WILD
HERITAGE

August 29, 2022

Re: Request for information (RFI) on Federal Old-growth and Mature Forests EO 14072
Submitted via Jamie Barbour, Assistant Director, Ecosystem Management Coordinator via
roy.barbour@usda.gov; https://cara.fs2c.usda.gov/Public/CommentInput?project=NP-3239

Please accept these comments and supporting citations (with pdf links) for the public record regarding President Biden's Executive Order (EO 14072): Strengthening the Nation's Forests, Communities, and Local Economies (i.e., herein referred to as mature-old growth - MOG - assessment). The materials provided herein are responsive to EO 14072 specifically and are in support of our request for national rulemaking. We also reference the president's EO on Tackling the Climate Crisis at Home and Abroad (i.e., 30 x 30 – EO 14008), Secretary Vilsack's June 23, 2022 memorandum to the Forest Service on natural climate solutions, and relevant US commitments to international climate agreements and forest pledges. Regarding the secretarial memo, we respond to the following:

"identifying forests at risk, how those areas are currently managed, and analyzing how potential data gaps might be resolved. The Forest Service analysis will then be used to develop a decision support tool to enhance carbon stewardship, wildlife habitat, watersheds, outdoor recreation and more."

Wild Heritage is a science-based non-profit dedicated to the protection of primary forests (unlogged forests of all seral stages) around the world (Mackey et al. 2014). Nearly all primary and old-growth forests (a subset of primary) in the conterminous US were cut down decades-centuries ago. In many regions, forests are now maturing (recovering) from prior logging and it is essential that they are protected from logging to recover old-growth forest losses given the substantial national deficit from logging. We offer Mackey et al. (in review) and DellaSala et al. (in review) (as attachments) along with all relevant datasets and raster files available for the MOG assessment and decision support tool request at matureforests.org/data.

In sum, the federal agencies should keep the definition and inventory process simple while concurrently initiating national rulemaking to protect all federal MOG. Importantly, the federal MOG inventory needs to fully recognize historical and contemporary widespread logging of old-growth forests as the main driver of the current national deficit of old-growth forests, which logging was curiously missing in the EO and Secretarial memo. The loss of old-growth forests and large trees from widespread logging, in turn, is contributing to the global and biodiversity crises that the president called out in his EO. To keep it simple, we request that you set the reference standard for mature forests/trees at ≥80 years nationwide from which all other metrics can be added as co-relational indices. Specifically, mature is defined in this context as forests ≥80 years having a subset of old growth characteristics necessary to begin the recovery of depleted old-growth forests. By protecting mature at this general age when old growth features emerge, federal agencies can ensure biodiversity, carbon stocks, and drinking water sources are best maintained. Our comments are designed to address key issues with respect to the definitions and questions noted in the RFI and the main reasons why MOG protections from logging are urgently needed.

LINKING MOG PROTECTIONS TO INTERNATIONAL POLICIES

We request that the MOG assessment and national rulemaking build on UNFCCC (2019) 1.CP/25 (para. 15) with the USDA and DOI promoting enforceable actions (i.e., a "bright-line rule") that directly address the accelerating climate and biodiversity crises contributed by logging and related land uses. The US government should announce forest protection commitments prior to the COP27 via a national rulemaking process to protect from logging MOG as natural climate solutions (Griscom et al. 2017, Moomaw et al. 2019, DellaSala et al. 2020).

Against the backdrop of the starkest warning yet from the IPCC (2021) on the need to front load far more ambitious action to prevent and reduce GHG emissions across all sectors (including forestry) this decade, the findings of the first ever joint workshop of IPBES and IPCC scientists assume critical importance as a fundamental reason for protection of MOG from logging that is best accomplished by national rulemaking. We request that this begin immediately and not have to wait until April 2024 for MOG inventories to be completed because there is already sufficient information to meet the MOG purpose and need concurrent with a rulemaking process (e.g., Mackey et al, DellaSala et al in review, FIA datasets on forest age distributions such as Pan et al. 2011 – which needs to be updated).

The key message from the joint IPBES – IPCC workshop is that "biodiversity loss and climate change are both driven by human economic activities and mutually reinforce each other (and that) neither will be successfully resolved unless both are tackled together." The first recommendation from the joint workshop was "**stopping the loss and degradation of carbon-and-species rich ecosystems on land and in the ocean**, especially forests, wetlands, peatlands, grasslands and savannahs and sea grass meadows as well as deep water and polar blue carbon habitats" (emphasis added).

