiliency Guidebook—which includes a step-by-step guide for identifying vulnerabilities and preparedness planning within its transportation network[70]—could be used in tandem with the Travel Analysis Process (TAP) and Watershed Condition Framework[71] (WCF) to inform forest plan revisions. TAP reports should

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[66] Lloyd, R.A. et al. "Influence of road reclamation techniques on forest ecosystem recovery." *Frontiers in Ecology and the Environment* (2013)11(2): 75-81. https://doi.org/10.1890/120116.

[67] Madej, M.A. et al. "Effects of road decommissioning on carbon stocks, losses, and emissions in North Coastal California." *Restoration Ecology* (2013) 21(4): 439–446. https://doi.org/10.1111/j.1526-100X.2012.00911.x.

[68] Seney, J. and M.A. Madej. "Soil carbon storage following road removal and timber harvesting in redwood forests." *Earth Surface Processes and Landforms* (2015) 40(15): 2084-2092. https://doi.org/10.1002/esp.3781.

[69] Ramlow, M. et al. "Promoting revegetation and soil sequestration on decommissioned forest roads in Colorado, USA: A comparative assessment of organic soil amendments." *Forest Ecology and Management* (2018) 427: 230-241. https://doi.org/10.1016/j.foreco.2018.05.059.

[70] Rasmussen, B. et al. "U.S. Forest Service transportation resiliency guidebook: Addressing climate change impacts on U.S. Forest Service transportation assets." *U.S. Department of Transportation* DOT-VNTSC-USDA-19-01. John A. Volpe National Transportation Systems Center, Washington, D.C. (2018). https://rosap.ntl.bts.gov/view/dot/38737 (last accessed June 29, 2023).

[71] Potyondy, J. et al. "Watershed condition framework: A framework for assessing and tracking changes to watershed condition." *USDA Forest Service* (2011) FS-977. https://www.fs.usda.gov/sites/default/files/legacy_files/media/types/publication/field_pdf/Watershed_Condition_Framework.pdf (last accessed June 29, 2023); Potyondy, J. et al. "Watershed Condition Classification Technical Guide." *USDA Forest Service* (2011) FS-978. https://www.fs.usda.gov/sites/default/files/legacy_files/media/types/publication/field_pdf/watershed_classification_guide2011FS978_0.pdf (last accessed June 29, 2023); *USDA Forest Service* (2011) FS-978. https://www.fs.usda.gov/sites/default/files/legacy_files/media/types/publication/field_pdf/watershed_classification_guide2011FS978_0.pdf (last accessed June 29, 2023).

be updated or replaced to recommend a road system that contributes to a "good" WCF rating for each subwatershed and to recognize how roads exacerbate fire risk. Updated TAP reports should also bolster compliance with the National Environmental Policy Act and promote the recovery of species listed under the Endangered Species Act. Furthermore, the agency should issue a clear policy to favor road decommissioning over storage or closure.

Throughout these comments, we explain how protecting MOG from logging will bolster the resilience values that the agency is prioritizing. As a complement to those protections, improving the agency's roads-related policies could further advance many of the same values, consistent with the ANPR's comprehensive evaluation of forest resilience.

b. Adaptation Practices:

i. Fostering Climate Resilience for a Suite of Key Ecosystem Values.

Introduction

In its ANPR, the agency asks, "How might the agency maintain or foster climate resilience for a suite of key ecosystem values including water and watersheds, biodiversity and species at risk, forest carbon uptake and storage, and mature and old-growth forests, in addition to overall ecological integrity?" The ANPR further asks, "What are effective adaptation practices to protect those values?" and "How should trade-offs be evaluated, when necessary?"[72] Similarly, EO 14072 directs the Forest Service to manage forests in a manner that maintains and enhances carbon storage and conserves biodiversity, as well as mitigates wildfire risk and enhances climate resilience.[73] Further below in these comments, we address the outsized role played by mature and old-growth trees and stands in carbon uptake and storage and biodiversity in our national forests. Here, we discuss reasons to conserve these trees and, in moister forests, entire MOG stands, focusing on younger trees and drier sites when treatment is used to pursue ecological resilience through fire risk reduction.

Mature and Old-Growth Forests Are More Fire-Resistant Than Younger Forests.

Mature and old-growth trees are more fire-resistant than young trees, and, in fact, stands of mature and old-growth can act as refugia for imperiled species during wildfire events.[74] The rate of forest fire spread is typically dictated by the quantity of highly flammable foliage and branches in smaller (drier) trees and shrubs.[75] Older trees typically do not contribute significantly

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[72] U.S. Forest Service. "Advance notice of proposed rulemaking and request for comments." 88 *Fed. Reg.* 24,502 (April 21, 2023).

[73] Biden, J. "Executive Order 14072: Strengthening the Nation's Forests, Communities, and Local Economies." 87 *Fed. Reg.* 24,851, 24,852 (April 27, 2022).

[74] Lesmeister, D.B. et al. "Mixed-severity wildfire and habitat of an old-forest obligate." *Ecosphere* (2019) 10(4): e02696. https://doi.org/10.1002/ecs2.2696.

[75] Rothermel, R.C. "How to predict the spread and intensity of forest and range fires." *USDA Forest Service* Gen. Tech. Rep. INT-GTR-143. Intermountain Forest and Range Experiment Station, Ogden, UT (1983). https://doi.org/10.2737/INT-GTR-143; Anderson, H.E. "Aids to determining fuel models for

to the rate of fire spread, due to their high moisture content, much more fire energy and exposure is required for them to ignite. Mature and old-growth trees can contribute to burn duration *if* they ignite, but containing a fire usually involves slowing its rapid spread, which is typically driven by ladder fuels like smaller trees and shrubs.[76]

Individual trees develop a variety of defenses against fire as they mature, including growing thick bark, self-pruning lower branches, growing taller with canopies farther from the ground, and developing more open crowns.[77] Mature ponderosa pines, cedars, Douglas-fir, western larch, and giant Sequoia are all common trees with very developed fire resistance.[78] Even fire-intolerant species like white, grand, and other true fir species are more likely to survive wildfire if they have developed into maturity.[79] Some conifers that appear to have been killed by fire will grow new needles and shoots in the spring.[80] Similarly, entire stands of mature and old-growth trees typically have larger moisture content, resulting in less proportionate biomass that is available to burn. This moisture, combined with larger basal area, also results in mature stands having increased shade and humidity, as well as lower temperatures and wind speeds, improving overall fire resistance.[81]

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estimating fire behavior." *USDA Forest Service* Gen. Tech. Rep. INT-GTR-122. Intermountain Forest and Range Experiment Station, Ogden, UT (1982). https://doi.org/10.2737/INT-GTR-122; Agee, J.K. and C.N. Skinner. "Basic principles of forest fuel reduction treatments." *Forest Ecology and Management* (2005) 211: 83–96. https://doi.org/10.1016/j.foreco.2005.01.034; Keane, R.E. "Wildland Fuel Fundamentals and Applications." *Springer Cham*, New York, NY (2015). https://doi.org/10.1007/978-3-319-09015-3.

[76] Rothermel, R.C. "How to predict the spread and intensity of forest and range fires." *U.S. Forest Service.* Gen. Tech. Rep. INT-143. Intermountain Forest and Range Experiment Station, Ogden, UT (1983). https://doi.org/10.2737/INT-GTR-143; Anderson, H.E. "Aids to determining fuel models for estimating fire behavior." *U.S. Forest Service.* Gen. Tech. Rep. GTR-INT-122. Intermountain Forest and Range Experiment Station, Ogden, UT (1982). https://doi.org/10.2737/INT-GTR-122; Agee, J.K. and C.N. Skinner. "Basic principles of forest fuel reduction treatments." *Forest Ecology and Management* (2005) 211(1-2): 83–96. https://doi.org/10.1016/j.foreco.2005.01.034; Robert E. Keane. "Wildland Fuel Fundamentals and Applications." *Springer* (2015). https://doi.org/10.1007/978-3-319-09015-3.

[77] Agee, J.K. "Fire Ecology of Pacific Northwest Forests.*" Island Press* (1993) 121-124; Brown, P.M. et al. "Identifying old trees to inform ecological restoration in montane forests of the central Rocky Mountains, USA." *Tree Ring Research* (2019) 75(1): 34–48. https://doi.org/10.3959/1536-1098-75.1.34.

[78] Stevens, J.T. "Fire resistance trait data for 29 western North American conifer species." *U.S. Geological Survey data release* (2020). https://doi.org/10.5066/P97F5P7L; Habeck, R.J. "*Sequoiadendron giganteum*." In: "Fire Effects Information System." *USDA Forest Service* Rocky Mountain Research Station, Fire Sciences Laboratory (1992). https://www.fs.usda.gov/database/feis/plants/tree/seqgig/all.html. .

[79] Zouhar, K. "*Abies concolor*." In: "Fire Effects Information System." *USDA Forest Service* Rocky Mountain Research Station, Fire Sciences Laboratory (2001). https://www.fs.usda.gov/database/feis/plants/tree/abicon/all.html.

[80] Hanson, C.T. and M.P. North. "Post-fire survival and flushing in three Sierra Nevada conifers with high initial crown scorch." *International Journal of Wildland Fire* (2009) 18(7): 857–864. https://doi.org/10.1071/wf08129.

[81] Countryman, C.M. "Old-growth conversion also converts the fire climate." *USDA Forest Service* Fire Control Notes (1956) 17(4): 15–19. https://www.fs.usda.gov/sites/default/files/fire-management-today/FSPubs-FMT-79%283%29.pdf (last accessed June 30, 2023); ; Kitzberger, T. et al. "Decreases in

In contrast, younger forests—particularly dense plantations—are the least fire-resistant among stand age classes.[82] Trees in younger forests have shallower roots unable to reach water in deep soil layers and thinner bark that cannot effectively insulate living tree tissue from fire exposure. Younger stands also have more continuous canopies relatively close to the ground that are easier to ignite and do not provide cool-moist microclimate benefits comparable to mature forests' canopies.

Mature and Old-Growth Stands May Not Benefit from Modified Fire Behavior.

Forest Service direction needs to recognize that vegetation treatments aimed at protecting mature and old-growth stands from potential wildfires are not always effective—and may even increase fire risk. This is particularly so in forest types with infrequent fire return intervals. Treatments that open mature and old-growth forest stand understories or decrease crown densities may increase air temperatures, increase surface winds, and allow surface fuels to become drier, elevating fire risk.[83]

Even where fuel treatments are potentially effective, they may not encounter severe fire in time to affect its behavior—*i.e.*, before fuels regrow and accumulate again. Compounding this limitation on treatment efficacy, the severity of fire is substantially influenced by weather conditions.[84] Additionally, fuel reduction generally has less benefit on low-severity fires or high-severity fires than on moderate-severity ones. Thus, the probability of a match between fire, weather conditions, and a treated mature or old-growth stand during the window of a treatment's effectiveness is small.[85]

Fire Spread Probability with Forest Age Promotes Alternative Community States, Reduced Resilience to Climate Variability and Large Fire Regime Shifts." *Ecosystems* (2012) 15: 97–112. https://doi.org/10.1007/s10021-011-9494-y; Frey, S.J.K. et al. "Spatial models reveal the microclimatic buffering capacity of old-growth forests." *Science Advances* (2016) 2(4): e1501392. https://doi.org/10.1126/sciadv/1501392; Agee, J.K. "Fire Ecology of Pacific Northwest Forests.*" Island Press* (1993) 121-124; Agee, J.K. and C.N. Skinner. "Basic principles of forest fuel reduction treatments." *Forest Ecology and Management* (2005) 211: 83–96. https://doi.org/10.1016/j.foreco.2005.01.034.

[82] *See* Thompson, W.A. et al. "Using forest fire hazard modelling in multiple use forest management planning." *Forest Ecology and Management* (2000) 134(1–3): 163–176. https://doi.org/10.1016/S0378-1127(99)00255-8; Zald, H.S.J. and C.J. Dunn. "Severe fire weather and intensive forest management increase fire severity in a multi-ownership landscape." *Ecological Applications* (2018), 28(4): 1068–1080. https://doi.org/10.1002/eap.1710.

[83] Pimont, F. et al. "Validation of FIRETEC wind-flows over a canopy and a fuel-break." *International Journal of Wildland Fire* (2009) 18(7): 775–790. https://doi.org/10.1071/WF07130; Parsons, R.A. et al. "Modeling thinning effects on fire behavior with STANDFIRE." *Annals of Forest Science* (2018), 75:7. https://doi.org/10.1007/s13595-017-0686-2.

[84] Rhodes, J.J. and W.L. Baker. "Fire Probability, Fuel Treatment Effectiveness and Ecological Tradeoffs in Western U.S. Public Forests." *The Open Forest Science Journal* (2008) 1: 1–7. http://dx.doi.org/10.2174/1874398600801010001.

[85] *Ibid.*; Campbell, J.L. et al. "Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions?" *Frontiers in Ecology and the Environment* (2012) 10(2): 83–90. https://doi.org/10.1890/110057.

In other words, a much greater number of forested acres has to be treated than will actually experience wildfire in a manner and timeframe that could reap significant treatment benefits.[86] Such limited benefits would come at significant cost to mature and old-growth biodiversity and carbon storage, and watershed protection values.

Given that fuel treatments' periods of effectiveness are typically relatively short in duration (often ten years or less),[87] the Forest Service needs also to consider the monetary costs, budget implications, and funding mechanisms for repeated maintenance of treatments in mature and old-growth stands. And for the same reason, the agency needs to consider the ecological and societal costs of repeated treatments, including degradation and removal of mature and old-growth habitat values, lost and delayed carbon storage, and increased carbon emissions.

Wildfires Produce Needed Ecological Effects

Mechanical treatments can also hinder the many beneficial ecological effects that fires can produce, particularly within mature and old-growth forests. Notwithstanding recent changes in fire severity and seasonality in western U.S. forests, fire is a natural process to which most native plant and wildlife species are adapted, and there is still a deficit of natural fire processes across many forested landscapes.[88] Wildfires help moderate fuel loads,[89] create a mosaic of habitat types that many species rely on for various essential behaviors,[90] and regulate nutrient cycling.[91] Wildfires can also deliver large downed wood and pulses of sediment needed by aquatic ecosystems.[92] Even where unusual mortality occurs from fire, drought, or insects, the potential for intense disturbance in the next few decades is often reduced.[93]

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[86] Stenzel, J.E. et al. "Restoration Thinning in a Drought-Prone Idaho Forest Creates a Persistent Carbon Deficit." *Journal of Geophysical Research: Biosciences* (2021) 126(3): e2020jG005815. https://doi.org/10.1029/2020JG005815.

[87] Omi, P.N. and E.J. Martinson, "Effectiveness of Fuel Treatments for Mitigating Wildfire Severity: A Manager-Focused Review and Synthesis." *Joint Fire Science Program* Final Report, Project Number 08-2 (2010). https://www.firescience.gov/JFSP_fuels_treatment.cfm.

[88] Marlon, J. R. "Long-term perspective on wildfires in the western USA." *PNAS* (2012) 109 (9): E535-E543. https://doi.org/10.1073/pnas.1112839109; Parisien, M. A. et al. "Fire deficit increases wildfire risk for many communities in the Canadian boreal forest." *Nat Commun* (2020) 11, 2121. https://doi.org/10.1038/s41467-020-15961-y.

[89] Miller, C. "Wildland Fire Use: A Wilderness Perspective on Fuel Management." *USDA Forest Service Proceedings*, RMRS-P-29 (2003). http://winapps.umt.edu/winapps/media2/leopold/pubs/480.pdf.

[90] *See*, *e.g.,* Clark, D.A. "Demography and Habitat Selection of Northern Spotted Owls in Post-Fire Landscapes of Southwestern Oregon." *Oregon State University* M.S. Thesis (2007). Robert Anthony, Advisor. https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/5m60qt980.

[91] McLauchlan, K.K. et al. "Fire as a fundamental ecological process: Research advances and frontiers." *Journal of Ecology* (2020) 108(5): 2047–2069. https://doi.org/10.1111/1365-2745.13403.

[92] Rhodes, J.J. and W.L. Baker. "Fire Probability, Fuel Treatment Effectiveness and Ecological Tradeoffs in Western U.S. Public Forests." *The Open Forest Science Journal* (2008) 1: 1–7. https://doi.org/10.2174/1874398600801010001

[93] Meigs, G.W. et al. "Does wildfire likelihood increase following insect outbreaks in conifer forests?" *Ecosphere* 6(7): 1-24. https://doi.org/10.1890/ES15-00037.1; Simler-Williamson, A.B. et al. "Wildfire

Mature and Old-Growth Forests Retain Their Carbon Storage After Wildfire

It also remains the case that most U.S. wildfires burn at low to moderate severities and leave a large amount of area within their perimeters unburned. For example, large wildfires have impacted Oregon's Western Cascades in recent years, including the Beachie Creek, Lionshead, Riverside, and Holiday Farm fires of 2020. However, the majority of acres within these fires' burn perimeters did not burn at high severities.[94] Up to a third of the acreage within these fires' perimeters was left unburned.[95]

When mature and old-growth trees are affected by fire, they can survive with their carbon stores very largely intact, protected—as discussed above—by adaptations such as thick bark[96] and high crowns,[97] and continue to grow. Even when severe fire does kill these mature and old-growth trees, field research indicates that only a relatively small amount of their carbon is combusted into the atmosphere, and the remainder can persist in the forest for decades or even centuries as the trees slowly decompose,[98] as documented in more detail below.

Logging Activities in Mature and Old-Growth Forest Produce Known Adverse Effects

Just as importantly for the question of actively managing mature and old-growth resources, mechanical treatments result in known adverse effects to forest ecosystems, including lost and delayed carbon storage opportunities. Changes in canopy cover and understories through logging can also alter microclimates that moderate temperatures and moisture levels.[99] Creating more

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alters the disturbance impacts of an emerging forest disease via changes to host occurrence and demographic structure." *Journal of Ecology* (2020) 109(2): 676-691. https://doi.org/10.1111/1365-2745.13495; Donato, D.C. et al. "Bark beetle effects on fuel profiles across a range of stand structures in Douglas-fir forests of Greater Yellowstone." *Ecological Applications* (2013) 23(1): 3–20. https://doi.org/10.1890/12-0772.1.

