PROTECTING LARGE TREES & MATURE-OLD GROWTH FORESTS (MOG) FROM LOGGING IS CLIMATE SMART FORESTRY: COMMENTS ON ADVANCED NOTICE FOR PROPOSED RULEMAKING (36 CFR PART 200) SUBMITTED BY DR. DOMINICK A. DELLASALA, CHIEF SCIENTIST, WILD HERITAGE, A PROJECT OF EARTH ISLAND INSTITUTE (JUNE 25, 2023)

Submitted to *www.regulations.gov*

Wild Heritage would like to thank the Forest Service and BLM for their mature and old-growth (MOG) inventory of April 2023, and for soliciting comments via this advanced noticed for proposed rulemaking (ANPRM) regarding conservation options for MOG in response to Presidential Executive Order 14072 and related climate and forest policies. Included in our comments are clickable links to all published sources rather than a literature cited section. Attached are supporting materials (Exhibits A-H) that provide the best available science underscoring our request to protect all large trees and MOG from logging: Exhibit A (forestprotectionattributes) is a literature review by MOG topic, Exhibit B (matureforestwater) connects MOG to water supplies, Exhibit C (largetreesarenotfireproblem) outlines the importance of all large trees, Exhibit D (largedeadtreesarenotfireproblem) dispels the notion that large dead trees are a fire problem, and Exhibits E-H are scientist support letters calling for full protections (no logging exemptions) for all MOG and large trees within MOG.

Pursuant to the ANPRM, we request that you immediately withdraw all timber sales within MOG, not the least of which are the nearly two dozen timber sales identified by the climate-forests coalition report on threatened forests. There is no ecological, climate, resilience, or climate smart reason for logging large trees or MOG as noted herein. All MOG and large trees within MOG should be designated as Research Natural Areas (RNAs), carbon reserves, or some other protective designation where logging is strictly prohibited. We emphasize that no logging exemptions be granted for fire, insects, or other natural disturbance concerns as discussed herein.

A MOG logging moratorium would begin good faith efforts toward national rulemaking that truly conserves all older forests and large trees while eliminating the potential for up to 50M acres of MOG logging that has no recognized protective status (DellaSala et al. 2022a).

We request that you identify all forms of commercial logging as the primary threat to the irreplaceable biodiversity and natural climate solution functions of MOG and large trees, including selective logging, thinning, biomass utilization, post-disturbance logging and tree planting, and "restoration logging" for perceived "resilience" and/or "climate smart forestry" purposes. Those approaches have no purpose in forest-climate policy.

We have direct experience with many of the federally threatened MOG areas identified in the climate-forest.org threatened forest report, especially the Black Ram "resilience" project on the Kootenai National Forest in Montana that is clearly inconsistent with EO 14072 (see attached Exhibit E scientist letter to Deputy Chief Robert Bonnie of Feb 17, 2021). This harmful project proposes commercial logging of >4,000 acres, including clearcutting >2,000 acres (>3 sq. miles) and ~700 acres of MOG logging. **We request that you cancel that sale immediately.**

A prohibition on logging MOG and large trees is requested throughout our comments that sets in motion the need for a preferred alternative that includes protective designations such as RNAs, carbon reserves, or similar designations.

We note that while the ANPRM references related agency directives, policies, and laws, we request that you also include the following relevant policies in rulemaking:

- **Glasgow Forest Pledge** – At the COP26, President Joe Biden was one of 145 world leaders to pledge a global end to deforestation and forest degradation by 2030. Ongoing MOG logging on federal lands sends the wrong message to the global community about halting global forest losses if we cannot do so in our own backyard (i.e., the appearance **of NIMBY (not-in-my-backyard) on MOG is counterproductive**). We request that you analyze all forms of logging for cumulative impacts to MOG especially to large trees, carbon stocks, soil integrity, imperiled species, water quality (also from roads), and the natural climate resilient properties of MOG as noted. Secretary's Vilsack's June 23, 2022 MEMO directing the Forest Service to "take bold action to restore forests, improve resilience, and curb climate change" does not even mention ongoing logging as the main threat to MOG. Forest Service Chief Randy Moore has repeatedly testified in Congress denying such logging in MOG exists despite extensive documentation (climate-forest.org report). **We request recognition of the top threat to MOG –logg**ing.

- **Paris Climate Agreement (Article 5.1)** – accordingly, "governments should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention which refers to all terrestrial and marine ecosystems with specific mention of forests." **We request that the ANPRM identify MOG sinks and reservoirs of carbon as a top reason for their conservation and include a preferred alternative to protect all MOG and large trees within MOG from commercial logging**. Best available science (Krankina et al. 2014, Law et al. 2021, 2022, Boute et al. 2022, DellaSala et al. 2022a) and the importance of late-successional reserves to carbon sinks as exemplified by the Northwest Forest Plan (Krankina et al. 2012) establish precedent for inclusion of MOG in RNA designations, forest carbon reserves (Law et al. 2021, 2022) or some other protective designation (DellaSala et al. 2022a). Importantly, MOG forests do not need active management aside from passive restoration (remove human stressors) whereas logged areas need both active and passive restoration. The net positive value of protecting MOG as sinks and reservoirs of carbon far exceeds any perceived benefit from restoration, especially if there is commercial logging involved that would degrade MOG benefits and ecosystem integrity.

- **Executive Order 14008** (tackling the climate crisis at home and abroad) directs federal agencies to protect 30% of all lands and waters by 2030. Noting, **Sec. 216** (a) The Secretary of the Interior, in consultation with the Secretary of Agriculture, the Secretary of Commerce, the Chair of the Council on Environmental Quality, and the heads of other relevant agencies, **shall submit a report** to the Task Force within 90 days of the date of this order recommending steps that the United States should take, working with State, local, Tribal, and territorial governments, agricultural and forest landowners, fishermen, and other key stakeholders, **to achieve the goal of conserving at least 30 percent of our lands and waters by 2030 (emphasis added).** To our knowledge, the Forest Service has contributed nothing toward the 30 x 30 targets. We request that you include a preferred alternative that demonstrates how the Forest Service will contribute to 30 x 30 targets and how much of federal MOG has no recognized protection (e.g., GAP 3) or has limited protections (e.g., Inventoried Roadless Areas - IRAs) that could be used to begin a process toward 30 x 30 on federal lands. DellaSala et al. (2022a), for example, identified ~50M acres of MOG not within GAP1 or GAP 2 coverages, meaning 76% of federal MOG can be subjected to commercial logging at some point.

- White House Roadmap on Nature-based Solutions –the White House recently announced that it would make nature-based solutions "a go-to option for fighting climate change and boost progress towards U.S. climate goals." DellaSala et al. (2022a, 2023) identified MOG as the nation's top terrestrial natural climate solution because MOG has the following climate-beneficial and biodiversity attributes also noted in Exhibits A-D:

  (1) Disproportionate amounts of carbon are tied up in the largest trees that continue to sequester carbon as they age (Stephenson et al. 2014, Krankina et al. 2014, Lutz et al. 2018, Moomaw et al. 2019, Mildrexler et al. 2020, 2023, DellaSala et al. 2022a, Birdsey et al. 2023).
  (2) Relatively fire resistant properties accrue in large trees over time compared to smaller/younger trees that lack those properties and burn more readily (Leismester et al. 2019, 2021).
  (3) If fire occurs, MOG often burns in lower severities and bounces back quickly compared to logged areas (Bradley et al. 2016, Leismester et al. 2019, 2021).
  (4) MOG provides cooler temperatures than surrounding logged areas, thereby acting as climate refugia (Frey et al. 2016, Betts et al. 2017, Lombaerde et al. 2021, Wolf et al. 2021, De Frenne et al. 2021, Kim et al. 2022).
  (5) There are high concentrations of IUCN Red-listed ecosystems and species within MOG (DellaSala et al. 2022a).
  (6) Along with IRAs (DellaSala et al. 2011), MOG provide the highest quality drinking water on the national forest system (Brooks et al. 2002, DellaSala et al. 2022a).
  (7) MOG is important to the health of the environment (as in a NEPA context) and human well-being (Gilhen-Baker et al. 2022).

One of our main concerns is that the ANPRM overstates natural disturbance impacts to MOG, while understating the magnitude of historic and ongoing logging and road building that created the national MOG deficit in the first place. This distinction needs to be clearly made using both historic and contemporary logging trends available from agency datasets and by aptly noting the difference between chronic anthropogenic disturbances that accumulate spatially and temporally vs. natural disturbance events that are a net positive for ecosystem processes because they trigger natural forest succession, carbon sequestration and storage is maintained, and other disturbance processes (e.g., biological legacy creation) are essential to ecosystem integrity. Continued logging (especially on nonfederal lands) disrupts the unique climate and biodiversity properties of MOG and disrupts the entire successional gradient (young to old forest). Importantly, federal lands are the only place for large-scale conservation considering that MOG levels are excessively low outside federal jurisdiction (DellaSala et al. 2022a). **This is the only opportunity to recover an entire ecosystem nationwide and we request that you recognize this in the ANPRM.**

We submit these historical maps originating from Forest Service Chief Greeley in the 1920s that clearly show the progression of logging as the root cause for the national deficit in the first place. These maps should be in the ANPRM as the only historical baseline available, although historical estimates can be derived from potential vegetation mapping and assumed disturbance dynamics (those are available in some regions – e.g., Pacific Northwest (NWFP) and eastern hardwoods (via Mary Bird Davies seminal work)).

4 ECONOMIC GEOGRAPHY

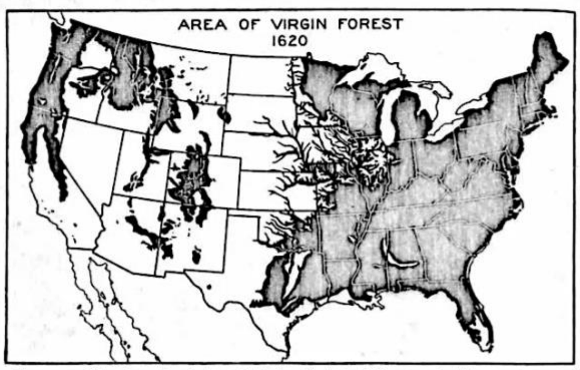

FIGURE 2.—When the early colonists settled along the Atlantic Coast nearly all the country east of the Mississippi River, and much land to the westward, notably in Arkansas, Louisiana, Texas, and the Pacific Northwest, was covered with a vast virgin forest,—about 820 million acres in all. (Map from U. S. Forest Service.)

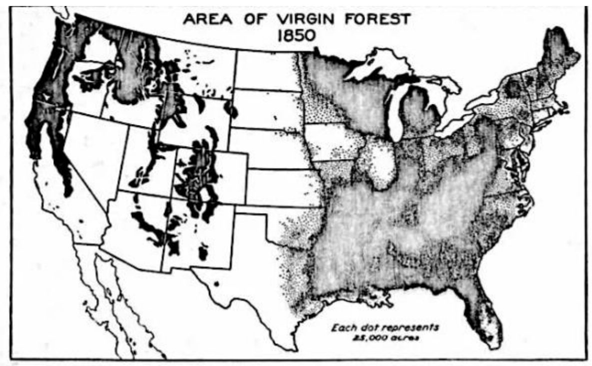

FIGURE 3.—Even in 1850 much of the forest in the eastern United States was still in a virgin condition, and the forests in the Rocky Mountain and Pacific states had scarcely been touched by man. The map was based on estimates by states and the dots are not all correctly located. Northwestern instead of south central Ohio should be densest, as the Black Swamp was almost a solid forest in 1850. Northern Indiana should likewise show a denser distribution of virgin forest, and in southern Indiana, where settlement first occurred, the dotting should be thinner. (Map from U. S. Forest Service.)

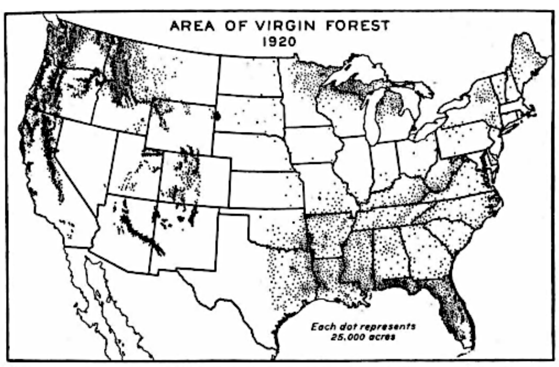

FIGURE 4.—By 1920 the area of virgin timber in the United States had been reduced to about 138 million acres, of which more than half was in the Rocky Mountain and Pacific Coast states. Culled and second growth trees of sufficient size for lumber covered about 114 million acres more, and there were about 136 million acres of forest having small young growth or trees of cord-wood size. In the United States in 1920 the amount of virgin timber has been estimated at 1,600 billion board feet, and the culled and second growth stands at 600 billion feet, a total of 2,200 billion feet, as compared with probably 5,200 billion feet originally. Over half of this remaining saw timber is in the Pacific Coast states. (Map from U. S. Forest Service.)

We also submit with our comments Exhibit F of August 28, 2022, and Exhibit G of June 15, 2023 signed by many prominent scientists with backgrounds in climate change, carbon sequestration and storage, biodiversity, aquatics, forest ecosystems, wildfire ecology, and natural resource economics. These scientists unequivocally called for **strict protection of all large trees and MOG regardless of species composition and disturbance regimes** because of the unique properties in older/larger trees related to carbon, fire resistance, resilience, genetic adaptations, and fish/wildlife habitat.

We request that you also acknowledge in the ANPRM the **irreplaceable values of large trees of all species and the national deficit regardless of species composition as mentioned in Exhibits F-H and throughout our comments**. Importantly, in the dry forests of eastern Oregon and Washington, large firs are now contributing to the recovery of historic large tree deficits and have accumulated substantial carbon stocks and fire-resistant properties overtime. Recent research shows that despite claims of large firs outcompeting large pines and that logging is needed to reduce competition, there is very little, large tree overlap between species at the FIA plot level (Mildrexler et al. 2023). Thus, all large trees (>20 in dbh) regardless of species need protection for climate and biodiversity benefits (Mildrexler et al. 2020, 2023, Exhibit H). This best available science specifically needs to be acknowledged in the ANPRM.

Setting the Baseline for Mature Forests & Large Trees

Forests at the reference age of 35-80 years accumulate carbon at accelerated rates (Birdsey et al. 2023). Protection and enhancement of carbon is specifically called out in the EO 14072. Setting an age threshold based on carbon accumulation rates is requested to maintain at least 40% of the carbon stores in a forest and this is based on best available science (Stephenson et al. 2014, Lutz et al. 2018, Mildrexler et al. 2020, 2023, Law et al. 2022, Birdsey et al. 2023). This is needed because the rate of carbon accumulation accelerates with increasing tree size and age – that is, as forests mature, carbon stocks in the large trees increase dramatically (citations noted). The Northwest Forest Plan is precedent setting for defining a reference condition for mature forests at ≥80 years as complex structural features and carbon are accumulating rapidly at this age of the dominant/codominant trees (Krankina et al. 2012). Additionally, at 80 years or so, for that region, growth rates of dominant/codominant trees begin to slow (i.e., also can be referred to as the culmination of mean annual increment; culmination of net primary productivity; age of biological maturity). **We request that when large trees are this age (80) in the PNW and have mature characteristics they are no longer available for commercial logging (also see below for dbh cross walk for other regions).**

As trees mature and grow tall, leaf area increases and that provides more absorption of sunlight (photosynthesis), resulting in greater carbon accumulation and moisture retention (e.g., more surface area to retain and release moisture back to the atmosphere and surroundings). At this age, soils also develop structurally with increasing organic matter from decomposition and nutrient cycling, and soil builds and retains substantial carbon (i.e., up to 50% of carbon in a forest can be in the soils alone). In this fashion, structure (large trees), function (wildlife habitat, climate regulation), and process (e.g., carbon storage and sequestration, hydrological cycle, nutrient cycling) can be thought of as a three-dimensional orthogonal axis of increasing forest complexity inherent in mature forests as they reach culmination (around 80 years). Gap phase dynamics maintains successional sequences at the tree/gap level and natural disturbances in MOG already with complexity result in complex early seral forests that are connected structurally through succession - please acknowledge this basic forest dynamic as essential - that is the entire successional gradient in MOG needs to be maintained even when it is severely disturbed by fires or insects because these stages are interconnected ((Swanson et al. 2010).

Since age is difficult to determine in the field without coring trees, age can be cross walked to dbh and carbon accumulation rates for a range of forest types assessed using FIA data (as in Birdsey et al. 2023: Table 4). Below is an example from Birdsey to define large trees based on carbon accumulation rates cross walking age to dbh. While 80 years works in some places (e.g., Arizona, PNW), in other areas trees culminate at younger ages leading to large trees defined as 9-16 dbh as they reach culmination of net primary production (CNPP). This is an acceptable/robust method for defining "large" and relating it to mature characteristics and carbon. It is exportable to all national forests and forest types and should be used to set the standard for what is a large tree. In other regions, such as the dry forests of the eastern Cascades, large has been defined as trees >20 in dbh based on carbon accumulation rates (Mildrexler et al. 2020, 2023). Again, "large" can be defined based on carbon accumulation and structure, which is consistent with the emphasis on carbon in EO 14072. We request that you adopt this approach in rulemaking for all national forests.

TABLE 4 Average age and tree diameter at culmination of net primary production (CNPP), all forest types combined on 11 National Forests in our study area.

National Forest	Average CNPP age (Years)	Diameter threshold (Inches/cm)
Gifford Pinchot	45	13/33
Malheur	45	12/30
Black Hills	75	14/36
Chequamegon-Nicolet	45	9/23
Green and White Mountains	35	12/30
Appalachian Forests	35	11/28
White River	55	6/15
Flathead	45	8/20
Arizona Forests	75	12/30
Central California Forests	50	16/41
Arkansas Forests	40	10/25
Average of all Forests	50	11/28

Tree diameters represent the lower age bound of mature forests (i.e., age at CNPP). Detailed ages and tree diameters by forest type are shown in supplementary Table 2.

We want to underscore the importance of protecting accumulated carbon stores in large trees (Table 4 above) as some scientists at the Forest Service science panel discussion (Aug 4, 2022) incorrectly conflated sequestration with accumulated stores. Specifically, keeping carbon out of the atmosphere by protecting accumulated stores in large trees is the most important natural climate solution in a climate emergency (Law et al. 2021, 2022) and, while all forests sequester carbon at different rates, the more important natural climate solution is holding on to carbon already present in large, older trees and soils that has been accumulating for decades to centuries. Such features take on added climate and biodiversity significance as forests mature.

Large trees in mature forests also develop relative fire resistance as they age. Certain pines, cedars, and firs, for instance, accumulate thick fire-resistant bark and drop their lower branches (self-prune) as they age, rendering them less prone to fire. However, if they do burn severely, the creation of snags and logs are critically important biological legacies that jump start forest succession (DellaSala 2019).

In sum, 35-80 years is the age of biological maturity of trees and a requested reference level for when mature features emerge by focusing on the large trees in rulemaking. Importantly, age can be cross-walked to dbh using CNPP approaches derived from FIA datasets (Birdsey et al. 2023). While site factors, climate, and biogeographical differences can affect the age at which older features emerge and hence large tree definitions, closing the deficit on old growth by protecting large trees as forests mature is urgently needed for climate mitigation/adaptation strategies (carbon sequestration, carbon storage, water). Doing so provides a natural climate buffer against extreme climatic conditions that are much more prevalent in heavily logged areas. This approach can be adapted to any forest type and any natural disturbance regime.

Top Issues to Evaluate in Scoping for the ANPRM

1. **Build the ANPRM from Section 2 of EO 14072 and related climate-forest policies.**

Importantly, the risks that MOG continue to face from logging (DellaSala et al. 2022a, climate-forests.org), along with how historic logging created the national deficit in the first place, need to be clearly analyzed in the ANPRM under cumulative effects (NEPA or FLPMA for BLM). To reiterate, timber harvest is the main reason large trees and MOG are so rare today across all ownerships and this is grossly understated in the ANPRM and related agency policies such as the Secretarial MEMO. We request that you stop blaming natural processes for ongoing risks to MOG and focus on the one thing you can control – logging practices. Nothing short of a strong rulemaking will suffice in this regard particularly in relation to EO 14008 that as far as we can tell the Forest Service has made absolutely no progress towards 30 x 30 related to that Presidential directive (as noted). We certainly support the reinstatement of the Tongass roadless rule but even that policy needs additional protections (e.g., mining restrictions) to qualify in 30 x 30 target setting (see DellaSala et al. 2022ab). Further, while a transition out of old growth logging is thankfully underway on the Tongass, which we **now request that all national forests adopt** (DellaSala et al. 2023), such administrative changes are not permanent. However, to build public acceptance and accelerate **transition of all the national forests out of MOG logging (which we request)**, the Forest Service should provide financial support to communities as, for example, the Southeast Alaska Sustainability Initiative assisting with Tongass transition.

Of great concern and contrary to the spirit and intent of EO 14072, the Forest Service is no longer abiding by the "eastside screens" that were protecting large trees on six national forests in eastern Oregon and Washington for over two decades. The agency has been backing questionable science that supports commercial logging of large trees up to 150-years-old, even though large older trees of all species remain in short supply relative to historic conditions. Independent scientists (see Exhibit H of December 14, 2020) have repeatedly advised against this ill-founded approach and requested restoring the eastside screens (DellaSala and Baker 2020, Mildrexler et al. 2020, 2023, Exhibit H). The agency is also promoting clearcut logging in mature eastern hardwood forests (e.g., Nantahala Pisgah National Forest) under the misguided premise that early seral is in short supply despite evidence showing clearcutting does not regenerate early seral complexity (Swanson et al. 2010, Kellett et al. 2022) and MOG is still substantially below historic levels especially on nonfederal lands where logging is rampant (i.e., a cumulative effects analysis under NEPA would show this). MOG logging policies for early seral run counter to the intent of EO 14072 and should be rejected by the agency.