In the conterminous US, most old-growth forests were logged decades-centuries ago. Consequently, **logging was and still is the top stressor of MOG** and that must be called out in the MOG assessment, particularly since logging is still happening on national forests and BLM lands with MOG as currently observed[1]. In Alaska, the Tongass, with the largest

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[1] Worth standing: 10 climate-saving forests threatened by federal logging (https://www.climate-forests.org/_files/ugd/73639b_03bdeb627485485392ac3aaf6569f609.pdf).

concentration of old growth, periodically faces major challenges in protecting MOG as witnessed by the numerous attempts to overturn roadless protections and derail the transition out of old-growth logging. Neither President Biden's executive order or USDA's memo calls out logging specifically and that is a serious omission of overwhelming evidence demonstrating why we have an old-growth forest deficit in the first place.

Protecting MOG from logging is the most effective natural climate solution as supported by the IPCC Special Report on Land in 2019[2] that noted protecting carbon dense ecosystems have immediate mitigation benefits while others, such as restoration and tree planting, take decades to realize. US obligations under the ecosystem provisions of the UNFCCC (Article 4.1 (d)) and the Paris Agreement (Article 5) have never been fully realized, especially those centered on MOG protection. Indeed, the flaws in current UNFCCC approaches have been well documented regarding protective strategies for natural climate solutions such as MOG and this needs to be corrected going forward with policy development specific to the protection from logging of MOG[3].

We request that the Biden administration make a statement prior to the COP27 on how this MOG inventory process is going to inform national rulemaking to protect from logging MOG as natural climate solutions pursuant to EO 14008 (i.e., 30 x 30) as well. The purpose and need statement for both the inventory process and a concurrent rulemaking that addresses EO 14008 would aptly recognize the importance of protecting the natural climate solutions uniquely provided by MOG and large trees as follows:

(1) Climate priority actions to improve resilience, integrity and stability of ecosystems must ensure protection from logging of long-term carbon stocks in MOG and large trees. These are irreplaceable carbon reservoirs (see Article 5.1 of the Paris Climate Agreement) that are not simply compensated for by net sequestration in logged forests, tree planting, storing a small portion of carbon in harvested wood product pools, or wood substitution (Harmon 2019, Hudiburg et al. 2019, Law et al. 2022).
(2) Protection of MOG and large trees from logging is necessary to ensure the long-term accumulation of carbon stocks as the most effective natural climate solution (Mackey et al. 2013). Protecting stocks is a far more important climate measure than any other federal forest-climate policy under consideration, including planting 1 billion trees or storing a minor portion of the carbon in wood products, which in no way is compensatory for logging (Law et al. 2018, Hudiburg et al. 2019).
(3) The MOG assessment should tie in the president's 30 x 30 executive order 14008 on Tacking the Climate Crisis at Home and Abroad. Notably only 12% of all US lands

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[2] IPCC 2019 special report on Climate Change and Land https://www.ipcc.ch/srccl/

[3] See: *The Nexus Report: Nature Based Solution to the Biodiversity and Climate Crises* (https://www.foundations-20.org/wp-content/uploads/2020/11/The-Nexus-Report.pdf); CAN International Briefing Note for COP26 on *The Role of Ecosystems & Biodiversity for Climate change Mitigation Ambition and Adaptation & Resilience*; and the *Reforming Carbon Accounting to Support Nature Based Solutions: Summary for Policy Makers* https://climatenetwork.org/wp-content/uploads/2021/07/CAN-briefing_The-role-of-ecosystems-and-biodiversity-for-climate-change-mitigation-ambition-and-adaptation-and-resilience_-June-2021-7.pdf).

have strict protections, which is far below the 30 x 30 target, especially given MOG protections fall below even the lowest bound 30% targets (DellaSala et al. in review).

(4) Implement a climate smart strategy that allows mature forests and large trees to continue growing naturally, a process called proforestation (Moomaw et al. 2019).