[94] *See* Rasmussen, M. et al. "Beachie Creek Fire." *see also,* "Lionshead Fire." *see also,* "Riverside Fire." *see also,* "Holiday Farm Fire." In: "2020 Labor Day fires: Economic impacts." *Oregon Forest Research Institute* (2021). https://oregonforests.org/node/840.

[95] *Ibid.*

[96] Agee, J.K. "Fire Ecology of Pacific Northwest Forests.*" Island Press* (1993) 121–124.

[97] Schwilk, D.W. and D.D. Ackerly. "Flammability and serotiny as strategies: correlated evolution in pines." *Oikos* (2001) 94(2): 326–336. https://doi.org/10.1034/j.1600-0706.2001.940213.x.

[98] Meigs, G.W. et al. "Forest Fire Impacts on Carbon Uptake, Storage, and Emission: The Role of Burn Severity in the Eastern Cascades, Oregon." *Ecosystems* (2009) 12: 1246–1267. https://doi.org/10.1007/s10021-009-9285-x; Stenzel, J.E. et al. "Fixing a snag in carbon emissions estimates from wildfires." *Global Change Biology* (2019) 25(11): 3985–3994. https://doi.org/10.1111/gcb.14716.

[99] *See* Gilhen-Baker, M. et al. "Old growth forests and large old trees as critical organisms connecting ecosystems and human health. A review." *Environmental Chemistry Letters* (2022) 20: 1529–1538. https://doi.org/10.1007/s10311-021-01372-y.

open canopy and understory conditions can in turn increase surface temperatures and wind speeds and decrease surface moisture levels, elevating certain fire risk factors.[100]

Within mature and old-growth stands, logging creates more fragmented habitats, reduces connectivity needed for species movement and dispersal, and often reduces habitat quality for imperiled species.[101] Even when modeling shows habitat conditions will improve in the long-term following logging prescriptions, adverse short-term habitat impacts may not be acceptable due to the rapid downward population trajectories of mature and old-growth-dependent species.[102]

Finally, as explained above, use and construction of roads—even "temporary" roads—to facilitate logging operations can result in greater erosion and sedimentation of streams, the spread of invasive species, and disruption of wildlife habitat.[103] When considering proposals to reduce fire risk through logging or removal of mature and old-growth trees, these known adverse effects must be appropriately weighed against the limited likelihood of such treatments producing tangible benefits.

Emissions from Logging on Federal Forests Are Greater Than from Wildfire

A further important consideration in implementing the President and Secretary's direction is that, on a per-acre basis, emissions from logging are generally greater than those from wildfire—and often substantially so. As a result, total national carbon emissions from logging exceed those from fire, even though in many areas more acres of land are affected by fire.[104] Timber harvest drives 92% of annual forest carbon losses in the U.S. South, 86% in the North, and 66% in the West. For comparison, the second greatest impacts on forest carbon in each region are as follows: West: fire (15%); South: wind damage (5%); North: insect damage (9%).[105] The government's own assessment found similar patterns on forests owned and managed by the federal government across the county, where overall fire affects many more acres than logging. As noted above, in a first-of-its-kind assessment from 2018 focused on carbon emissions associated with federal lands, the U.S. Geological Survey estimated that across the conterminous

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[100] Pimont, F. et al. "Validation of FIRETEC wind-flows over a canopy and a fuel-break." *International Journal of Wildland Fire* (2009) 18(7): 775–790. https://doi.org/10.1071/WF07130; Parsons, R.A. et al. "Modelling thinning effects on fire behavior with STANDFIRE." *Annals of Forest Science* (2018) 75:7. https://doi.org/10.1007/s13595-017-0686-2.

[101] *See* Wan, H.Y. et al. "Managing emerging threats to spotted owls." *The Journal of Wildlife Management* (2018) 82(4): 682–697. https://doi.org/10.1002/jwmg.21423.

[102] *See* Franklin, A.B. et al. "Range-wide declines of northern spotted owl populations in the Pacific Northwest: A meta-analysis." *Biological Conservation* (2021) 259: 109168. https://doi.org/10.1016/j.biocon.2021.109168.

[103] Trombulak, S.C. and C.A. Frissell. "Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities." *Conservation Biology* (2000) 14(1): 18-30. https://doi.org/10.1046/j.1523-1739.2000.99084.x.

[104] Harris, N.L. et al. "Attribution of net carbon change by disturbance type across forest lands of the conterminous United States." *Carbon Balance and Management* (2016) 11: 24. https://doi.org/10.1186/s13021-016-0066-5.

[105] *Ibid.*

United States, carbon emissions from logging of federal forests were more than double those from fire on those lands.[106]

Suggested Trade-Off Evaluation Framework

In our view, these findings militate strongly against cutting mature and older trees for fire risk reduction purposes and against mechanical treatments in mature and older stands where fire return intervals are long (outside the immediate vicinity of structures). Before authorizing any wildfire risk mitigation logging in mature and old-growth stands, decisionmakers would need to know that fire is likely to occur in treated stands within the window of effectiveness and cause significant harm to key ecosystem or other values. They would need to show that the comparative effects of the logging would be beneficial to the mature and old-growth stands, and more so than fire with regard to carbon storage and emissions, wildlife habitat, watershed protection, and other values, taking into account both short-term adverse effects and purported longer-term ecological or societal benefits.

Such showings by the Forest Service would be unlikely in mature and old-growth stands, highly unlikely for mature and older trees, and essentially impossible outside short return interval fire systems. Mature and old-growth stands are naturally more fire-resistant and provide critical biodiversity, watershed protection, and carbon storage benefits—even after they interact with fire— that generally outweigh any time-limited benefits from fuel reduction treatments. The Forest Service should instead focus fuel reduction logging and other treatments on younger trees and stands—particularly plantations, which present greater wildfire risks than naturally regenerating stands—especially in forest types with frequent fire return intervals.

In sum, before authorizing fuel reduction logging that will affect mature and old-growth trees and stands, Forest Service officials would need to fully account for the known adverse impacts of such treatments to forest ecosystem values and the unlikelihood that treated areas will even interact with fire, as well as recognize that often the combined effects of treatments *and* fire will be more damaging to such values than fire alone.

ii. Supporting Resilience Investments for Multiple Uses and Ecosystem Services.

The Forest Service should prioritize two critical types of management investment that lower risks to multiple uses, infrastructure, and ecosystem services. First, it should prioritize treatments that reflect the inverse correlation between recency of last burn in dry and mesic forests on the one hand and the intensity and control difficulty of wildfire on the other.[107] Thus, the agency should seek to maximize its use of wildland fire—or prescribed fire where that is not feasible. Additionally, it needs to focus on mechanical treatments that ensure fire occurs or is reintroduced on something approximating its historic occurrence. Priority areas for treatment should have long-term fire plans in place that make historical fire intervals the norm. Repeated mechanical

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[106] Merrill, M.D. et al. "Federal lands greenhouse gas emissions and sequestration in the United States: Estimates 2005-14." *U.S. Geological Survey data release* (2018). https://doi.org/10.5066/F7KH0MK4.

[107] Cansler, C.A. et al. "Previous wildfires and management treatments moderate subsequent fire severity." *Forest Ecology and Management* (2022) 504: 119764. https://doi.org/10.1016/j.foreco.2021.119764.

and other active treatments are not ecologically sustainable in the long term because they do not replace the critical benefits provided by natural fires. And, indeed, opening stands to the drying effects of wind and sun and creating fine fuels without getting fire back into the forest could well increase, rather than reducing, threats to human uses and users of forested areas.

Second, intensive mechanical treatment should be focused on the immediate area around buildings and infrastructure. A solid body of Forest Service research, corroborated by other fire authorities, shows that this is the effective zone for reducing structure ignition through vegetative manipulation.[108] While firebrands travelling from far outside this "home ignition zone" can burn structures, there is little evidence that distant forest thinning prevents the transport of firebrands in the high winds that characterize uncontrollable forest fire conditions. Illustratively, the Camp Fire that so tragically burned Paradise, California, with a terrible loss of human life, started in relatively sparsely timbered lands,[109] in one of the most heavily thinned national forests on the West Coast, the Plumas.[110]

iii. Post-disaster Response and Recovery Practices.

The way the ANPR poses the question about the need for "post disaster response" suggests that natural disturbances are always "disastrous." When disturbances like wildfire cause lives to be lost, or burn down communities and critical infrastructure, those are disasters. In other contexts, though, disturbances like wildfire, windthrow, and insect outbreaks (the most common forest disturbances) operate as essential ecological processes that regulate forests, maintain biodiversity, benefit hydrological function and many other ecosystem services.[111] Wildfires, insect outbreaks, and windthrow can naturally accomplish at least some of what the Forest Service attempts to do via active management, such as reduce stand density and reduce hazardous fuels. Active intervention after such disturbances can often impede, rather than enhance, forest recovery.[112] Salvage logging—and the road building it often entails—is particularly damaging.

Salvage logging often sets back forest recovery

Salvage logging, or post-disturbance logging, is a long practiced but scientifically unsupported method of forest management. Such logging is often cited as a necessary management tool for

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[108] Mall, A. and F. Matzner. "Safe at Home: Making the Federal Fire Safety Budget Work for Communities." *Natural Resources Defense Council* (2007). https://www.nrdc.org/resources/safe-home-making-federal-fire-safety-budget-work-communities (last accessed July 5, 2023); Cohen, J. "The wildland-urban interface problem: a consequence of the fire exclusion paradigm." *Forest History Today* (2008) Fall: 20-26. https://foresthistory.org/wp-content/uploads/2016/12/Cohen_wildland-urban-interface-fire-problem.pdf (last accessed July 5, 2023).

[109] Patel, K. "Camp Fire Rages in California." *NASA earth observatory* (2018). https://earthobservatory.nasa.gov/images/144225/camp-fire-rages-in-california (last accessed July 5, 2023).

[110] Cheng, A.S. et al. "Figure 2" In: "Is There a Place for Legislating Place-Based Collaborative Forestry Proposals?: Examining the Herger-Feinstein Quincy Library Group Forest Recovery Act Pilot Project." *Journal of Forestry* (2016) 114(4): 494-504. https://doi.org/10.5849/jof.15-074.

[111] Perry, D.A. "Forest Ecosystems." *Johns Hopkins University Press* (1994).

[112] Leverkus, A.B. et. al. "Tamm review: Does salvage logging mitigate subsequent forest disturbances?" *Forest Ecology and Management* (2021) 481: 118721. https://doi.org/10.1016/j.foreco.2020.118721.

aiding in forest restoration and recovery after a fire or other natural disturbance.[113] But it can have the opposite result.[114]

A recent scientific review of 96 publications investigated the following relevant questions: (1) *Does salvage logging modify resistance to subsequent disturbances?* (2) *Through what mechanisms do such effects operate?*[115] In summary, the review found that salvage logging does not necessarily prevent subsequent disturbances, and it may increase disturbance likelihood and magnitude.[116]

Specifically, the review found that salvage logging can reduce total ecosystem fuels but increase small ground fuels and produce drier fuels in the short term, reduce bark beetle host trees and beetle-tree connectivity (though with little evidence for outbreak mitigation[117]), magnify erosion and flood impacts of disturbance but with uncertain watershed-scale implications, increase susceptibility to windthrow at artificially created stand edges, remove the protective function of deadwood in preventing rockfall and avalanches, alter browsing pressure by modifying forage availability and hiding cover for herbivores and predators, and increase microclimatic stress due to greater radiation and temperature fluctuations.[118]

The USDA also conducted a review which evaluated 43 scientific studies since 2000 and confined the scope to Western United States and Canada.[119] It confirmed early studies that found negative consequences of post-fire logging on many fronts. In terms of impacts to wildlife, negative impacts were documented including to cavity nesters, wildfire dependent species such as the Black-backed woodpeckers, elk (which avoid logged areas because of increased predation risk from wolves), and negative effects on insects, which are a critical element of postfire landscapes.[120] Studies also confirmed that road construction associated with post disturbance logging is a major factor in disruption of ecosystem dynamics.[121] Lasting impacts of salvage logging were found on certain soil parameters, most notably reduction in soil organic carbon.[122]

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[113] Nemens, D.G. et al. "Environmental effects of postfire logging: An updated literature review and annotated bibliography." *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-975. Pacific Northwest Research Station, Portland, OR (2019). https://doi.org/10.2737/PNW-GTR-975.

[114] *Ibid;* Hanson, C.T. and M.P. North. "Post-fire survival and flushing in three Sierra Nevada conifers with high initial crown scorch" *International Journal of Wildland Fires* (2009) 18: 857-864. https://doi.org/10.1071/WF08129.

[115] Leverkus, A.B. et. al. "Tamm review: Does salvage logging mitigate subsequent forest disturbances?" *Forest Ecology and Management* (2021) 481: 118721. https://doi.org/10.1016/j.foreco.2020.118721.

[116] *Ibid.*

[117] Gibson, K. et al. "Forest Insect & Disease Leaflet 2: Mountain Pine Beetle." *U.S. Department of Agriculture: Forest Service* (2009). https://www.fs.usda.gov/research/treesearch/10939.

[118] Leverkus, A.B. et. al. "Tamm review: Does salvage logging mitigate subsequent forest disturbances?" *Forest Ecology and Management* (2021) 481: 118721. https://doi.org/10.1016/j.foreco.2020.118721.

[119] Nemens, D.G. et al. "Environmental effects of postfire logging: An updated literature review and annotated bibliography." *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-975. Pacific Northwest Research Station, Portland, OR (2019). https://doi.org/10.2737/PNW-GTR-975.

[120] *Ibid.*

[121] *Ibid.*

[122] *Ibid.*

Further, this review found that post fire logging can be a major contributor to soil disturbance and compaction and increased erosion in burned watersheds that were logged.[123]

Post fire logging was also found to influence water quality and stream biota.[124] Researchers also documented a marked decrease in the amount of carbon stored in salvaged sites, particularly those that received intensive management.[125] In terms of fuels, many studies found that in the short term, post fire logging increases fine fuel loading when compared with unmanaged stands. Two studies found fire hazard unaffected by additional fuels from post fire logging.[126]

Thompson et al. refutes the reburn hypothesis showing that salvage-logged stands burned at higher severities than comparable unlogged stands, though the authors noted that the high live fuel loading resulting from postfire planting in logged stands was the most likely driver of fire severity and were not able to separate this variable from the effect of logging alone.[127] While the USDA review cited some studies that found inconclusive or opposite effects of those noted here, and said that more studies are needed, the preponderance of research confirmed that post disturbance logging has negative effects overall can be considered a tax on ecological recovery.[128]

Salvage logging also has a deleterious effect on forest carbon, particularly when it targets large standing dead and dying trees. Most tree carbon is not combusted even in high severity fires and remains on site. For example, a study of above ground combustion following fires in the Sierra Nevada Mountains found that:[129]

> In high severity fire patches, most combustion loss was from branches < 2 cm diameter; in low to moderate severity patches, most was from bole charring. Combustion rates decreased as fire severity declined and with increasing tree size.

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[123] *Ibid.*

[124] *Ibid;* Emelko, M.B. et al. “Implications of land disturbance on drinking water treatability in a changing climate: demonstrating the need for ‘source water supply protection’ strategies.” *Water Res.* (2011) 45(20): 461-472. https://doi.org/10.1016/j.watres.2010.08.051; Silins, U. et al. “Five-year legacy of wildfire and salvage logging impacts on nutrient runoff and aquatic plant, invertebrate, and fish productivity.” *Ecohydrol.* (2014) 7: 1508-1523. https://doi.org/10.1002/eco.1474.

[125] Powers, E.M. et al. “Post-fire management regimes affect carbon sequestration and storage in a Sierra Nevada mixed conifer forest.” (2013) *Forest Ecology and Management* 291: 268-277. https://doi.org/10.1016/j.foreco.2012.07.038.

[126] Nemens, D.G. et al. “Environmental effects of postfire logging: An updated literature review and annotated bibliography.” *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-975. Pacific Northwest Research Station, Portland, OR (2019). https://doi.org/10.2737/PNW-GTR-975.

[127] Thompson, J.R. et al. “Reburn severity in managed and unmanaged vegetation in a large wildfire.” *PNAS* (2007) 104(25): 10743-10748. https://doi.org/10.1073/pnas.0700229104.

[128] Nemens, D.G. et al. “Environmental effects of postfire logging: An updated literature review and annotated bibliography.” *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-975. Pacific Northwest Research Station, Portland, OR (2019). https://doi.org/10.2737/PNW-GTR-975.

[129] Harmon, M.E. et al. “Combustion of Aboveground Wood from Live Trees in Megafires, CA, USA.” *Forests* (2022) 13: 391. https://doi.org/10.3390/f13030391.

> [C]ombustion rates are very low overall at the stand (0.1%–3.2%) and landscape level (0.6%–1.8%), because large trees with low combustion rates comprise the majority of biomass, and high severity fire patches are less than half of the area burned. Our findings of low live wood combustion rates have important implications for policies related to wildfire emissions and forest management.

Salvage logging removes or largely eliminates complex early seral habitat. Complex early seral forest habitat is characterized by high densities of snags, the development of shrub cover and other native post-disturbance vegetation, downed wood, and natural conifer regeneration. Structurally complex early-seral forests host a diversity of plants and wildlife, including several early-seral obligates and opportunists.[130] Post-disturbance biological legacies and high fractions of hardwood shrubs provide irreplaceable habitat for a multitude of invertebrates, birds, reptiles, and mammals).[131]

In addition to avoiding salvage logging for its negative ecological effects, we recommend the Forest Service:

a. Assess natural regeneration potential using appropriate field methodologies:
In the case of wildfires, it is important to thoroughly assess the potential for natural regeneration before decisions are made to salvage and replant. Depending on the forest type and burn patterns, this can take a few years to determine. Methodology for assessing the extent of conifer regeneration must avoid using plot sizes that are too small and can mask the extent of natural regeneration.[132]As discussed above, avoiding salvage logging, and allowing for natural regeneration is the preferred method for ecological recovery.

b. Ensure accurate assessment of tree survival.
Following wildfire, rapid assessments of various fire effects are made by interagency Burned Area Emergency Rehabilitation (BAER) teams using remotely sensed data and field visits, often within several weeks of a fire.[133] Assessments that attempt to estimate conifer stand mortality may gather data immediately after fire or during the following year.