2. **EO 14072 needs to calls further attention to the importance of MOG for its role in nature-based climate solutions by storing vast amounts of carbon and providing for biodiversity and clean water (ecosystem benefits).**

The ANPRM did not go far enough in stating the irreplaceable biodiversity and carbon values of MOG, and did not cite the best available science related to carbon accumulation rates that increase with tree size and age (Stephenson et al. 2014, Lutz et al. 2018, Mildrexler et al. 2020, 2023; Birdsey et al. 2023, Exhibits A-D), nor the outsized role of large trees and MOG as carbon reservoirs (Luyssaert et al. 2008, Keith et al. 2009, Lindenmayer et al. 2012, Mackey et al. 2013, 2015; Krankina et al. 2012, 2014; Law et al. 2018, Moomaw et al. 2019, Law et al. 2022, DellaSala et al. 2022a). The importance of large trees and MOG to long-term carbon stocks and the substantial emissions generated by logging them need to be analyzed in rulemaking that includes best available carbon life cycle assessments (Hudiburg et al. 2019, Harmon 2019). Such studies show that logging at regional and national levels produces far more (up to 10 times) emissions than natural disturbances combined (Harris et al. 2016, Merrill et al. 2018, Law et al. 2018, Bartowitz et al. 2022, Harmon et al. 2022), yet the agency is fixated on blaming natural disturbances that it cannot possibly control at scale rather than logging that is clearly within its control. Notably, logging in MOG is known to release over 80% of the stored carbon in the forest over time with only a tiny fraction stored in short-term (paper) to a few decades (structural beams) wood product pools, thereby creating a substantial carbon debt that is ill-advised in a global climate emergency (Law et al. 2018, Moomaw et al 2019, Hudiburg et al. 2019). Commercial logging is anything but climate smart forestry. We request that you include published carbon life cycle analysis in quantifying emissions at the appropriate scale and select an alternative that maximizes retention of carbon stocks in large trees and MOG.

We quote directly from the abstract in Bartowitz et al. 2022 on the importance of large trees and carbon stocks in MOG by avoiding emissions-producing thinning and other logging treatments to reduce fire and fire-related emissions, as simply stated, the carbon on large tree logging/thinning just does not pencil out:

"Climate change has intensified the scale of global wildfire impacts in recent decades. In order to reduce fire impacts, management policies are being proposed in the western United States to lower fire risk that focus on harvesting trees, including large-diameter trees. Many policies already do not include diameter limits and some recent policies have proposed diameter increases in fuel reduction strategies. While the primary goal is fire risk reduction, these policies have been interpreted as strategies that can be used to save trees from being killed by fire, thus preventing carbon emissions and feedbacks to climate warming. This interpretation has already resulted in cutting down trees that likely would have survived fire, resulting in forest carbon losses that are greater than if a wildfire had occurred. To help policymakers and managers avoid these unintended carbon consequences and to present carbon emission sources in the same context, we calculate western United States forest fire carbon emissions and compare them with harvest and fossil fuel emissions (FFE) over the same timeframe. We find that forest fire carbon emissions are on average only 6% of anthropogenic FFE over the past decade. While wildfire occurrence and area burned have increased over the last three decades, per area fire emissions for extreme fire events are relatively constant. In contrast, harvest of mature trees releases a higher density of carbon emissions (e.g., per unit area) relative to wildfire (150–800%) because harvest causes a higher rate of tree mortality than wildfire. Our results show that increasing harvest of mature trees to save them from fire increases emissions rather than preventing them. Shown in context, our results demonstrate that reducing FFEs will do more for climate mitigation potential (and subsequent reduction of fire) than increasing extractive harvest to prevent fire emissions. On public lands, management aimed at less-intensive fuels reduction (such as removal of "ladder" fuels, i.e., shrubs and small-diameter trees) will help to balance reducing catastrophic fire and leave live mature trees on the landscape to continue carbon uptake."

3. **Consider together EO 14008, 14072, White House roadmap to nature-based solutions, the Paris Climate Agreement (Article 5.1), AR6 climate report, and the Glasgow Forest Pledge in formulating ANPRM alternatives.**

We request that the ANPRM **develop a preferred alternative that includes strict protections from logging of all large trees and MOG citing to best available science** (Moomaw et al. 2019, Mildrexler et al. 2020, 2023, DellaSala et al. 2022ab, Law et al. 2022, DellaSala et al. 2023, Birdsey et al. 2023, Exhibits A-H) and national and international agreements as noted above. We refer you to the scientist letter in Exhibit G:

"As federal agencies develop older forest conservation policies, we note that the recent IPCC AR6 report states, in relation to natural climate solutions, "…protection of forest ecosystems is the highest priority for reducing GHG emissions (Moomaw et al. 2019) and restoration may not always be practical." Protecting irreplaceable natural systems from logging is therefore the first step. The IPPC report also noted that maintaining the resilience of biodiversity and ecosystem services at a global scale is "fundamental" to climate mitigation and adaptation, requiring "effective and equitable conservation of approximately 30 to 50% of Earth's land, freshwater and ocean areas, including current near-natural ecosystems"[1].

4. **Fully Disclose Relative Benefits and Limitations of Published MOG Inventories.**

We applaud the significant effort that went into the federal MOG report. However, we request more detailed methodology on the criteria used to determine MOG, the mapping, and a discussion of error rates among estimators. A side-by-side comparison with DellaSala et al. (2022ab) vs the federal MOG report, for example, would be instructive in disclosing error rates. As an example, by setting the canopy threshold at 10%, the agency report pulled in a lot more pinyon-juniper, skewing findings toward more open conditions (errors of commission).

[1]Law et al. 2022. Ibid.

DellaSala et al. (2022a) used a higher canopy threshold (≥20%) and got less MOG while missing some open areas (errors of omission). Also, Barnett et al. (2023) used a somewhat arbitrary cut off for old growth as the age when the density of total forest carbon stored in live and dead biomass **reaches 95%** of a maximum, while the mature forest stage was presumed between peak average carbon increment and age of onset of old growth. We believe their method, while contributing to MOG characteristics overall, missed productive sites in the Coast Range of N. California to Washington (although no maps were provided to cross check). It is not that we cannot collectively agree on MOG but that the criteria used in these studies come with errors in the estimators that need to be better understood to arrive at the true MOG amount (as in a statistically robust manner).

We support the inclusion of pinyon-juniper in your survey of MOG and stress the need for greatly stepped up conservation of that type given destructive logging of old junipers and cattle grazing are major threats across the Great Basin and into the southwest. Fire regimes are much different than other dry MOG and thinning absolutely is inappropriate. Thus, how will you conserve this important MOG type and reduce these stressors?

Key ANPR Questions & Issues Stated in the Federal Register Notice

1. Given that climate change and related stressors are resulting in increasing impacts with rapid and variable rates of change on national forests and grasslands, how should the Forest Service adapt current policies to protect, 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?

The biggest threat to natural grasslands, especially riparian areas, is livestock grazing acting in concert with climate change (Beschta et al. 2012). Those researchers called on federal agencies to establish large livestock free exclosure zones especially in riparian and wetland areas where livestock mostly congregate. We request that you include carbon life cycle analysis on livestock damages to riparian areas, springs/seeps, other wetlands, soils, and native plant communities that are anything but climate smart. Impacts to aquatic systems from livestock include damages to channel morphology and water quality that should be addressed in a climate smart manner given increasing drought and demand on aquatic resources. Moreover, life cycle analysis should document the loss of carbon from heavily grazed areas, especially soils (see Beschta et al. 2012).

With respect to MOG, by far the single most important management direction you can change is how you view natural vs anthropogenic disturbances. Ecosystems are uniquely adapted to natural disturbances. In cases where natural disturbances are increasing due to climate change, by far the most important response from a resilience standpoint is to limit anthropogenic stressors that degrade ecosystem integrity and impair species adaptations (Paine et al. 1998, DellaSala et al. 2022ac). The cumulative impacts of roads, livestock, ORVs, logging, invasive plants, soil compaction and damages from pile burns, and other active management disturbances before, during, and after fires and insect outbreaks are top threats to MOG and other ecosystems that often occur on the same site (DellaSala et al. 2022c). We request you acknowledge these stressors directly and cumulatively as best available science for the rulemaking.

And while the agency is deeply wedded to terms like "restoration," "fuels reduction," "restoration logging," "resilience," "active management," these all have substantial and cumulative co-lateral damages (DellaSala et al. 2022c). The letters from scientists (Exhibits E-H) and supporting best available published science (Moomaw et al. 2019, Mildrexler et al. 2020, 2022, Law et al. 2022, DellaSala et al. 2022abc, DellaSala et al. 2023) clearly demonstrate the importance of excluding large trees and MOG from logging because of their unique fire/climate resistance, resilience, biodiversity, clean water, and carbon stock properties. There is plenty to do that does not involve logging, including culvert improvements; closing and obliterating roads for connectivity and to reduce human-caused fire ignitions; stream improvements; beaver, imperiled species, and large carnivore recovery; and reducing the threat of fire spilling over from heavily logged private lands into urban areas by preparing towns directly (Downing et al. 2022). Importantly, the fire problem impacting communities is mostly coming from extreme fire weather triggered by GHGs (Westerling et al. 2006, 2016, Bartowitz et al. 2022, Dahl et al. 2023) acting in concert with heavily logged landscapes (Bradley et al. 2016, Zald and Dunn 2018, Downing et al. 2022). This association needs to be acknowledged in the ANPRM as protected forests and MOG burn in lower severities (Bradley et al. 2016). The lack of home-hardening/defensible space and ex-urban sprawl contribute to losses and working from the home-out should be the principal focus of fire risk reduction for communities, not backcountry thinning. Moreover, human-caused ignitions nationwide are the main catalyst of extreme wildfires, yet the agency seldom mentions this nor the association of high road densities with unwanted human-caused fire ignitions (Balch et al. 2017). The human-fire ignition problems need to be addressed in the ANPRM by limiting at least unwanted ignitions through road closures and road obliteration.

The Forest Service cannot possibly solve the fire-climate problem by promoting thinning in the backcountry and the agency needs to be strategic about active management, focusing on heavily logged areas and teaming with homeowners in working from the home-out (DellaSala et al. 2022c). Further, while prescribed fire and Indian burning practices can be ecologically and culturally appropriate, they are not a panacea for extreme fires that escape containment under extreme fire weather. Agency burning practices also generate substantial smoke, and sometimes escape containment, presenting a public risk that needs to be managed better in a changing climate by not burning in shoulder seasons, for instance. While important, cultural burning historically played a much smaller role in wildfire activity compared to climatic factors in the Sierra region, for instance, because burning practices were concentrated nearest travel routes and villages and wildfire activity was much more influenced by climatic factors like drought (Vachula et al. 2019). This limitation is seldom recognized and needs to be addressed in the ANPRM given climate is a much bigger determinant of fire behavior than Indian burning practices and prescribed fire. Notably, pile burning is no substitute for prescribed fire and is most damaging to soils and mycorrhizae. The agency needs to include pile burning as a threat and not a restorative action, especially since its coupled with logging practices generally. We request that you recognize the importance of soil carbon and mycorrhizae as a carbon sink of strategic importance needing protecting from logging and pile burning (Hawkins et al. 2023).

We cannot overstate the importance of the Forest Service incorporating more of the conservation best available science that overwhelming supports protecting areas of high conservation value such as MOG and IRAs on the Tongass (DellaSala et al. 2022b), large trees of all species within

MOG (Mildrexler et al. 2020, 2023, Birdsey et al. 2023, Exhibits A-H), all MOG on federal lands (Moomaw et al. 2019, Law et al. 2022, DellaSala et al. 2022a, DellaSala et al. 2023, Birdsey et al. 2023), native grasslands, wetlands, pinyon-juniper, and riparian areas free of livestock (Beschta et al. 2012) as carbon reservoirs/reserves. There is strong support in the science community for achieving the conservation goal of 30% to 50% of all lands in strict protection (Noss et al. 2012, Dinerstein et al. 2017, DellaSala et al. 2022a, Law et al. 2022, DellaSala et al. 2023, Wilson 2023, scientist letters in Exhibits E-H) and this is central to the President's Executive Order 14008. Protecting large trees and MOG is consistent with the best available science emphasized in the 2012 planning rule and with the multiple-use mandates of the Forest Service given conservation should be a central focus of multiple use policies.

2. In some places, **high severity burns are resulting in long-term loss of forest cover**, along with the loss of associated plant and animal communities **dependent upon those forest ecosystems**, including MOG-forest communities and at-risk species (emphasis added).

Respectfully, this statement makes no sense and appears contradictory. If high severity burns are indeed resulting in long-term loss of forest cover (which we disagree) than how can they be associated with loss of plant and animal communities that depend on these same burns?

We note that numerous studies have documented the importance of mixed-severity fire complexes (which include high severity patches) to biodiversity – the so called pyrodiversity begets biodiversity hypothesis is well-documented (e.g., Fontaine et al. 2009, Fontaine and Kennedy 2012, Donato et al. 2012, DellaSala et al. 2017, Moritz et al. 2023, Stillman et al. 2023). This association is strongest in fire complexes having both large and small high severity patches (DellaSala and Hanson 2019). The Forest Service statement about high severity as a threat reflects an inherent bias against patch complexity that is essential in regenerating biological legacies characteristic of complex early seral forests that have levels of biodiversity as high as old growth (Swanson et al. 2010). The agency instead is justifying clearcut logging in places like the eastern hardwood forests that will trade away mature forests recovering from old-growth logging for overly simplistic early seral that lacks integrity (Kellett et al. 2022).

The statement above also runs counter to best available science that instead shows no statistical increases in high severity fire in most regions (Odion and Hanson 2008, Baker 2012, Law and Waring 2015, Parks et al. 2015, Baker 2015, DellaSala and Hanson 2019, Baker et al. 2023) and that high severity patches were and still are characteristic of mixed-severity fires across the West (Odion et al. 2014, DellaSala and Hanson 2019, Baker et al. 2023), including historic evidence of very large patches (Perry et al. 2011, Odion et al. 2014, DellaSala and Hanson 2019). Moreover, one study found that there were no statistically significant increases in large (>400 ha) high severity burn patches across 11 western states from the 1990s to 2015 and that natural conifer establishment was documented out to at least 300-m from the nearest unburned seed source (DellaSala and Hanson 2019). Further, Hanson and Chi (2022) documented sampling problems in studies that concluded a lack of conifer establishment in large burn patches mainly because sample plots were too small, biased in placement, or too soon after fire to pick up natural regeneration. There are also examples of misclassifying high severity in large fire complexes due to interpretation problems with remote sensing (see supplemental in DellaSala et al. 2022c). This is especially the case for RAVG determinations that consistently overestimate high burn severity. Additionally, some conifers are known to flush needles in the spring following severe burns even though they were remotely (RAVG) classified as killed by the fire, leading to grossly exaggerated levels of high severity and misleading claims about how large burn patches produce miles of dead trees (Hanson and Chi 2022), which simply is untrue (DellaSala and Hanson 2019). Finally, agency backburning has contributed to increased levels of high severity and this is seldom if ever recognized in fire severities determinations (DellaSala et al. 2022c).

The importance of high severity burn patches is an ongoing dispute in the scientific literature (see DellaSala et al. 2022c) with misleading accounts by some researchers about high severity that omit substantial evidence about ecosystem benefits of severe burn patches (see Baker et al. 2023). Moreover, the Forest Service has repeatedly been selective in using only the science that backs active management regardless of the expansive co-lateral damages from cumulative active management approaches (DellaSala et al. 2022c, Baker et al. 2023), which often leads to controversy, appeals, and lawsuits. We request that you include the best available science cited herein on ecological importance of high severity patches to better address the ecosystem benefits and not just the views of scientists that support active management (see DellaSala et al. 2022c, Baker et al. 2023 for problems with falsification of the scientific record). Use of the precautionary principle, an international standard of evidence-based decision making, is essential to minimize damages despite misinformed claims by some that it is overused (DellaSala et al. 2022c).

3. Climate change is leading to increasingly extreme storms and droughts, extensive pest and disease occurrence, more widespread chronic stress, and shifting fire regimes across forests and grasslands in the United States. Climate change also amplifies other existing stresses, including those from historic forest management and fire suppression approaches. Increasing activity and development within the wildland-urban interface further adds to these stressors, leading to increasingly rapid degradation of the health and ecological integrity of our forests and grasslands.

This statement is somewhat true but needs refinement to better reflect best available science and not just the science that supports the agency position on active management. It is important to note specifically the causal mechanisms involved and effects on ecosystems from climate change acting in concert with not just historic forest management but current as well (DellaSala et al. 2022c). Ongoing emissions from burning of fossil fuels and forestry are main contributors to global overheating and related climate change impacts including extreme fires – that needs to be clearly stated especially the role of deforestation (globally) and forest degradation (including federal logging practices) in this regard. Nationwide, logging emissions are up to 10x that of all combined natural disturbances (wind, fire, insects – see Harris et al. 2016, Law et al. 2018, Merrill et al. 2018, Bartowitz et al. 2022) – that is, the more forests are logged to presumably contain or reduce fire risks, the more emissions contribute to the cause-effect relation among wildfires, climate change, and logging (Bartowitz et al. 2022). This dangerous feedback with wildfire activity is exacerbated by active management practices that undermine ecosystem integrity and release more emissions than natural disturbances (DellaSala et al. 2022c) yet it is not even mentioned in EO 14072 nor the Secretary's memo. Logging combined with extreme fire weather is what is mostly behind the large fires of today (see Zald and Dunn 2018, DellaSala et al. 2022c) and this needs to be clearly analyzed in the ANPRM.

As to the WUI issue, that is an outdated concept. If the concern is about home ignitions, then overwhelming evidence points to treating the home-ignition zone by working from the home-out (defensible space) to a radius of about 60-100 feet (numerous publications by Dr. Jack Cohen). Treatments beyond that zone have absolutely no impact on home ignition – please cite the extensive home-ignition science when discussing community impacts regarding wildfires along with the fact that most fires spill over from private lands – where logging is most intense (Downing et al. 2023). The Forest Service should strategically target defensible space in partnership with private landowners and homeowners and not the federal backcountry that does nothing to limit home losses from fires.

4. More ecosystems and watersheds are becoming vulnerable to severe disturbance, with some geographies and ecosystem types experiencing more rapid and compounding impacts than others.

What exactly does this statement mean – it is way too general in a proposed rulemaking. Most ecosystems have been subject to cumulative anthropogenic stressors, yet the agency continues to blame natural disturbances. Anthropogenic disturbances render ecosystems much less adaptive and less resilient to change over time (Paine et al. 1998). The agency needs to examine the cumulative impacts of anthropogenic disturbances against the backdrop of natural disturbances and attribute diminished resilience to the proper anthropogenic causal factors. As to severity of disturbances, like the response above to high severity fires, please make sure you include the long list of studies showing no statistical increases in high severity fires (Odion and Hanson 2008, Odion et al. 2014, Parks et al. 2015, Law and Waring 2015, Baker 2015, DellaSala and Hanson 2019, Baker et al. 2023).

Regarding beetle-killed forest, the following evidence is quite robust and needs to be cited in the ANPRM as outbreaks are not associated with high fire risks and they play a critical role in ecosystem processes and resilience:

- Wildfires and beetle outbreaks are not co-linked (Bond et al. 2009, Simard et al. 2011, Donato et al. 2013, Black et al. 2013, Harvey et al. 2014, Six et al. 2014, 2018, Kulonkowski and Veblen 2015, Meigs et al. 2016, Hart et al. 2015, Taluci and Krawchuck 2019, Hart and Preston 2020).
- Increases in beetle-killed forests – mainly in the Rockies – have been attributed to warming allowing overwintering beetles to build populations – this is related to unprecedented emissions from burning fossil fuels and forestry that have simplified ecosystems, reducing checks and balances on outbreaks (citations as noted above).
- Logging can intensify beetle-killed impacts by oversimplifying forest structure and homogenizing landscapes, particularly type conversions of MOG to over simplified plantations that then are over-run in outbreaks (citations as noted above).
- Surviving tree species in the aftermath of outbreaks in natural forests contain vital genetic adaptations yet are often post-disturbance logged (Six et al. 2018).

As to watersheds, the cumulative effects of logging, road building, failing culverts, beaver extirpations, livestock grazing, mining, invasives associated with livestock and road use, and other anthropogenic impacts are primary threats that degrade watershed integrity and resilience (please note this in the ANPRM). In regions with riparian reserves and stream protective buffers, watersheds are recovering and that should be noted as well (e.g., the Northwest Forest Plan aquatic ecosystem monitoring reports are extensive in documenting the importance of protecting riparian reserves and dealing with road obliteration to reduce road-stream crossings). In general, more emphasis on passive restoration is needed to remove cumulative stressors.

5. Beginning with the Organic Act of 1897, the Federal Government shifted the focus of forest management towards: (1) improving and protecting forests; (2) securing favorable conditions for water flows (i.e., protecting watersheds); and (3) furnishing a continual supply of timber. At the same time, over the past 15 years data shows that disturbance driven primarily by wildfire and insect and disease has adversely impacted more than 25 percent of the 193 million acres across the National Forest System. This rapidly changing environment is now the primary driver of forest loss and type conversion. Wildfire alone causes approximately 80 percent of reforestation needs on National Forest System lands, and we expect those needs to continue to grow: More than half of the 4 million acres of potential reforestation needs on National Forest System lands stems from wildfires in 2020 and 2022.