We also request that you reference the following international forest-climate policies that the US government is currently engaged in and how this current process will contribute to them:

- Article 5.1 of the Paris Climate Agreement calls on governments to protect and enhance "carbon sinks and reservoirs."
- Article 21 of the UNFCCC COP26 Glasgow Climate Pact emphasizes "the importance of protecting, conserving and restoring nature and ecosystems, including forests… to achieve the long-term global goal of the Convention by acting as sinks and reservoirs of greenhouse gases and protecting biodiversity…" (UNFCCC 2021).
- The United States was one of 140 nations at COP26 that pledged to end forest **degradation** and deforestation by 2030 (United Nations 2021); therefore, how will you lead by example? We note that any form of logging (e.g., "thinning," "fuels reduction," post-disturbance logging) should be recognized as MOG degradation.
- The Summary for Policy Makers (SPM.D.4) in the Intergovernmental Panel on Climate Change (2022) report mentions safeguarding biodiversity and ecosystem integrity as fundamental to climate resilient developments. Allowing mature forests time to recover from logging would certainly improve ecosystem integrity as recognized in agency planning documents (e.g., National Forest Management Act 2012 rule in relation to ecosystem integrity, carbon stocks, biodiversity).

Thus, protection of MOG and large trees via national rulemaking would present global leadership on these most vital forest-climate policies and should be announced prior to the upcoming COP27 meeting.

PURPOSE AND INTENT FOR PROTECTING MOG AND LARGE TREES

The MOG assessment needs to have a more direct purpose and need statement regarding the importance of MOG as the most effective natural climate solution and logging as the main threat responsible for the national deficit. Old-growth forests and large trees in particular support exceptional levels of biodiversity globally and have declined world-wide from logging and developments (Lindenmayer et al. 2012, 2013) Their loss is coupled with the unprecedented escalation of both the climate (Lawrence et al. 2022) and biodiversity crises (IPBES 2021), forgoing opportunities for natural climate solutions (Griscom et al. 2017, Moomaw et al. 2019). This loss needs to be properly called out as the top MOG stressor globally and nationally.

Historically, as the US expanded westward, nearly all old-growth forests and large trees were cut down and replaced by industrial tree farms, secondary forests, agricultural fields, and other developments. Today, the vast majority of old-growth forests is on national forest lands with less, but significant, amounts on BLM and National Park Service lands (DellaSala et al.

in review). The biodiversity and climate mitigation benefits of MOG have been well documented in every forested region, including Alaska (Vynne et al. 2021, DellaSala et al. 2022), Pacific Northwest (Strittholt et al. 2006, Krankina et al. 2012, Krankina et al. 2014), Intermountain and Southwest (Kauffman et al. 2007), Central (Shifley et al. 1995), Great Lakes (Carleton 2003), Southeast (Hanberry et al. 2018), and Northeast (Davis 1996, Ducey et al. 2013). In sum, MOG contain irreplaceable levels of biodiversity (especially imperiled species and ecosystems), carbon stocks (carbon per acre), and drinking water (forests to faucets in DellaSala et al. in review).

The drawn maps of former US Forest Service Chief Greeley provide historical context for estimated losses from logging and development over 3 centuries.

4 ECONOMIC GEOGRAPHY

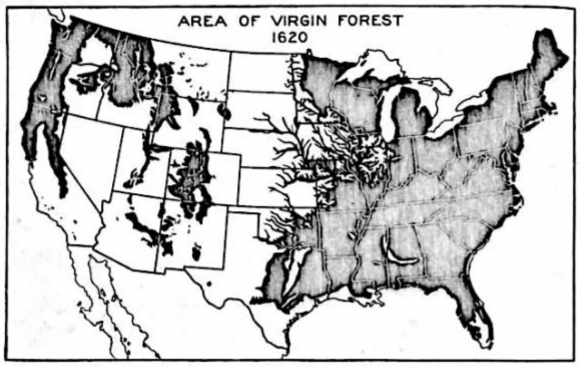

FIGURE 2.—When the early colonists settled along the Atlantic Coast nearly all the country east of the Mississippi River, and much land to the westward, notably in Arkansas, Louisiana, Texas, and the Pacific Northwest, was covered with a vast virgin forest,—about 820 million acres in all. (Map from U.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

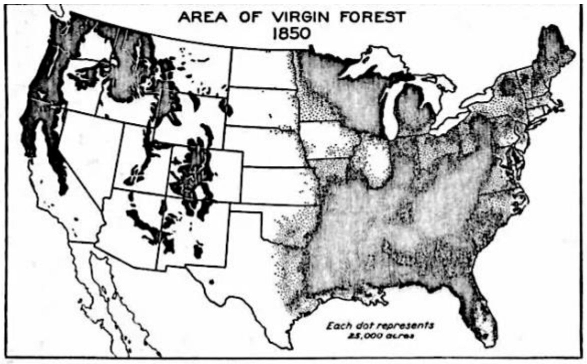

FIGURE 3.—Even in 1850 much of the forest in the eastern United States was still in a virgin condition, and the forests in the Rocky Mountain and Pacific states had scarcely been touched by man. The map was based on estimates by states and the dots are not all correctly located. Northwestern instead 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.)