The accuracy of fire severity measurements will be affected if trees that initially appear to be fire-killed prove to be viable after longer observation. Specifically, trees may appear dead, but may still be living and will "flush"—produce new foliage in the years following a fire from

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[130] Swanson, M.E. et al. "The forgotten stage of forest succession: early-successional ecosystems on forest sites." *Frontiers in Ecology and the Environment* (2011) 9: 117-125. https://doi.org/10.1890/090157.

[131] Phalan, B.T. et al. "Impacts of the Northwest Forest Plan on forest composition and bird populations." *PNAS* (2019) 116 (8): 3322-3327. https://doi.org/10.1073/pnas.1813072116; Betts, M. G. et al. "Thresholds in forest bird occurrence as a function of the amount of early-seral broadleaf forest at landscape scales." *Ecological Applications* (2010) 20: 2116–2130. https://doi.org/10.1890/09-1305.1.

[132] Hanson, C.T. and T.Y. Chi. "Impacts of postfire management are unjustified in Spotted Owl habitat." *Frontiers in Ecology and Evolution* (2021) 9. https://doi.org/10.3389/fevo.2021.596282.

[133] Robichaud, P.R. et al. "Emergency post-fire rehabilitation treatment effects on burned area ecology and long-term restoration." *Fire Ecology* (2009) 5: 115–128. https://doi.org/10.4996/fireecology.0501115.

scorched portions of the crown.[134] If land managers do not wait to determine the extent of post-fire flushing, intermediate and large trees that might otherwise survive could be felled because they appear to be dead. The earliest assessment should not be made until mid- or late summer of the year following the fire. However, field studies have also shown that flushing was not apparent until the second or third growing season following fire and was the result of epicormic branching.[135] For example, one study in the Sierra Nevada found that among ponderosa pines and Jeffrey pines with 100% initial crown scorch (no green foliage following the fire), the majority of mature trees flushed, and survived. Red fir with high crown scorch also flushed, and most large trees survived.[136]

Overall, given the negative effects of post disturbance logging, we urge extreme caution and a thorough assessment before proceeding with road construction, post-disturbance logging, and replanting. The review by Leverkus et al. recommends a framework for assessing post-disturbance sites.[137] We recommend the Forest Service consider using this framework.

iv. Work with Partners in the WUI.

The continued vulnerability of many communities in and near forested landscapes to wildfire, particularly in the West, creates problems and unsustainable incentives for incident commanders and forest managers. When communities downwind of wildfires are not prepared to withstand them—even at low intensities—incident responders will find it particularly challenging to let the fires burn. The upshot is predictably aggressive suppression decisions that in the long haul make future fire risks and control problems worse, by extending the time since last burn. Similarly, in the wake of wildfires that cause serious damage to communities, land managers are under intense pressure to take some action that might reassure people they are minimizing future risks. That can lead to aggressive thinning that misdirects agency resources, opens stands to the drying effects of wind and sun, encourages rapid growth of understory fuels, and sometimes creates dangerous woody residues.

Thus, the Forest Service has strong incentives to help communities make themselves more fire-survivable—as a good neighbor and employer of local residents certainly, but also to help ensure that its decision making as an incident responder and land manager can properly reflect ecological realities. In addition to vegetative removal in the immediate vicinity of structures, community survivability is largely a matter of retrofitting and designing buildings to incorporate a few basic features.[138] Indeed, in the absence of these precautions, buildings ignite when fire

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[134] Hanson, C. T. and M. P. North. "Post-fire survival and flushing in three Sierra Nevada conifers with high initial crown scorch." *International Journal of Wildland Fire* (2009) 18: 857–864. https://doi.org/10.1071/WF08129; Woolley, T. et al. "A review of logistic regressional models used to predict post-fire tree mortality of western North American conifers." *International Journal of Wildland Fire* (2012) 21: 1-35. http://dx.doi.org/10.1071/WF09039.

[135] *Ibid.*

[136] *Ibid.*

[137] Leverkus, A.B. et. al. "Tamm review: Does salvage logging mitigate subsequent forest disturbances?" *Forest Ecology and Management* (2021) 481: 118721. https://doi.org/10.1016/j.foreco.2020.118721.

[138] Mall, A. and F. Matzner. "Safe at Home: Making the Federal Fire Safety Budget Work for Communities." *Natural Resources Defense Council* (2007). https://www.nrdc.org/resources/safe-home-making-federal-fire-safety-budget-work-communities (last accessed July 5, 2023).

burns through a development even though immediately adjacent trees do not. It is commonplace to see news photos and videos of wildfire disasters showing buildings blazing or reduced to ash-filled cellar holes amid standing green trees.[139] The agency has an important constructive role to play, assisting with vegetation treatments in public spaces, and providing expertise and advice to officials and owners on structure preparedness. It can and should also use its expertise and credibility to help Congress and state legislatures create fiscal and regulatory incentives that address root causes and help ensure national forest management can be guided by the imperative of ecological sustainability rather than of a nearby community's avoidable vulnerabilities.

v. Eastern Forests Present Irreplaceable Opportunities to Recover Forest Carbon and Biodiversity Benefits without Active Management.

The Midwest and Eastern U.S. (USFS Regions 8 and 9) have lost a greater percentage of their old-growth forests than any other regions of the U.S. Private lands across the region are managed much more heavily for timber harvest compared with public lands. In New England, this discrepancy in harvest intensity has resulted in dramatic differences in carbon storage based on land ownership. For example, across the New England region, public lands were found to store, on average, 30% more carbon than private lands.[140] In a region where the vast majority of forests are privately owned (for example, ~94% of Maine), this makes public lands especially important for long-term carbon storage and uptake, as well as providing habitat values associated with mature and old-growth forests. Recent modeling suggests that logging will continue to be the greatest adverse factor in New England's aboveground forest carbon over at least the next 50 years, greater even than outright forest conversion.[141]

Numerous recent studies have shown that the forests of the Eastern U.S. are essential for long-term climate stability and mitigation based on their high, untapped potential for carbon accumulation and storage compared to forested regions with greater frequency of high-intensity

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[139] Cohen, J. and D. Strohmaier. "Community destruction during extreme wildfires is a home ignition problem." *Wildfire Today* (Sept. 21, 2020). https://wildfiretoday.com/2020/09/21/community-destruction-during-extreme-wildfires-is-a-home-ignition-problem/ (last accessed July 5, 2023); Simon, C. et al. "'Destroyed': In Paradise, California, entire community of 27,000 was ordered to evacuate." *USA Today* (Nov. 9, 2018). https://www.usatoday.com/story/news/nation/2018/11/09/camp-fire-paradise-california-destroyed-evacuations/1940450002/ (last accessed July 5, 2023); Sokol, C. and M. Quinlan. "'It happened so fast': Malden, Pine City residents describe fleeing Monday's inferno." *The Spokesman-Review* (Sept. 8, 2020). https://www.spokesman.com/stories/2020/sep/08/it-all-happened-so-fast-malden-pine-city-residents/ (last accessed July 5, 2023).

[140] Gunn, J.S. et al. "Late-successional and old-growth forest carbon temporal dynamics in the Northern Forest (Northeastern USA)." *Forest Ecology and Management* (2013) 312: 40-46. http://dx.doi.org/10.1016/j.foreco.2013.10.023.

[141] Duveneck, M.J. and J.R. Thompson. "Social and biophysical determinants of future forest conditions in New England: Effects of a modern land-use regime." *Global Environmental Change* (2019) 55: 115–129. https://doi.org/10.1016/j.gloenvcha.2019.01.009.

disturbance.[142] In fact, USFS Regions 8 and 9 are second only to Alaska in terms of the relative impact of timber harvest on carbon storage compared to other disturbances.[143]

Forests in temperate zones such as in the Eastern U.S. have a particularly high untapped capacity for carbon storage and sequestration because of high growth and low decay rates, along with exceptionally long periods between stand-replacing disturbance events, similar to the moist coastal forests of the Pacific Northwest. Further, because of recent recovery from an extensive history of timber harvesting and land conversion for agriculture in the 18th, 19th, and early 20th centuries, median forest age is about 75 years,[144] which is only about 25–35% of the lifespan of many of the common tree species in these forests.[145] Because of the remarkable forest ecosystems in eastern North America, several global studies have highlighted the unique potential of our temperate deciduous forests to contribute on the global stage to climate stabilization and resilience.[146]

Northeast U.S. secondary forests have the potential to dramatically increase biological carbon sequestration and storage. A 2011 paper found that:

> [T]here is a significant potential to increase total carbon storage in the Northeast's northern hardwood-conifer forests. Young to mature secondary forests in the northeastern United States today have aboveground biomass (live and dead) levels of ~107 Mg/ha on average (Turner et al. 1995, Birdsey and Lewis 2003). Thus, assuming a maximum potential aboveground biomass range for old-growth of approximately 250–450 Mg/ha, a range consistent with upper thresholds in our data set and the lower threshold observed at Hubbard Brook, our results suggest a potential to increase in situ forest carbon storage by

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[142] Cook-Patton, S.C. et al. "Mapping carbon accumulation potential from global natural forest regrowth." *Nature* (2020) 585: 545–550. https://doi.org/10.1038/s41586-020-2686-x; Keeton, W.S. et al. "Late-Successional Biomass Development in Northern Hardwood-Conifer Forests of the Northeastern United States." *Forest Science* (2011) 57(6): 489-505. https://doi.org/10.1093/forestscience/57.6.489; Raiho, A.M. et al. "8000-year doubling of Midwestern forest biomass driven by population- and biome-scale processes." *Science* (2022) 376(6600): 1491-1495. https://www.science.org/doi/full/10.1126/science.abk3126.

[143] Birdsey R.A. et al. "Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of U.S. national forests." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-402. Rocky Mountain Research Station, Fort Collins, CO (2019). https://doi.org/10.2737/RMRS-GTR-402.

[144] Moomaw W.R. et al. "Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good." *Frontiers in Forests and Global Change* (2019) 2: 27. https://doi.org/10.3389/ffgc.2019.00027.

[145] *Ibid.*

[146] Dinerstein, E. et al. "A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate." *Science Advances* (2020) 6(36): eabb2824. https://www.science.org/doi/full/10.1126/sciadv.abb2824; Jung, M. et al. "Areas of global importance for conserving terrestrial biodiversity, carbon and water." *Nature Ecology and Evolution* (2-21) 5: 1499–1509. https://doi.org/10.1038/s41559-021-01528-7.

> a factor of 2.3–4.2, depending on site-specific variability. This would sequester an additional 72–172 Mg/ha of carbon.[147]

A 2013 study provides proof that strict protections from logging are strongly associated with secure, long-term carbon sequestration and storage. Strictly protected areas prohibiting logging (i.e., GAP 1, IUCN Category 1, or equivalent classification) cover just 5% of the total land area of the mid-Atlantic and northeast U.S. (VA, PA, DE, NJ, NY, CT, RI, MA, VT, NH, ME). However, these protected areas account for "30% of the carbon stored in all forests in the region."[148]

More recent studies explicitly call into question active management strategies that seek to increase forest carbon sequestration rates:

> Our findings call into question mitigation strategies that aim to increase stand-level or regional scale carbon sequestration rates through forest management. Not only are sequestration rates unlikely to increase in managed forests relative to wildland forests in the northeastern U.S. (cf. Brown et al. 2018; Canham 2021), they will likely decline for 15–20 years compared to surrounding intact forests. Moreover, the re-growing forest will generally not equal the carbon lost from a harvested mature stand (and the foregone carbon the stand would have sequestered) for many decades to over a century (Harmon et al. 1990; Keeton et al. 2011).[149]

Focusing on early successional habitat creation is counterproductive to climate mitigation, adaptation, resilience, and biodiversity goals.

The eastern U.S. was historically dominated by old forests, and it remained that way for millennia prior to European arrival.[150] Although Indigenous communities practiced burning in concentrated areas around settlements, along travel corridors, and in lowland areas, the majority of northeastern U.S. forests were primarily impacted by forces such as wind, ice, and beavers prior to expansive clearing by European settlers.[151]

Despite widespread forest regrowth since agricultural abandonment, rates of timber harvest in the Northeast are such that trends in late successional forest structure are static, and the amount

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[147] Keeton, W.S. et al. "Late-successional biomass development in northern hardwood-conifer forests of the northeastern United States." *Forest Science* (2011) 57(6): 489-505. https://doi.org/10.1093/forestscience/57.6.489.

[148] Lu, X. et al. "A contemporary carbon balance for the northeast region of the United States." *Environmental Science and Technolgy* (2013) 47(23): 13230–13238. https://doi.org/10.1021/es403097z.

[149] Faison, E.K. et al. "Adaptation and mitigation capacity of wildland forests in the northeastern United States." *Forest Ecology and Management* (2023) 544: 121145. https://doi.org/10.1016/j.foreco.2023.121145.

[150] Lorimer, C.G. and A.S. White. "Scale and frequency of natural disturbances in the northeastern US: implications for early successional forest habitats and regional age distributions." *Forest Ecology and Management* (2003) 185(1–2): 41-64. https://doi.org/10.1016/S0378-1127(03)00245-7.

[151] Oswald, W.W. et al. "Conservation implications of limited Native American impacts in pre-contact New England." *Nature Sustainability* (2020) 3: 241–246. https://doi.org/10.1038/s41893-019-0466-0.

of large diameter standing snags is declining.[152] "Even though forests of the Northeast are aging, changes in silviculture and forest policy are necessary to accelerate restoration of old-growth structure."[153] Another recent study notes that "[a]lthough 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…is…dominant—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., passive management).[154]

The Forest Service's recent emphasis on early successional habitat creation is counterproductive to climate mitigation, adaptation, and resilience goals, as well as the science surrounding conservation and restoration of mature and old-growth forests. The Forest Service, in partnership with certain NGOs, is working to dramatically increase the percentage of seedling-sapling-aged stands or "young forest." The oft-stated rationale for creating stand age class diversity through clearcuts, shelterwood cuts, and group selection, among other harvest methods, is rooted in several unscientific assumptions including the arbitrary selection of common species that prefer early successional conditions—such as American woodcock, ruffed grouse, and white-tailed deer—for preferential management. This biased perspective on forest management picks winners and losers based on a desire for conditions that were briefly present in eastern U.S. forests after agricultural abandonment.[155]

The Forest Service's early successional-driven management is also misguided based on the characteristics of stand development and tree age diversity in many eastern forests. According to the definitive paper on disturbance frequency and intensity in New England, "[t]he proportion of the pre-settlement landscape in seedling–sapling forest habitat (1–15 years old) ranged from 1 to 3% in northern hardwood forests (*Fagus–Betula–Acer–Tsuga*) of the interior uplands…. The current estimates of 9-25% [seedling-sapling habitat] for the northern New England states are probably several times higher than presettlement levels." Stand-replacing events occurred, on average, only every 1,000 to 7,500 years.[156] Gap size in spruce-fir and hemlock-northern

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[152] Ducey, M.J. et al. "Late-successional and old-growth forests in the northeastern United States: structure, dynamics, and prospects for restoration." *Forests* (2013) 4(4): 1055-1086. https://doi.org/10.3390/f4041055.

[153] *Ibid.*

[154] Faison E.K. et al. "The importance of natural forest stewardship in adaptation planning in the United States." *Conservation Science and Practice* (2023) 5(6): e12935. https://doi.org/10.1111/csp2.12935.

[155] Kellett, M.J. et al. "Forest-clearing to create early-successional habitats: questionable benefits, significant costs." *Frontiers in Forests and Global Change* (2023) 5: 1073677. https://doi.org/10.3389/ffgc.2022.1073677.

[156] Lorimer, C.G. and A.S. White. "Scale and frequency of natural disturbances in the northeastern US: implications for early successional forest habitats and regional age distributions." *Forest Ecology and Management* (2003) 185(1–2): 41-64. https://doi.org/10.1016/S0378-1127(03)00245-7.

hardwood forests, for example, averaged just 53 square meters, or .013 acres.[157] Beech was the dominant species among Northern Hardwoods, comprising perhaps 30% of the forest.[158]

Management to create artificial "young-forest" conditions negatively impacts a wide variety of imperiled species that depend upon mature and old-growth forests. Many native fish and wildlife species, including those that are often most imperiled, depend on large, unfragmented landscapes and structurally complex old forests for suitable habitat. Mature, unfragmented, interior forests are rare across the eastern U.S., making national forests important concentrations of such habitat. When this habitat is fragmented or degraded, such as through road construction and logging projects, these species experience increased threats from interactions with humans, predation, changes in microclimates, the spread of invasive species, and other fragmentation and edge effects.

Birds such as blackburnian and cerulean warblers, scarlet tanagers, and wood thrush are in decline due to harvesting levels and habitat loss.[159] A recent study from New Brunswick, Canada found that "forest degradation has led to habitat declines for the majority of forest bird species with negative consequences for bird populations, particularly species associated with older forest…. Notably, over the same time period, forest cover changed very little . . . and harvest practices in this region are considered sustainable from a wood-production standpoint."[160]

As mentioned previously, the rare pine marten[161] and endangered northern long-eared bats are harmed by logging of mature forests.[162]

> *Natural forest stewardship (passive management) is a low-cost, high-reward strategy in eastern forests to maintain and restore mature and old-growth forests and associated biodiversity, adaptation and resilience co-benefits.*

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[157] Seymour, R.S. et al. "Natural disturbance regimes in northeastern North America—evaluating silvicultural systems using natural scales and frequencies." *Forest Ecology and Management* (2002) 155(1-3): 357-367. https://doi.org/10.1016/S0378-1127(01)00572-2.

[158] Thompson J.R. et al. "Four centuries of change in northeastern United States forests." *PLOS ONE* (2013) 8(9): e72540. https://doi.org/10.1371/journal.pone.0072540.

[159] Askins, R.A. "The critical importance of large expanses of continuous forest for bird conservation." *Biology Faculty Publications* (2015) 25. http://digitalcommons.conncoll.edu/biofacpub/25.

[160] Betts, M.G. et al. "Forest degradation drives widespread avian habitat and population declines." *Nature Ecology and Evolution* (2022) 6: 709–719. https://doi.org/10.1038/s41559-022-01737-8.