These statements above show a clear bias toward blaming natural disturbances for presumed problems in forest regeneration and watershed integrity. Following even the most severe fires, natural conifer establishment is often more than enough without planting (Donato et al. 2006, DellaSala and Hanson 2019, Hanson and Chi 2023). Notably, wildfires are a pulse disturbance associated with increases in stream productivity 1-3 years postfire while logging, roads, and cows are chronic disturbances (e.g., Karr et al. 2004, Beschta et al. 2004 Beschta et al. 2012). Postfire logging, for instance, is by far a much bigger problem for forest establishment as it kills natural conifer regeneration especially when followed by pile burning (see Donato et al. 2006) and this can upset the entire successional gradient (Donato et al. 2012). The figure below from the FRN is misleading as it says nothing about differences in disturbance dynamics between natural causes (fire, insects) and anthropogenic (logging and roads, livestock, ORVs etc). Severe fire, for instance, in MOG results in complex early seral forests that are as diverse as unburned MOG but differ compositionally (Swanson et al. 2010, DellaSala et al. 2017). In no way does logging mimic natural disturbances in frequency, intensity or creation of biological legacies (DellaSala 2019) despite claims often made that logging is needed to create early seral (Kellett et al. 2022). Thus, Figure 2 below is like comparing apples to oranges as there is no equivalence in disturbance dynamics between the two types as implied. We request that you separate out natural from anthropogenic disturbances as there are vast difference in ecosystem responses and that you prohibit post disturbance logging and tree planting within MOG as tree planting is nearly always coupled with logging of biological legacies (see Lindenmayer et al. 2008ab, Thorn et al. 2017, Leverkus et al. 2018, Georgiev et al. 2020). Our request is specific not only to identifying acres of natural vs. anthropogenic disturbances but how they differ in ecosystem responses.

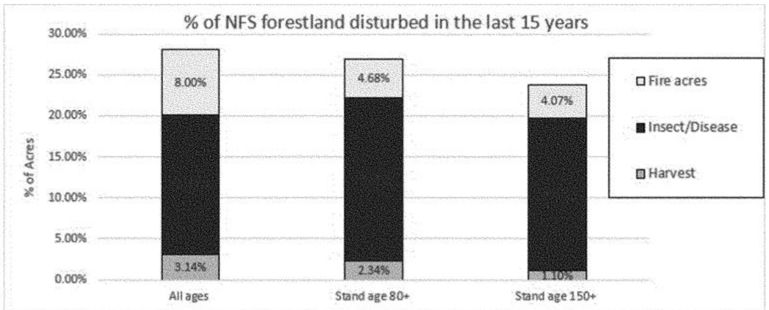

Figure 2. National Forest disturbance has increased over the past fifteen years driven primarily by overstocked forests that are susceptible to insects, disease and wildfire. Forests are also disturbed by timber harvest (these figures include harvest for ecological restoration and fire risk reduction). Most forest disturbances result in different plants, animals, and fungi colonizing an area due to the shift of environmental factors in the area of disturbance.

6. Climate change and related stressors, such as wildfire, drought, insects and disease, extreme weather events, and chronic stress on ecosystems are resulting in increasing impacts with rapid and variable rates of change on national forests and grasslands. These impacts can be compounded by fire suppression, development in the Wildland Urban Interface (WUI), and non-climate informed timber harvest and reforestation practices.

Like the statements above, the Forest Service is lumping natural disturbance dynamics with anthropogenic stressors – they are not equivalent processes given ecosystems adapt readily to the former but are pushed to thresholds due to cumulative anthropogenic disturbances. We reiterate the need to clearly **acknowledge major differences in scale, intensity, and frequency of anthropogenic vs. natural disturbances in the ANPRM and their effects on ecosystem processes, biological legacies, and ecosystem integrity especially in the context of climate change**. Additionally, what is meant by "non-climate informed timber harvest?" That implies timber harvest can somehow be "climate informed?" All forms of timber harvest result in the transfer of most biogenic carbon to the atmosphere with very little stored in wood product pools, resulting in a carbon debt that is not made up for given short rotation logging operation. We request that you use best available carbon life cycle analysis on quantifying the substantial emissions from all forms of logging at the project, regional and national scales (see Harris et al. 2016, Law et al. 2018, Merrill et al. 2018, Hudiburg et al. 2019, Bartowitz et al. 2022). In particular, the benefits of carbon stored in wood products have been grossly exaggerated (Harmon 2019), especially in Forest Service carbon assessments that over state carbon stores in wood product pools and grossly underestimate emissions in, for instance, making inappropriate comparisons of logging emissions to the nation's entire GHGs. This inappropriate use of scale is rampant within Forest Service EISs and is not based on best available carbon life cycle analysis.

7. 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?

This is simple – end all commercial logging within MOG on federal lands and maximize retention of carbon stocks in large trees (Mildrexler et al. 2020, 2023; Law et al. 2022, DellaSala et al. 2022a, 2023, Bartowitz et al. 2022). There is no ecological reason for logging large trees as stated in the scientist letters included in the Exhibits and supporting best available science (e.g., Law et al. 2018, DellaSala and Baker 2020, Mildrexler et al. 2022, 2023, Bartowitz et al. 2022). Mapped-based assessments of MOG are also available (DellaSala et al. 2022a) for designation of nationwide carbon reserves (Law et al. 2022), RNAs, or other designations and that should be the priority for MOG conservation. Protecting MOG would also secure key co-ecosystem benefits and biodiversity (Brandt et al. 2014, DellaSala et al. 2022a). The Siuslaw and Tongass National Forests are exemplary in transitioning local/regional economies out of MOG logging and into second growth on a smaller logging footprint. Those examples should be replicated nationally with economic assistance provided to communities to transition as for example the Southeast Alaska Sustainability Initiative mentioned.

8. 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)?

The agency needs to provide national rulemaking at least equivalent to the roadless conservation rule of 2000 with no exceptions for commercial logging of any large trees or MOG. National direction would then provide for consistent policy across all forests and grasslands related to MOG, large trees, and ecosystem integrity. To reiterate, there is no ecological or climate reason to log large trees and MOG forests and doing so – even on a limited basis – compromises ecosystem integrity, carbon stocks, biodiversity, and other ecosystem services uniquely provided by these forests and large trees.

9. What kinds of conservation, management or adaptation practices may be effective at fostering climate resilience on forests and grasslands at different geographic scales?

MOG of all forest types needs strict protection from commercial logging including all MOG types identified by the agency report and published studies (e.g., DellaSala et al. 2022a, Barnett et al. 2023). Mature in this context is related to structural attributes that correlate with older stages of forest development – as, for example, relatively high levels of canopy cover, tree height, and above ground biomass are generally present when dominant trees are around 80 years, but this varies biogeographically as noted above. An example is the Northwest Forest Plan that defined and placed late-seral forests ≥80 years into reserves. The reserve approach is transferrable to all forest types with the age or dbh of dominant trees determined on a relative geographic basis using carbon accumulation rates as noted above (Birdsey et al. 2023) and structural proxies as also noted. For instance, DellaSala et al. (2022a) used structural correlates specific to the variability in geographic and forest types based on relative pixel (30-m) rankings of structural attributes to define MOG. This process is easily transferrable to all forest types and landownerships. FIA datasets can also be used to cross check large tree and MOG definitions by including number of large trees, canopy height, snags, logs and other factors that best define MOG and large trees. The agency report is a sound step toward science-based MOG definitions that now needs to be followed with adherence to strict protections of all large trees and MOG of all types from commercial logging. There is simply no substitution for protecting MOG and large trees given their irreplaceable ecosystem and climate attributes and the cumulative impacts from active management (Law et al. 2021, 2022, DellaSala et al. 2022c). There are far greater needs for active management outside MOG.

10. 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?

The agency is preoccupied with wildfire prevention that has come with substantial ecosystem damages (DellaSala et al. 2022c). Cumulative impacts need to be addressed in rulemaking and as well as greater recognition of the fire problem stemming from the unprecedented increase in extreme fire weather attributed to GHGs that interact with heavily logged landscapes to produce large conflagrations (Zald and Dunn 2018). Forests protected from logging tend to burn in lower fire severities (Bradley et al. 2016, Leismeister et al. 2019, 2022) and should not be the focus of active management (Bartowitz et al. 2022). Additionally, most fires spill over from private lands that then impact communities (Downing et al. 2022). There is a much bigger problem in logged landscapes in terms of fire susceptibility compared to MOG and the same can be said for beetle-killed forests as noted– they are not a fire problem – nor do they need any tree planting after natural disturbances especially since such planting is nearly always coupled to logging and pile burning that damages complex early seral forests (Lindenmayer et al. 2008, Swanson et al. 2010, DellaSala et al. 2017).

11. 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?

Acres of MOG protected from commercial logging and number of large trees being recruited overtime by simply letting them grow should be the main indicators of a MOG-based rule. Additionally, extending the excellent monitoring of late-seral forests under the Northwest Forest Plan to all national forests would be prudent. Rates of carbon accumulation as large trees recover from prior logging could also be tracked as a means for "proforestation" (Moomaw et al. 2019). Federal lands represent the only such opportunity for large-scale monitoring and conservation and protected areas are the only baseline for tracking restoration efficacy and adaptive management in areas outside protective designations. Thus, designating all MOG within the RNA program would establish an appropriate reference to compare restorative actions in degraded areas through proper statistical analysis and sample design.

12. How can Forest Service land managers better operationalize adaptive management given rapid current and projected rates of change, and potential uncertainty for portions of the National Forest System?

Adaptive management seldom includes unlogged reference areas to assess restoration efficacy. All MOG and large trees within should function as a baseline for comparing to restoration areas as RNAs (ACECs for BLM) and allowed to age on their own (proforestation). MOG monitoring is needed at all scales of biodiversity from genetic variation in naturally regenerating seedlings to viable wildlife populations and natural communities with high ecosystem integrity. RNAs therefore become the baseline for monitoring adaptive management approaches and all MOG should be designated as RNAs.

13. Specifically, for the Forest Service Climate Risk Viewer (described above), what other data layers might be useful, and how should the Forest Service use this tool to inform policy?

Acres of MOG protected from logging, large trees protected from logging (numbers live and dead), progress toward 30 x 30, landscape connectivity (up-down and latitudinal migration corridors), viable populations, water quality, carbon accumulation rates (tree and stand level) all need to be included. Replicate the Northwest Forest Plan monitoring approach nationwide.

14. Adaptation Planning and Practices. How might explicit, intentional adaptation planning and practices for climate resilience on the National Forest System be exemplified, understanding the need for differences in approach at different organizational levels, at different ecological scales, and in different ecosystems?

As mentioned, the most important practice to enable adaptation is to reduce anthropogenic stressors that accumulate spatially and temporally –logging, ORVs, roads, mining, grazing, biomass burning, pile burning, invasives, energy development are all stressors that need to be carefully monitored and greatly constrained in adaptive management. Fire and insects are not main threats to MOG, nor can they be contained via "active management." The only stressors you can actually control are anthropogenic.

15. How should the Forest Service implement the 2012 Planning Rule under a rapidly changing climate, including for assessments, development of plan components, and related monitoring?

Ecosystem integrity needs proper metrics such as MOG acres in each National Forest tracked over time, MOG acres protected from logging, large tree numbers (live and dead – FIA plot scale), viable MOG populations are all important indicators. Retention of carbon stocks needs greater emphasis in project planning, especially in relation to large trees (see Mildrexler et al. 2020, 2023, Birdsey et al. 2023). Placing all MOG within the RNA program would establish a monitoring baseline for assessing status over time and recovering the ecosystem writ large.

16. How might the Forest Service use management and geographic areas for watershed conservation, at-risk species conservation and wildlife connectivity, carbon stewardship, and mature and old-growth forest conservation?

Active management needs to be context specific with passive restoration emphasized within MOG and active and passive in heavily degraded areas. As noted, all MOG should be designated RNAs as reference conditions for assessing progress in restoring ecosystem integrity in degraded areas over time. We request that you define conservation in rulemaking as a prohibition on commercial logging of large trees within MOG and MOG in general. Prioritize mature forests to develop into old growth by eliminating anthropogenic stressors and manage them to restore old growth conditions over time (proforestation – Moomaw et al. 2019).

17. 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? What are effective adaptation practices to protect those values? How should trade-offs be evaluated, when necessary?

Prohibit all commercial logging within MOG and designate MOG for carbon and biodiversity benefits as RNAs, carbon reserves, or other protective designations that begin a process toward 30 x 30. The agency can also track rate of carbon accumulation in large trees as there is a solid scientific foundation for this (Krankina et al. 2012, 2014, Lutz et al. 2018, Law et al. 2018, Law et al. 2022, Barnett et al. 2023, Birdsey et al. 2023, Exhibits E-H). Progress in this regard should be used in reporting on Paris Climate Agreement (sinks and reservoirs), Glasgow Forest Pledge (halting forest degradation), FAO, White House nature-based climate solutions, and 2012 planning rule compliance on ecosystem integrity, carbon management, and connectivity.

18. How can the Forest Service mitigate risks to and support investments in resilience for multiple uses and ecosystem services? For example, how should the Forest Service think about the resilience of recreation infrastructure and access; source drinking water areas; and critical infrastructure in an era of climate change and other stressors?

Protecting MOG from commercial logging comes with a "basket of ecosystem services" (Brandt et al. 2014, Morgan et al. 2022). This is especially true for roadless areas (DellaSala et al. 2011) and MOG on federal lands that have the highest quality drinking water, which will be at a premium in a changing climate (DellaSala et al. 2011, DellaSala et al. 2022a). Anthropogenic stressors that the agency needs to recognize and limit as cumulative impacts to MOG include commercial logging; road building; livestock grazing; ORVs; invasive species and their vectors of spread; mining; energy development; biomass burning; and postfire logging and tree planting. Those stressors in combination or alone accumulate spatially and temporally by degrading ecosystem integrity and resilience (Paine 1998, DellaSala et al. 2022c).

19. How should the Forest Service address the significant and growing need for post-disaster response, recovery, reforestation and restoration, including to mitigate cascading disasters (for example, post-fire flooding, landslides, and reburns)?

End postfire logging and tree planting after natural disturbances. These coupled activities (along with pile burning) are by far the most damaging stressors following natural disturbances (see postfire logging citations above). Tree planting is not needed after large fires even in large high severity burn patches (DellaSala and Hanson 2019, Hanson and Chi 2022). Avoiding emissions from logging is a far superior climate mitigation benefit than planting trees and because tree planting is nearly always coupled to logging (see Moomaw et al. 2019, Law et al. 2021, 2022).

20. Eastern forests have not been subject to the dramatic wildfire events and severe droughts occurring in the west, but eastern forests are also experiencing extreme weather events and chronic stress, including from insects and disease, while continuing to rebound from historic management and land use changes. Are there changes or additions to policy and management specific to conservation and climate resilience for forests in the east that the Forest Service should consider?

The Nantahala Pisgah is a disappointing example of the Forest Service wrongly applying clearcut logging to generate early seral based on the false notion of too much MOG and not enough early seral. Logging MOG for early seral runs counter to EO 14072 and any effective MOG conservation strategy would not include this approach. It also will not produce complex early seral forests that are regenerated by severe natural disturbances in forests already having complex structures (pre-burn MOG) (Swanson et al. 2010, Kellett et al. 2022). Climate related increases in hurricane frequency and intensity in this region will more than compensate for any perceived shortages in early seral while forests regain MOG characteristics by recovering from unprecedented logging over a century ago. It is important to note that federal lands are the only place where large-scale conservation of MOG and complex early seral can take place as essential to climate resilience and broad-scale conservation objectives (DellaSala et al. 2022a).

21. Today there are concerns about the durability, distribution, and redundancy of these systems, given changing climate, as well as past and current management practices, including ecologically inappropriate vegetation management and fire suppression practices. Recent science shows severe and increasing rates of ecosystem degradation and tree mortality from climate-amplified stressors. Older tree mortality due to wildfire, insects and disease is occurring in all management categories.

Older forests are quite resistant to fire (Leismester et al. 2019, 2021) and if they burn they do so in lower severities compared to logged areas (Bradley et al. 2014, Leismeister 2019, 2021). High severity fire rotations are also within historic bounds at the landscape level allowing for sufficient recruitment of old forests over time (Odion et al. 2014ab, Baker 2015). The Northwest Forest Plan is a good example of where rates of recruitment of older forests into the reserve network are outpacing anticipated losses from natural causes. Having redundant reserves built into regional conservation area design allows for anticipated MOG losses including in dry forests with frequent fires without greatly impacting the reserve network. A national system of large, redundant carbon reserves and RNAs would accommodate natural processes (Law et al. 2022).

The Forest Service needs to track high severity fire based on landscape-scale fire rotations instead of fire return intervals that are mostly based on limited point sampling (see Baker 2009, Williams and Baker 2014, Baker 2017 for errors in high severity estimates using fire return intervals and way to correct for sampling problems so they do not overestimate high severity fire occurrence). Fire rotations are currently not a problem in most regions especially when compared to the much bigger threat of logging/thinning as recommended for instance in the recovery plan of the northern spotted owl. Simulation studies (Odion et al. 2014b), including one involving government scientists (Raphael et al. 2014), concluded that thinning in MOG under the spotted owl recovery plan would result in far greater losses to owl habitat than high severity fire over a four-decade period including with climate change increases in fire (also see Bond et al 2022). Additionally, the very low probability of fire even encountering a treated area makes the assertion that active management can somehow "save" those forests from severe burns completely unattainable (Schoenaggel et al. 2017). Scaling up to improve the extremely low odds of fire encountering a treated site will only result in even more co-lateral damages, including greater emissions from logging than the fires themselves (Law and Waring 2015, Harris et al. 2016, Law et al. 2018, DellaSala et al. 2022a, Harmon et al 2022, Bartowitz et al. 2022). There are plenty of areas needing treatment outside MOG where risks are much greater.

22. How might the Forest Service use the mature and old-growth forest inventory (directed by E.O. 14072) together with analyzing threats and risks to determine and prioritize when, where, and how different types of management will best enable retention and expansion of mature and old growth forests over time?

The agency should supplement its MOG inventory with previously published accounts (Pan et al. 2011, DellaSala et al. 2022ab) and recognize that other studies were actually the first to be published on a national inventory well before the agency even announced its "first of a kind" MOG inventory. Already published studies provide the foundation for protecting all large trees and MOG from logging (DellaSala et al. 2022a, Birdsey et al. 2023) including the designation of carbon reserves (Law et al. 2022), RNAs, and the comparable use of FIA datasets in such designations (as in Pan et al. 2011).

23. Given our current understanding of the threats to the amount and distribution of mature and old-growth forest conditions, what policy, management, or practices would enhance ecosystem resilience and distribution of these conditions under a changing climate?

Plain and simple – end commercial logging of large trees and MOG before and after natural disturbance events (Mildrexler et al. 2020, 2023, Law et al. 2022, DellaSala et al. 2022abc, DellaSala et al. 2023). Doing so would accrue substantial carbon benefits (Birdsey et al. 2023) and avoid up to 9% of the nation's annual GHG emissions over at least a decade if such forests were instead logged (DellaSala et al. 2022a). Large trees can be defined using age (e.g., 80 years), structure (dbh), and carbon accumulation rates (e.g., Mildrexler et al. 2020, 2023, Birdsey et al. 2023).

In closing, our topline requests for the ANPRM include:

1. Document the substantial historic and ongoing loss of all MOG forest types from logging as the main reason for the unprecedented national decline and the ongoing threat to MOG persistence in a changing climate (DellaSala et al. 2022abc, 2023).
2. Clearly distinguish the difference between natural vs. anthropogenic disturbances in terms of cumulative ecosystem and imperiled species losses.
3. Quantify degree, intensity, and frequency of cumulative impacts (pre-and post-disturbance) from commercial logging and related active management on ecosystem integrity and resilience (i.e., co-lateral damages, DellaSala et al. 2022c).
4. Recognize the protection of MOG from logging as the best adaptation strategy in a changing climate and the relevance of federal lands as the only remaining place where large-scale conservation can be accomplished.
5. Designate MOG as RNAs, carbon reserves, or some other equivalent protection status and remove them from the commercial logging base.
6. Discuss the importance of large trees and MOG in the context of EO 14008, 14072, Paris Agreement, Glasgow Forest Pledge, and White House nature-based solutions.
7. Provide best available carbon life cycle analysis of impacts of large tree and MOG logging on sequestration, gross emissions, and stocks using published methodologies (e.g., Krankina et al. 2012, Hudiburg et al. 2019, Harmon 2019) at the appropriate spatial (project, regional levels) and temporal (2030, 2050, end of century) scales (see DellaSala

et al. 2022b for example) and do not compare logging emissions to total US GHGs as this is an inappropriate scale of analysis.

8. Transition logging on federal lands out of MOG as exemplified by the Tongass and Siuslaw National Forests with a moratorium on all forms of logging in those forests by initially withdrawing proposed timber sales (climate-forests.org report, DellaSala et al. 2022a, 2023).
9. Restore large-tree protections for the "eastside screens" in Oregon and Washington (Mildrexler et al. 2020, 2023) and withdraw proposals that artificially create "early seral" via logging on the Nantahala and Pisgah National Forests and elsewhere.
10. Restore native grasslands and MOG by removing anthropogenic stressors (passive restoration) and compare such efforts to baseline (high ecosystem integrity in MOG, roadless areas) conditions – this should include an analysis of emissions avoided by not degrading MOG and including all MOG within RNAs as reference conditions.
11. Develop a preferred alternative that starts to contribute to 30 x 30 targets and nationally determined contributions to the Paris Agreement (article 5.1) via protecting natural climate solutions afforded by MOG.

Importantly, we note that the Forest Service uses this definition of an RNA that provides precedent in agency policy for designating all MOG as RNA for permanent protection because it meets this definition alone:

> "A Research Natural Area (RNA) is any tract of land or water which supports high quality examples of terrestrial or aquatic ecosystems, habitats, and populations of rare or endangered plant or animal species, or unique geological study of the features, and is managed in a way that allows natural processes to predominate, with minimal human intervention…..Nationally, there are 450+ designated Research Natural Areas on 175 National Forest Service lands; of which 570,000 + acres are **permanently protected**" (emphasis added).

However, we strongly disagree with this Forest Service statement that is inconsistent with the importance of allowing natural processes and ecosystem integrity to be maintained in the face of eventually natural disturbances in RNAs, "unless catastrophic circumstances significantly alter the conditions for which a research natural area was originally created such that it no longer may serve that function, the designation of a research natural area shall be in perpetuity."

Thus, the designation of all MOGs as RNAs should avoid this disturbance exemption that disqualifies them for protection if/when they are altered by natural disturbances, as that is completely contradictory to the importance of RNAs.

Finally, we urge you to produce a national rule that leaves a legacy of MOG protections at least as strong as the roadless conservation rule that you all can be proud of as the administration's landmark conservation achievement for the nation's most important natural climate solution.