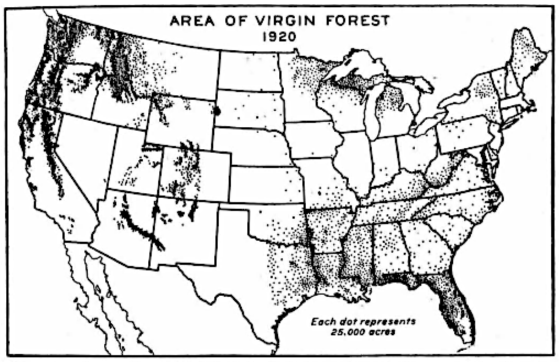

FIGURE 4.—By 1920 the area of virgin timber in the United States had been reduced to about 138 million acres, of which more than half was in the Rocky Mountain and Pacific Coast states. Culled and second growth trees of sufficient size for lumber covered about 114 million acres more, and there were about 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.)

Protection from logging of mature forests in particular is urgently needed to restore the national gap in old growth as MOG collectively offer unparalleled climate refugia benefits for myriad imperiled species/ecosystems, store massive amounts of carbon mainly in large trees and productive soils, and provide clean drinking water, ecosystem benefits that will only become increasingly important for drought stricken and flood prone regions facing worsening climate impacts (DellaSala et al. in review). Additionally, even on the Tongass rainforest in Alaska, there is a deficit of the largest trees with the greatest timber volume (per acre) that were high-graded decades ago. The Tongass is the nation's top carbon champion (DellaSala et al. 2022) and can serve as exemplary climate refugia if protected from logging (DellaSala et al. 2015).

In sum, from the coast redwoods and giant sequoia to Alaska's temperate rainforest, to the dry pine/mixed conifers of the intermountain and southwest, to the Hartwick pines and beach-maple forests of the Great Lakes, to the northern hemlock-fir stands of New England, to the mixed hardwoods of Appalachia, and to the long-leaf pine wiregrass and bottomland cypress swamps of the deep south, **all MOG are unique, complex, biodiverse, carbon dense, at-risk to logging, and critical to forest-climate policies**. Protecting federal MOG and large trees would establish a baseline for "America the Beautiful" (30 x 30) and ensure their climate and biodiversity benefits continue for future generations. We request you analyze the contribution that the protection from logging of MOG and large trees would make towards the president's 30 x 30 executive order and you begin rulemaking immediately to join the two executive orders.

WHAT ARE THE OVERARCHING OLD-GROWTH AND MATURE FOREST CHARACTERISTICS THAT BELONG IN A DEFINITION FRAMEWORK?

WHAT CRITERIA ARE NEEDED FOR A UNIVERSAL DEFINITION FRAMEWORK THAT MOTIVATES MATURE AND OLD-GROWTH FOREST CONSERVATION AND CAN BE USED FOR PLANNING AND ADAPTIVE MANAGEMENT?

We consider these two questions related enough to group them in our response. Exactly when a forest is considered to be in the later structural development stages depends on many co-related diagnostic features. For old growth, here are some general characteristics that can be obtained quickly from FIA, published sources, and Regional Old Growth Definitions:

- Age, height, and diameter-at-breast height of dominant-codominant trees (FIA).
- Canopy and understory complexity (vertical and horizontal layering) (FIA).
- Large standing dead (snags) and down trees (logs) (FIA).
- Large trees with broken and highly branched tops (via literature).
- Complex development of soil horizons and mycorrhizae connections (literature).
- Accumulated **carbon stores** in the largest trees (FIA). Notably, the largest trees in a forest stand contain the greatest amount of accumulated carbon in old-growth forests as noted below.

For mature, we suggest that you start with what mature forest conditions are necessary to restore the massive deficit in old-growth forests. We request that you set the reference condition for mature at 80 years and then add in the structural features that emerge at this age as a means for restoring the old-growth deficit.