[161] Evans, B.E. and A. Mortelliti. "Effects of forest disturbance, snow depth, and intraguild dynamics on American marten and fisher occupancy in Maine, USA." *Ecosphere* (2022) 13(4): e4027. https://doi.org/10.1002/ecs2.4027.

[162] Burkhart, J. et al. "Species status assessment report for the northern long-eared bat (Myotis septentrionalis)." *U.S. Fish and Wildlife Service* (2022) Version 1.1. https://www.fws.gov/sites/default/files/documents/Species%20Status%20Assessment%20Report%20for%20the%20Northern%20long-eared%20bat-%20Version%201.1%20%282%29.pdf (last accessed July 5, 2023).

A 2019 study led by the University of Vermont looked into the climate resilience of older compared to younger forests. The research found that:

> [Older forests] simultaneously support high levels of carbon storage, timber growth, and species richness. Older forests also exhibit low climate sensitivity…compared to younger forests… [S]trategies aimed at enhancing the representation of older forest conditions at landscape scales will help sustain ecosystem services and biodiversity in a changing world… Although our analysis suggests that old forests exhibit the highest combined [ecosystem services and biodiversity (ESB)] performance, less than 0.2% of the investigated sites are currently occupied by forests older than 200 years. This suggests a large potential to improve joint ESB outcomes in temperate and boreal forests of eastern North America by enhancing the representation of late-successional and older forest stand structures.[163]

In moist forest types, like those that dominate the Upper Midwest and Appalachian regions, natural forest stewardship or passive management results in the reestablishment of the local disturbance regime and has been shown to be more effective than active management for improving forest adaptation and resilience. Vermont Conservation Design, a blueprint for statewide ecosystem management and restoration produced by the state's Agency of Natural Resources, notes that, "[i]n most forests, passive restoration will result in old forest conditions."[164]

An extensive review of the relevant scientific literature published in 2023 found that:

> [E]xpensive 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.[165]

Using several established metrics for the onset of old-growth characteristics, a recent study funded in part by a USDA grant found convincing evidence that in the northeastern United

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[163] Thom, D. et al. "The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal–temperate North America." *Global Change Biology* (2019) 25(7): 2446–2458. https://doi.org/10.1111/gcb.14656.

[164] Zaino R. et al. "Vermont Conservation Design, Part 2: Natural Communities and Habitats Technical Report." (2018) *Vermont Agency of Natural Resources.* https://anr.vermont.gov/sites/anr/files/maps/biofinder/Vermont%20Conservation%20Design%20-%20Natural%20Community%20and%20Habitat%20Technical%20Report%20-%20March%202018.pdf (last accessed July 6, 2023).

[165] Faison, E.K. et al. "The importance of natural forest stewardship in adaptation planning in the United States." *Conservation Science and Practice* (2023) 5(6): e12935. https://doi.org/10.1111/csp2.12935.

States, passive management is superior to active management for achieving goals such as increasing structural complexity and carbon sequestration:

> Aboveground carbon was 20% higher in wildlands… Basal area increment…was 37% higher in wildlands (P = 0.03) than in recently harvested areas. Structural complexity was generally higher in wildlands, with four structural variables – large live (>60 cm DBH) and large dead (>45 cm DBH) tree density, maximum tree height, and diversity of diameter size classes) – greater in wildlands than in unprotected forests.[166]

Large blocks of intact, passively managed forest minimize harmful vectors for the spread of invasive species and allow natural disturbances to play out across a sufficiently large landscape to ensure that there is a mix of early and late successional habitats required by the full spectrum of forest-dependent species.[167] Older temperate forests of the eastern U.S. exhibit greater species richness,[168] forest structural complexity,[169] resilience,[170] and carbon storage.[171]

3. Mature and Old Growth Forests.

a. MOG, Resilience, Climate Change, Biodiversity, and Social Benefits.

We agree wholeheartedly with the ANPR that older forests exhibit structures that contribute importantly to climate resilience. For U.S. forests, resilience in a climate change context is disproportionately associated with the presence and characteristics of mature and older trees and stands—particularly strongly with relatively large trees and mesic and moist mature stands. For forests, climate resilience means the ability of trees and stands to withstand natural (wildfire, insects, drought, wind, etc.) and anthropogenic (logging) disturbances, and persisting as major storehouses of terrestrial carbon. In general, by the time trees and stands in U.S. federal forests have reached 60-80 years, they have achieved substantial resilience in these senses. While

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[166] Faison, E.K. et al. "Adaptation and mitigation capacity of wildland forests in the northeastern United States." *Forest Ecology and Management* (2023) 544: 121145. https://doi.org/10.1016/j.foreco.2023.121145.

[167] Zaino R. et al. "Vermont Conservation Design, Part 2: Natural Communities and Habitats Technical Report." (2018) *Vermont Agency of Natural Resources.* https://anr.vermont.gov/sites/anr/files/maps/biofinder/Vermont%20Conservation%20Design%20-%20Natural%20Community%20and%20Habitat%20Technical%20Report%20-%20March%202018.pdf (last accessed July 6, 2023).

[168] Thom, D. et al. "The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal–temperate North America." *Global Change Biology* (2019) 25: 2446– 2458. https://doi.org/10.1111/gcb.14656; Miller, K.M. et al. "Eastern national parks protect greater tree species diversity than unprotected matrix forests." *Forest Ecology and Management* (2018) 414: 74-84. https://doi.org/10.1016/j.foreco.2018.02.018.

[169] Miller, K.M. et al. "National parks in the eastern United States harbor important older forest structure compared with matrix forests." *Ecosphere* (2016) 7(7): e01404. https://doi.org/10.1002/ecs2.1404.

[170] Faison, E.K. et al. "The importance of natural forest stewardship in adaptation planning in the United States." *Conservation Science and Practice* (2023) 5(6): e12935. https://doi.org/10.1111/csp2.12935.

[171] Thom, D. et al. "The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal–temperate North America." *Global Change Biology* (2019) 25: 2446– 2458. https://doi.org/10.1111/gcb.14656.

natural disturbances can result in tree death, they do not often result in significant release of carbon to the atmosphere. Logging, by contrast, results in near term carbon emissions that may, depending on the prescription, be major.[172] Further arguing for conservation of mature and older trees and stands are the manifold social, economic, and cultural—including Tribal—values they harbor, briefly adverted to in the ANPR and discussed in detail here.

i. MOG Trees Sequester and Store Most Above-Ground Forest Carbon.

As a tree ages and grows larger, research indicates that it will continue to absorb carbon at an increasing rate, storing carbon faster than younger trees do.[173] As it develops, a tree's total leaf area increases, which means more light can be intercepted, which in turn, through photosynthesis, means more atmospheric carbon absorbed.[174] Moreover, the increase in the rate of carbon accumulation continues even as a tree's overall growth rate per unit leaf area declines.[175] Older, larger trees thus hold significantly more carbon than their younger brethren in the forest, and the older stands that these trees dominate hold a substantial and disproportionate portion of a forest's carbon.[176]

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[172] Duncanson, L. et al. "The effectiveness of global protected areas for climate change mitigation." *Nature Communications* (2023) 14: 2908. https://doi.org/10.1038/s41467-023-38073-9; Birdsey, R. A. et al. "Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands." *Frontiers in Forests and Global Change* (2023) 5:1074508. https://doi.org/10.3389/ffgc.2022.1074508; Law, B. E. et al. "Land use strategies to mitigate climate change in carbon dense temperate forests." *Proceedings of the National Academy of Sciences* (2018) 201720064. https://doi.org/10.1073/pnas.1720064115; Law, B. E. and M.E. Harmon. "Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change." *Carbon Management* (2011) 2(1). https://doi.org/10.4155/cmt.10.40; Hudiburg, T. W. et al. "Meeting GHG reduction targets requires accounting for all forest sector emissions." *Environmental Research Letters* (2019) 14 (9). https://doi.org/10.1088/1748-9326/ab28bb.

[173] Stephenson, N.L. et al. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* (2014) 507: 90-93. https://doi.org/10.1038/nature12914.

[174] *Ibid.*; Xu, C-Y. et al. "Age-related decline of stand biomass accumulation is primarily due to mortality and not to reduction in NPP associated with individual tree physiology, tree growth or stand structure in a *Quercus*-dominated forest." *Journal of Ecology* (2012) 100(2): 428-440. https://doi.org/10.1111/j.1365-2745.2011.01933.x; Pregitzer, K.S. and E.S. Euskirchen. "Carbon cycling and storage in world forests: biome patterns related to forest age." *Global Change Biology* (2004) 10(12): 2052-2077. https://doi.org/10.1111/j.1365-2486.2004.00866.x; Mildrexler, D.J. et al. "Large trees dominate carbon storage in forests east of the Cascade Crest in the United States Pacific Northwest." *Frontiers in Forests and Global Change* (2020) 3: 594272. https://doi.org/10.3389/ffgc.2020.594274.

[175] Stephenson, N.L. et al. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* (2014) 507: 90-93. https://doi.org/10.1038/nature12914.

[176] Mildrexler, D.J. et al. "Large trees dominate carbon storage in forests east of the Cascade Crest in the United States Pacific Northwest." *Frontiers in Forests and Global Change* (2020) 3: 594272. https://doi.org/10.3389/ffgc.2020.594274; Lutz, J.A. et al. "Global importance of large-diameter trees." *Global Ecology and Biogeography* (2018) 27(7): 849-864. https://doi.org/10.1111/geb.12747; Brown, S.A. et al. "Spatial distribution of biomass in forests of the eastern USA." *Forest Ecology and Management* (1999) 123(1): 81-90. https://doi.org/10.1016/S0378-1127(99)00017-1.

When looking at rates of this carbon sequestration in forest types around the U.S., a critical value is the culmination of net primary productivity (CNPP). CNPP is the age at which the rate of carbon sequestration in a stand is at a maximum, which can serve as a proxy for the onset of maturity.[177] After this age, the rate of carbon sequestration begins to level off or decrease slightly, as shown in Figure 1 below using Apache-Sitgreaves National Forest in Arizona as an example.[178] In most forest types, this rate peaks around maturity and levels off throughout maturity and old-growth stages (although the amount of carbon stored will increase over the entire lifetime of the stand).[179] Birdsey et al. 2023 looked at NPP trends and CNPP distributions for 11 representative national forests throughout the U.S. In this paper, the authors correlated CNPP with a diameter threshold separating smaller and larger trees to identify larger mature forests and trees. This method would enable implementation of ground-truthing identification of maturity in forest stands by measuring diameter at breast height and notably works with any definition of maturity, not just with CNPP. Using this correlation, they identified "that the unprotected carbon stock in larger trees in mature stands ranged from 36 to 68% of the total carbon in all trees in a representative selection of 11 National Forests."[180]

When looking at CNPP ages for all national forests in the contiguous U.S., the median is 50 ± 15 years and the number average (all values weighted equally) is 54 ± 15 years. When weighted by area of forest type/national forest, the average is 57 ± 15 years.[181]

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[177] Birdsey R.A. et al. "Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands." *Frontiers in Forests and Global Change* (2023) 5: 1074508. https://doi.org/10.3389/ffgc.2022.1074508.

[178] He, L. et al. "Relationships between net primary productivity and forest stand age in U.S. forests." *Global Biogeochemical Cycles* (2012) 26(3). https://doi.org/10.1029/2010GB003942; Birdsey, R.A. et al. "Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of U.S. national forests." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-402. Rocky Mountain Research Station, Fort Collins, CO (2019). https://www.fs.usda.gov/sites/default/files/Appendix-4-NFS-Disturbance-Carbon-Assessment-Southern-Region.pdf; Birdsey R.A. et al. "Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands." *Frontiers in Forests and Global Change* (2023) 5: 1074508. https://doi.org/10.3389/ffgc.2022.1074508.

[179] *Ibid;* Birdsey, R.A. et al. "Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of U.S. national forests." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-402. Rocky Mountain Research Station, Fort Collins, CO (2019). https://www.fs.usda.gov/sites/default/files/Appendix-4-NFS-Disturbance-Carbon-Assessment-Southern-Region.pdf.

[180] Birdsey, R.A. et al. "Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands." *Frontiers in Forests and Global Change* (2023) 5: 1074508. https://doi.org/10.3389/ffgc.2022.1074508.

[181] He, L. et al. "Relationships between net primary productivity and forest stand age in U.S. forests." *Global Biogeochemical Cycles* (2012) 26(3). https://doi.org/10.1029/2010GB003942; Birdsey, R.A. et al. "Assessment of the influence of disturbance, management activities, and environmental factors on carbon stocks of U.S. national forests." *USDA Forest Service* Gen. Tech. Rep. RMRS-GTR-402. Rocky Mountain Research Station, Fort Collins, CO (2019). https://www.fs.usda.gov/sites/default/files/Appendix-4-NFS-Disturbance-Carbon-Assessment-Southern-Region.pdf .

Stand level carbon sequestration dynamics are different from those of individual trees. While aggregate rates of carbon sequestration decline slightly after CNPP, rates of carbon sequestration continue to increase for individual trees.[182]

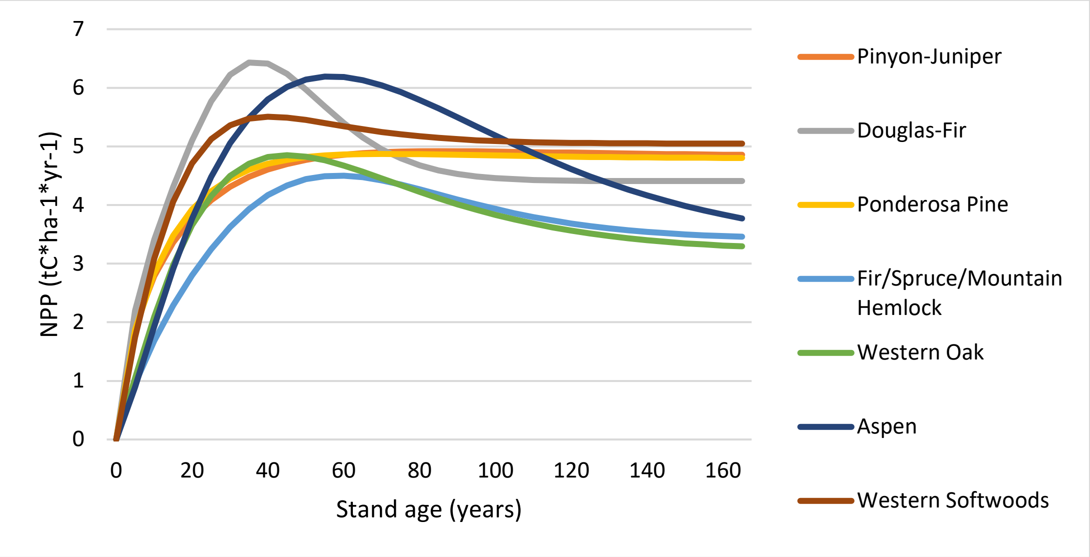

Figure 1. NPP vs. stand age for Apache-Sitgreaves National Forest in Arizona. Forest types shown in legend. Data from He et al.[183]

On USFS forested lands, the great majority of carbon is found in mature and old-growth forests. Figure 2a shows total carbon on USFS forestlands broken down by age class. Two thirds of total carbon on USFS forested lands is contained in forest stands over the age of 80 years old. Figure 2b shows total area of USFS forestlands. Stands over 80 years old, however, make up just one third of total area.

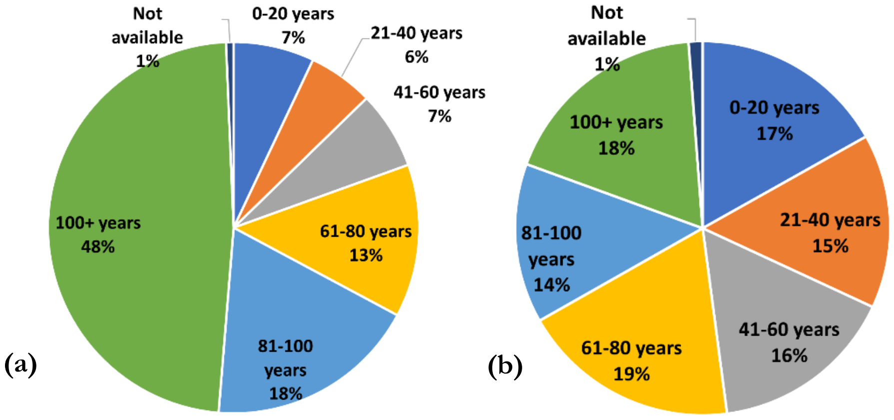

Figure 2. (a) Total carbon on USFS forested lands by stand age class; (b) USFS forest area vs. stand age class (data queried from FIA using EVALIDator tool).

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[182] Stephenson, N.L. et al. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* (2014) 507: 90–93. https://doi.org/10.1038/nature12914.

[183] He, L. et al. "Relationships between net primary productivity and forest stand age in U.S. forests." *Global Biogeochemical Cycles* (2012) 26(3). https://doi.org/10.1029/2010GB003942.

When we look at a total carbon breakdown by USFS region, we see that this trend follows in most regions quite significantly, except in regions 8 and 9 which comprise the eastern US.

This makes sense considering the history of expansive clearcut logging during the beginning of colonization and early history of the U.S. The Forest Reserve Act of 1891 helped to preserve mature and old-growth forests in the west.[184] Figure 3 shows significant carbon content in western stands >80-year-old (regions 1-6) with evidence of younger forests nearing mature/old-growth age classes in the east (regions 8 & 9), demonstrated by the prevalence of stands in the 61-100-year-old age classes. Data for figures 2 and 3 are shown in the Appendix in tables A1-A3.