MATURE & OLD-GROWTH FORESTS

Biodiversity

PNW Eastern Cascades Forests: OG forests have exceptional bird, herps, mammals, plants; incredibly rare - most forest types <1% left in classic OG. Davis, M. 1996: Eastern Old-Growth Forests, Island Press

PNW Western Cascades: Late-successional (>80 yrs) and old-growth forests in the PNW (range of northern spotted owl) essential for the viability of >1,000 spp. Federal ecosystem management assessment team (FEMAT: 1993) https://www.blm.gov/or/plans/nwfpnepa/FEMAT-1993/1993_%20FEMAT_Report.pdf.

PNW Western Cascades continued: Superior biodiversity benefits of OG forests by ecoregion - large losses with remaining areas mostly on fed lands. Strittholt et al. 2006. Status of mature/OG in the Pacific Northwest, https://www.jstor.org/stable/3591344. Also Carey 1998. Fifteen years of research on old-growth and managed coniferous forests have provided sufficient understanding of biodiversity to suggest a basis for ecosystem management. First, natural old forests have a metaphysics values associated with their existence and function can never be addressed fully with the scientific method alone; we cannot recreate old growth. Second, five processes underly forest development: crown-class differentiation, decadence, canopy stratification, understory development, and development of habitat breadth. Habitat breadth results from fine scale spatial heterogeneity that produces structural and compositional diversity-tree species diversity, foliage-height diversity, and variety of recurring vegetation site-types. Third, the processes shape trophic pathways, lead to niche diversification, and help to structure fungal, invertebrate, and vertebrate communities. The contribution of each process to niche diversification differs in strength from its contribution to variance in forest structure and composition. Decadence seems the most fundamental, unpredictable, and intractable of the processes https://www.fs.usda.gov/treesearch/pubs/5526

Western Forests (Rockies, PWS, SW, Dry forests): Numerous plants, fungi, bryophytes, vertebrates (marten, flammulated owls, cavity nesting birds) use OG. OG identified by features linked to forest stand age, including heterogeneous physiognomy, high biomass, high woody necromass, and high species diversity. Kauffman et al. 2007. Defining old growth for fire-adapted forests of the western United States. https://www.ecologyandsociety.org/vol12/iss2/art15/. Also see - Kauffman et al. 1992. Old-Growth Forests in the Southwest and Rocky Mountain Regions Proceedings of a Workshop. https://www.fs.fed.us/rm/pubs_series/rm/gtr/rm_gtr213.pdf.

Southeast: A large extent of the eastern USA historically was dominated by oak or pine forests, which likely were open old growth forests due to a frequent, low-to-moderate severity fire regime that reduced tree densities and infrequently disturbed overstory trees. Open old growth forests should be recognized as distinct ecosystems with unique characteristics, ecological functioning, and associated management practices. Hanberry et al. 2018. Recalling open old growth forests in the southeastern Mixed Forest province of the United States. https://www.srs.fs.usda.gov/pubs/56638

Northeast: LSOG forests considered high conservation value due to carbon, biodiversity, recreation values. LSOG is coming back in places due to ingrowth from past century logging. Ducey et al. 2013. https://www.mdpi.com/1999-4907/4/4/1055.Old-growth forests function to maintain habitat, nutrient cycling, and biodiversity <0.5% LSOG remain. Ford (2016). https://scholarworks.uvm.edu/cgi/viewcontent.cgi?article=1432&context=graddis

Southcentral (MidAtlantic): Only ~7,900 acres of remnant old-growth forest in Missouri, but public land management plans call for old-growth acreage to increase to more than 200,000 acres. OG sites consistently had
more trees 17 in dbh than second-growth sites. The absolute number of these larger trees was small; 14 per acre for the old-growth sites compared to 7 per acre for the mature secondgrowth sites. The white and red oak species groups dominated the overstories at all sites. Mean volume of down woody debris 2 4 inches in diameter was 476 ft3mac-' (33.3 m3*ha-') on the old-growth sites vs. 240 ft3aac-'
(16.8 m3*ha-') on the second-growth comparison site. Shifley et al. 1995. Structural and compositional differences between old-growth and mature second-growth forests in the Missouri Ozarks. https://www.nrs.fs.fed.us/pubs/6450

Alaska & Pacific Coastal Rainforests: Breeding/winter bird richness and abundance highest in old growth compared to young growth. Old growth greater mammal richness, bird richness, lichen richness. DellaSala et al. 1996. Effects of silvicultural modifications of temperate rainforest on breeding and wintering bird communities, Prince of Wales Island, southeast Alaska. https://academic.oup.com/condor/article/98/4/706/5124189?login=true. Also, DellaSala, 2011. Temperate and boreal rainforests of the world: ecology and conservation. Island Press. https://link.springer.com/chapter/10.5822/978-1-61091-008-8_2

National

LARGE TREES BY REGION AND GLOBAL

Biodiversity

PNW Eastern Cascades Forests: In DellaSala and Baker 2020 -large-diameter tree is vital because the chamber typically consists only of the former heartwood. To be most useful, the chamber must be large enough for a swift to fly up and down, for a pileatedwoodpecker to enter; or for a bear to occupy. All of these wildlife species typically use entrances from 30 to 80 feet off the ground, where the heartwood cylinder needs to be large enough to provide a chamber of suitable size. The average size of 21 trees used by swifts for nesting was 27 inches d.b.h. and 85 feet in height in northeastern Oregon (Bull and Collins 1993). Bear dens in hollow trees with top entries averaged over 43 inches d.b.h. and 57 feet tall in northeastern Oregon (Akenson and Henjum 1994). Pileated woodpeckers roosted in hollow treesthat averaged 28 inches d.b.h. and 74 feet tall in northeastern Oregon (Bull and others 1992). "In northeastern Oregon, grand fir and western larch make up most of the hollow treesused by wildlife. All 56 nest and roost trees used by swifts were grand fir (Bull 1996a). Sixty- one percent of 123 pileated woodpecker roost trees (Bull and others 1992), and 8 of 10 arboreal bear dens were in grand fir as well (Akenson and Henjum 1994). The remainder of hollow trees used by pileated woodpeckers or black bears were primarily western larch and a few ponderosa pine." https://wild-heritage.org/wp-content/uploads/2020/12/Large-Trees-Report-12.2020.pdf

PNW Western Cascades - Mazurek et al. 2004. In commercial forests, large and old trees sometimes exist only as widely-dispersed residual or legacy trees. Legacy old-growth trees in coast redwood containing basal hollows were equipped with ‘guano traps’. Every basal hollow contained bat guano and genetic methods confirmed use by four species of bats. Vaux’s swifts (Chaetura vauxi), pygmy nuthatches (Sitta pygmaea), violet-green swallows (Tachycineta thalassina), and the long-legged myotis (Myotis volans) reproduced in legacy trees. As measured by species richness, species diversity, and use by a number of different taxa, legacy trees appear to add significant habitat value to managed redwood forests. This value probably is related to the structural complexity offered by legacy trees. The presence of a basal hollow, which only occur in legacy trees, was the feature that appeared to add the greatest habitat value to legacy trees and, therefore, to commercial forest stands. The results of our study call for an appreciation for particular individual trees as habitat for wildlife in managed stands.The cumulative effects of the retention of legacy trees in commercial forest lands could yield important benefits to vertebrate wildlife that are associated with biological legacies.https://www.sciencedirect.com/science/article/abs/pii/S0378112704000386. Also Lutz et al. 2013. Large-diameter trees (here defined as those with a diameter ≥100 cm at breast height (1.37 m; dbh) contribute disproportionately to ecosystem function [3], [4], including biomass and carbon storage [5], [6]. The heterogeneous structure of late-successional forests includes variation in tree density and size across the landscape [7], [8], [9], as well as the variation in vertical canopy structure [10], [11] and tree crown architecture [12], [13].https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0082784

Western forests - Schwartz et al. 2013. Fishers disproportionately used both stand sites and regional landscapes characterized by large diameter trees and avoided areas with ponderosa (a shade-intolerant species characteristic of xeric sites in the NRM) and lodgepole pine according to our best supported model. These results are consistent with other studies in the western US and Canada where large trees were deemed important, although we show that this selection in the Rocky Mountains occurs at multiple scales. These results highlight the importance of late-successional forests, consistent with a recent conservation strategy for fishers, and the importance of both stand- and landscape-level factors when directing forest management of fisher habitat in the US Rocky Mountains.https://www.sciencedirect.com/science/article/abs/pii/S0378112713003137.
Riley et al. 1999. Pileated woodpeckers select large old trees in NW Montana forests. Old-growth stands containing western larch were common nesting sites for pileated woodpeckers. Old-growth ponderosa pine, black cottonwood, and trembling aspen were locally important, but their distribution was more restricted. Compared to other nest-tree species in Montana, undecayed larch wood is hard, making excavation difficult for woodpeckers. Heartwood decay, which softens the wood, becomes more prevalent as a forest matures and was characteristic of western larch nest trees. Large trees, logs, snags, carpenter ants (Camponotus spp.), and heartwood decay are intrinsic components of "healthy" old growth that sustains pileated woodpeckers.
https://www.jstor.org/stable/3784108

Southeast - endangered Red-cockaded woopeckers need large old trees.Jackson et al. 1986. www.jstor.org/stable/3782255. Mature long-leaf pine wiregrass among the most biodiverse conifer forests in world (Blaustein 2008: https://www.jstor.org/stable/10.1641/b580904?seq=1#metadata_info_tab_contents).

Northeast & Great Lakes - DellaSala 1986. My Ph. D documented use of large trees by songbirds in Michigan's hardwood forests**.** Response of three songbird species to forest disturbances in large tracts of northern hardwoods. University of Michigan, School of Natureal Resources. Ann Arbor. McGee and Kimmerer. 2002. This study suggested that epiphytic bryophyte diversity can be sustained in Adirondack managed northern hardwood forests by maintaining host tree species diversity and retaining large or old, thick-barked residual hardwood stems when applying even-aged and uneven-aged silviculture systems. https://cdnsciencepub.com/doi/abs/10.1139/x02-083
Southwest - Reynolds et al. 1992. old forests and large trees are important to goshawks the nest in older forests and foraging in open areas. http://openknowledge.nau.edu/id/eprint/2521/

Eastern Deciduous Forests - Pederson 2010. The common indicators of old (> 250 year old) EDF angiosperms are presented to aid in the recovery and preservation of these living sources of information. Six common external characteristics of old angiosperm trees include: (1) smooth or "balding" bark; (2) low stem taper; (3) high stem sinuosity; (4) crowns comprised of few, large-diameter, twisting limbs; (5) low crown volume; and (6) a low ratio of leaf area to trunk volume. The existence of old trees in the landscape can also be related to life-history traits or land-use histories. Both professionals and lay folk can be trained to identify these traits and environmental conditions. While these characteristics and settings generally signal the potential for old trees, there is no guarantee that they represent old ages. However, these characteristics should aid in the discovery of old trees throughout the EDF.https://bioone.org/journals/natural-areas-journal/volume-30/issue-4/043.030.0405/External-Characteristics-of-Old-Trees-in-the-Eastern-Deciduous-Forest/10.3375/043.030.0405.short

Global - Lindenmayer et al. 2013. Large old trees are critical organisms and ecological structures that play many essential ecological roles ranging from the storage of large amounts of carbon to the provision of key habitats for wildlife. Some of these roles cannot be replaced by other structures. Large old trees are disproportionately vulnerable to loss in many ecosystems worldwide as a result of accelerated rates of mortality, impaired recruitment, or both. New policies and practices are urgently needed to conserve existing large old trees and restore ecologically effective and viable populations of such trees by managing trees and forests on much longer time scales than is currently practiced, and by protecting places where they are most likely to develop. Without these steps, large old trees will vanish from many ecosystems, and associated biota and ecosystem functions will be severely diminished or lost.https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/conl.12013. Also see Lindenmayer and Laurance 2016. Large old trees play an extraordinary range of critical ecological roles including in hydrological regimes, nutrient cycles and numerous ecosystem processes. Large old trees strongly influence the spatial and temporal distribution and abundance of individuals of the same species and populations of numerous other plant and animal species.https://onlinelibrary.wiley.com/doi/10.1111/brv.12290. Also Lindenmayer et al. 2012.Populations of large old trees are rapidly declining in many parts of the world, with serious implications for ecosystem integrity and biodiversity.https://science.sciencemag.org/content/338/6112/1305.summary.

Blicharska and Mikusinski 2014. In addition to providing key ecological functions, large old trees provide numerous social-cultural benefits Awareness of large old trees is a part of human identity and cultural heritage is essential when addressing the issue of their decline worldwide. Large old trees provide aesthetic, symbolic, religious, and historic values, as well as concrete tangible benefits, such as leaves, branches, or nuts. In many cultures particularly large trees are treated with reverence. Also, contemporary popular culture utilizes the image of trees as sentient beings and builds on the ancient myths that attribute great powers to large trees. Accounting for human-related values of these trees is an important part of conservation policy because it may strengthen conservation by highlighting the potential synergies in protecting ecological and social values.https://conbio.onlinelibrary.wiley.com/doi/abs/10.1111/cobi.12341

Dead Tree Importance (General)

Bunnell and Houde 2010. PNW - Many species require or use down wood (fine and coarse woody debris) as habitat. Where forestry has been practiced for several rotations large proportions of these species are considered threatened. Both quantity and distribution of suitable down wood influence species' presence and abundance. Current evidence suggests that the “extinction debt” apparent for nonvertebrates is approaching for vertebrates. Predictions derived from underlying natural history hold when tested. From that basis we derive broad guidelines for forest planning and practice, and suggest how regional target values can be derived.https://cdnsciencepub.com/doi/abs/10.1139/a10-019. Franklin 1992. Structures such as large trees, snags, and down logs are focal points in management, because they can act as surrogates for organisms and functions that are often difficult to quantify. Important considerations at the landscape level include special attention to riparian habitats (including headwaters), creation of an interconnected system of reserved areas, and selection of appropriate patch sizes for managed areas. https://link.springer.com/chapter/10.1007/978-1-4612-4382-3_3.

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https://link.springer.com/chapter/10.1007/978-1-4612-4382-3_3D18

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Also see DellaSala 2019 for importance of large dead trees as habitat and legacies. https://www.taylorfrancis.com/chapters/edit/10.1201/9780429095146-3/fire-mediated-biological-legacies-dry-forested-ecosystems-pacific-northwest-usa-dominick-dellasala"

Rabe 1998. Large diameter ponderosa pine snags used by bats in northern AZ.https://www.jstor.org/stable/3802337. Also by 75 different species of animals for nesting, denning, foraging - see Chambers and Mast 2005. https://www.sciencedirect.com/science/article/abs/pii/S0378112705003555. And high use by wildlife of large snags in the southwest mixed conifer and pine stands - Ganey and Vojta 2004. These results support management to protect and recruit large snags well distributed across the landscape. The relatively high use of ponderosa pine and Gambel oak snags in both forest types suggests that recruitment of large pine and oak snags should be emphasized, and previous studies suggest emphasizing aspen recruitment as well. This may require special management efforts in mixed-conifer forest.

Dove and Keeton 2015. Dead tree and downed log recruitment, as well as maintenance of high levels of aboveground biomass, under strructural complexity enhancement had a particularly strong effect on fungal diversity. Findings show it is possible to increase fungal diversity using forestry practices that enhance stand structural complexity and late-successional forest characteristics.
https://www.sciencedirect.com/science/article/abs/pii/S1754504814001305

Carbon

Largest trees in dry forests of OR/WA held 33 to 46% of total AGC stored by each species. Study includes carbon for trees and forest elve. Mildrexler et al. 2020. https://www.frontiersin.org/articles/10.3389/ffgc.2020.594274/full

Carbon balance has been increasing in the PNW due to the NWFP logging restrictions. Krankina et al. 2012. https://www.researchgate.net/publication/257198033_Carbon_balance_on_federal_forest_lands_of_Western_Oregon_and_Washington_The_impact_of_the_Northwest_Forest_Plan

High biomass (>200 Mg/ha) were mapped and quantified for landowerships in the PNW showing high C stores on fed lands compared to nonfed. Krankina et al. 2014 - https://link.springer.com/article/10.1007/s00267-014-0283-1

Carbon sequestration via forest preservation a viable climate mitigation strategy in the western forests with high potential sequestration and low vulnerability to future drought and fire. High-productivity, low-vulnerability forests have the potential to sequester up to 20% of the global mitigation potential for all temperate and boreal forests, or up to ~6 yr of current regional fossil fuel emissions. Forests have high carbon density, high tree species richness, and high proportion of critical habitat for T&E spp, indicating a strong potential to support biodiversity. Others have low carbon but high biodiversity. Buotte et al. 2020. https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/eap.2039

SE pine forests experienced the largest biomass removals, with paper products leading all end-uses. Averaging across all SE forestlands, mean annual net ecosystem productivity decreased from 116 gC · m−2 · year−1 in 1986 to 71 gC · m−2 · year−1 in 2007, and 85 gC · m−2 · year−1 in 2010, equating to a range of 25 to 41 Tg C/year (mean of 34 Tg C/year). Interannual variability in forest-atmosphere carbon exchange is dominated by the extent of harvesting, with removals ranging from 23 to 56 Tg C/year. Two thirds of harvest removals emitted within 50 years, 8% as methane, causing the forest sector to act as a large CO2-equivalent source. Gu et al. 2019. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018JG004841

Late-successional (LS) Old-growth (OG) aboveground live C stocks 2.0-2.5 times higher than regional mean. LS plots accumulating aboveground live C at a positive rate (0.61 Mg ha−1 year−1), while C stocks on OG plots are declining (−0.54 Mg ha−1 year−1). OG loss driven by presence of beech bark fungus (Nectria sp.) leading to mortality in larger diameter American beech trees. Northeast Variant of the Forest Vegetation Simulator is not a reliable predictor of aboveground live carbon accumulation rates in Northeastern LSOG. Overall, LSOG can play an important role mitigating climate change, but understanding and quantifying natural disturbance risk to forest carbon stocks is critical. Further, regional forest carbon models will need calibration to accurately predict carbon accumulation rates in older forests. Gunn et al. 2014. https://www.sciencedirect.com/science/article/abs/pii/S0378112713006907. Also see Darcey et al. 2013. Old-growth forests provide a range of ecosystem services, including carbon storage (e.g., [1,2]), biodiversity elements [3], and recreational and amenity benefits [4]. General structural patterns associated with temperate old-growth forests have been well-established in the existing literature (see [20] for a recent review). These include large quadratic mean diameter (QMD), increased abundance of large trees, and elevated amounts of standing and downed necromass in comparison to younger forests.https://www.mdpi.com/1999-4907/4/4/1055. Also see Nunery et al. 2010. Mean carbon sequestration was significantly (α = 0.05) greater for "no management" compared to any of the active management scenarios. Of the harvest treatments, those favoring high levels of structural retention and decreased harvesting frequency stored the greatest amounts of carbon. . Modeling results from this study show that harvesting frequency and structural retention significantly affect mean carbon storage.https://www.sciencedirect.com/science/article/abs/pii/S0378112710000058

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Carbon

Largest trees in dry forests of OR/WA held 33 to 46% of total AGC stored by each species. Study includes carbon for trees and forest elve. Mildrexler et al. 2020. https://www.frontiersin.org/articles/10.3389/ffgc.2020.594274/full

Lutz et al. 2020. These large logs contribute directly to biodiversity by changing the microenvironment (Chen et al. 1995; Vrška et al. 2015; Chu et al. 2019), serving as substrate for seedlings (Harmon and Franklin 1989) and bryophytes (Taborska et al. 2015), and contributing to complex and prolonged patterns of carbon cycling (Harmon et al. 1986; Privetivy et al. 2018; Stenzel et al. 2019). In addition to the large pieces of deadwood that come from the main stem of large-diameter trees, large trees contribute smaller pieces of wood as well. Chronic wind disturbance in Pacific Northwest forests is a defining ecological process (Lutz and Halpern 2006; Larson and Franklin 2010), and the tops of older, taller trees are frequently broken. Wood that originates from the tops of larger trees may persist longer on the forest floor compared to a full tree of the same diameter by virtue of being generally older and having tighter rings and more heartwood. Old-growth forests contain large stores of biomass in living trees, as well as in snag and deadwood biomass pools that are stable long after tree death. Ignoring biomass (or carbon) in deadwood pools can lead to substantial underestimations of sequestration and stability. Baseline levels of tree mortality can, over time, contribute to high snag densities and high levels of deadwood (down woody debris) if fire is infrequent and decomposition is slow. Deadwood can be important for tree recruitment, and it plays a major role in terrestrial carbon cycling, but deadwood is rarely examined in a spatially explicit context

Lutz et al. 2012. Large-diameter trees comprised 1.4% of individuals but 49.4% of biomass, with biomass dominated by Abies concolor and Pinus lambertiana (93.0% of tree biomass). The large-diameter component dominated the biomass of snags (59.5%) and contributed significantly to that of woody debris (36.6%) in mixed conifers of the Sierra. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0036131.