Setting a Mature Forest Reference (standard)- forests at the reference age of 80 need to be in this MOG inventory due in part to accumulated carbon stocks. Protection and enhancement of carbon is specifically called out in the EO. Setting an age 80 reference, for instance, would likely capture at least 40% of the carbon stores accumulated over long periods in the largest trees (Mildrexler et al. 2021). This is because the rate of carbon accumulation accelerates with increasing tree size and age – that is, as forests mature, carbon stocks increase dramatically (Stephenson et al. 2014, Mildrexler et al. 2021, Law et al. 2022). The Northwest Forest Plan provides a precedent for defining a reference condition for mature at ≥80 years where complex structural features and processes begin to take on older forest characteristics. Additionally, when forests reach 80 or so years, growth rates of dominant/codominant trees slow (i.e., also can be referred to as the culmination of mean annual increment; culmination of net primary productivity; age of biological maturity). Any forester can tell you when a tree is mature based on slowed growth rate – we suggest turning this around so that mature becomes the age/characteristics when forests are no longer available for commercial logging and 80 years is a reasonable standard.

As trees mature and grow tall (≥80 yrs), 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 in mature forests, and they build and retain 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.

We want to underscore the importance of protecting accumulated carbon stores from logging as some scientists at the science panel discussion (Aug 4, 2022) incorrectly conflated sequestration with stores. Specifically, keeping additional carbon out of the atmosphere by protecting accumulated carbon stores in mature forests/large trees is the most important forest-climate factor in a climate emergency and, while all forests sequester carbon, 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 in large trees, coarse woody debris (especially large logs), snags, and soils. These features begin to take on added climate and biodiversity importance as forests reach maturation.

Large trees in mature forests also develop relative fire resistance at around 80 years. Certain pines, cedars, and firs, for instance, accumulate thick fire-resistant bark and drop their lower branches (self-prune) at this 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, 80 years can generally be thought of as the age of biological maturity of trees and a reference level for when old-growth features start to emerge. While site factors, climate, and biogeographical differences can affect the age at which older features emerge, the majority of forest types can be considered mature at a reference age of 80 needed to close the deficit on old growth. Protecting MOG features are also necessary for climate mitigation/adaptation strategies (carbon sequestration, carbon storage, water purification) and provide a natural climate buffer against extreme climatic conditions that are much more prevalent in heavily logged surroundings (DellaSala et al. 2015, Frey et al. 2016, Betts et al. 2017). Alternatively, setting an age limit above this threshold comes with substantial costs to carbon sequestration and accumulated stores, water quality, and biodiversity unduly compromised when trees older than 80 are logged.

HOW CAN A DEFINITION REFLECT CHANGES BASED ON DISTURBANCE AND VARIATION IN FOREST TYPE/COMPOSITION, CLIMATE, SITE PRODUCTIVITY AND GEOGRAPHIC REGION?

MOG are Present in Every Forested Region of the Nation and Can Be Easily Defined and Inventoried Using Existing and Soon to Be Published Datasets (Spatial Analysis) and Existing Inventories

The greatest concentration of old-growth forests in the US is on Alaska's Tongass and Chugach national forests; the national champs for old-growth forest extent and intactness. But even on the Tongass, which has over 5 million acres of 'commercially productive old growth' (generally >150 yr old trees), past high-grade logging is the only reason why most of the largest, highest volume trees are gone today (Albert and Schoen 2013). There is an urgent need to cease all logging of remaining old growth while continuing to support the rapid transition of the timber industry into young forests restocked naturally from prior logging (DellaSala and Furnish 2020). In fact, the Tongass transition could be a national model for protecting all federal MOG while moving forested regions to logging that is ecologically scaled to what forests can provide without further damages to MOG.

The Tongass also has experienced numerous attempts to rollback protections for 9.3 million acres of Inventoried Roadless Areas (IRAs), including millions of acres of old-growth in roaded areas and IRAs (DellaSala et al. 2022). National rulemaking for MOG would provide more assurances that protections of Tongass old-growth forests within and outside IRAs would stand the test of time along with all MOG on federal lands. We request that you recognize the importance of IRAs and the Tongass transition out of old growth logging generally as a national model for all federal MOG protections. Additionally, we believe forest protections should extend to the 22,000 acres of young naturally regenerating forests within IRAs on the Tongass to allow those intact forests time to structurally develop MOG features and relevant co-benefits (Moomaw et al. 2019, DellaSala et al. 2022).

Based on our MOG nationwide mapping, MOG is found in every one of the 8 forested regions of the conterminous US and mostly on federal lands (DellaSala et al. in review). In the eastern portion of the country, forests are maturing from prior logging and old-growth characteristics are emerging (DellaSala et al. in review). However, despite the ongoing major historical deficit in old-growth forests, the Forest Service recently revised forest plans on the Nantahala and Pisgah National Forest to greatly increase mature forest logging under the assumption that there is an overabundance of mature forests and a lack of early seral forests, even though logging does not create complex early seral forests having high levels of biodiversity (Swanson et al. 2011). Again, in this context, logging is the main stressor and mature forests should be allowed to continue on their trajectory to old growth. Simply put, while the northeast has considerable mature forests, there is still a substantial historical deficit in old growth and no need to set that process back via logging for early seral forests that lack the complexity needed at both ends of the seral continuum.