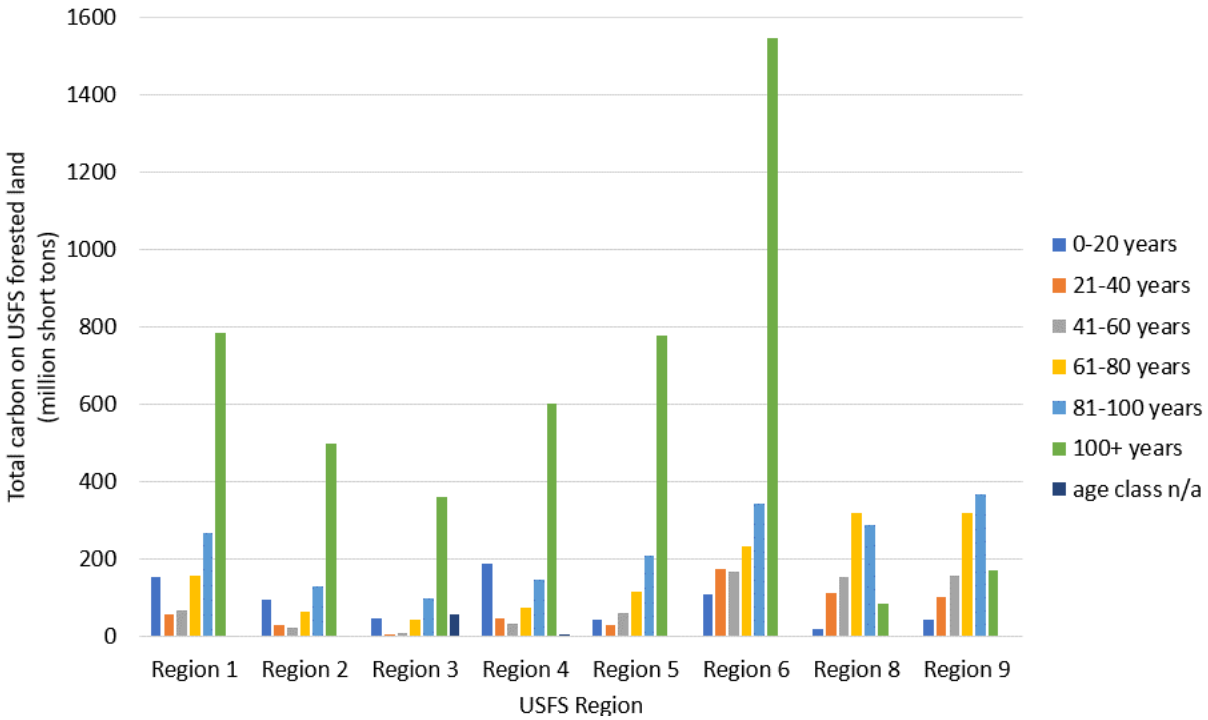

Figure 3. Total carbon on USFS forested lands vs. USFS regions in contiguous U.S. Data queried from FIA using EVALIDator.

ii. Most Carbon Accumulated by Mature Trees Naturally Persists after Death.

As mentioned above, the carbon accumulated by trees will persist as wood throughout the tree's life and beyond. Once an older tree dies from old age or natural disturbance the carbon contained in its wood does not disappear into the atmosphere. Instead, the tree—with the lion's share of the carbon it holds—is retained in the forest as a snag (a standing dead tree) or as coarse woody debris (CWD) slowly decomposing over decades to centuries. This remains true even in

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[184] Williams, G.W. "The USDA Forest Service—The First Century." *USDA Forest Service* (2005) FS-650. https://www.fs.usda.gov/sites/default/files/media/2015/06/The_USDA_Forest_Service_TheFirstCentury.pdf.

scenarios where older, larger trees are affected by wildfire.[185] For example, research on post-fire decomposition rates in the nearly half-million acre Biscuit fire in southwest Oregon reported that 85 percent of the carbon remained 10 years after the fire.[186] Additionally, field measurements in two of California's largest, most severe forest fires, the Rim and Creek fires in the Sierra Nevada, indicated that approximately 99% of the carbon remained in the large trees postfire.[187]

After they die, larger, mature trees often decay more slowly than smaller, younger trees, in both snag and CWD form. Snags are an important aboveground carbon pool[188] and can take upwards of a century (or more) to decompose.[189] Their longevity is due in large part to being more isolated from the agents of decomposition that live on the forest floor (fungi, bacteria, etc.).[190] One of the primary determinants of fall rates among snags is mean annual temperature: warmer climates tend to accelerate decomposition and tree collapse.[191] That said, older, larger trees tend to last substantially longer as snags than smaller trees.[192] In the Cascade Mountains of Oregon, for example, snags of trees greater than 21 inches diameter at breast height lasted 2 to 5 times longer than smaller trees of the same species.[193]

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[185] Campbell, J.L. et al. "Pyrogenic carbon emission from a large wildfire in Oregon, United States." *Journal of Geophysical Research: Biogeosciences* (2007) 112(G4). https://doi.org/10.1029/2007JG000451; Meigs, G.W. "Forest fire impacts on carbon uptake, storage, and emission: the role of burn severity in the Eastern Cascades, Oregon." *Ecosystems* (2009) 12: 1246-1267. https://doi.org/10.1007/s10021-009-9285-x; Stenzel, J.E. et al. "Fixing a snag in carbon emissions estimates from wildfires." *Global Change Biology* (2019) 25(11): 3985-3994. https://doi.org/10.1111/gcb.14716; Harmon, M.E. et al. "Combustion of aboveground wood from live trees in megafires, CA, USA." *Forests* (2022) 13(3): 391. https://doi.org/10.3390/f13030391.

[186] Campbell, J.L. et al. "Carbon emissions from decomposition of fire-killed trees following a large wildfire in Oregon, United States." *Journal of Geophysical Research: Biogeosciences* (2016) 121(3): 718–730. https://doi.org/10.1002/2015JG003165.

[187] Harmon, M.E. et al. "Combustion of aboveground wood from live trees in megafires, CA, USA." *Forests* (2022) 13(3): 391. https://doi.org/10.3390/f13030391.

[188] Lutz, J.A. et al. "The importance of large-diameter trees to the creation of snag and deadwood biomass." *Ecological Processes* (2021) 10: 28. https://doi.org/10.1186/s13717-021-00299-0.

[189] Kelsey, R.G. et al. "Changes in heartwood chemistry of dead yellow-cedar trees that remain standing for 80 years or more in Southeast Alaska." *Journal of Chemical Ecology* (2005) 31: 2653–2670. https://doi.org/10.1007/s10886-005-7618-6.

[190] Maser, C. et al. "From the Forest to the Sea: A Story of Fallen Trees." *USDA Forest Service* Gen. Tech. Rep. PNW-GTR-229. Pacific Northwest Research Station, Portland OR (1988). https://doi.org/10.2737/PNW-GTR-229; Harmon, M.E. and C. Hua. "Coarse woody debris dynamics in two old-growth ecosystems: comparing a deciduous forest in China and a conifer forest in Oregon." *BioScience* (1991) 41(9): 604-610. https://doi.org/10.2307/1311697; Bradford, M.A. et al. "Belowground community turnover accelerates the decomposition of standing dead wood." *Ecology* (2021) 102(11): e03484. https://doi.org/10.1002/ecy.3484.

[191] Bradford, M.A. et al. "Belowground community turnover accelerates the decomposition of standing dead wood." *Ecology* (2021) 102(11): e03484. https://doi.org/10.1002/ecy.3484.

[192] Dunn, C.J. and J.D. Bailey. "Temporal dynamics and decay of coarse wood in early seral habitats of dry-mixed conifer forests in Oregon's Eastern Cascades." *Forest Ecology and Management* (2012) 276: 71-81. https://doi.org/10.1016/j.foreco.2012.03.013.

[193] Mellen-McLean, K. and J.L. Ohmann. "Snag Dynamics in Western Oregon and Washington." *USDA Forest Service* (2016) https://apps.fs.usda.gov/r6_decaid/views/snag_dynamics.html (last accessed July 6, 2023).

CWD often decomposes faster than snags, but the CWD generated by older stands can still retain carbon for extended periods of time.[194] In the Pacific Northwest, for instance, large water-saturated logs in old-growth Douglas-fir forests can last for more than 300 years.[195] And even as this dead wood decomposes, not all of its carbon is lost to the atmosphere—some is absorbed into the forest soil.[196]

iii. Much of the Carbon in Logged and Processed Trees is Rapidly Lost.

Conversely, logging releases much of a tree's stored carbon to the atmosphere in a relatively short time through the transportation and manufacturing process (and particularly if the biomass is burned for energy).[197] Substantial quantities of logging debris will decompose or be burned, a carbon loss frequently under-reported.[198] The milling of logs into products quickly releases substantial stored carbon from the harvested tree boles.[199]

Losses from decomposition vary over time and depend on the lifespan of the wood product being produced from the timber. Paper and wood chips, for example, have very short lifetimes and will release substantial carbon into the atmosphere within a few months to a few years of production. Bioenergy production and burning have been found to release more emissions than burning even coal, including methane.[200] Product disposal in landfills results in anaerobic decomposition that releases methane. Methane has a global warming potential about 30 times that of carbon dioxide

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[194] Harmon, M.E. et al. "Ecology of coarse woody debris in temperate ecosystems." *Advances in Ecological Research* (2004) 34: 59-234. https://doi.org/10.1016/S0065-2504(03)34002-4.

[195] Means, J.E. et al. "Comparison of decomposition models using wood density of Douglas-fir logs." *Canadian Journal of Forest Research* (1985) 15(6): 1092-1098. https://doi.org/10.1139/x85-178.

[196] Magnússon, R.Í. et al. "Tamm Review: Sequestration of carbon from coarse woody debris in forest soils." *Forest Ecology and Management* (2016) 377: 1-15. https://doi.org/10.1016/j.foreco.2016.06.033.

[197] Law, B.E., et al. "Land use strategies to mitigate climate change in carbon dense temperate forests." *Proceedings of the National Academy of Sciences of the United States of America* (2018) 115(14): 3663-3668. https://doi.org/10.1073/pnas.1720064115; Hudiburg, T.W. et al. "Meeting GHG reduction targets requires accounting for all forest sector emissions." *Environmental Research Letters* (2019) 14(9): 095005. https://doi.org/10.1088/1748-9326/ab28bb; Sterman, J. et al. "Does wood bioenergy help or harm the climate?" *Bulletin of the Atomic Scientists* (2022) 78(3): 128-138. https://doi.org/10.1080/00963402.2022.2062933.

[198] Hudiburg, T.W. et al. "Meeting GHG reduction targets requires accounting for all forest sector emissions." *Environmental Research Letters* (2019) 14(9): 095005. https://doi.org/10.1748-9326/ab28bb.

[199] *Ibid;* Harmon, M.E. et al. "Modeling carbon stores in Oregon and Washington forest products: 1900-1992." *Climatic Change* (1996) 33: 521-550. https://doi.org/10.1007/BF00141703; Law, B.E. et al. "Land use strategies to mitigate climate change in carbon dense temperate forests." *Proceedings of the National Academy of Sciences* (2018) 115(14): 3663–3668. https://doi.org/10.1073/pnas.1720064115; Sterman, J. et al. "Does wood bioenergy help or harm the climate?" *Bulletin of the Atomic Scientists* (2022) 78(3): 128–138. https://doi.org/10.1080/00963402.2022.2062933.

[200] Garg, A. et al. "2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 2: Energy." *Intergovernmental Panel on Climate Change* (2006). https://s3.documentcloud.org/documents/1146713/ipcc-guidelines-for-national-greenhouse-gas.pdf.

over 100 years, and over 80 times that of carbon dioxide over 20 years,[201] magnifying the impact of disposal of short-term wood products.

Longer term wood products can store carbon for many decades, but this depends on the life of the product. To give a sense of the larger picture, a study modeling carbon stores in Oregon and Washington from 1900-1992 showed that only 23% of carbon from logged trees during this period was still stored as of 1996.[202] Similarly, more than 80% of carbon removed from forests in logging operations in West Coast forests since 1900 was transferred to landfills and the atmosphere within decades. Additionally, state and federal carbon reporting had erroneously excluded some product-related emissions, resulting in a 25-55% underestimation of state total carbon emissions from logging.[203] Importantly, the longevity of carbon storage in wood products is virtually always shorter than the longevity of carbon storage in mature and old forests.[204]

iv. Mature Forests and Trees Provide Critical Ecological Co-Benefits.

Executive Order 14072 instructs federal agencies to safeguard ecological co-benefits, including high levels of biodiversity, that reflect the specific structural attributes and ecological processes found in mature forests.[205] Scientists have long recognized that mature forests across the country possess unique ecological features. One leading forest ecology textbook, for instance, reports that the "mature forest stage" is when "the initial cohort of trees lose their youthful appearance," "[o]verstory trees will achieve most of their height growth and crown spread," "epicormic or other adventitious branch systems may begin developing," and "[d]ecadent canopy and bole features . . . become more abundant."[206] These mature forests develop a complex structural arrangement. Large trees (dead and alive), understory plants, and the organic soil layer (top soil horizons) all contribute to this complexity.[207] Structure accumulates in the form of, for instance, snags and CWD, cavities in trees created by branch breakage or by animal activity (e.g., woodpeckers), the horizontally complex understory arrangement of foliage, and crown layering and upper branching patterns. As discussed in more detail below, the benefits of this complexity are readily identified in the places where mature forests and trees have been allowed to develop.

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[201] Forster, P. and T. Storelvmo. "Chapter 7: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity." In: "Climate Change 2021 – The Physical Science Basis." *Intergovernmental Panel on Climate Change* (2021) AR6 WG1: 923-1054. https://doi.org/10.1017/9781009157896.009.

[202] Harmon, M.E. et al. "Modeling carbon stores in Oregon and Washington forest products: 1900–1992." *Climatic Change* (1996) 33: 521–550. https://doi.org/10.1007/BF00141703.

[203] Hudiburg, T.W. et al. "Meeting GHG reduction targets requires accounting for all forest sector emissions." *Environmental Research Letters* (2019) 14(9): 095005. https://doi.org/10.1748-9326/ab28bb.

[204] Law, B. E. and M. E. Harmon. "Forest sector carbon management, measurement and verification, and discussion of policy related to climate change." *Carbon Management* (2011) 2(1): 73-84. https://doi.org/10.4155/cmt.10.40.

[205] Brandt, P. et al. "Multifunctionality and biodiversity: Ecosystem services in temperate rainforests of the Pacific Northwest, USA." *Biological Conservation* (2014) 169: 362–371. https://doi.org/10.1016/j.biocon.2013.12.003.

[206] Franklin, J.F. et al. "Ecological Forest Management." *Waveland Press* (2018).

[207] *Ibid*; Perry, D.A. "Forest Ecosystems." *Johns Hopkins University Press* (1994).

As forests age over decades and centuries, they form complex ecosystems with vibrant living trees at their foundation. Left undisturbed, conditions such as shade from canopy closure and reduced temperatures due to evapotranspiration nurture a variety of plants and wildlife that would often struggle to survive elsewhere.[208] These benefits do not end once a tree dies. Older forests also naturally have a variety of dead trees that provide habitat including snags that are important habitat elements for numerous woodpeckers, owls, and rodents, and CWD that provides forage for bears, habitat and cover for furbearers, and essential nutrients for new vegetation and saplings.[209]

As a result of these and other features, mature and old growth forests serve as irreplaceable regional climate refugia for a wide variety of threatened, endangered, and sensitive species in the U.S. Examples include:

- Spotted owl (northern and Mexican subspecies listed as threatened): Spotted owls need mature and old-growth forests for nesting and roosting, and, in the Pacific Northwest, for withstanding invasive barred owl invasions. When older forests are logged, including by reducing canopy levels via thinning and fuel reduction treatments, northern spotted owls are forced to compete with barred owls.[210] Additionally, studies have found that any reduction in canopy cover by logging harms spotted owls by negatively impacting site occupancy, reproduction, and survival.[211] These impacts from logging can be dramatic within just a few years. Indeed, based on modeling studies, the rate of old forest loss from proposed thinning in the northern spotted owl recovery plan exceeds the anticipated loss of nesting and roosting habitat from fires over a 40-year period, even with climate change in the model.[212]

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[208] Grier, C.G. and S.W. Running. "Leaf area of mature northwestern coniferous forests: relation to site water balance." *Ecology* (1977) 58(4): 893-899. https://doi.org/10.2307/1936225; Nagy, R.C. et al. "Water resources and land use and cover in a humid region: the Southeastern United States." *Journal of Environmental Quality* (2011) 40(3): 867-878. https://doi.org/10.2134/jeq2010.0365.

[209] Franklin, J.F. et al. "Ecological Forest Management," *Waveland Press* (2018); Perry, D.A. "Forest Ecosystems." *Johns Hopkins University Press* (1994).

[210] Dugger, K.M. et al. "The effects of habitat, climate, and Barred Owls on long-term demography of Northern Spotted Owls." *The Condor* (2016) 118(1): 57-116. http://dx.doi.org/10.1650/CONDOR-15-24.1.

[211] Blakesley, J.A. et al. "Site occupancy, apparent survival, and reproduction of California Spotted Owls in relation to forest stand characteristics." *Journal of Wildlife Management* (2005) 69(4): 1554-1564. https://doi.org/10.2193/0022-541X(2005)69[1554:SOASAR]2.0.CO;2; Seamans, M.E. and R.J. Gutiérrez. "Sources of variability in spotted owl population growth rate: testing predictions using long-term mark-recapture data." *Oecologia* (2007) 152(1): 57-70. https://doi.org/10.1007/s00442-006-0622-x; Stephens, S.L. et al. "California Spotted Owl, songbird, and small mammal responses to landscape fuel treatments." *BioScience* (2014) 64(10): 893–906. https://doi.org/10.1093/biosci/biu137; Tempel, D.J. et al. "Effects of forest management on California Spotted Owls: implications for reducing wildfire risk in fire-prone forests." *Ecological Applications* (2014) 24(8): 2089-2106. https://doi.org/10.1890/13-2192.1; Tempel, D.J. et al. "Meta-analysis of California Spotted Owl (*Strix occidentalis occidentalis*) territory occupancy in the Sierra Nevada: Habitat associations and their implications for forest management." *The Condor* (2016) 118(4): 747-765. https://doi.org/10.1650/CONDOR-16-66.1.

[212] Odion, D.C. et al. "Effects of fire and commercial thinning on future habitat of the Northern Spotted Owl." *The Open Ecology Journal* (2014) 7: 37-51. http://dx.doi.org/10.2174/1874213001407010037.