Samuelson et al. 2016. Quantified carbon (C) density in 20 managed longleaf pine (Pinus palustris Mill.) forests ranging in age from 5 to 118 years located across the southeastern United States and estimated above- and belowground C trajectories. Ecosystem C stock (all pools including soil C) and aboveground live tree C increased nonlinearly with stand age and the modeled asymptotic maxima were 168 Mg C/ha and 80 Mg C/ha, respectively. Accumulation of ecosystem C with stand age was driven mainly by increases in aboveground live tree C, which ranged from <1 Mg C/ha to 74 Mg C/ha and comprised <1% to 39% of ecosystem C. Live root C (sum of below-stump C, ground penetrating radar measurement of lateral root C, and live fine root C) increased with stand age and represented 4–22% of ecosystem C. Soil C was related to site index, but not to stand age, and made up 39–92% of ecosystem C. Live understory C, forest floor C, downed dead wood C, and standing dead wood C were small fractions of ecosystem C in these frequently burned stands. Stand age and site index accounted for 76% of the variation in ecosystem C among stands. Long-term accumulation of live tree C, combined with the larger role of belowground accumulation of lateral root C than in other forest types, indicates a role of longleaf pine forests in providing disturbance-resistant C storage that can balance the more rapid C accumulation and C removal associated with more intensively managed forests. Although other managed southern pine systems sequester more C over the short-term, we suggest that longleaf pine forests can play a meaningful role in regional forest C management.
https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/eap.1439
Thom and Keeton 2019. Northeastern hardwood forests - structural complexity was overall positively associated with carbon storage, whereas this effect was more distinctive in hardwood compared to softwood-dominated forests. In particular, five variables exhibited a positive (conifer ratio, diameter variation, dead basal area, large live trees, and live basal area), one a negative (live tree density), and two (dead tree density and species diversity) a mixed relationship with carbon storage.Sustaining ecosystem functions such as carbon storage or provision of specialist species habitat will likely require different management strategies when the functions are performed primarily by a few large trees as opposed to many smaller trees.
https://www.sciencedirect.com/science/article/abs/pii/S0378112718321959

Brown et al. (includes Birdsey) 1997. Old-growth forests generally had AGBD of 220–260 Mg ha−1 with up to 30% in trees with diameter > 70 cm. In contrast, maximum AGBD for the FIA units was about 175–185 Mg ha−1 with 8%–10% in large trees. Most units, however, were below these maximum values, suggesting that the forests represented by the FIA inventory are in various stages of recovery from past disturbance. Biologically, therefore, they have the potential to accumulate significant quantities of additional biomass, if left unharvested, and thus storing atmospheric C into the future.https://www.sciencedirect.com/science/article/abs/pii/S0378112797000443

Lutz et al. 2018. Because large-diameter trees constitute roughly half of the mature forest biomass worldwide, their dynamics and sensitivities to environmental change represent potentially large controls on global forest carbon cycling. We recommend managing forests for conservation of existing large-diameter trees or those that can soon reach large diameters as a simple way to conserve and potentially enhance ecosystem service.https://onlinelibrary.wiley.com/doi/abs/10.1111/geb.12747

Stephenson et al. 2014. Global analysis of 403 tropical and temperate tree species showed that for most species mass growth rate increases continuously with tree size. Large, old trees do not act simply as senescent carbon reservoirs but actively fix large amounts of carbon vs smaller trees; at the extreme, a single big tree can add the same amount of carbon to the forest within a year as is contained in an entire mid-sized tree.The apparent paradoxes of individual tree growth increasing with tree size despite declining leaf-level and stand-level productivity can be explained, respectively, by increases in a tree's total leaf area that outpace declines in productivity per unit of leaf area and, among other factors, age-related reductions in population density. For all continents, aboveground tree mass growth rates (and, hence, rates of carbon gain) for most species increased continuously with tree mass (size) (Fig. 2). The rate of mass gain increased with tree mass in eachmodel bin for 87%of species, and increased in the bin that included the largest trees for 97% of species; the majority of increases were statistically significant

Dead Trees and Fuel Effects (including postfire logging effects)

Passovy and Fule 2006. Following severe wildfires in southwestern ponderosa pine forests, dead trees remain on the landscape and eventually fall. Total CWD biomass in the surface fuel load remained roughly comparable from 8–9-year-old fires to a 27-year-old fire but the state of the CWD changed from sound to rotten. The change to a rotten condition suggests an increase in ignitability of the post-fire fuel load, but fine fuels that could support high fireline intensity were relatively low. The number of "jackstraws," points where intersecting downed logs could create a hot spot if reburned, was slightly higher in the oldest fire. Few fire-created snags remained by the 27th year post-fire. https://www.sciencedirect.com/science/article/abs/pii/S0378112705007139

Schulz 2003. Kenai Peninsula AK - spruce bud worm die off. Small trees lost moisture faster than large trees and small trees are more of a fire hazard. Logged areas had the highest fine fuels (fire hazard). https://books.google.com/books?hl=en&lr=&id=2-PIYnm1KgUC&oi=fnd&pg=PA2&dq=large+jack+straw+dead+trees+fire&ots=Mfrrrgy3zF&sig=sj5pgYFjALvu_XHuR-R-_vOLvpc#v=onepage&q&f=false

Lutz et al. 2021. In this mixed-species forest, there was relatively high density and basal area of live *Picea engelmannii* 20 years after the beetle outbreak (36 trees ha−1 and 1.94 m2 ha−1 ≥ 10-cm diameter) contrasting with the near total mortality of mature *Picea* in forests nearby. Wood from tree boles ≥ 10-cm diameter on the ground had biomass of 42 Mg ha−1, 7 Mg ha−1 of *Picea engelmannii*, and 35 Mg ha−1 of other species. Total live aboveground biomass was 119 Mg ha−1, while snag biomass was 36 Mg ha−1. Mean total fuel loading measured with planar transects was 63 Mg ha−1 but varied more than three orders of magnitude (0.1 to 257 Mg ha−1). Planar transects recorded 32 Mg ha−1 of wood ≥ 7.62-cm diameter compared to the 42 Mg ha−1 of wood ≥ 10-cm diameter recorded by explicit mapping. Multiple pieces of deadwood were often stacked, forming a vertical structure likely to contribute to active fire behavior.https://ecologicalprocesses.springeropen.com/articles/10.1186/s13717-020-00275-0. also - cross reference to beetle-killed forests referenced in my paper in review for how intense fire is not a problem in those stands following beetle kill

Donato et al. 2012. In mixed-evergreen forests of Oregon, USA, we quantified fuel profiles 3–4 years after stand-replacement fire – assessing three post-fire logging intensities (0, 25–75, or >75% basal area cut) across two climatic settings (mesic coastal, drier interior). Post-fire logging significantly reduced standing dead biomass, with high-intensity treatment leaving a greater proportion (28%) of felled biomass on site compared with moderate-intensity treatment (14%) because of less selective tree felling. Down wood cover increased by 3–5 times and became more spatially homogeneous after logging. Post-fire logging altered the fuel profile of early-seral stands (standing material removed or transferred, short-term increase in surface fuels, likely reduction in future large fuel accumulation), with moderate-intensity and unlogged treatments yielding surface fuel loads consistent with commonly prescribed levels, and high-intensity treatment resulting in greater potential need for follow-up fuel treatments. https://www.publish.csiro.au/WF/WF12109

Ritchie et al. 2012. This study contradicts the others in showing 1000-hr fuels were greatest in unsalvaged plots. The 1000 h and larger surface fuels increased with salvage basal area retention level. ▸ Highest levels of 1000 h fuels were associated with unsalvaged areas. ▸ In year 8, 1000 h surface fuel was 81% of retained bole biomass. ▸ White fir snags were more stable than pine over the life of this study. ▸ Fine fuels (1–100 h) remained at low levels for all observations. https://www.sciencedirect.com/science/article/abs/pii/S0378112712005348

Petersen et al. 2014. This study showed large fuels removed but small fuels increased after logging. We measured woody fuels 1–39 years after wildfires in dry coniferous forests.
Logging reduced large diameter woody fuels from 6 to 39 years after fire. Logging increased small and medium diameter fuels for 5–7 years after fire. Logging later reduced small and medium fuels from ~12 to 23 years after fire.
https://www.sciencedirect.com/science/article/abs/pii/S0378112714006823

McIver and Ottmar. 2016. Similar findings - large 1000-hr fuels were logged out, but slash went up. Stand structure and fuel mass were measured before and after a post-fire logging operation conducted 2 years after the 1996 Summit Wildfire (Malheur National Forest), in a ponderosa pine-dominated forest in northeastern Oregon. Post-fire logging resulted in a significant decrease in mean basal area, down to 46% pre-treatment level in commercial units, and down to 25% in fuel reduction units. Logging significantly reduced tree density, especially for the smallest (<22 cm diameter) and intermediate (23–41 cm) diameter classes. Fuel reduction units also had significantly fewer snags (dead trees >30 cm diameter—4 ha−1), compared to both commercial (23 ha−1) units and to un-logged controls (64 ha−1) in the year following timber harvest. Logging did not change ladder height or tree species composition (% ponderosa pine, Douglas-fir and grand fir). Total woody fuel mass increased significantly in fuel reduction units when compared to controls, with the greatest difference among treatments occurring in the slash fuel (<7.6 cm diameter) component (mean of 6.2 Mg/ha for fuel reduction stands versus 1.3 Mg/ha for un-logged stands). Model projections of 1000-h fuels (woody fuels >7.6 cm diameter) indicate that standing structure in all stands would collapse quickly, with the result that un-logged stands would contain two- or three-fold greater masses at 25 and 50 years post-logging, leading to much higher consumption rates of fuel in the event of a re-burn in the same place. Variation in dead tree fall and decay rates did not change the relationship among treatments in 1000-h fuel loads, but changed the time at which treatment differences were projected to disappear. Despite treatment differences in heavy fuel accumulations over time however, FVS–FFE predicts no differences among treatments in mortality of young trees due to either moderate or high intensity fire occurring in the same place at 25, 50, or 100 years post-fire logging. The lack of a re-burn effect is in part due to the reliance on flame length as the primary mechanism leading to tree death in the fire effect models used by FVS–FFE. If tree death turns out to be caused more by root burning or cambial heating, the observed variations in 1000-h fuel loadings among treatments could be significant in the event of a future re-burn.

Johnson et al. 2020. Fine fuels increased following post fire logging - quantified change in stand structural metrics (snag densities and snag basal areas), dead woody fuel loadings, tree regeneration survival, and percentage change in vegetation cover before and after post-fire logging 1 year after the 2015 Stickpin Wildfire on the Colville National Forest in northeastern Washington State, USA. In a generalized randomized block design three salvage logging prescriptions were randomly assigned within each block: no treatment control (C); standard salvage retention (SSR; thin to 3.4 m2/ha basal area); and mimic green tree thinning (GTR; thin to 10.3 m2/ha basal area). SSR reduced average snag basal area 73–83% to 4.1–8.8 m2/ha (68–674 trees ha−1). GTR reduced average snag (standing dead trees) basal area 41–71% to 6.5–15.9 m2/ha (90–794 trees ha−1). There were mixed results for the change in dead woody fuel loadings depending on fuel size class. In general, fine (FWD) and coarse woody (CWD) debris tended to increase immediately post-treatment in logged areas relative to the controls but did not exceed management loading threshold for providing acceptable risk of fire hazard. Treated stands had a significant increase in FWD relative to controls, including the individual 1-, 10-, and 100-hr fuel size classes. The 1000-hr sound class did not have a significant treatment effect. Changes in surface fuel loading were inconsequential to modeled wildfire behavior metrics (rate-of-spread, flame lengths). The Fire and Fuels Extension to Forest Vegetation Simulator (FFE-FVS) modeling projected CWD accumulation in the controls exceeded total accumulation in both treatments. Future fuel loadings may affect reburn severity as our simulated wildfire 20 years after harvesting caused significant mortality (89%) to regenerating forest. Almost all blocks showed a decrease in seedling counts pre and post-logging, including the control plots.
https://www.sciencedirect.com/science/article/abs/pii/S0378112719323187

Dunn and Bailey. 2015. Peak fine woody fuel loadings occurred 17–18 year post-fire in unmanipulated stands. Salvage logging increased fine fuel loadings 160–237% for 18–22 years post-fire. Maximum 1000-h fuel loadings occurred 24–31 years post-fire in unmanipulated stands. Decomposition reduced loadings by 35–50% of initial snag necromass by peak years. Salvage logging significantly reduced 1000-h fuel loadings after 7 years post-fire.
https://www.sciencedirect.com/science/article/abs/pii/S0378112715000043

Lutz et al. 2012. Reintroducing fire causes tree mortality that can have unintended ecological outcomes related to woody biomass, with potential impacts to fuel accumulation, carbon sequestration, subsequent fire severity, and forest management. Beginning pre-fire, and continuing 6 years post-fire, we tracked all live, dead, and fallen trees ≥ 1 cm in diameter and mapped all pieces of deadwood (downed woody debris) originating from tree boles ≥ 10 cm diameter and ≥ 1 m in length in 25.6 ha of an *Abies concolor* /*Pinus lambertiana* forest in the central Sierra Nevad. Six years after moderate-severity fire, deadwood ≥ 10 cm diameter was 73 Mg ha−1, comprised of 32 Mg ha−1 that persisted through fire and 41 Mg ha−1 of newly fallen wood (compared to 72 Mg ha−1 pre-fire). Woody surface fuel loading was spatially heterogeneous, with mass varying almost four orders of magnitude at the scale of 20 m × 20 m quadrats (minimum, 0.1 Mg ha−1; mean, 73 Mg ha−1; maximum, 497 Mg ha−1). Wood from large-diameter trees (≥ 60 cm diameter) comprised 57% of surface fuel in 2019, but was 75% of snag biomass, indicating high contributions to current and future fuel loading. Reintroduction of fire does not consume all large-diameter fuel and generates high levels of surface fuels ≥ 10 cm diameter within 6 years. Repeated fires are needed to reduce surface fuel loading.https://ecologicalprocesses.springeropen.com/articles/10.1186/s13717-020-00243-8
also - cross reference to beetle-killed forests referenced in my paper in review for how intense fire is not a problem in those stands following beetle kill

Water

Wondzell 2001. Dense riparian vegetation might help regulate the amount of sediment that reaches streams, but this effect would be strongly dependent on the geomorphic setting. The largest risk of accelerated erosion is expected from ground-disturbing activities during fuels reduction treatments, such as construction of roads and firebreaks or salvage logging or thinning. Intense grazing has changed composition and cover of riparian vegetation, leading to bank erosion, and in many places, widening or incision of stream channels. Given the current state of knowledge, dramatically changing forest land use practices across eastern Oregon and Washington-including the widespread use of prescribed fires, salvage logging, and mechanical fuel treatments-is a long-term, landscape-scale experiment, the cumulative effects of which are unknown.https://research.libraries.wsu.edu/xmlui/handle/2376/989

Old-growth forests PNW have exceptional carbon and water values. OG maintains water balance in forested watersheds. Jjang et al. 2019 https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.2692Also Perry and Jones 2016. Analysis of 60-year records of daily streamflow from eight paired-basin experiments in the Pacific Northwest (Oregon) revealed conversion of old-growth to Douglas-fir plantations had a major effect on summer streamflow. Average daily streamflow in summer (July through September) in basins with 34- to 43-year-old plantations of Douglas-fir was 50% lower than streamflow from reference basins with 150- to 500-year-old forests. Young Douglas-fir trees, which have higher sapwood area, higher sapflow per unit of sapwood area, higher concentration of leaf area in the upper canopy, and less ability to limit transpiration, appear to have higher rates of evapotranspiration than old trees of conifer species, especially during dry summers. Reduced summer streamflow in headwater basins with forest plantations may limit aquatic habitat and exacerbate stream warming, and it may also alter water yield and timing in much larger basins. https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1790. Also see Frissell in Williams et al. 1997. In general, uncut watersheds with older forests are more functional and with higher levels of biodiversity. https://fisheries.org/bookstore/all-titles/professional-and-trade/x55024xm/. Also see Ham 1982. Net precipitation under old growth Douglas fir forest in the Bull Run Municipal Watershed (Portland, Oregon) totaled 1739 mm during a 4Cbweek period, 387 mm more than in adjacent clearcut areas. Expressing data on a full water year basis and adjusting gross precipitation for losses due to rainfall interception suggest fog drip could have added 882 mm (35 in) of water to total precipitation during a year when precipitation measured 2160 mm in a rain gage in a nearby clearing. Standard rain gages installed in open areas where fog is common may be collecting up to 30 percent less precipitation than would be collected in the forest. Long term forest management (Le., timber harvest) in the watershed could reduce annual water yield and, more importantly, summer stream flow by reducing fog drip. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.1982.tb00073.x

Forests provide natural filtration and storage systems that process nearly two-thirds of the water supply in the U.S. Forest vegetation and soils, if healthy and intact, can benefit human water supplies by controlling water yield, peak flows, low flows, sediment levels, water chemistry and quality. Increases in water yield after forest harvesting are transitory; they decrease over time as forests re-grow, and in the meantime water quality may be reduced. Oregon State University. "Greatest Value Of Forests Is Sustainable Water Supply." ScienceDaily. ScienceDaily, 21 July 2008. www.sciencedaily.com/releases/2008/07/080714162600.htm. Pypker et al. 2006. Old-growth Douglas-fir contain large populations of epiphytic lichens and bryophytes. Epiphytes increase the canopy water storage of a typical old growth Douglas-fir forest by >1.3 m. https://cdnsciencepub.com/doi/abs/10.1139/X05-298. From Crampe et al. 2021. Hydrologic processes altered by harvest of old-growth conifer forest more than 50 years ago (transpiration, interception, snowmelt, and flow routing) continued to modify streamflow, with no clear evidence of hydrologic recovery. https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.14168. From Harmon and Sexton 1995. The proportion of water stored by and evaporated from logs in this study indicates that in old growth forests they may intercept 2–5% of the canopy throughfall to the forest floor and that, even in early stages of decomposition, they may affect the hydrological cycle of Pacific Northwest old-growth forests. https://link.springer.com/article/10.1007/BF00020868. Also se Olson et al. 2007. Stream–riparian areas represent a nexus of biodiversity, with disproportionate numbers of species tied to and interacting within this key habitat.. High biodiversity in riparian areas can be attributed to cool moist conditions, high productivity and complex habitat. All 47 northwestern amphibian species have stream–riparian associations, with a third being obligate forms to general stream–riparian areas, and a quarter with life histories reliant on headwater landscapes in particular. Recent recognition that stream-breeding amphibians can disperse hundreds of meters into uplands implies that connectivity among neighboring drainages may be important to their population structures and dynamics. Microclimate studies substantiate a "stream effect" of cool moist conditions permeating upslope into warmer, drier forests. We review forest management approaches relative to headwater riparian areas in the U.S. Pacific Northwest, and we propose scenarios designed to retain all habitats used by amphibians with complex life histories. These include a mix of riparian and upslope management approaches to address the breeding, foraging, overwintering, and dispersal functions of these animals. We speculate that the stream microclimate effect can partly counterbalance edge effects imposed by upslope forest disturbances, hence appropriately sized and managed riparian buffers can protect suitable microclimates s. We propose one approach that focuses habitat conservation in headwater areas – where present

Note - Need to be aware of this 1975 USFS doc that supports patch cuts to increase snow runoff and water delivery to streams in many Intemountain forests- https://www.fs.fed.us/rm/pubs_rm/rm_rp142.pdf. Same with this study - at least under certain conditions,water yield can temporarily increase with cutting - Goeking and Tarboton 2020. https://academic.oup.com/jof/article/118/2/172/5734757?login=true. And this - moderate logging increased water yield in mixed conifers Arizona - Gottfried 1991 -https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.1991.tb01454.x. And this - short term increase in water yield from logging in southwest watersheds. Neary et al. 2003. https://www.tucson.ars.ag.gov/ICRW/Proceedings/Neary.pdf

Nagy et al. 2011. forest removal leads to increased stream sediment and nutrients, more variable flow, altered habitat and stream and riparian communities, and increased risk of human health effects. Although indicators such as the percentage of impervious cover signify overall watershed alteration, the threshold to disturbance, or the point at which effects can been observed in stream and riparian parameters, can be quite low and often varies with physiographic conditions. In addition to current land use, historical practices can greatly influence current water quality. General inferences of this study may extend to many humid regions concerning climate, environmental thresholds, and the causes and nature of effects.
https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/jeq2010.0365

Shanon et al. 2019. Even-aged stands are often more vulnerable to insect pests anddiseases, many of which are likely to increase in range and severity as aresult of climate change. Uneven-aged systems may expose a smallerproportion of the population to a particular threat at any one time,which can increase the resistance or resilience of a stand to a widerrange of disturbances (O'Hara and Ramage, 2013). Maintaining a mix ofages, sizes, or canopy positions will help buffer the overall stand tostressors specific to a single age class (Noss, 2001). Likewise, standswith higher species diversity may be less vulnerable to climate changeimpacts and disturbances because they distribute risk among multiplespecies, reducing the likelihood that the entire system will decline orlose productivity even if one or more species suffer adverse effects.
https://reader.elsevier.com/reader/sd/pii/S2405880718300694?token=49F5FDBBC6F2D3487A33990E99742BE31CE7B77F30570655CD838FFB00089F5FE15FBFCC8A2C321AE0D9BFDBB7D8EA67&originRegion=us-east-1&originCreation=20210830183809

Schaberg and Abt 2004. These forests are vulnerable to disturbance and fragmentation from changing patterns of land use in the Mid-Atlantic Region, and from harvests of commercially mature and relatively inexpensive timber.https://link.springer.com/article/10.1023/B:EMAS.0000016882.72472.e1. Also - Hayes et al. 2019. Traditional stream restoration efforts throughout the mid-Atlantic and northeastern United States a have limited success because many fluvial systems remain in a disequilibrium condition after a century of widespread logging in these watersheds. By the mid-1800s sediment delivery to most streams was greatly increased and many channels were dredged, straightened, and cleared of trees and large boulders to facilitate log drives. Today these watersheds remain in a protracted phase of fluvial adjustment, with episodic movement of logging legacy sediments during large floods, resulting in widespread aggradation, chute cut-offs, floodplain sedimentation, and channel avulsion. Damage to roads, bridges, and infrastructure can be catastrophic.https://ui.adsabs.harvard.edu/abs/2019AGUFM.H33J2063H/abstract

Bilby and Ward 1991. Amount of large woody debris (LWD) surveyed in 70 stream reaches flowing through old-growth, clear-cut, and second-growth forests decreased with increasing stream size for all stand types but was greatest at old-growth sites. Average piece volume was larger at old-growth sites than at other stand types in streams >10 m wide, but no differences were seen in smaller streams. Scour pools accounted for 90% of the wood-associated pools at second-growth and clear-cut sites but only 50% at old-growth sites, which contained more pools than other stand types, particularly for larger streams. Sediment and fine organic matter retained by woody debris decreased with increasing stream size for ail stand types, but old-growth sites contained greater amounts of both materials than other stand types. The frequency of pool formation, the type of pool formed, and sediment accumulation were influenced by the amount of fine debris associated with LWD. Changes in LWD amount, characteristics, and function occurred very rapidly following removal of streamside vegetation. https://cdnsciencepub.com/doi/abs/10.1139/f91-291. Also - Murphy & Koski 2011. Natural rates of input and depletion of large woody debris (LWD) in southeast Alaska streams were studied to provide a basis for managing streamside zones to maintain LWD for fish habitat after timber harvest. Longevity of LWD was directly related to bole diameter: small LWD (10–30 cm in diameter) was less than 110 years old, whereas large LWD (>60 cm in diameter) was up to 226 years old. A model of changes in LWD after timber harvest (which accounted for depletion of LWD and input from second-growth forest) indicated that 90 years after clear-cut logging without a stream-side buffer strip large LWD would be reduced by 70% and recovery to prelogging levels would take more than 250 years. Because nearly all LWD is derived from within 30 m of the stream, the use of a 30-m wide, unlogged buffer strip along both sides of the stream during timber harvest should maintain LWD.https://www.tandfonline.com/doi/abs/10.1577/1548-8675(1989)009%3C0427%3AIADOWD%3E2.3.CO%3B2

Roadless forests- which include older forests - have superior water quality and quantity benefts. DellaSala et al. 2011. doi:10.2489/jswc.66.3.78A. Forested watersheds, for example, areessential to sustaining the Nation's freshwater supply. More than 50 percent of this supply originates on forest lands. In the Western United States, 65% of the water supply comes from forests. National forests alone provide 18 percent of the Nation's water, and over half the water in the West (Brown et al. 2008) (see fig. 2). High-elevation forests are particularlyimportant because these headwater catchments store vast quantities of water as snow during the winter, then release it gradually through spring and summer, sustaining downstream water supplies during dry seasons. The amount and quality of these services depend on the condition of the forest—when watershed conditions are stressed or degraded, critical services can be threatened or compromised. Today, essential watershed services are threatened by a variety of human impacts on watersheds and aquatic ecosystems. Climate change has directly affected and will continue to affect the global hydrologic cycle and thus the quality, quantity, and timing of streamflows from forests. https://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf

The issue of tree cutting for water yield was recently summarized by the National Research Council (2008: 1): Removing forest cover accelerates the rate that precipitation becomes streamflow; therefore, in some areas, cutting trees causes a temporary increase in the volume of water flowing downstream. This effect has spurred political pressure to cut trees to increase water supply, especially in Western States where population is rising. However, cutting trees for water gains is not sustainable: increases in flow rate and volume are typically short-lived, and the practice can ultimately degrade water quality and increase vulnerability to flooding. So what is the answer? The primary driver of water yield in large basins is precipitation, which will likely become more variable with a changing climate. Optimizing long-term water yield, water quality, and healthy aquatic and terrestrial ecosystems will best be accomplished by keeping watersheds forested and in good condition and using available supplies as efficiently as possible. Efficient use can be facilitated through better information about the state of water storage in the snowpacks, water bodies,and soil in headwater watersheds. https://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf

Water

Conifer forests generally - The hydraulic model based on Darcy's law takes into account many of the physical characteristics of the hydraulic pathway between the stem and the foliage. For an individual tree, the volume flow rate of water through a tree stem of length is related to the cross-sectional sap-wood area, the water potential difference, the saturated permeability of the sapwood, and the viscosity of the water. In other words, larger trees generally store more water - Margolis et al. 1995 https://www.sciencedirect.com/science/article/pii/B9780080925936500128. Also - see Grier et al. 1977. Leaf areas of these stands were linearly correlated with a simple site H2O balance index computed from measurements of growing season precipitation, open pan evaporation, and estimates of soil H2O storage. Species composition had no apparent influence on the relation between community leaf area and site H2O balance. in other words,larger trees have more leaf area an greater water balance.
https://esajournals.onlinelibrary.wiley.com/doi/abs/10.2307/1936225

Grier and Running 1977. Leaf area of mature coniferous forest communities of western Oregon appears to be related primarily to site H2O balance rather than characteristics of tree species composing the community. Leaf areas were determined for stands in communities ranked along measured gradients of precipitation and evaporative potential. Nine coniferous and 1 deciduous tree species were found in the various stands along these gradients. Leaf areas of these stands were linearly correlated with a simple site H2O balance index computed from measurements of growing season precipitation, open pan evaporation, and estimates of soil H2O storage. Species composition had no apparent influence on the relation between community leaf area and site H2O balance.https://esajournals.onlinelibrary.wiley.com/doi/abs/10.2307/1936225. Brooks et al. 2002. In a 20-year-old Douglas-fir stand, approximately 28% of the water removed daily from the upper 2 m of soil was replaced by nocturnal hydraulic redistribution during late August. In an old-growth ponderosa pine stand, approximately 35% of the total daily water utilization from the upper 2 m of soil appeared to be replaced by hydraulic redistribution during July and August. Hydraulic redistribution would allow 21 and 16 additional days of stored water to remain in the upper soil horizons in the ponderosa pine and Douglas-fir stands, respectively, after a 60-day drought. Hydraulic redistribution may enhance seedling survival and maintain overstory transpiration during summer drought. These first approximations of the extent of hydraulic redistribution in these ecosystems suggest that it is likely to be an important process in both wet and dry forests of the Pacific Northwest. https://academic.oup.com/treephys/article/22/15-16/1107/1633834?login=true. Harmon and Sexton (1995). Seasonal and long-term changes in the water balance of conifer logs during the first 8 years of decomposition were studied in an old-growth Pseudotsuga/Tsuga forest in the Oregon Cascade Mountains. After the logs had decomposed from 1 to 2 years, 38–47% of the canopy throughfall landing upon them ran off the surface, 29–34% leached from the bottom, and 21–30% was absorbed and evaporated. After 8 years of decomposition, water entering and then leaching from logs increased 1.3 times while runoff decreased a similar amount. The proportion of water stored by and evaporated from logs in this study indicates that in old growth forests they may intercept 2–5% of the canopy throughfall to the forest floor and that, even in early stages of decomposition, they may affect the hydrological cycle of Pacific Northwest old-growth forests.https://link.springer.com/article/10.1007/BF00020868. Perry and Jones (2016). Average daily streamflow in summer (July through September) in basins with 34- to 43-year-old plantations of Douglas-fir was 50% lower than streamflow from reference basins with 150- to 500-year-old forests dominated by Douglas-fir, western hemlock, and other conifers. Young Douglas-fir trees, which have higher sapwood

Need to be aware of these studies asthey show burned and insect killed and drought stressed forests release more water than reference areas - which might be good for reservoirs but it will be argued this is why thinning is needed! The objectives of this study were to document net rainfall and snow water equivalent (SWE) in burned and unburned (reference) forest stands over a 10-year period to characterise the effects of severe wildfire on net precipitation in the Canadian Rocky Mountains. Differences in summer (June–September) rainfall between burned and reference stands suggest that wildfire reduced rainfall interception by 65%, resulting in a 48% increase in net rainfall from 2006 to 2008. This represented an average annual increase in net rainfall of 122 mm (36%) for 10 years after the fire. Similarly, a burned stand had 152 mm (78%) higher mean annual peak SWE than a paired reference stand. Collectively, burned stands had 274 mm (191–344 mm; 51%) more mean annual net precipitation for the first decade after fire. These results suggest that increases in net precipitation are likely following wildfire in subalpine forests and that, owing to the slow growth of these forests, post-fire changes may alter precipitation–runoff relationships for many years. https://www.publish.csiro.au/wf/wf18181. Reilly 2014. This research examined how mountain pine beetle MPB-disturbance affects the forest water balance in three plots in western Montana using direct observation and modeling methods. No significant differences in peak SWE and snowmelt timing were measured between the MPB-disturbed and non-disturbed due to the higher stand density and basal area. However, post-snowmelt measurements of soil moisture, rainfall, understory evapotranspiration and canopy transpiration indicated higher net precipitation and understory evapotranspiration in the MPB-disturbed plot. Additionally, soil moisture was higher in the MPB-disturbed plot, which was likely explained by the absence of canopy transpiration fluxes.https://scholarworks.umt.edu/etd/4235/. Emanual et al. 2010. Areas having tall vegetation and low topographic index experienced the greatest water stress, yet they had some of the highest evapotranspiration rates in the watershed (northern Rockies). https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2009WR008890. Vose et al. 2016. Management options may be implemented to minimize the impacts of drought on water quantity and quality. Examples include reducing leaf area by thinning and regenerating cut forests with species that consume less water, although a high level of uncertainty in both drought projections and anticipated responses suggests the need for monitoring and adaptive management.
https://www.sciencedirect.com/science/article/abs/pii/S0378112716301013.

However, here is a presentation and paper that counters claims about thinning to increase water yield - https://reclaimingthesierra.org/wp-content/uploads/2017/06/Douglas-Bevington_min.pdf. Also, here is the Rhodes and Frissell 2015 paper. https://legacy-assets.eenews.net/open_files/assets/2018/07/23/document_pm_01.pdfWater yield increases are highly variable and not amenable to accurate prediction solely as a function of the amount of forest removed. However, aggregate data indicate that, on average, only very modest increases in water yield can be expected. 🎬 At the scale of major watersheds which supply water, any actual water yield increase from forest removal is likely to be too small to verify via field flow measurement. 🎬 Increases are very strongly affected by seasonal precipitation. Flow increases aremost unlikely and smallest during dry years and during dry seasons. Thus, theapproach has very nominal potential to improve water yield during droughts. Same reasons, the approach is unlikely to provide additional water during dry seasons when demand is high relative to supply. 🎬 Increases are typically greatest during the period of highest runoff and during the wettest years. Due to this timing, any realized increases may have negligible benefits for water supply, while contributing to increased flooding. 🎬 Any increases in water yield from forest removal are diminished by transmission losses and storage losses, reducing any increase in downstream water supply. 🎬 Increased water yield in response to forest removal is transient. Any increases are erased by vegetative regrowth within several years after forest removal. In effect, forest removal promotes regrowth that exacerbates water demand by second-growth.

Wooten et al. 2016. Landsliding is a recurring process in the southern Appalachian Highlands (SAH) region of the Central Hardwood Region. Forest cover is an important stabilizing factor on hillslopes by intercepting precipitation, increasing evapotranspiration, and reinforcing roots. Precipitation and hillslope-scale landforms have a controlling effect on soil moisture, root strength, and debris flow hazards. Anthropogenic influences have increased the frequency of mass wasting for a given storm event above historical natural levels through changes in vegetation and disturbances on mountain slopes. Climate change that results in increased occurrences of high intensity rainfall through more frequent storms, or higher intensity storms, would also be expected to increase the frequency of debris flows and other forms of mass-wasting in the SAH. The interdisciplinary technical and scientific capacity exists to investigate, analyze, identify and delineate landslide prone areas of the landscape with increasing reliability.https://link.springer.com/chapter/10.1007/978-3-319-21527-3_9

Kolka et al. 2010. Partitioning hydrologic contributions to an 'old-growth' riparian area in the Huron Mountains of Michigan, USA. Abstract is vague and it's not open access but this would be good to get. https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.112

Jones et al. 2020. Forest cover has declined in the past half-century, despite an increase in plantation forestry. Natural and human disturbances affect forest components (e.g. canopy and leaf area, litter and soil surface, rooting depth, and soil porosity) that in turn affect hydrological processes (e.g. interception, evapotranspiration, infiltration, soil moisture storage, and percolation). Many of these changes result from several influential natural disturbance processes including insects and pathogens, wildfire, ice storms, and windthrow, and human disturbances including establishment and harvest of forests, plantations, agroforestry areas, and urban/peri-urban forests. However, each disturbance process affects different components of the forest, producing distinctive hydrologic effects. Climate change will directly alter forest hydrological processes, and social and economic factors will directly alter forest management, via intensive plantations, deforestation, forest degradation, selective logging, loss of riparian forest, and loss of urban trees, and changes in disturbance regimes. Despite extensive knowledge of forest hydrology, forest changes and their effects on hydrology are poorly documented in many areas of the world, and novel combinations of processes and contexts may produce surprising outcomes. Thus, there is a clear need for more geographically extensive and long-term place-based studies of forest and water. In summary, future climate and social changes will alter forests and water, requiring continued research and collaboration with forest managers and forest owners both for improved resilience to such changes, and to better realize multiple benefits.https://link.springer.com/chapter/10.1007/978-3-030-26086-6_24

Exhibit B: Mature Forests are Nature's Wellsprings for Clean Water

Forests play a pivotal role in the hydrological cycle that regulates the continuous circulation of water between the biosphere and the atmosphere. In doing so, forests help circulate precipitation by uptake of water from roots to canopies and the release of water back to the atmosphere via evapotranspiration through leaf pores. Simply put, forests can be thought of as giant water towers. Importantly, the water function of trees increases with tree size (maturation) because leaf area is related to site water balance and soil water storage/retention. Species composition has no influence on the relation between leaf area and site water balance, but tree size does matter. In other words, larger trees have more leaf area and greater water balance[1].

Forests also help reduce flooding by buffering streams from peak high flows – that is – they slow runoff through absorption and slow release of water. And they provide shade along riparian areas by keeping stream and ambient temperatures from overheating. The older and larger the trees, the greater the ecosystem benefits.

In contrast, the hydrological cycle can be disrupted by logging. For instance, deforestation of tropical rainforests (i.e., "rivers in the sky") has contributed to droughts in China, India, and the U.S. Midwest[2]. In the temperate zone, logging large, canopy trees, results in drier conditions, whereby the amount of sunlight and heat reaching the ground causes more evaporative losses and higher surrounding temperatures[3]. In sum, forest canopies regulate the rate at which moisture and heat are exchanged with the atmosphere from local to global scales, which in turn influences water retention and the makeup of forest ecosystems. Logging and development are known to produce downwind continental interiors with declining rainfall and water availability that heighten drought and wildfire risks[4].

Old-growth forests are essential for maintaining water balance in forested watersheds[5]. Analysis 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[6].

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[1] https://esajournals.onlinelibrary.wiley.com/doi/abs/10.2307/1936225

[2] Wolosin, M., and N. Harris. 2018. Tropical forests and climate change: the latest science. https://wriorg.s3.amazonaws.com/s3fs-public/ending-tropical-deforestation-tropical-forests-climate-change.pdf

[3] Wheeling, K. (2019), How forest structure influences the water cycle, *Eos*, *100*, https://doi.org/10.1029/2019EO134709. Published on 15 October 2019. Also - (https://eos.org/research-spotlights/how-forest-structure-influences-the-water-cycle

[4] Ellison, D., B. Muys, and S. Wunder. 2021. What role do forests play in the water cycle? https://efi.int/sites/default/files/files/publication-bank/2021/K2A%20-%20Forest%20Question%207.pdf

[5] Jjang et al. 2019 https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.2692 - Also Perry and Jones 2016)

[6] https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1790. Also see Frissell in Williams et al. 1997

In general, uncut watersheds with older forests and dense riparian vegetation are more hydrologically functional with have higher levels of terrestrial and aquatic biodiversity in several regions as follows.[7]

- In southeast Alaska, longevity of large woody debris (LWD) in streams was directly related to tree bole diameter: small LWD (10–30 cm in diameter) was less than 110 years old, whereas large LWD (>60 cm in diameter) was up to 226 years old. Changes in LWD after timber harvest indicated that 90 years after clear-cut logging without a stream-side buffer strip large LWD would be reduced by 70% and recovery to pre-logging levels would take more than 250 years[8].

- 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[9]. Further, logging has lasting impacts to evapotranspiration, water interception, snowmelt, flow routing, and streamflow that were still evident >50 years after clearcutting old-growth forests[10]. Large logs in old-growth forests also intercept 2–5% of the canopy throughfall to the forest floor and that too may affect the hydrological cycle when forests are logged in this region[11]. 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[12].

- In western Washington, the amount of large woody debris (LWD) surveyed in 70 stream reaches flowing through old-growth, clear-cut, and second-growth forests was greatest at old-growth sites (Bilby and Ward 1991). Changes in LWD amount, characteristics, and function occurred very rapidly following logging.

- In the coast redwood zone, standard rain gages installed in open areas where fog is common collected up to 30 percent less precipitation than in old-growth forests[13]. 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 region, logging resulted in increased stream sediment and nutrients, more variable flow, altered fish and wildlife habitat of stream and riparian communities,

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[7]Also see Ham 1982. Net precipitation under old growth Douglas fir forest in the Bull Run Municipal Watershed (Portland, Oregon) totaled 1739 mm during a 4Cbweek period, 387 mm more than in adjacent clearcut areas).
[8] https://www.tandfonline.com/doi/abs/10.1577/1548-
[9] https://cdnsciencepub.com/doi/abs/10.1139/X05-298. From Crampe et al. 2021
[10] https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.14168. From Harmon and Sexton 1995
[11] https://link.springer.com/article/10.1007/BF00020868
[12] https://research.libraries.wsu.edu/xmlui/handle/2376/989
[13]https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-1688.1982.tb00073.x

and increased risk of human health effects (floods) (Nagy et al. 2011). Importantly, the threshold to disturbance of the hydrological cycle can be quite low in this region and impacts from altered hydrological cycles may extend to other humid regions[14].

- In the southern Appalachian Highlands (SAH) of the Central Hardwood Region, landslides commonly occur[15]. Forest cover is an important stabilizing feature by intercepting precipitation, increasing evapotranspiration, and reinforcing roots. Logging 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.

- In the Mid-Atlantic and northeastern states, forests are vulnerable to disturbance and fragmentation from logging commercially mature forests[16]. Traditional stream restoration efforts throughout this region have limited success because many fluvial systems remain in a degraded state after a century of widespread logging. This is because by the mid-1800s sediment delivery to most streams greatly increased and channels were dredged, straightened, and cleared of trees and large boulders to facilitate log drives.

- Intact forested watersheds present in inventoried roadless areas also tend to be at the headwaters of streams with the cleanest drinking water source areas[17].

Finally, the issue of tree cutting for water yield has been politically charged, particularly in western and other drought-stricken regions[18]. Researchers have concluded that while removing forest cover can temporarily accelerate the rate that precipitation becomes streamflow, cutting trees for water gains is not climate smart management[19]. This is because increases in flow rate and volume are typically short-lived (pulse activity), and the practice can ultimately degrade water quality and increase vulnerability to flooding for extended periods (chronic impacts). Thus, optimizing long-term water yield, water quality, and aquatic and terrestrial ecosystem integrity is best accomplished by keeping watersheds in mature forest and intact condition.

[14] https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/jeq2010.0365
[15] https://link.springer.com/chapter/10.1007/978-3-319-21527-3_9
[16] https://link.springer.com/article/10.1023/B:EMAS.0000016882.72472.e1. Also - Hayes et al. 2019.
[17] DellaSala, D.A., J.R. Karr, and D.M. Olson. 2011. Roadless areas and clean water. Journal of Soil and Water Conservation 66:78A-84A. doi:10.2489/jswc.66.3.78A
[18] https://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf
[19] Rhodes, J., and C.A. Frissell. 2015. The High Costs and Low Benefits of Attempting to Increase Water Yield by Forest Removal in the Sierra Nevada. 108 pp. Report prepared for Environment Now, 12400 Wilshire Blvd, Suite 650, Los Angeles, CA 90025. http://www.environmentnow.org

Exhibit C: Protecting Large Trees and Older Forests in a Changing Climate
Dominick A. DellaSala, Ph. D, Chief Scientist, Wild Heritage, May 6, 2021

Executive Summary - This briefing paper is to inform decision makers about the importance of protecting large trees and older forests on federal lands in forestalling the climate and biodiversity crises. I counter misinformed claims about how the lack of "active management" from such protection measures would result in more extreme insect outbreaks, droughts, and wildfires. I explain serious limitations and tradeoffs of thinning over large landscapes in a changing climate. I show how studies have documented logging emissions in the south (92%), west (66%), and northern forests (86%) as far greater than natural disturbances responsible for only 5 to 15% of total emissions. In Oregon, net wood product emissions were nearly four-fold greater than that of a record fire year. Thus, the most expeditious way to reduce severe climate change consequences is to avoid emissions from anthropogenic sources including forestry and by storing more carbon in ecosystems by protecting carbon-dense older forests and large trees while allowing young forests time to fully recover diminished carbon stocks. Large trees are responsible for up to 50% or so of the aboveground carbon and most of that carbon is emitted when a forest is logged. Forest thinning is ineffective when it removes large trees, it will not stop or reduce the intensity of large disturbances governed mainly by climate change, and may elevate fire risks via flammable logging slash and fast-growing vegetation in clearcuts. Even if done judiciously, with large trees retained, the odds of a fire intersecting a thinned site are extremely small. Increasing the scale and pace of thinning will only compound tradeoffs and prove ineffective and costly given we can never know precisely where a fire will occur. Federal managers should be more surgical in limiting thinning to nearest homes and towns. Industrial logging has primed the fire pump to burn in uncharacteristic ways especially in extreme fire weather so more logging would not help. A new forest carbon management strategy is needed that retains carbon in large trees and older forests, and recovers the carbon debt from logging by allowing young forests time to mature.

Older Forests and Large Trees Can Help Close the Carbon Debt from Historic Logging And Avoid Additional Emissions

Historic forest losses - Three-hundred years of logging liquidated nearly all older forests initially in the eastern United States by the 1900s, while expanding westward and accelerating after WW II. The carbon released from logging remains in the atmosphere for centuries. The good news is much of the forests in the northeast are recovering as they approach maturity (but not yet old growth), and there are still significant tracks of older forests and large trees nationwide, particularly in the Pacific Northwest and Alaska. Protecting them – along with allowing already established forests time to regrow carbon stocks (Moomaw et al. 2019) and other forestry improvements – can begin to close the gap on depleted carbon stocks as discussed herein.

Large trees and carbon - Large trees are a major stock of above ground carbon and are in decline globally (Lindenmayer et al. 2012, Lutz et al. 2018) and regionally (e.g., Mildrexler et al. 2020, DellaSala and Baker 2020). Even though the growth of trees slows as they age, because of their large size, the absolute carbon they store (carbon stock) is much greater than that in younger trees (Stephenson et al. 2014). Recent studies show the largest 1% of trees in older forests worldwide store >50% of the total live-tree stand level carbon (Lutz et al. 2018). In the Cascades of eastern Oregon and Washington, the largest trees hold 33% to 46% of aboveground carbon (Mildrexler et al. 2020).