- Marbled murrelet (federally listed as threatened): This is a seabird that nests in old-growth forests found along the Pacific coast. Logging these forests fragments nesting areas, which then results in elevated nest predation by corvids.[213]

- Kaibab squirrel (Arizona-state listed as imperiled and vulnerable): This is an endemic and rare subspecies of tassel-eared squirrel found only on Arizona's Kaibab Plateau. It depends on the structure and complex interactions of old-growth forests to facilitate its movements and provide food.[214]

- Canada lynx (federally listed as threatened): This elusive cat species depends on complex, multistory forests for denning habitat and to find its main prey species: snowshoe hares. This type of high-quality denning habitat is limited to mature forest, which provides the coarse woody debris needed for thermal cover and protection for the lynx's young.[215]

- Fisher (federally listed as sensitive): This is a medium mustelid that can be found in the northern Rockies, primarily Montana and Idaho. Research shows that fishers are associated with older forests throughout their range.[216] Fishers need dense overhead cover, abundant coarse woody debris, and large trees.[217] Female fishers use cavities in large-diameter live trees and snags because tree cavities regulate temperatures and protect kits from predators.[218] Forest configuration figures just as much into the type of habitat that fisher need as composition, specifically the proximity of mature forest patches. Researchers found that

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[213] Hebert, P.N. and R.T. Golightly. "Observations of predation by corvids at a Marbled Murrelet nest." *Journal of Field Ornithology* (2007) 78(2): 221-224. https://doi.org/10.1111/j.1557-9263.2007.00105.x; Malt, J.M. and D.B. Lank. "Marbled Murrelet nest predation risk in managed forest landscapes: dynamic fragmentation effects at multiple scales." *Ecological Applications* (2009) 19(5): 1274-1287. https://doi.org/10.1890/08-0598.1.

[214] Dodd, N.L. et al. "Tassel-Eared Squirrel population, habitat condition, and dietary relationships in North-Central Arizona." *Journal of Wildlife Management* (2003) 67(3): 622-633. https://doi.org/10.2307/3802719; Loberger, C.D. et al. "Use of restoration-treated ponderosa pine forest by tassel-eared squirrels." *Journal of Mammalogy* (2011) 92(5): 1021-1027. https://doi.org/10.1644/10-MAMM-A-321.1.

[215] Koehler, G.M. and K.B. Aubry. "Lynx." In: "The Scientific Basis for Conserving Forest Carnivores: American Marten, Fisher, Lynx, and Wolverine in the Western United States." *USDA Forest Service* Gen. Tech. Rep. RM-254. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO (1994). Edited by Ruggiero, L.F. et al. https://www.fs.usda.gov/rm/pubs_rm/rm_gtr254.pdf.

[216] Aubry, K.B. et al. "Meta-Analysis of habitat selection by fishers at resting sites in the pacific coastal region." *The Journal of Wildlife Management* (2013) 77(5): 965-974. http://dx.doi.org/10.1002/jwmg.563; Olson, L.E. et al. "Modeling the effects of dispersal and patch size on predicted fisher (*Pekania* [*Martes*] *pennanti*) distribution in the U.S. Rocky Mountains." *Biological Conservation* (2014) 169: 89-98. https://doi.org/10.1016/j.biocon.2013.10.022; Sauder, J.D. and J.L. Rachlow. "Both forest composition and configuration influence landscape-scale habitat selection by fishers (*Pekania pennanti*) in mixed coniferous forests of the Northern Rocky Mountains." *Forest Ecology and Management* (2014) 314: 75-84. http://dx.doi.org/10.1016/j.foreco.2013.11.029; Weir, R.D. and F.B. Corbould. "Factors affecting landscape occupancy by Fishers in North-Central British Columbia." *Journal of Wildlife Management* (2010) 74(3): 405-410. https://doi.org/10.2193/2008-579.

[217] *Ibid.*

[218] *Ibid.*

fishers in Idaho's Clearwater Basin used landscapes with large patches of mature forest arranged in connected patterns.[219]

- Pacific (formerly American or Pine) marten (coastal distinct population in northwest California and southwest Oregon federally listed as sensitive; Vermont-state listed as endangered): The marten is a mustelid species that has been eliminated from much of its historic range. According to the Fish and Wildlife Service, "[m]artens across North America generally select older forest stands that are structurally complex (e.g., late-successional, old-growth, large-conifer, mature, late-seral). These forests generally have a mixture of old and large trees, multiple canopy layers, snags and other decay elements, dense understory, and have a biologically complex structure and composition."[220] As mature and old-growth forests are lost, martens decline. A 2022 study analyzing marten populations in Maine found that "even partial harvest activities can diminish the canopy cover, structural complexity and overall basal area [that marten] require."[221] The same study found that "Marten…showed lower initial occupancy probability in areas of increasingly disturbed forest and had both higher extinction rates and lower colonization rates in these areas."[222]

- Northern long-eared bat (federally listed as threatened, proposed for uplisting to endangered): The bat depends on mature and old forests for roosting and foraging.[223] Its preferred roosting habitat is large-diameter live or dead trees of a variety of species, with exfoliating bark, cavities, or crevices. And its preferred foraging habitat is old forest with complex vertical structure on hillsides and ridges.[224]

Similarly, mature forests interact with other landscape features to enhance biodiversity. Riparian zones—critical floodplain and land adjacent to bodies of water like streams and rivers—are also critical to many ecosystem values and services that are enhanced by the presence of MOG. Mature and old growth forests regulate water temperature, provide critical inputs of woody

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[219] Sauder, J.D. and J.L. Rachlow. "Both forest composition and configuration influence landscape-scale habitat selection by fishers (*Pekania pennanti*) in mixed conifer forests of the Northern Rocky Mountains." *Forest Ecology and Management* (2014) 314: 75-84. http://dx.doi.org/10.1016/j.foreco.2013.11.029.

[220] U.S. Fish & Wildlife Service. "Designation of Critical Habitat for the Coastal Distinct Population Segment of the Pacific Marten." 86 *Fed. Reg*. 58,831, 58,833 (Oct. 25, 2021). https://www.federalregister.gov/documents/2021/10/25/2021-22994/endangered-and-threatened-wildlife-and-plants-designation-of-critical-habitat-for-the-coastal (last accessed July 12, 2023).

[221] Evans, B.E. and A. Mortelliti, "Effects of forest disturbance, snow depth, and intraguild dynamics on American marten and fisher occupancy in Maine, USA." *Ecosphere* (2022) 13(4): e4027. https://doi.org/10.1002/ecs2.4027.

[222] *Ibid.*

[223] Burkhart, J. et al. "Species Status Assessment Report for the Northern long-eared bat (*Myotis septentrionalis*)." *U.S. Fish and Wildlife Service* (2022) Version 1.1. https://www.fws.gov/sites/default/files/documents/Species%20Status%20Assessment%20Report%20for%20the%20Northern%20long-eared%20bat-%20Version%201.1%20%282%29.pdf.

[224] *Ibid.*

debris, and stabilize streambanks.[225] These zones provide water for a range of wildlife and cool, moist growing conditions for many vegetative species.[226] The bigger, older trees that form the core of mature and old-growth forests play an important part in hydrological cycles. Forests generally circulate precipitation via uptake of water from roots to canopies and release water back to the atmosphere by evapotranspiration through leaf pores. This function of trees increases as they get older and bigger because leaf area—which is greater in larger trees—is related to site water balance, soil water storage/retention, and better water retention in trees.[227]

Field data from a spectrum of forest sites bear out these hydrologic benefits. Analysis, for example, of 60-year records of daily streamflow from eight paired-basins in the Pacific Northwest showed how conversion of old-growth forests to Douglas-fir plantations reduced stream flow by 50%. This is because young trees have less ability to limit evapotranspiration, especially during dry summer months. Additionally, researchers noted that reduced summer streamflow in headwater basins with forest plantations may limit aquatic habitat and exacerbate stream warming, while altering water yield and timing of peak flows in larger basins.[228] Even though removing forest cover can temporarily accelerate the rate that precipitation becomes streamflow,[229] increases in flow rate and volume are typically short-lived, and the practice can ultimately degrade water quality and increase vulnerability to flooding for extended periods.

The hydrological importance of intact mature and old-growth forests also extends underground due to mycorrhizae support found in many species, including Douglas-fir forests on BLM lands. Study after study has revealed that soil biota, particularly fungi that form symbioses with plant roots (mycorrhizae), provide a suite of ecosystem services that support the integrity and

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[225] Pypker, T.G. et al. "The role of epiphytes in rainfall interception by forests in the Pacific Northwest. I. Laboratory measurements of water storage." *Canadian Journal of Forest Research* (2006) 36(4). https://doi.org/10.1139/x05-298; Crampe, E.A. et al. "Fifty years of runoff response to conversion of old-growth forest to planted forest in the H. J. Andrews Forest, Oregon, USA." *Hydrological Processes* (2021) 35(5): e14168. https://doi.org/10.1002/hyp.14168.

[226] Ham, R.D. "Fog drip in the Bull Run Municipal Watershed, Oregon." *Journal of the American Water Resources Association* (1982) 18(5): 785-789. https://doi.org/10.1111/j.1752-1688.1982.tb00073.x; Crampe, E.A. et al. "Fifty years of runoff response to conversion of old-growth forest to planted forest in the H. J. Andrews Forest, Oregon, USA." *Hydrological Processes* (2021) 35(5): e14168. https://doi.org/10.1002/hyp.14168; Wondzell, S.M. "The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of Eastern Oregon and Washington." *Northwest Science* (2001) 75: 128-140. https://research.libraries.wsu.edu/xmlui/handle/2376/989; Wheeling, K. "How forest structure influences the water cycle." *Eos* (2019) Vol. 100. https://doi.org/10.1029/2019EO134709.

[227] Grier, C.G. and S.W. Running. "Leaf area of mature northwestern coniferous forests: relation to site water balance." *Ecology* (1977) 58(4): 893-899. https://doi.org/10.2307/1936225; Jiang, Y. et al. "Linking tree physiological constraints with predictions of carbon and water fluxes at an old-growth coniferous forest." *Ecosphere* (2019) 10(4): e02692. https://doi.org/10.1002/ecs2.2692.

[228] Perry, T.D. and J.A. Jones. "Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA." *Ecohydrology* (2017) 10(2): e1790. https://doi.org/10.1002/eco.1790.

[229] Rhodes, J. and C.A. Frissell. "The high costs and low benefits of attempting to increase water yield by forest removal in the Sierra Nevada." *Environment Now* (2016). http://dx.doi.org/10.13140/RG.2.1.1893.9926.

resiliency of natural and human communities.[230] Mycorrhizae are known to reduce erosion and nutrient loss,[231] increase plant water use efficiency and retention (which improves cooling capacity in the landscape),[232] store carbon in the ground,[233] help plants adapt to changes in climate,[234] and resist pests and pathogens.[235]

Mycorrhizae enhance nutrient retention in vegetation, mycelium and soils—decreasing leaching that negatively affects water quality.[236] Mycorrhizal mycelia aggregate soil particles, improving soil porosity, and enhancing water infiltration and moisture retention.[237] They mediate hydrological functioning by modulating surface soil-to-water attraction and repellency.[238] In

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[230] Markovchick, L.M. et al. "The gap between mycorrhizal science and application: existence, origins, and relevance during the United Nation's Decade on Ecosystem Restoration." *Restoration Ecology* (2023) 31(4): e13866. https://doi.org/10.1111/rec.13866.

[231] Burri, K. et al. "Mycorrhizal fungi protect the soil from wind erosion: a wind tunnel study." *Land Degradation & Development* (2011) 24(4): 385–392. https://doi.org/10.1002/ldr.1136; Mardhiah, U. et al. "Arbuscular mycorrhizal fungal hyphae reduce soil erosion by surface water flow in a greenhouse experiment." *Applied Soil Ecology* (2016) 99: 137–140. https://doi.org/10.1016/j.apsoil.2015.11.027.

[232] Querejeta, J.I. et al. "Differential modulation of host plant $\delta^{13}C$ and $\delta^{18}O$ by native and nonnative arbuscular mycorrhizal fungi in a semiarid environment." *New Phytologist* (2005) 169(2): 379–387. https://doi.org/10.1111/j.1469-8137.2005.01599.x; Gehring, C.A. et al. "Tree genetics defines fungal partner communities that may confer drought tolerance." *Proceedings of the National Academy of Sciences* (2017) 114(42): 11169–11174. https://doi.org/10.1073/pnas.1704022114; Wu, Q.-S. and R.-X. Xia. "Arbuscular mycorrhizal fungi influence growth, osmotic adjustment and photosynthesis of citrus under well-watered and water stress conditions." *Journal of Plant Physiology* (2006) 163(4): 417–425. https://doi.org/10.1016/j.jplph.2005.04.024.

[233] Orwin, K.H. et al. "Organic nutrient uptake by mycorrhizal fungi enhances ecosystem carbon storage: a model-based assessment." *Ecology Letters* (2011) 14(5): 493–502. https://doi.org/10.1111/j.1461-0248.2011.01611.x; Nautiyal, P. et al. "Role of glomalin in soil carbon storage and its variation across land uses in temperate Himalayan regime." *Biocatalysis and Agricultural Biotechnology* (2019) 21: 101311. https://doi.org/10.1016/j.bcab.2019.101311.

[234] Gehring, C.A. et al. "Tree genetics defines fungal partner communities that may confer drought tolerance." *Proceedings of the National Academy of Sciences* (2017) 114(42): 11169–11174. https://doi.org/10.1073/pnas.1704022114; Patterson, A. et al. "Common garden experiments disentangle plant genetic and environmental contributions to ectomycorrhizal fungal community structure." *New Phytologist* (2018) 221(1): 493–502. https://doi.org/10.1111/nph.15352.

[235] Reddy, B.N. et al. "Approach for enhancing mycorrhiza-mediated disease resistance of tomato damping-off." *Indian Phytopathology* (2006) 59(3): 299–304. https://epubs.icar.org.in/index.php/IPPJ/article/view/17367; Rinaudo, V. et al. "Mycorrhizal fungi suppress aggressive agricultural weeds." *Plant and Soil* (2009) 333: 7–20. https://doi.org/10.1007/s11104-009-0202-z.

[236] van der Heijden, M.G.A. "Mycorrhizal fungi reduce nutrient loss from model grassland ecosystems." *Ecology* (2010) 91(4): 1163–1171. https://doi.org/10.1890/09-0336.1.

[237] Augé, R.M. et al. "Moisture retention properties of a mycorrhizal soil." *Plant and Soil* (2001) 230: 87–97. https://doi.org/10.1023/A:1004891210871; Rillig, M.C. and D.L. Mummey. "Mycorrhizas and soil structure." *New Phytologist* (2006) 171(1): 41– 53. https://doi.org/10.1111/j.1469-8137.2006.01750.x.

[238] Rillig, M.C. et al. "Mycelium of arbuscular mycorrhizal fungi increases soil water repellency and is sufficient to maintain water-stable soil aggregates." *Soil Biology and Biochemistry* (2010) 42(7): 1189–1191. https://doi.org/10.1016/j.soilbio.2010.03.027; Zheng, W. et al. "Ectomycorrhizal fungi in association with *Pinus sylvestris* seedlings promote soil aggregation and soil water repellency." *Soil Biology and Biochemistry* (2014) 78: 326–331. https://doi.org/10.1016/j.soilbio.2014.07.015.

Douglas-fir stands, "EM [ectomycorrhizal] networks may increase in importance for forest regeneration where climate change increases water stress."[239] Research shows that the germination and survival of seedlings linked into the network of older Douglas-fir trees was substantially greater in a very dry climate compared to a wet climate due to the transfer of water to the new germinants. In the dry climate especially, the mycorrhizal network appeared to extend the niche breadth of interior Douglas-fir seedlings.[240] Removal of older trees that serve as hubs directing the flow of water and nutrients could significantly disrupt this network.

Additionally, the complex canopies associated with mature and old-growth forests help regulate the rate at which moisture and heat are exchanged with the atmosphere, which in turn influences water retention and the makeup of forest ecosystems. In the temperate zone, logging large canopy trees results in drier conditions, because sunlight and heat reaching the ground can cause more evaporative losses and higher surrounding temperatures.[241] (This contrasts with logging and development, which are known to produce downwind continental interiors with declining rainfall and water availability that heighten drought and wildfire risks.)[242]

More broadly, unlogged watersheds with older forests and dense riparian vegetation are more hydrologically functional and contain higher levels of terrestrial and aquatic biodiversity, as the following examples illustrate:[243]

- In the Pacific Northwest, relatively high biodiversity in riparian forests is attributed to cool moist conditions, high productivity, and complex structural conditions present in older streamside forests. Notably, old-growth Douglas-fir stands generally contain abundant populations of epiphytic lichens and bryophytes that increase the canopy water storage in forests.[244] Further, logging has lasting impacts on evapotranspiration, water interception,

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[239] Bingham, M.A. and S.W. Simard. "Do mycorrhizal network benefits to survival and growth of interior Douglas-fir seedlings increase with soil moisture stress?" *Ecology and Evolution* (2011) 1(3): 306–316. https://doi.org/10.1002/ece3.24.

[240] Simard, S.W. et al. "Meta-networks of fungi, fauna and flora as agents of complex adaptive systems." In: "Managing Forests as Complex Adaptive Systems: Building Resilience to the Challenge of Global Change." *Routledge* (2013) 133–164. Edited by K. Puettman, C. Messier, K. Coates. https://www.researchgate.net/publication/282661300_Meta-networks_of_fungi_fauna_and_flora_as_agents_of_complex_adaptive_systems.

[241] Aron, P.G. et al. "Stable water isotopes reveal effects of intermediate disturbance and canopy structure on forest water cycling." *Journal of Geophysical Research* (2019) 124(10): 2958-2975. https://doi.org/10.1029/2019JG005118; Perry, T.D. and J.A. Jones. "Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA." *Ecohydrology* (2017) 10(2): e1790. https://doi.org/10.1002/eco.1790.

[242] Ellison, D. et al. "Trees, forests and water: cool insights for a hot world." *Global Environmental Change* (2017) 43: 51-61. https://doi.org/10.1016/j.gloenvcha.2017.01.002.

[243] Ham, R.D. "Fog drip in the Bull Run Municipal Watershed, Oregon." *Journal of the American Water Resources Association* (1982) 18(5): 785-789. https://doi.org/10.1111/j.1752-1688.1982.tb00073.x.