As trees increase in size, they acquire unique structural features associated with high levels of biodiversity and superior ecosystem benefits compared to young trees (Lindenmayer et al. 2014, Zoltan et al. 2020). This includes having large diameter, canopy emergence, complex upper tree branching (e.g., broken tops), tree cavities, and dense canopy matts comprised of epiphytes, mosses, and lichens that support an upper canopy ecosystem (Van Pelt 2007, 2008, Lindenmayer et al. 2014, DellaSala and Baker 2020). Large dead standing (snags) and downed logs present in abundance in older forests are vital for ecosystem functions such as nutrient cycling, below-ground processes, carbon storage, forest succession, and aquatic ecosystem woody debris inputs. These important features are generated during pulse (periodic) disturbance events that then sustain ecosystem functions for decades (DellaSala 2020). They are the legacies of older forests that then jump start the renewal post-disturbance process.

Critics of large tree protections are missing the forest for the carbon – Some argue that large tree protections would prevent “restoration” of historic fire regimes, as in eastern Oregon and Washington where the US Forest Service has removed large tree protections (Johnston et al. 2021). However, that argument is specious mainly because: (1) removing protections allows broad discretion by managers to log the largest (>30 in dbh) fire-resistant trees that have (and still are) accumulating substantial carbon stocks (Mildrexler et al. 2020); (2) it is supported by only a handful of localized studies using very limited fire-scar sampling to set the historic baseline at an artificially low large tree density that is then inappropriately extrapolated over a large landscape and ignores historical evidence to the contrary (DellaSala and Baker 2020); (3) ignores the substantial CO_2 released to the atmosphere from accelerated logging (Hudiburg et al. 2019, Mildrexler et al. 2020, DellaSala and Baker 2020); and (4) does not consider the ecological tradeoffs (DellaSala and Baker 2020). In a climate emergency where every year of emissions to the atmosphere is a setback, logging large trees is counter-productive especially when they remain below historic levels (DellaSala and Baker 2020).

Natural Disturbances Produce Far Less Emissions Than Logging Over Comparable Area
Reoccurring wildfires, insect outbreaks, droughts and storms are essential to the integrity of forest ecosystems as they reset natural forest succession, create canopy gaps, recycle soil nutrients and provide a critically important pulse of biological legacies (snags, logs, shrubs; DellaSala 2020) associated with extraordinarily diverse complex early seral forests (DellaSala and Hanson 2015). Ecosystem are resilient to pulse disturbances that operate within natural bounds (DellaSala 2020). In contrast, chronic (also called press) anthropogenic disturbances

accumulate over space and time (Paine 1998) such as logging large trees and older forests and associated road building.

When a forest or tree dies from natural causes (e.g., wildfire, insects, drought), most of its stored carbon remains in the trees and forests for decades. Carbon simply transfers from the living into the dead carbon pools and soils maintain carbon for millennia if not logged (Mitchell 2015). Even when the standing dead tree (snag) falls and then decomposes over decades, new growth is taking up carbon. Overall, U.S. forests continue to be major net carbon sinks even with periodic natural disturbances (CRS 2020). By contrast, logging greatly increases carbon emissions especially compared to natural disturbances like fire and insects (see below). In a climate emergency, keeping emissions, especially from logging, out of the atmosphere matters most (Mackey et al. 2013, Law et al. 2018, Moomaw et al. 2019). To paraphrase, Dr. Beverley Law (Oregon State University), carbon is slow to enter the forest via sequestration but fast to leave it via logging.

Importantly, Harris et al. (2016) monitored net forest carbon exchange (flux) in forests from 2006-2010 across the nation, noting that carbon losses were greatest from logging compared to natural disturbances. C loss in the southern US was highest (105 ± 6 Tg C year−1) with greatest contributions from logging (92%) and wind storms (5%). C loss in the western US (44 ± 3 Tg C year−1) was due predominantly to logging (66%) vs. fire (15%) and insect damage (13%). The northern forests had the lowest C loss (41 ± 2 Tg C year−1) but most of it was from logging (86%) vs. insects (9%) and forest conversion (3%). Additionally, Law et al. (2018) reported Oregon's net wood product emissions from 2001-2005 were nearly four-fold greater than that of a record fire year.

Large Trees are Naturally Resistant to Wildfires

As trees increase in size, they acquire properties that insulate them from low-moderate wildfires, including natural pruning of lower branches, thick bark, and tall crowns (Agee 1993). Large ponderosa pine and Douglas-fir are generally resistant to most fires. As these trees develop thick bark and naturally prune lower branches their resistance builds up (generally at diameter >20 in dbh, ~80 years) (Agee 1993). Giant Sequoia are among the most fire-resistant trees on the planet, capable of withstanding flame lengths reaching into their crowns (Sillett et al. 2019). Large western larch, various pines, and many other conifers all have insulating bark properties difficult to burn as they mature (e.g., see Agee 1993, Hood et al. 2018) while others have thin bark and either are fire avoiders (shade intolerants) or need to burn to release seeds (Hood et al. 2018). Additionally, older forests generally burn in lower fire intensities (Lesmeister et al. 2019) especially compared to logged areas (Bradley et al. 2016). Lower fire intensities in older forests are mainly due to the preponderance of large fire-resistant trees, structurally diverse canopies that break up fuel continuity, and moist microclimates created by shading and downed logs (e.g., Odion et al. 2004). Downed logs serve as natural fire breaks as they readily absorb moisture and retain it even during summer droughts (Harmon 1995).

Notably, if an intense wildfire occurs in a forest, large dead trees (standing and down) contribute mainly to burn duration as there is no canopy fuel to carry fire into tree crowns. That is - they do not contribute to rapid fire spread or high burn intensity. By contrast, rapid fireline spread, including fire that reaches into the tree crowns, are characteristic of uniform tree plantations (continuous fuels) where small trees are densely packed and logging slash is prolific (Odion et al. 2004). Thus, industrial logging has actually primed the fire pump to burn in uncharacteristic ways (Bradley et al. 2016, Zald and Dunn 2018) while retaining large trees and mature forests best prepares a forest for more natural mixed intensity burn effects (Lesmeister et al. 2019).

Thinning Large Trees Is Ineffective at Altering Natural Disturbances

Thinning on federal lands often includes large trees to offset the cost involved, on the mistaken rationale that it is needed to reduce the intensity of natural disturbances such as wildfires, insect outbreaks and drought (tree stress) and to create forest gaps for heterogeneity. I counter each of these as follows.

Wildfires - Under certain conditions (low-moderate fire weather), thinning can reduce fire intensity but only IF all of these factors are in place: (1) large trees and overstory canopies are fully retained; (2) logging "fuels" are treated with prescribed fire (broadcast burn, not pile burns that cause soil damages); (3) roads are closed (preferably decommissioned) to reduce human-caused ignitions; and (4) other land-use stressors removed to limit spread of invasive flammable weeds (see review in DellaSala et al. 2018). Even if done properly, there is <1% chance of a thinned site encountering a wildfire during the very short period when flammable vegetation is lowest (~10-15 yrs; Schoennagel et al. 2017) and there are substantial tradeoffs in carbon from greater emissions due to logging compared to if the area had burned (Mitchell et al. 2009, Campbell et al. 2011, Law et al. 2013). And while some argue for even more thinning to increase those odds (e.g., Hessburg et al. 2016), we still do not know precisely where a fire will occur, irreparable harm will come to ecosystems and the climate from soil damage, invasive species, carbon emissions, large tree removals, degraded wildlife habitat, fish, water quality, and endangered species, and it may not even work for the reasons noted (reviewed in DellaSala et 2018). All of these tradeoffs would be compounded, as thinning requires ongoing site maintenance (every 10 years or so) and a well-maintained, costly, and damaging road system leading to even more impacts and expenditures. Notably, thinning large trees opens the canopy to increased wind penetrance that can then contribute to greater fire spread rates, dries out the understory, and, within years, produces more flammable vegetation from regrowth. This is why it is essential to maintain large trees in thinning operations.

Recognizing the increasing role of extreme fire weather (Abatzoglou and Williams 2016) in governing fire behavior and low odds of fire encountering properly thinned sites, many scientists are recommending treatments should focus on cost-effective home-hardening and defensible space (Moritz et al. 2016, Schoenaggel et al. 2017). That is – working from the home outward, instead of the wildlands inward (http://bit.ly/Home-Outward-Report-2021). Doing so, means fire-hardened homes would have >90% chance of making it through a fire event (Cohen 2000, Syphard et al. 2012, 2014).

Insects - If done properly (as noted), thinning can reduce tree stress in, for instance, a tree plantation. However, thinning does not reduce the intensity or duration of an insect outbreak in progress and can actually make the situation much worse by removing naturally resistant large trees (Black et al. 2013). The biggest insect infestations run unchecked when they encounter forestry-homogenized landscapes lacking large trees and a diversity of tree species that otherwise provide habitat for insect predators, which in turn, can lengthen the period between outbreak cycles (see Black et al. 2013 for comprehensive review). Notably, contrary to agency views about insect outbreaks exacerbating wildfire intensity, outbreaks only result in a short-lived increase in flammable canopy levels when conifers are in the very early stages of an outbreak and have dead needles. This lasts for about 1-3 years before needles fall to the ground and the canopy is devoid of flammable needles (e.g., Donato et al. 2013). In fact, outbreak areas that then encounter wildfires most often burn in low fire intensities (Six et al. 2014, Hart et al. 2015, Kulakowski and Veblen 2015, Meigs et al. 2016). This is true even when the dead trees eventually fall down because they do not fall all at once and do not contribute to fire spread given fire spread is mainly a problem of fine fuels (needles, twigs, branches) not large fuels.

Drought stress –mortality increases when trees are densely packed and stressed by competing for limited nutrients and soil moisture. This may intensify where climate change triggers extensive droughts that pre-dispose trees to insect outbreaks and other natural stressors (e.g., Rocky Mountains). However, thinning large trees would only exacerbate such effects by removing habitat structure for predatory bats, birds, and small mammals that provide natural checks and balances of insect outbreaks (Black et al. 2013). And just like reported above, the lack of a live forest canopy after insect-kill means if a fire were to occur it would likely be low intensity. Notably, under future climate scenarios, researchers (Law et al. 2018) have postulated greater net C uptake due to CO_2 fertilization may outweigh tree mortality losses from fire and drought.

Forest Gaps - because most wildfires, at least in western pine and mixed conifer forests, are of mixed intensities (i.e., burn in a mosaic pattern at the landscape scale), they generate large and small unburned to severely burned patches that create heterogeneity within and among forest stands (DellaSala and Hanson 2015). Some gap functions at the stand level can be mimicked by girdling trees to generate snags or tipping trees into streams for aquatic ecosystem functions. Killing large trees can be used in places where in-growth of fire intolerant trees (e.g., large firs) has raised concerns about competition with pines. In this case, dead trees then reduce competition with pines, provide habitat structure, retain the carbon on site, and can be used to improve stream habitat. However, natural disturbances in most places will more than suffice gap creation as even with fire suppression acres burning have been rising since the 1980s (Abatzoglou and Williams 2016), and hurricanes on the east coast are more common and intense due to climate change (see https://yaleclimateconnections.org/2019/07/how-climate-change-is-making-hurricanes-more-dangerous/).

Conclusions

Storing carbon in large trees and older forests while allowing already established young forests time to recover carbon stocks (Moomaw et al. 2019) is critical in climate mitigation policy (Zoltan et al 2020). Keeping carbon in the forests and large trees along with keeping fossil fuels in the ground are the most expedient solutions to the climate and biodiversity crises. Anytime large trees and older forests are logged, a cost is inflicted to the ecosystem and atmosphere. In a climate emergency, the price of forestry is compounded over centuries of emissions, adding to the overall carbon debt in forests and associated climate consequences. Forgoing thinning or other forms of logging does not mean the risks of fire, insects, and other natural disturbances would rise, in fact, the opposite is true. As the climate increasingly overheats and dries out in places, the efficacy of thinning will be called into even more question as extreme fire weather over-rides vegetation treatments (DellaSala et al. 2018). Thus, thinning needs to be more surgically applied by focusing on small trees (Hurteau et al. 2019), tree-killing methods that address in-growth of large trees in places rather than removing them for commercial value, and targeting areas closest to homes and towns. A new forest carbon management needs to be adopted whereby carbon retention in large trees and recovering the carbon debt from logging by allowing young forests time to mature is given higher importance in management decisions. Doing so, would mean a broad suite of ecosystem services, biodiversity, and ecosystem integrity are also maintained (Brandt et al. 2014).

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Exhibit D: Large Dead Trees Are Not a Fire Hazard or Major Source of Carbon Emissions
Dominick A. DellaSala, Ph. D, Chief Scientist, Wild Heritage

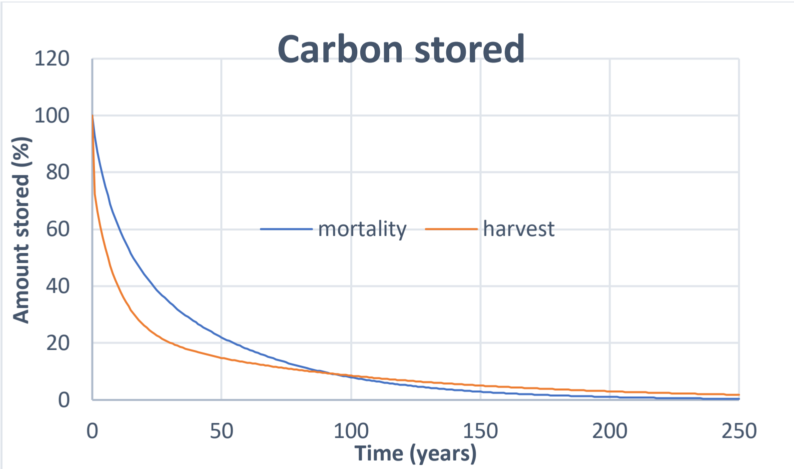
Forests are rejuvenated through natural tree mortality caused by insects, diseases, pathogens, wildfires, and weather events (to name a few). When a tree or large areas of forests die back, the dead trees perform vital ecosystem services such as nutrient cycling and act "biological legacies" (e.g., large dead trees – snags and logs) that transfer their ecological functions from the pre- to post-disturbed forest (DellaSala 2019). Dead trees also contain substantial carbon reserves for decades (especially in soils and root wads) while new vegetation naturally reseeding jumpstarts sequestration. In contrast, most forestry practices result in very few large dead trees, as in a tree plantation, and are not a healthy forest as often claimed. Large tree mortality also is not a major contributor of fire hazard or emissions. The combination of extreme fire weather, increasing mostly in western forests, and industrial logging has predisposed forests to greater die back, wildfires, and emissions in a dangerous feedback loop (e.g., Zald and Dunn 2018, Lindenmayer and Sato 2018, Lindenmayer et al. 2021).

Tree Mortality is Varied but Typically Highest in Young Forests – tree mortality levels have been increasing with climate change (e.g., droughts, high temperatures) (van Mantegem et al. 2009). However, it is important to note that while mortality rates are climbing in places, young trees often have higher mortality. For instance, in mature Douglas-fir forests of the Pacific Northwest annual mortality rates averaged $\leq$1% compared to more than twice that in 45 to 80 year-old stands, with some young stands exceeding 5% (Lutz and Halpern 2006, also see Larson et al. 2015). Additionally, mature deciduous forests in the eastern US had an annual mortality of ~1% and giant sequoia in northern California had annual mortality rates of 0.3% in 1100-year-old stands (Lutz and Halpern 2006). Mortality rates in younger forests in general tend to be highest because of tree competition in the early stages of forest succession (Larson and Franklin 2010). However, young trees in dry forests of Oregon have been shown to survive insect outbreaks and therefore they too confer resilience (Baker and Williams 2015). In general, mortality has mostly been concentrated in low elevation Douglas-fir subject to unprecedented droughts, climate-related increases in overwintering beetles (Harvey et al. 2014), and high elevation forests subject to temperature stress (Stanke et al. 2021). Logging can intensify all of these effects (Paine et al. 1998).

Large Dead Trees are Not a Major Fire Hazard (*note for this section all citations for insect outbreaks are already available as hyperlinks in the main comments) – Perhaps the most illustrative means to examining potential fire hazards from large tree die offs is beetle-killed forests in the western USA. In the San Bernardino Mountains of California, for instance, researchers found pre-fire beetle kill forests were unrelated to subsequent fire severity and that the locations dominated by the largest trees (>24 in dbh) burned in lower fire severities compared to smaller (11-24 in dbh) trees that burned more severely (Bond et al. 2009). In the Greater Yellowstone Ecosystem, beetle-killed forests had lower canopy and surface fuels, representing reduced fire potential in outbreak stands (Donato et al. 2013). The net effect of beetle-kill was to shift stand structures from closed canopy mesic forests toward more open conditions with lower canopy fuels. Additionally, contrary to the supposition of increased wildfire activity in recently infested stands, researchers found no increase in fire severity during the red (1-3 years post outbreak) or subsequent gray-needle stage (4-14 years post outbreak) in peak wildfire activity years (Hart et al., 2015). They concluded "although MPB [mountain pine beetle] infestation and fire activity both independently increased in conjunction with recent warming, our results demonstrate that the annual area burned in the western United States has not increased in direct response to bark beetle activity."

Similarly, in a comprehensive review of western forests, researchers found that insect outbreaks actually decreased live vegetation susceptible to wildfire by reducing subsequent burn severity (Meigs et al. 2016). They concluded, "native insects could buffer rather than exacerbate fire regime changes expected due to land use and climate change" and recommended "a precautionary approach when designing and implementing forest management policies intended to reduce wildfire hazard and increase resilience to global change." Interestingly, surviving trees may possess unique genetic adaptations to subsequent outbreaks that are heritable (Six et al. 2018). However, often surviving resilient trees are included in timber harvests and adaptive traits are not carried forward. Finally, in a literature review of presumed efficacy of timber harvest on suppressing beetle outbreaks, researchers concluded, "given the uncertainty about the effectiveness of many beetle timber harvest treatments, the high financial costs of those treatments, the impacts on other environmental resources and values, and the possibility that in the long-run those treatments may interfere with the ability of North American forests to adapt to climate change, our position is that weakening or eliminating environmental laws to allow more beetle timber harvest treatments is the wrong choice for advancing forest health in the United States (Six et al. 2014).

Large Dead Trees Are Not a Major Source of Fire Emissions – simply stated, wildfires do not consume massive amounts of vegetation leading to major greenhouse gas releases. Instead, most fires – even the largest and severest ones – consume the living biomass (needles, leaves, twigs, duff, ground foliage), which is a small portion of the overall combustible materials in a forest that mostly consists of the soils, tree boles, and roots present after fire (Mitchell 2015). Highest combustion factors measured postfire have been shown to be in small trees and not the large ones due to their fire susceptibility (Mitchell 2015). Simulation modeling by Dr. Mark Harmon, emeritus professor Oregon State University, for western conifer forests shows more carbon is lost rapidly in initial decades from logging compared to wildfires in western forests (personal communications).



In addition, using simulation modeling, researchers showed that for every unit of carbon protected from wildfire combustion (e.g., if thinning works), the cost to the atmosphere from removal was ~3 units of carbon (Mitchell 2015).

Importantly, in a nationwide synthesis of emissions from natural disturbances vs. logging, researchers concluded that carbon loss in the southern US was >18 times greater from timber harvest compared to wind; in the western US logging released ~4-5 times more emissions than wildfire and insects, respectively; and in the northern US timber harvest released ~9-29 times more emissions than insect damage and forest conversion losses, respectively (Harris et al. 2016). Additionally, in natural forests sequestration post-disturbance is usually rapid compared to logged areas that function as sequestration dead zones until young trees begin uptake (https://sustainable-economy.org/wp-content/uploads/2017/12/Oregon-Forest-Carbon-Policy-Technical-Brief-1.pdf).

In conclusion, trees die, forests burn, these are natural processes and they are increasing in places due to climate change. Putting even more emissions into the atmosphere by logging forests based on the baseless assumption that logging will reduce fire intensity, tree mortality, and emissions is unsupported and dangerous. Protecting forests from logging that include large dead trees will not increase fire hazards appreciably, especially when compared to timber harvest (logging slash, removing fire resistant large trees) that releases more emissions than natural disturbances and does nothing to prevent insect outbreaks (Black et al. 2013). The carbon removed from the forest to reduce what is a perceived benefit is not worth the cost to the forest or the atmosphere.

Exhibit E Black Ram Project

February 17, 2021

Robert Bonnie, Deputy Chief of Staff for Policy
U.S. Department of Agriculture
1400 Independence Avenue, S.W.
Washington, DC 20250
Robert.bonnie@usda.gov

Re: Black Ram Project's Climate Analysis Ignores Sound Science, Undermining President Biden's Policies

Dear Deputy Chief of Staff Bonnie:

We understand that the U.S. Department of Agriculture is reviewing the Kootenai National Forest's proposed Black Ram project because it threatens to conflict with policies of the Biden administration. We write recognizing that the climate analysis for the project conducted under the Trump administration was not informed by reliable science and inappropriately dismisses climate impacts that would accrue from clear-cut logging and road building on 900 acres of mature forests and 57 million board feet of timber. Such a large-scale timber sale typifies the Trump administration's neglect for carbon accounting and emissions reductions and is inconsistent with the Biden administration's focus on climate mitigation informed by the best available science.

On the day he was inaugurated, President Biden committed to directly addressing the climate emergency: "It is… the policy of my Administration to listen to the science… [and] to reduce greenhouse gas emissions."[1] He acknowledged that "it is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account".[2] The president said his administration must "drive assessment, disclosure, and mitigation of climate pollution and climate-related risks in every sector."[3]

To comply with the President's directives, we urge the USDA to ensure that the Forest Service carefully accounts for logging that degrades carbon stores. Recent studies demonstrate that logging older forests releases up to two-thirds of on-site carbon and delays sequestration for over a decade, setting up a carbon debt that cannot be mitigated for by planting trees or storing a small portion of the carbon in wood product pools.[4] The volume of those carbon losses can be quantified.[5] Studies also confirm that the most effective way to maintain forest carbon stores is to allow trees to mature over time, not to log them and convert them to wood products.[6] A 2019 report found that protecting Northwest national forests, including those in Montana, could substantially reduce the contribution of land management to climate pollution[7].

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[1] Executive Order 13,990, 86 Fed. Reg. 7037 (Jan. 20, 2021) at Sec. 1.
[2] *Id.*, 86 Fed. Reg. at 7040, Sec. 5(a).
[3] Executive Order 14,008, 86 Fed. Reg. 7619, 7622 (Jan. 27, 2021) at Sec. 201
[4] *See* B. Law, *The Status of Science on Forest Carbon Management to Mitigate Climate Change* (June 1, 2020), attached. T. Hudiburg *et al.*, Meeting GHG reduction targets requires accounting for all forest sector emissions, Environ. Res. Lett. 14 (2019).
[5] B. Law et al., *Land use strategies to mitigate climate change in carbon dense temperate forests*, Proceedings of the Nat'l Academy of Sciences, vol. 115, no. 14 (Apr. 3, 2018).
[6] T. Hudiburg *et al.*, Meeting GHG reduction targets requires accounting for all forest sector emissions, Environ. Res. Lett. 14 (2019).
[7] P. Buotte *et al.*, *Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States*, Ecological Applications, Article e02039 (Oct. 2019) at 8, available at https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/eap.2039.

In light of this scientific information, the Kootenai National Forest should have conducted a robust study of the Black Ram project's impacts on carbon stores and logging emissions. The Kootenai "Carbon Report" fails to do so and[8] --

- Cursorily dismisses the importance of mature and intact forests to maintain carbon stores, concluding that "[t]he Black Ram Project would affect only a tiny percentage of the forest carbon stocks of the Kootenai National Forest, and an infinitesimal amount of the total forest carbon stocks of the United States".[9]

- Declines to quantify climate impacts, providing only a "qualitative analysis".[10]

- Fails to consider any science concerning climate change and/or carbon sequestration published in the last eight years.[11]

The Black Ram's Carbon Report constitutes climate and science denial. The report's glib assessment that impacts from logging at the scale of hundreds or thousands of acres cause negligible impacts on the climate is disingenuous and dishonest. That is the fundamental difficulty at the heart of climate change. Climate change is the product of thousands of different decisions, yet each one adding to and worsening a problem that threatens our health, climate safety, and all uses on the national forests.

The Kootenai National Forest's failure to acknowledge peer-reviewed scientific approaches to estimate carbon flux from logging and road building conflicts with President Biden's directive that federal agencies now must "listen to the science," and must "drive assessment, disclosure, and mitigation of climate pollution and climate-related risks in every sector of our economy." We request that the Forest Service now protect all mature, carbon-dense forests on the Kootenai, and on all other national forests, in fulfillment of the president's 30 x 30 executive order. As such, mature carbon-dense forests need to be enrolled in a "strategic natural carbon reserve"[12] reflecting the administration's developing nationally determined commitments to the Paris agreement.[13]

To comply with President Biden's climate vision and the Paris agreement, we urge the USDA to repudiate the un-scientific approach used by the Kootenai National Forest for the Black Ram Project, reverse previous findings, and hold the project in abeyance unless and until the Forest Service completes a robust analysis of the project's life-cycle carbon impacts.

Thank you for your attention to this matter. We look forward to your reply.

Sincerely (*affiliations are for identification purposes only),

Dominick A. DellaSala, Ph. D
Chief Scientist, Wild Heritage, Talent, OR

William J. Ripple, Ph. D
Richardson Endowed Chair & Distinguished Professor Ecology, Dept. Forest Ecosystems & Society, Oregon State University, Corvallis

[8] *See* N. Macy, Kootenai Nat'l Forest, Black Ram Carbon Report (Apr. 12, 2019), attached.
[9] *See id*. at 5.
[10] *Id*. at 1.
[11] *Id*. at 7-10.
[12] DellaSala et al. 2020 https://www.seattletimes.com/opinion/a-strategic-natural-carbon-reserve-to-fight-climate-change/.
[13] *See* UNFCC, Paris Climate Agreement, Article V (2015) ("Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases," including forests).

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Chris French, Associate Deputy Chief, National Forest System, chris.french@usda.gov

Enc.: B. Law, *The Status of Science on Forest Carbon Management to Mitigate Climate Change* (June 1, 2020)
N. Macy, Kootenai Nat'l Forest, Black Ram Carbon Report (Apr. 12, 2019)

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The science behind environmental solutions

President Emeritus
William H. Schlesinger

28 August 2022

VIA https://cara.fs2c.usda.gov

Randy Moore
Chief
U.S. Forest Service
1400 Independence Ave. SW
Washington DC 20250

Tracy Stone-Manning
Director
Bureau of Land Management
1849 C Street
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Re: Request for Information on Federal Old-growth and Mature Forests

Dear Chief Moore and Director Stone-Manning:

We are writing as experts in climate change and natural resource sciences, responding to a comment request by the U.S. Forest Service and Bureau of Land Management regarding definitions of old-growth and mature forests on Federal land. Your agencies seek this input as part of implementing the recent Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies. That order recognizes the importance of mature and old-growth forests in limiting climate change and makes their conservation a national policy. It also sets a number of ambitious goals for the Forest Service and BLM, including "to conserve our mature and old-growth forests on Federal lands and restore the health and vibrancy of our Nation's forests by reducing the threat of catastrophic wildfires through ecological treatments that create resilient forest conditions."

As you consider how to define mature and old-growth forests for these and related purposes, we urge you to provide local officials with straightforward tools that will yield reliable and comparable results for the many different forest types on our nation's public lands. For some decisions, for example about mapping and protecting mature and old-growth stands, forest managers will need definitions that are multi-faceted and location specific. They can, nonetheless, be phrased in terms that are readily applied in the field without specialized expertise. The essential metric for climate mitigation is the amount of carbon stored per acre in aboveground live and dead biomass. For purposes of carbon conservation, because mature and older forests accumulate and store the greatest amount of carbon over time, they could be defined as those with relatively high carbon per unit of ground area, *sensu* Law et al., 2021,[1] among stands of similar species composition within an ecoregion (so delimited as to account for major soil and climate influences). Similarly, a benchmark such as medium to high amounts of critical

[1] Law, B.E., Berner, L.T., Buotte, P.C. *et al.* Strategic Forest Reserves can protect biodiversity in the western United States and mitigate climate change. *Commun Earth Environ* **2**, 254 (2021). https://doi.org/10.1038/s43247-021-00326-0.

habitat and species richness can be used to define mature and older forests that are high priority areas to protect for biodiversity purposes. This approach would identify priority mature and older stands to conserve for vital functions within each forest type and region.

Additionally, your agencies should adopt a uniform definition and logging prohibition for large individual mature trees nationwide. These are specimens that provide our most durable above-ground forest carbon storage—even if killed by insects, disease, or fire. They and their carbon could be lost to logging in a variety of ways, even given protection of the most carbon-rich stands (those with high carbon density). Such trees could occur outside stands identified as mature or old-growth, fall to silvicultural treatment of mature stands, and be logged where mature stands are locally abundant. To guard effectively against such avoidable losses of carbon storage, agencies should avoid logging and removal of large mature trees, defined by diameter and height as those that across federal forests hold most of the above-ground carbon density.

The Roadless Rule is a good model for ensuring that when logging is authorized, it does not cause serious losses of carbon. The Forest Service has used that regulation for more than two decades to protect wildlands. It provides local managers with a simple, readily applied prohibition on most logging and associated road-building in unroaded areas over 5,000 acres (and in some cases smaller ones). It has a set of defined exceptions for legal obligations and special considerations, such as fuel management of generally small-diameter trees. And it helps the agency protect some of its—and the public's—most important natural assets from controversial, potentially damaging, and avoidable management impacts.

In summary, straightforward definitions of maturity will support implementation of the executive order in two essential regards. For most ecologically based decision-making, the key areas are those stands with relatively high density of carbon (i.e., tons per acre) and biodiversity per acre (e.g. species richness and critical habitat), for the forest type and ecoregion. And, where logging is authorized in mature stands or younger mixed-aged ones, a simple metric should protect at a minimum the large or old trees that store the most above-ground carbon—just as the Roadless Rule protects wildlands above a minimum size nationally.

Thank you for considering our advice.

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IMPORTANCE OF LARGE TREES AND MATURE/OLD-GROWTH FORESTS OF ALL TYPES TO HELP STEM THE BIODIVERSITY AND CLIMATE CRISES

"As a researcher of old-growth forests and old trees I am strongly convinced that every possible old tree should be preserved if possible. We have lost too many of those living witnesses of the past. Old trees and old-growth forests are the "island" containing the genes of resilience, which is increasingly important in these times of climate extremes and forecasts of warming and more extreme climate."
Dr. M Panayotov, University of Forestry, Bulgaria

Submitted to www.regulations.gov regarding Advanced Notice for Proposed Rulemaking (36CFR Part 200)

As scientists with expertise in forest ecosystems, climate change, and natural resources, we fully support global efforts to protect large trees and old forests (mature and old growth) from logging along with restoring logged forests as natural climate solutions[1]. In response to President Joe Biden's Executive Order 14072 on forests and climate change, federal agencies are in the process of formulating conservation policies for large trees and old forests in the United States via national rulemaking. We urge conservation groups, decision makers, and land managers to maximize protection of **large trees of all species as well as mature and old-growth forests** as the nation's most effective "climate-smart forestry" approach. Simply put, there is no substitute for their outsized role, and no ecological reason to log large trees and old forests. Many of the current and proposed forest management actions in the US are inconsistent with climate goals and global efforts to protect 30% to 50% of lands for myriad ecosystem and biodiversity benefits[2].

Large, old trees are among the biggest terrestrial organisms on the planet but are on the decline globally mainly due to logging and development[3]. These trees and old forests that harbor them are the most critical terrestrial sinks and easily scalable climate mitigation opportunities at our disposal. They are also essential to soil integrity and complexity, water circulation, stable microclimates, nutrient exchange, and wildlife habitat, regardless of whether the trees are alive or dead. Protecting them enables irreplaceable ecosystem services and biodiversity benefits, including habitat for hundreds of imperiled species[4]. Importantly, while large trees make up just 1% (globally)[5] to 3% (eastern Oregon)[6] of the overall tree density in older forests, they contain 50% to 42%, respectively, of the above ground carbon in forests. As they age, large trees and old forests continue to sequester and accumulate massive amounts of atmospheric carbon in biomass and soils[7]. From a climate and biodiversity perspective, it is essential not to log the large trees and old forests. Broad-scale thinning (e.g., ecoregions, regions) to reduce fire risk or severity results in more carbon emissions than fire, creating a long-term carbon deficit that undermines climate goals[8].

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[1]Lindenmayer et al. 2012. Global decline in large old trees. Science Vol 338:1305-1306. 10.1126/science.1231070. Mackey et al. 2015. Policy options for the world's primary forests in multilateral environmental agreements Conservation Letters 8:139-147 doi: 10.1111/conl.12120. Griscom et al. 2017. Natural climate solutions. PNAS 114 pnas.org/cgi/doi/10.1073/pnas.1710465114. Moomaw et al. 2019. Intact forests in the United States: proforestation mitigates climate change and serves the greatest good. Frontiers in Forests and Global Change https://doi.org/10.3389/ffgc.2019.00027. Law et al. 2022. Creating strategic reserves to protect forest carbon and reduce biodiversity losses in the United States. Land 2022, 11, 721. https://doi.org/10.3390/land11050721. DellaSala et al. 2022. Mature and old-growth forests contribute to large-scale conservation targets in the conterminous United States. Frontiers in Forests and Global Change https://doi.org/10.3389/ffgc.2022.979528. Faison et al. 2023. The importance of natural forest stewardship in adaptation planning in the United States. Conservation Science and Practice 2023;e12935. https://doi.org/10.1111/csp2.12935.
[2]Law, B.E. et al. 2022. Ibid
[3]Lindenmayer et al. 2012. Ibid. Lutz et al 2018. Global importance of large diameter trees. Global Ecol Biogeogr:1-16.
[4]Brandt et al. 2014. Multi-functionality and biodiversity: ecosystem services in temperate rainforests of the Pacific Northwest, USA. Biol. Cons.169:362-71. http://dx.doi.org/10.1016/j.biocon.2013.12.003. Buotte et al. 2020. Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States. Ecol. Applic. 30(2), 2020, e02039. Morgan et al. 2021. Capturing multiple forest ecosystem services for just benefit sharing. The basket of benefits approach. Ecos. Services https://doi.org/10.1016/j.ecoser.2022.10142. Law et al. 2022. Ibid. DellaSala et al. 2022. Ibid.
[5]Lutz et al. 2018. Ibid
[6] Mildrexler et al. 2020. Ibid
[7] Stephenson et al. 2014. Ibid. Birdsey et al. 2023. Assessing carbon stocks and accumulation of mature forests and large trees in U.S. federal forests. Frontiers in Forests and Global Change https://doi.org/10.3389/ffgc.2022.1074508.
[8]Law et al. 2022. Ibid

In the US, most large trees and old forests were eliminated decades ago following European colonization and expansion. What remains is mostly on federal lands[9] that are vital to restoring forest ecosystems from the coastal rainforests of Alaska and the endemic *Sequoia giganteum* groves of California to mixed hardwoods, pines, oaks, cypress and many other forest types across the country. We note this includes protecting forests affected by insect outbreaks and characterized by **frequent and infrequent fire return intervals and mixed fire severities**. Notably, large trees and old forests tend to be the most fire and drought resistant ecosystem elements, serving as critically important fire[10] and climate refugia[11]. They also contain unique genetic adaptations for conferring resilience to natural disturbances and climate change[12]. Increased forest protections would not result in greater fire risks[13] but would instead allow forest managers to focus limited resources on previously logged and degraded forests that are more likely to burn and be located near residences. However, large trees have often been inappropriately targeted in "fuel reduction" by land managers,[14] despite myriad benefits and relative fire resistance and resilience.

In some regions (e.g., eastern Cascades of Oregon/Washington, Appalachia, northeast, Great Lakes), large tree densities and older forests have increased due to restrictions on logging and fire suppression policies but still remain far below historical levels due to logging writ-large[15]. Concerns have been raised by federal managers in eastern hardwood forests that despite the rarity of old forests in the landscape, they are replacing young forests and now need intensive logging to reset succession even though such practices do not mimic complex early seral forests generated by natural disturbances[16]. Moreover, trees in eastern Oregon's Cascades have increased in density and size due largely to fire suppression, potentially competing for limited resources. However, large trees in these forests now represent the remaining old-forest cohort that have developed fire resistant properties overtime by dropping lower branches and increasing bark thickness. A recent study showed that despite a claim that there is substantial encroachment and competition from large grand fir (*Abies grandis*) on ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*) in six National Forests in eastern Oregon, large pine and large fir are found together on only 8% of all plots (n=1616) sampled, while large grand fir and large larch co-mingled on only 4%. In other words, large pines are by far the most common tree and infrequently co-mingle with large grand firs at the plot scale. **There is no ecological reason to remove large trees of any species**[17].

As federal agencies develop older forest conservation policies, we note that the recent IPCC AR6 report states, in relation to natural climate solutions, "…protection of forest ecosystems is the highest priority for reducing GHG emissions (Moomaw et al. 2019) and restoration may not always be practical." Protecting irreplaceable natural systems from logging is therefore the first step. The IPCC report also noted that maintaining the resilience of biodiversity and ecosystem services at a global scale is "fundamental" to climate mitigation and adaptation, requiring "effective and equitable conservation of approximately 30 to 50% of Earth's land, freshwater and ocean areas, including current near-natural ecosystems"[18].

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[9] DellaSala et al. 2022. Ibid.
[10] Leismeister et al. 2019. Mixed-severity wildfire and habitat of an old-forest obligate. Ecosphere 10(4) Article e02696. Leismeister et al. Northern spotted owl nesting forests as fire refugia: a 30-year synthesis of large wildfires. Fire Ecology 17 https://doi.org/10.1186/s42408-021-00118-z. Law et al. 2022. Ibid. Mildrexler et al. 2023. Protect large trees for climate mitigation, biodiversity, and forest resilience. Conservation Science and Practice DOI: 10.1111/csp2.12944.
[11] Frey et al 2016. Spatial models reveal the microclimatic buffering capacity of old-growth forests. Sci Adv 2016:e1501392. 9 pp. doi: 10.1126/sciadv.1501392. Law et al. 2022. Ibid.
[12] Faison et al. 2023. Ibid.
[13] Bradley et al. 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7:Article e01492.
[14] DellaSala et al. 2022. Have western USA fire suppression and megafire active management approaches become a contemporary Sisyphus? Biol. Cons. https://doi.org/10.1016/j.biocon.2022.109499
[15] Mildrexler et al. 2020. Ibid. Kellett et al. 2023. Forest-clearing to create early-successional habitats: questionable benefits, significant costs. Frontiers in Forests and Global Change https://doi.org/10.3389/ffgc.2022.1073677. Mildrexler et al. 2023. Ibid.
[16] Swanson et al. 2010. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Front. Ecol. Environ doi:10.1890/090157. Kellet et al. 2023. Ibid.
[17] Mildrexler et al. 2023. Ibid.
[18] Law et al. 2022. Ibid.

The White House recently released its "roadmap to nature-based solutions," noting the importance of green infrastructure and other natural climate solutions. We submit that this policy must embrace the protection of large trees and old forests **of all types and species** as one of the nation's most important "nature-based solutions." Such an effort in rulemaking would send a clear message to the global community that the United States is making a serious effort to enlist natural climate solutions, while reducing its emissions across all sectors, including forestry. Protecting large trees and old forests in national rulemaking would also comply with the Paris Climate Agreement (Article 5.1), the IPCC AR6 Report, demonstrate steps toward the President's Executive Order 14008 to protect 30% of all lands and waters by 2030, and showcase the President's national commitment to the Glasgow Forest Pledge to end global forest degradation and deforestation.

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Open Letter to The Forest Service on the Importance of Large, Old Trees and Forests

As scientists with expertise in ecology, natural resource management, climate change, and other disciplines we write concerning the protection of primary (unlogged) forests and large (>21 inches diameter-at-breast height, >53 cm dbh), old trees in forest planning decisions. The Forest Service is amending its forest plans on >9 million acres (3.6 million ha) in eastern Oregon[i] to lift protections for large trees that have been in place for over two decades. The planned amendment threatens to set back forest recovery that has only recently followed a century of clear-felling and high-grade logging. Protections were put into place in 1994 targeting forests that needed time to recover depleted large-tree populations particularly for wildlife species that are highly dependent on that now scarce element in these Eastside forest. Although removing protections for large trees is highly controversial from a scientific perspective, the Forest Service is rushing forward without adequately analyzing the impacts of the proposal on wildlife habitat, aquatic ecosystems, hydrological cycles and carbon values. We urge the Forest Service to reconsider this proposal, given the ongoing deficit of large trees and the fact that older forests have not yet recovered.

Primary forests and large, old trees, both living and dead, provide irreplaceable benefits to society that are essential to forestalling the loss of biodiversity and climate change related environmental emergencies. Those forests and trees have elevated conservation status, needing to reach maturation in order to achieve their ecological potential in supporting associated biodiversity, contributing to carbon storage and myriad ecosystem services[ii]. Trees greater than 18 inches dbh (>45 cm) have been declining in forests at all latitudes[iii]. With that decline occurring, the following values of large trees are of utmost importance in preserving:

- Large, old trees are among the most massive terrestrial organisms on Earth. They are bio-cultural elements of a natural inheritance that is declining globally[iv].
- The size of a tree increases over time accumulating keystone features that provide large internal cavities and canopy structures for wildlife not present in younger trees.
- Large, old trees, including snags and downed wood, are needed for nesting, roosting, foraging, denning, and other habitat elements that support numerous lichens, epiphytes, up to 30% of all vertebrates in some forests[v], and invertebrates, many of which are rare, endemic, or endangered[v].
- Large, old trees anchor soils through their massive root systems, stabilize slopes, and provide shading and habitat (logs) for aquatic species[vi].
- Large, old trees provide nutrients and soil carbon, are associated with high levels of plant varieties, play critical roles in hydrological cycles, and are "blueprints" for restoration[vii].
- Large, old trees store a disproportionate amount of carbon with greater leaf surface area for CO_2 absorption, and massive carbon-storing tree trunks and roots[viii]. For instance, a recent global study found half of carbon in living above ground biomass is stored in the largest 1% diameter trees[ix].
- Large, old trees provide stable microclimates and mitigate soil desiccation[x].
- Mycorrhiza fungal networks are more connected and carbon rich as forests age with large trees serving as central nodes in the networks[xi].
- Large, old trees are especially valuable when killed individually or in large patches by natural disturbance processes such as insects, forest pathogens, wind storms, and wildfire[xii] that generate "complex early seral forests[xiii]."

Conserving large trees and the forests within which they occur provides a vital nature-based solution to the climate crisis. Through their protection and overall improvements to the forests that store much carbon[xiv], nature-based solutions can provide at least one-third of the cost-effective climate mitigation needed to stabilize global overheating to below 2° C by 2030[xv]. That is why it is imperative to develop climate policies that protect the large tree component of forests, by allowing forests to recover diminished large tree populations and carbon stocks[xvi].

In sum, there is no substitute for large, old trees, living and dead, and the forest in which they can thrive. Their losses from anthropogenic stressors have impacted biodiversity, compromised water quality, and added damaging emissions to the atmosphere at a time when governments are being asked to do everything possible to sequester and store more atmospheric carbon in ecosystems to avoid imminent catastrophic climate impacts to nature and society.

We ask the Forest Service to keep large tree and forest protections in place and avoid making misguided attempts to lift those protections at a time when the nation is looking for leadership on the global biodiversity and climate crises.

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