[244] Pypker, T.G. et al. "The role of epiphytes in rainfall interception by forests in the Pacific Northwest. I. Laboratory measurements of water storage." *Canadian Journal of Forest Research* (2006) 36(4). https://doi.org/10.1139/x05-298; Crampe, E.A. et al. "Fifty years of runoff response to conversion of old-growth forest to planted forest in the H. J. Andrews Forest, Oregon, USA." *Hydrological Processes* (2021) 35(5): e1s4168. https://doi.org/10.1002/hyp.14168.

snowmelt, flow routing, and streamflow that were still evident more than 50 years after clearcutting old-growth forests.[245] Large logs in old-growth forests also intercept 2–5% of the canopy through-fall to the forest floor and that, too, may affect the hydrological cycle when forests are logged in this region.[246] Additionally, dense riparian vegetation helps regulate the amount of sediment that reaches streams, depending on geomorphology.

- In eastern Oregon and Washington, the largest risk of accelerated erosion occurred from fuels reduction projects that included road construction, fuel breaks, postfire logging, and thinning.[247]

- In the coast redwood zone, standard rain gauges installed in open areas where fog is common collected up to 30 percent less precipitation than in old-growth forests.[248] Researchers noted that long-term logging in the watershed could reduce annual water yield and, more importantly, summer stream flow by reducing fog drip.

- In the southeastern United States, logging resulted in "increased stream sediment and nutrients, more variable flow, altered [fish and wildlife] habitat and stream and riparian communities, and increased risk of human health effects" from floods.[249] Importantly, the threshold for disturbance of the hydrological cycle can be quite low in this region, and impacts from altered hydrological cycles may extend to other humid regions.[250]

- In the southern Appalachian Highlands, forest cover helps stabilize the landscape and prevent landslides "by intercepting precipitation, increasing evapotranspiration, and reinforcing roots."[251] Logging, on the other hand, increases the frequency of landslides for a given storm event. Climate change that results in increased occurrences of high-intensity rainfall through more frequent storms, or higher-intensity storms, would also be expected to exacerbate this effect.

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[245] Crampe, E.A. et al. "Fifty years of runoff response to conversion of old-growth forest to planted forest in the H. J. Andrews Forest, Oregon, USA." *Hydrological Processes* (2021) 35(5): e1s4168. https://doi.org/10.1002/hyp.14168.

[246] Harmon, M.E. and J. Sexton. "Water balance of conifer logs in early stages of decomposition." *Plant and Soil* (1995) 172: 141-152. https://doi.org/10.1007/BF00020868.

[247] Wondzell, S.M. "The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of Eastern Oregon and Washington." *Northwest Science* (2001) 75: 128-140. https://hdl.handle.net/2376/989.

[248] Ham, R.D. "Fog drip in the Bull Run Municipal Watershed, Oregon." *Journal of the American Water Resources Association* (1982) 18(5): 785-789. https://doi.org/10.1111/j.1752-1688.1982.tb00073.x.

[249] Nagy, R.C. et al. "Water resources and land use and cover in a humid region: the Southeastern United States." *Journal of Environmental Quality.* (2011) 40(3): 867-878. https://doi.org/10.2134/jeq2010.0365.

[250] *Ibid.*

[251] Wooten, R.M. et al. "Frequency and magnitude of selected historical landslide events in the Southern Appalachian Highlands of North Carolina and Virginia: Relationships to rainfall, geological and ecohydrological controls, and effects." In: "Natural disturbances and historic range of variation." *Springer* (2016) 203-262. Edited by Greenberg, C. and Collins, B. https://doi.org/10.1007/978-3-319-21527-3_9.

- Intact forested watersheds present in inventoried roadless areas, which have a greater composition of mature trees and where logging is generally prohibited, tend to be at the headwaters of streams with the cleanest drinking water source areas.[252]

MOG forests and trees also provide many social and cultural benefits. MOG on federal lands that are part of the Tribal federal land trusts as well as ceded Tribal ancestral lands provide historical and continued cultural significance. MOG on public lands also has general recreational value for all people who live in the United States. Access to nature provides opportunities for physical activity for many people. Mature and old growth forests provide mental health benefits and spiritual enrichment for people who experience these majestic forests. Preservation of MOG also critically responds to Executive Order 14008[253] for its potential contribution to environmental justice. Preserving forest lands proximate to minority-majority communities is important to not only provide outdoor access to marginalized communities, but also the myriad co-benefits of clean air, clean water, and climate stability that accompany MOG forests.

MOG forests and trees contribute to multiple other important ecological, social, cultural, and non-commodity economic values and goals. These contributions begin in earnest in the mature stage, as stands and trees start accounting for the bulk of above-ground carbon acquisition and storage and developing meaningful co-benefit characteristics that are currently underrepresented in U.S. forests.[254] As discussed in detail in the previous section, MOG provide key ecological structural characteristics in the live and dead wood pool and provide a critical baseline for forest biodiversity.[255]

b. Managing for Future Resilience.

The ANPR specifically seeks public input on options for increasing the future resilience of old and mature forest characteristics—noting concerns about past and current management choices (including "ecologically inappropriate vegetation management and fire suppression") and concerns about ecosystem degradation and mortality (including mortality attributed to climate-

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[252] DellaSala, D.A. et al. "Roadless areas and clean water." *Journal of Soil and Water Conservation* (2011) 66(3): 78A-84A. https://doi.org/10.2489/jswc.66.3.78A.

[253] Biden, J. "Executive Order 14008 of January 27, 2021: Tackling the Climate Crisis at Home and Abroad." 86 *Fed. Reg.* 7619(January 27, 2021). https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

[254] Ducey, M.J. "Late-successional and old-growth forests in the Northeastern United States: Structure, dynamics, and prospects for restoration." *Forests* (2013) 4(4): 1055-1086. https://doi.org/10.3390/f4041055; Betts, M.G. et al. "Forest degradation drives widespread avian habitat and population declines." *Nature Ecology & Evolution* (2022) 6: 709–719. https://doi.org/10.1038/s41559-022-01737-8.

[255] Lutz, J.A. et al. "The importance of large-diameter trees to the creation of snag and deadwood biomass." *Ecological Processes* (2021) 10: 28. https://doi.org/10.1186/s13717-021-00299-0; Kelsey, R.G. et al. "Changes in heartwood chemistry of dead Yellow-Cedar trees that remain standing for 80 years or more in Southeast Alaska." *Journal of Chemical Ecology* (2005) 31: 2653–2670. https://doi.org/10.1007/s10886-005-7618-6; Stephenson, N.L. et al. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* (2014) 507: 90–93. https://doi.org/10.1038/nature12914.

amplified stressors like wildfire, insects, and disease).[256] We strongly agree with the importance of managing for mature and older trees and stands in ways that account for and respond to climate change and associated phenomena. It is, however, quite important that the Forest Service stay factually accurate about how speculative a concept future resilience is, and one characterized by great uncertainty. As the agency formulates new directives to meet the challenges of managing in a time of increasing warming and shifting precipitation, a number of considerations counsel against over-reliance on theories about achieving future resilience at the expense of important, functionally irreplaceable, current forest values.

We note at the outset that striking examples of forest dieback do exist and are projected to continue or increase with climate change.[257] Some of this is attributable to wildfire, particularly in the forests of western North America where "the higher temperatures of human-caused climate change doubled burned area from 1984 to 2015, compared with what would have burned without climate change."[258] Nonetheless, forest mortality from wildfire remains highly variable.[259] Similarly, insects have widely varying effects on age class structure across species.[260] Thus increases in the areal extent of forest disturbance do not necessarily translate to complete or even substantial loss of mature and old forest characteristics.

Even where forests experience significant tree mortality from fire or other disturbance events, as elaborated on above, valuable carbon stocks remain.[261] The same is true for wildlife habitat. Many species evolved with fire and continue to use forest stands burned at all severities

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[256] U.S. Forest Service. "Advance Notice of Proposed Rulemaking and Request for Comments." 88 *Fed. Reg*. 24,497, 24503 *et seq.* (April 21, 2023).

[257] Van Mantgem, P.J. et al. "Widespread increase of tree mortality rates in the western United States." *Science* (2009) 323: 521-524. https://doi.org/10.1126/science.1165000.

[258] Parmesan, C. et al. "Terrestrial and freshwater ecosystems and their services." In: "Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change." *Cambridge University Press* (2022) 197-377. Edited by H. Pörtner et al. https://doi.org/10.1017/9781009325844.004.

[259] Beatty, R.M. and A.H. Taylor. "Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, California, USA." *Journal of Biogeography* (2001) 28(8): 955-966. https://doi.org/10.1046/j.1365-2699.2001.00591.x.

[260] Stephenson, N.L. et al. "Which trees die during drought? The key role of insect host-tree selection." *Journal of Ecology* (2019) 107(5): 2383–2401. https://doi.org/10.1111/1365-2745.13176.

[261] Meigs, G.W. et al. "Forest fire impacts on carbon uptake, storage, and emission: The role of burn severity in the Eastern Cascades, Oregon." *Ecosystems* (2009) 12: 1246–1267. https://doi.org/10.1007/s10021-009-9285-x; Eskelson, B.N.I. et al. "A 6 year longitudinal study of post-fire woody carbon dynamics in California's forests." *Canadian Journal of Forest Research* (2016) 46(5): 610–620. dx.doi.org/10.1139/cjfr-2015-0375; Harmon, M.E. et al. "Combustion of aboveground wood from live trees in megafires, CA, USA." *Forests* (2022) 13(3): 391. https://doi.org/10.3390/f13030391https://doi.org/10.3390/f13030391.

following large fires, including spotted owls,[262] black-backed woodpeckers,[263] deer mice,[264] and others.[265] Mixed-severity fires contribute to the natural mosaic of habitat types needed by imperiled species like spotted owls.[266] Spotted owls return to nest sites even where the majority of their territory has burned.[267] Low-severity fire appears to affirmatively benefit spotted owl occupancy and colonization, with suitable habitat used more frequently than random sites even after it has experienced moderate or high-severity fire.[268]

The very substantial uncertainty entailed in managing for future resilience stems in part from the wide range of future conditions possible under various warming scenarios. Projected changes in distribution of trees and shrubs in North America are widely disparate among different models.[269] Relatedly, while evapotranspiration is expected to increase—and water yields to decrease—on many national forests under some climate scenarios, the reverse is true under others.[270] Thus, what future conditions agencies might be managing for is largely a speculative matter.

Great uncertainty also exists about the overall effects of active management intended to promote resilience in the future.[271] Despite substantial research activity, fundamental questions about the

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[262] Lee, D.E. "Spotted owls and forest fire: A systematic review and meta-analysis of the evidence." *Ecosphere* (2018) 9(7): e02354. https://doi.org/10.1002/ecs2.2354; Lee, D.E. "Spotted owls and forest fire: Reply." *Ecosphere* (2020) 11(12): e03310. https://doi.org/10.1002/ecs2.3310; Bond, M.L. et al. "Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success." *Wildlife Society Bulletin* (2002) 30(4): 1022–1028. https://www.jstor.org/stable/3784267.

[263] Stillman, A.N. et al. "Incorporating pyrodiversity into wildlife habitat assessments for rapid post-fire management: A woodpecker case study." *Ecological Applications* (2023) 33(4): e2853. https://doi.org/10.1002/eap.2853.

[264] Zwolak, R. and K.R. Foresman. "Deer mouse demography in burned and unburned forest: No evidence for source-sink dynamics." *Canadian Journal of Zoology* (2008) 86(2): 83-91. https://doi.org/10.1139/Z07-126.

[265] Moritz, M.A. et al. "The role of fire in terrestrial vertebrate richness patterns." *Ecology Letters* (2023) 26(4): 563–574. https://doi.org/10.1111/ele.14177.

[266] Lee, D.E. "Spotted owls and forest fire: A systematic review and meta-analysis of the evidence." *Ecosphere* (2018) 9(7): e02354. https://doi.org/10.1002/ecs2.2354; Lee, D.E. "Spotted owls and forest fire: Reply." *Ecosphere* (2020) 11(12): e03310. https://doi.org/10.1002/ecs2.3310.

[267] Bond, M.L. et al. "Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success." *Wildlife Society Bulletin* (2002) 30(4): 1022–1028. https://www.jstor.org/stable/3784267.

[268] Clark, D.A. "Demography and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon." M.S. Thesis, Oregon State University (2007). https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/5m60qt980.

[269] Shafer, S.L. et al. "Potential changes in the distributions of western North America tree and shrub taxa under future climate scenarios." *Ecosystems* (2001) 4: 200–215. https://doi.org/10.1007/s10021-001-0004-5.

[270] Heidari, H. et al. "Impacts of climate change on hydroclimatic conditions of U.S. national forests and grasslands." *Forests* (2012) 12(2): 139. https://doi.org/10.3390/f12020139.

[271] Agra, H. et al. "Forest conservation." In: "What works in conservation" *Open Book Publishers* (2020) 323-366. Edited by W.J. Sutherland et al. https://www.openbookpublishers.com/books/10.11647/obp.0191.

efficacy of fuels treatments remain to be answered.[272] Thinning impacts on subsequent fire, empirically measured, can be substantially varied.[273] And, as discussed, benefits only accrue at all if treated stands encounter fire within a relatively limited treatment lifespan.[274]

Similarly, logging to increase resistance to insect-related mortality shows mixed results. For example, studies in Arizona forests produced contradictory results about the effects of thinning on soil water content in some cases (which can increase resin flow and stand health); one study found thinning increased soil water content, but a similar study found resin flow was greater in unmanaged stands.[275] A study in lodgepole pine showed there was greater probability of bark beetle attack in thinned plots and the size of thinned spaces between stands did not mitigate epidemics, while a different study showed thinning from below prevented bark beetle outbreaks.[276] Studies in ponderosa pine revealed logging had varying and inconsistent efficacy in mitigating insect risks to tree survival.[277] In a Mississippi study, which did show southern pine beetle outbreaks in control stands but not in those treated with thinning and prescribed fire, the infestations occurred mostly in stands younger than 45 years rather than in older stands, undermining the rationale for removing mature and old growth trees.[278]

Once an epidemic has begun, logging will not significantly alter the trajectory of the outbreak.[279] More broadly, "most evidence supporting thinning as a control for bark beetles is based on tree vigor, not on directly measured insect activity in the stand."[280] Further complicating the case for

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[272] Omi, P. "Theory and practice of wildland fuels management." *Current Forestry Reports* (2015) 1: 100-117. https://doi.org/10.1007/s40725-015-0013-9.

[273] Taylor, C. et al. "What are the associations between thinning and fire severity?" *Austral Ecology* (2021) 46(8):1425-1439. https://doi.org/10.1111/aec.13096; Raymond, C. and D.L. Peterson. "How did prefire treatments affect the Biscuit Fire?" *Fire Management Today* (2005) 65(2): 18-22. https://www.fs.usda.gov/research/treesearch/24900.

[274] Campbell, J.L. et al. "Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions?" *Frontiers in Ecology and the Environment* (2011) 10(2):83-90. https://doi.org/10.1890/110057.

[275] Fettig, C. J. et al. "The effectiveness of vegetation management practices for prevention and control of bark beetle infestations in coniferous forests of the Western and Southern United States." *Forest Ecology and Management* (2007) 238(1): 24–53. https://doi.org/10.1016/j.foreco.2006.10.011.

[276] *Ibid.*

[277] *Ibid.*

[278] Nowak, J. T. et al. "Southern Pine Beetle infestations in relation to forest stand conditions, previous thinning, and prescribed burning: Evaluation of the Southern Pine Beetle Prevention Program." *Journal of Forestry* (2015) 113(5): 454–462. https://doi.org/10.5849/jof.15-002.

[279] Black, S.H. et al. "Do bark beetle outbreaks increase wildfire risks in the central U.S. Rocky Mountains? Implications from recent research." *Natural Areas Journal* (2013) 33(1): 59–65. https://doi.org/10.3375/043.033.0107; Six, D.L. et al. "Management for mountain pine beetle outbreak suppression: Does relevant science support current policy?" *Forests* (2014) 5: 103–133. https://doi.org/10.3390/f5010103; Black, S.H. et al. "Insects and roadless forests: A scientific review of causes, consequences and management alternatives." *National Center for Conservation Science and Policy* (2010). https://xerces.org/sites/default/files/2018-05/10-004_02_XercesSoc_Insects%2BRoadless-Forests_web.pdf.

[280] Black, S. H. et al. "Insects and roadless forests: A scientific review of causes, consequences and management alternatives." *National Center for Conservation Science and Policy* (2010).

thinning, where insect outbreaks occur, they may decrease the risk of subsequent fire or infestations (though sometimes with loss of old forest structures).[281] Logging can also have numerous negative impacts on the resilience of forests and trees to insects (and other disturbances). For example, thinning can damage surviving trees and pack soil, negatively affecting tree growth and causing stress to stands, which in turn can increase chances of insect infestation.[282] Thinning can also increase the likelihood of other disturbances like windthrow, wood-boring insect infestation, and root pathogen infestation, all of which increase the risk of bark beetle infestation.[283] Notably, insect outbreaks, like fires, are inherent components of forest ecology and physically altering stand structure in an effort to greatly affect them should be expected to produce mixed results at best.[284]

Variable density thinning, in particular, remains an experimental approach to restoring resilience. Evidence exists for past age group clustering in some landscapes, prior to widespread anthropogenic alterations.[285] However, the historic record is mixed, with other studies showing relatively uniform distribution of many more large trees across forest landscapes than seen today.[286] Additionally, little empirical evidence exists about the long-term effects of attempts to refashion forest landscapes into clumps interspersed with substantial areas of little or no tree cover, whether they once predominated on a given landscape or not.

More generally, there is little evaluation in the scientific literature of the success of active management intended to increase climate adaptation and resilience, and benefit predictions rely heavily on modeling.[287] Among other problems, these models often over-estimate carbon loss

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https://xerces.org/sites/default/files/2018-05/10-004_02_XercesSoc_Insects%2BRoadless-Forests_web.pdf.

[281] *Ibid;* DellaSala, D. A. et al. "A critical role for core reserves in managing inland Northwest landscapes for natural resources and biodiversity." *Wildlife Society Bulletin 1973-2006* (1996), 24(2): 209–221. https://www.jstor.org/stable/3783109.

[282] Black, S.H. et al. "Do bark beetle outbreaks increase wildfire risks in the central U.S. Rocky Mountains? Implications from recent research." *Natural Areas Journal* (2013) 33(1): 59–65. https://doi.org/10.3375/043.033.0107.

[283] Fettig, C.J. et al. "The effectiveness of vegetation management practices for prevention and control of bark beetle infestations in coniferous forests of the western and southern United States." *Forest Ecology and Management* (2007) 238(1-3): 24–53. https://doi.org/10.1016/j.foreco.2006.10.011.

[284] Black, S.H. et al. "Do bark beetle outbreaks increase wildfire risks in the central U.S. Rocky Mountains? Implications from recent research." *Natural Areas Journal* (2013) 33(1): 59–65. https://doi.org/10.3375/043.033.0107.

[285] Knapp, E. et al. "The variable-density thinning study at Stanislaus-Tuolumne Experimental Forest." In: "Managing Sierra Nevada forests." Edited by M. North. *USDA Forest Service* Gen. Tech. Report PSW-GTR-237. Pacific Southwest Research Station, Albany, CA (2012). https://doi.org/10.2737/PSW-GTR-237.

[286] Hagman, R.K. et al. "Historical conditions in mixed-conifer forests on the eastern slopes of the northern Oregon Cascade Range, USA." *Forest Ecology and Management* (2014) 330: 158-170. https://doi.org/10.1016/j.foreco.2014.06.044.

[287] Prober, S.M. et al. "Shifting the conservation paradigm: a synthesis of options for renovating nature under climate change." *Ecological Monographs* (2019) 89(1): e01333. https://doi.org/10.1002/ecm.1333; Parmesan, C. et al. "Terrestrial and freshwater ecosystems and their services." In: "Climate change 2022:

from insects and fire.[288] What is clear is that where the goal is to promote carbon storage and biodiversity, active management holds the potential for negative outcomes.[289]

Of cardinal importance here, the disturbance resilience of unmanaged stands is typically greater than it is for managed ones.[290] And the best available evidence is that when fire-prone stands are thinned, maintaining larger trees enhances resistance to fire. While wildfire survival reflects multiple fire and autoecological factors, it generally correlates positively to tree diameter.[291] As discussed above, the thicker bark of larger trees resists cambial scorch[292] and their higher crowns also contribute to increased survival.[293]

This does not argue against all management efforts to increase resilience in the face of climate change. It does strongly argue for conservative, carefully considered use of active management techniques when applied to mature or old-growth trees in dry forests (there is no ecological

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Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change." *Cambridge University Press* (2022) 197-377. Edited by H. Pörtner et al. https://doi.org/10.1017/9781009325844.004; Agra, H. et al. "Forest conservation." In: "What works in conservation" *Open Book Publishers* (2020) 323-366. Edited by W.J. Sutherland et al. https://www.openbookpublishers.com/books/10.11647/obp.0191.

[288] Moore, D.J.P. et al. "Persistent reduced ecosystem respiration after insect disturbance in high elevation forests." *Ecology Letters* (2013) 16(6): 731-737. https://doi.org/10.1111/ele.12097; Raymer, P.C.L. et al. "Hemlock loss due to the hemlock woolly adelgid does not affect ecosystem C storage but alters its distribution." *Ecosphere* (2013) 4(5): 1-16. https://doi.org/10.1890/ES12-00362.1; Stenzel, J.E. et al. "Fixing a snag in carbon emissions estimates from wildfires." *Global Change Biology* (2019) 25(11): 3985-3994. https://doi.org/10.1111/gcb.14716.

[289] Donato, D.C. et al. "Evaluating post-outbreak management effects on future fuel profiles and stand structure in bark beetle-impacted forests of Greater Yellowstone." *Forest Ecology and Management* (2013) 303: 160–174. https://doi.org/10.1016/j.foreco.2013.04.022; Patton, R.M. et al. "Management trade-offs between forest carbon stocks, sequestration rates and structural complexity in the central Adirondacks." *Forest Ecology and Management* (2022) 525: 120539. https://doi.org/10.1016/j.foreco.2022.120539; Young, B.D. et al. "Seven decades of change in forest structure and composition in *Pinus resinosa* forests in northern Minnesota, USA: Comparing managed and unmanaged conditions." *Forest Ecology and Management* (2017) 395: 92–103. https://doi.org/10.1016/j.foreco.2017.04.003.

[290] Miller, K.M. et al. "National parks in the eastern United States harbor important older forest structure compared with matrix forests." *Ecosphere* (2016) 7: e01404. https://doi.org/10.1002/ecs2.1404; Miller, K.M. et al. "Eastern national parks protect greater tree species diversity than unprotected matrix forests." *Forest Ecology and Management* (2018) 414: 74–84. https://doi.org/10.1016/j.foreco.2018.02.018; Forzieri, G. et al. "Emerging signals of declining forest resilience under climate change." *Nature* (2022) 608: 534–539. https://doi.org/10.1038/s41586-022-04959-9.

[291] Johnston, J.D. et al. "Tree traits influence response to fire severity in the western Oregon Cascades, USA." *Forest Ecology and Management* (2019) 433: 690-698. https://doi.org/10.1016/j.foreco.2018.11.047; McCarthy, E.F. and I.H. Sims. "The Relation Between Tree Size and Mortality Caused by Fire in Southern Appalachian Hardwoods." *Journal of Forestry* (1935) 33(2): 155-157. https://doi.org/10.1093/jof/33.2.155.

[292] Hood, S.M. et al. "Evaluation of a post-fire tree mortality model for western USA conifers." *International Journal of Wildland Fire* (2007) 16(6): 679-689. https://doi.org/10.1071/WF06122.

[293] Kobziar, L. et al. "Tree mortality patterns following prescribed fires in a mixed conifer forest." *Canadian Journal of Forest Research* (2006) 36(12): 3222-3238. https://doi.org/10.1139/x06-183.

justification for active management of older trees and stands in wetter forest types). That reflects in part the potential for active management to produce negative outcomes and the need to preserve treatment options until we have better empirical evidence—rather than committing broad swathes of federal forest to particular management theories of unknown long-range effect. More centrally, that is the approach dictated by the urgent imperative, recognized by President Biden and Secretary Vilsack, of minimizing climate change. Over time, America—and the world—will win on climate through technological and economic changes. Until those can be developed and fully implemented at scale, however, it is vitally important to minimize near-term increases in greenhouse gasses that will increase radiative forcing for many decades. Otherwise, the world is likely to pass climate tipping points that cause widespread, novel damage and cannot be re-crossed back into safer temperatures for generations. And in the forest context, that means leaving in place the existing major drivers of carbon sequestration and durable carbon storage found in mature and older trees and stands.

d. A Policy for Enhancing MOG.

The agency should adopt a binding rule that secures major drivers of carbon sequestration and durable carbon storage across the forests it manages. The rule needs to meaningfully end logging and removal of mature trees above a set age, and of all trees in mature stands where fire is infrequent. It would give personnel in the field simple, readily administered guardrails on logging decisions and establish uniform national minimum standards for carbon conservation. In sub-mature stands and frequent-fire forests, it would leave intact managers' discretion to log smaller trees (e.g., for fire risk), to supply mills with the same kind of small-diameter logs that come off industrial timberlands, and to preserve additional tree carbon based on local considerations. Research indicates that an age cutoff of 80 years would generally ensure that where logging is authorized, most carbon would remain in the forest.

4. Fostering Social and Economic Climate Resilience.

a. Supporting Adaptive Capacity for Underserved Communities.

Executive order 14008[294] directs federal agencies to develop climate resilience and adaptation plans with an emphasis on environmental justice (EJ) communities. In response to this, USDA developed an Action Plan for Climate Adaptation and Resilience in 2021.[295] One of the climate vulnerabilities USDA appropriately identifies is "disproportionate impacts on vulnerable communities," defined as "socially disadvantaged, low-income, minority, and rural populations as well as American Indians, Alaska Natives, and sovereign Tribal governments."[296] Specific risks the Action Plan identifies for Indigenous communities include the loss of Native foods and practices, forced community displacement, and new pathogenic diseases, among others. Specific risks USDA identifies for all vulnerable communities' health include those to food access and

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[294] Biden, J. "Executive Order 14008: Tackling the Climate Crisis at Home and Abroad." 86 *Federal Register* 7619 (Feb. 1, 2021). https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

[295] "Action Plan for Climate Adaptation and Resilience." *U.S. Department of Agriculture* (2021). https://www.sustainability.gov/pdfs/usda-2021-cap.pdf.

[296] *Ibid.*

ecosystem services like clean air, water, medicine, timber, and fuel as well as cultural value of ancestral lands, and spiritual values of nature and recreation.[297] The plan specifically notes the vulnerability of rural communities that provide much of the employment for agriculture and forestry, including migrant workers. Additionally, severe weather threatens vulnerable populations because of a lack of resources to handle the economic and environmental effects of catastrophic weather including severe wildfire, flooding, drought, and invasive species.

USDA proposes a number of potentially positive actions to address these threats, but much will turn on how they are implemented. These proposals include engaging with these communities to understand their needs. To be effective, this engagement will need substantial funding that supports the participation of socioeconomically disadvantaged communities in sustainable relationships with the agency. While "[s]everal USDA programs have special provisions or dedicated funding for historically underserved producers,"[298] this needs expansion to comply with the Biden Administration's Justice40 Initiative[299] and ensure environmental justice communities are appropriately prioritized. USDA also proposes building "resilience across landscapes with investments in soil and forest health."[300] It is critical that these strategies are informed by the best available science and Traditional Ecological Knowledge. USDA notes an emphasis on co-benefits from land management including "enhanced soil carbon sequestration and reduced emissions,"[301] but must ensure these calculations accurately account for the adverse carbon effects of logging and removing mature and old growth trees.

USDA places a significant emphasis on wildfire as a risk to both crops and forestlands due to the effect severe fire can have on soil and plants. USDA also notes the expansion of the wildland-urban interface (WUI), which increases the risk of wildfires to communities—including underserved ones—because of increasing overlap between forest and grasslands and urban development.[302] This change in the WUI and the imperative of protecting human life creates challenges for many government bodies, including USDA. Priority measures to minimize wildfire risk to people need to focus, as discussed above, on fire-hardening structures using non-combustible materials (a critical approach not mentioned in any detail in the USDA report), minimizing fuel loads—particularly from more flammable small trees and shrubs—directly around the home or building, and having appropriate wildfire fighting response and evacuation procedures in place.[303]

Key in implementing effective wildfire mitigation strategies that also align with climate and EJ goals involves actively engaging EJ communities in partnership. USDA notes the relevance of

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[297] *Ibid.*
[298] *Ibid.*
[299] "Justice40." *The White House*. https://www.whitehouse.gov/environmentaljustice/justice40/ (last accessed July 9, 2023).
[300] "Action Plan for Climate Adaptation and Resilience." *U.S. Department of Agriculture* (2021). https://www.sustainability.gov/pdfs/usda-2021-cap.pdf.
[301] *Ibid.*
[302] *Ibid.*
[303] "Protect your property from wildfires." *Federal Emergency Management Agency.* https://www.fema.gov/sites/default/files/2020-11/fema_protect-your-property_wildfire.pdf (last accessed July 9, 2023).

their "Climate Hubs" for education of communities.[304] The success of the agency's outreach will hinge in substantial measure on its own ability to learn from EJ communities about their relationships to the land and local ecosystems, and how land management practices affect public health and well-being.

Finally, USDA's future success in building relationships with EJ and other underserved communities will depend in part on adoption of the timelines for ongoing and future objectives that have concrete dates and funding deliverables. To fully realize the EJ commitments from the federal government to EJ communities, funding needs to be provided for existing and future collaborations, and timelines for the implementation of EJ programs need to be outlined explicitly. While the Action Plan makes a start, much more needs to be done to create the accountability to communities required for genuine partnerships and long-term success.

b. Better Supporting Diversified Forest Economies.

We support USDA's strong interest in economic diversification and resilience for forest communities. Prioritizing retention of mature and old growth trees and stands contributes to this goal in several important ways. First, ending dependence—where it still exists—on large logs will bring local mills into step with the industry at large, which has long since moved on from processing old growth and now supplies American wood uses overwhelmingly from smaller diameter material; mills that modernize to supply that demand will likely have brighter futures. Second, the habitat and water conservation benefits associated with older forests support outdoor activities. Hunting, fishing, guiding, and other nature-related activities account for nearly one percent of U.S. gross domestic product.[305] And third, these treasured forest resources create amenity values that bring remote workers, retirees, and others with residence flexibility back into rural communities.

CONCLUSION

As the Forest Service increases its investment in recovering the ecological health of federal forests and returning lost resilience to them, it must be cognizant of just how urgent, existential, and globally critical the climate and biodiversity crises have become. In particular, as a Nation we cannot afford to miss opportunities for these forests to pull more carbon pollution out of the atmosphere and store it securely—especially in the next few decades. Fortunately, a key way of accomplishing that is entirely in the agency's hands, will serve its resilience goals well, and can provide enormous co-benefits for the natural world--and for social, economic, and cultural values too. To achieve that, the Forest Service needs to backstop and support its resilience work with a simple, nationally applicable rule that protects mature and old growth trees and forests from logging in this and future administrations. That will not only provide direct mitigation of climate and biodiversity threats, it will also serve as a much needed model for major forest-owning

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[304] "Action Plan for Climate Adaptation and Resilience." *U.S. Department of Agriculture* (2021). https://www.sustainability.gov/pdfs/usda-2021-cap.pdf.

[305] "2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation." *U.S. Fish & Wildlife Service* (revised 2018). https://www.census.gov/content/dam/Census/library/publications/2018/demo/fhw16-nat.pdf.

countries around the world. We look forward to working with you in the formulation, review, and adoption of such a regulation.

Sincerely,

350 Eugene
350PDX
Center for Biological Diversity
Chattooga Conservancy
Cottonwood Environmental Law Center
Earthjustice
Environment America
Environmental Law & Policy Center
Forest Keeper
Friends of Big Ivy
Friends of Douglas-fir National Monument
Gallatin Wildlife Association
Georgia ForestWatch
Great Old Broads for Wilderness, Cascade-Volcanoes Chapter
Great Old Broads for Wilderness, Willamette Valley Broadband
Interfaith EarthKeepers
Kentucky Heartwood
Klamath Forest Alliance
Natural Resources Defense Council
Natural Resources Law
New Mexico Wild
North Cascades Conservation Council
Ohio Environmental Council
Old-Growth Forest Network
Olympic Forest Coalition
Oregon Wild
Rocky Mountain Wild
Sierra Club
Standing Trees
South Umpqua Rural Community Partnership
The Larch Company
Western Alliance for Nature
WildEarth Guardians
Wilderness Workshop
Women's Earth and Climate Action Network (WECAN)
Yaak Valley Forest Council

Appendix: Raw data from FIA using EVALIDator

Table A1. Raw data extracted from FIA using EVALIDator for Figure 2 showing total carbon on forested lands vs. age class.

Age Class	Total Carbon (short tons)
0-20 years	706955162.2
21-40 years	570226529.3
41-60 years	681810226.8
61-80 years	1337651915
81-100 years	1857086697
100+ years	4825730048

Table A2. Raw data extracted from FIA using EVALIDator for Figure 2 showing total forested area vs. age class.

STAND_AGE_20_YR_CLASSES_(0_TO_100_PLUS)	Area (acres)
0-20 years	115068658.1
21-40 years	103045963.3
41-60 years	109321146.1
61-80 years	128802453.5
81-100 years	94293328.15
100+ years	124509025.1

Table A3. Raw data extracted from FIA using EVALIDator for Figure 3 showing total carbon on USFS lands sorted by USFS region and stand age.

FOREST_SERVICE_REGION	Stand Age	Total Carbon (mill. short tons)	SE
Region 1	0-20 years	155.6814613	5.464352
Region 1	21-40 years	57.68893912	3.852781
Region 1	41-60 years	68.78436434	4.831676
Region 1	61-80 years	157.9169193	7.985186
Region 1	81-100 years	268.5289834	10.71638
Region 1	100+ years	784.7464898	16.05439
Region 1	Not available	0.151160554	0.086692
Region 2	0-20 years	95.37328101	4.381199
Region 2	21-40 years	31.77095401	2.619918
Region 2	41-60 years	23.66748784	2.465476
Region 2	61-80 years	63.60801491	4.370588

Region 2	81-100 years	129.2641149	6.383705
Region 2	100+ years	500.6064347	11.11459
Region 3	0-20 years	48.86098103	2.970941
Region 3	21-40 years	6.50749241	1.030849
Region 3	41-60 years	11.27152533	1.42717
Region 3	61-80 years	45.32764493	3.284462
Region 3	81-100 years	101.1976627	4.939527
Region 3	100+ years	360.6062452	7.920045
Region 4	0-20 years	189.3168417	5.766447
Region 4	21-40 years	49.5375564	3.483657
Region 4	41-60 years	35.23620677	3.00551
Region 4	61-80 years	76.80285616	4.711902
Region 4	81-100 years	149.045997	6.967646
Region 4	100+ years	601.4503555	12.72094
Region 4	Not available	0.172219002	0.170762
Region 5	0-20 years	44.29119641	2.921256
Region 5	21-40 years	31.21925332	3.031265
Region 5	41-60 years	59.992542	5.239404
Region 5	61-80 years	117.2673363	7.99794
Region 5	81-100 years	211.0616126	11.07721
Region 5	100+ years	778.3539088	18.26712
Region 5	Not available	57.25237485	3.979379
Region 6	0-20 years	109.7421204	3.728631
Region 6	21-40 years	175.1338368	5.009591
Region 6	41-60 years	169.8135135	6.24985
Region 6	61-80 years	235.075562	7.791679
Region 6	81-100 years	342.6389013	10.09822
Region 6	100+ years	1544.293147	18.98326
Region 6	Not available	7.476639592	1.22781
Region 8	0-20 years	20.1686008	1.544243
Region 8	21-40 years	114.9404209	4.67746
Region 8	41-60 years	154.4514822	5.766919
Region 8	61-80 years	321.6297526	8.121404
Region 8	81-100 years	288.3636808	8.131184
Region 8	100+ years	84.16094094	4.74211

Region 9	0-20 years	43.38113867	3.047904
Region 9	21-40 years	103.5981602	4.659953
Region 9	41-60 years	159.0392971	6.121913
Region 9	61-80 years	320.2611873	8.037006
Region 9	81-100 years	366.6415605	8.476605
Region 9	100+ years	173.4340818	6.856736
Region 9	Not available	0.866354871	0.416277