MOG Provide Unparalleled Biodiversity and Climate Benefits at Multiple Scales

Complex forest structures in MOG beget biodiversity – To reiterate for context purposes, as forests mature, they develop a complex structural arrangement of large trees (dead and alive), coarse woody debris (including many large "nurse logs"), understory plants, and the organic soil layer (top soil horizons) associated with extraordinary levels of biodiversity and carbon storage (Lindenmayer et al. 2012; 2013; Lutz et al. 2014). This successional development from young to old forest is not a linear progression per se, rather it is circular when viewed at the proper spatio-temporal scales. For instance, an individual forest can be in the later seral stage at the stand level, but at a more granular tree level, overall forest stability is periodically punctuated by tree death operating individually or in cohorts. Old-growth forests eventually reach a dynamic equilibrium whereby natural tree death (~1-2% of the large trees die per year) is replaced by the younger tree cohort with net primary productivity maintained in balance. Even at equilibrium, however, older forests continue to sequester carbon and store massive amounts of it in the largest trees and soils as they age (Stephenson et al. 2014).

All forests eventually succumb to natural disturbances that restart their successional clock. When trees die, they become the building blocks – biological legacies – for forests to replenish and soils to further develop (i.e., nutrient cycling) (DellaSala 2021). So, while the focus here is on MOG, the entire successional pathway influencing MOG is important to protect as logging at any stage can disrupt this natural process at the detriment of carbon stores, biodiversity, and other ecosystem services. When a stand replacement event occurs in MOG, their ecosystem services and biodiversity are maintained if not logged. For instance, dead trees anchor soils, provide shade for new seedlings, habitat for scores of detritovores that speed decomposition and set the stage for future old-growth development (Donato et al. 2013). Large logs act as sponges on the forest floor, capturing and slowly releasing water during dry spells especially. Thus, it is vital that these critical biological legacies are protected from logging to allow forest succession to proceed through the cyclical process of young to MOG and back again. We request that you identify post-disturbance logging as a principal threat to the entire seral development of MOG (Lindenmayer et al. 2008, Thorn et al. 2018).

As noted, above ground MOG structure can be measured by the presence of large trees (diameter, height, age); dead standing (snags) and down wood (coarse woody debris); cavities in trees created by branch breakage or by animal activity (e.g., woodpeckers); understory complexity; crown layering and upper branching patterns and the presence of older forest associated species. For instance, many raptors nest and perch at the top of the tallest trees having complex branching patterns or broken tops where nests can be positioned as platforms. In coastal rainforests, moss and lichens accumulate thick layers on tree branches, providing a microsite ecosystem that is populated by epiphytes, invertebrates, salamanders, tree voles, some of which live out their entire existence in a single mature tree, and nesting marbled murrelets (a federally threatened coastal seabird). Woodpeckers also drill cavities into live and dead mature trees for nesting and foraging, which in turn, opens up niche space for other cavity nesting species incapable of drilling their own nest holes (many songbirds, bats, small mammals). Simply put, the larger the tree and more complex its branching patterns, the more valuable it is for wildlife.

Below ground structure of MOG also includes complexity noted by the upper soil horizons that accumulate organic layers and plant nutrients from centuries of decomposition of coarse woody debris, which includes carbon, nitrogen, other essential plant nutrients and biological legacies in the form of seed banks. Nutrient cycling in these forests is facilitated by fungi, saprophytes, and invertebrates present in abundance. In fact, the richness of soil invertebrates in mature temperate forests is much greater than those in boreal and tropical mature forests. Additionally, mycorrhizae symbiotically attach to plant roots and are fully developed within MOG, providing nutrient and chemical exchange pathways among plants. Mycorrhizae can be thought of as an underground chemical/nutrient "highway" with connections strongest for trees within the same cohort (clustering of large trees) and same species (particularly the progeny of older trees). The largest trees within a cohort are a central hub for mycorrhizae development and exchange with the surrounding trees. When large trees are selectively cut down within tree cohorts this can break linkages in the remaining trees (Simard 2021).

To add to the ecological complexity argument, MOG are connected to other ecosystems and vice versa. A large tree that dies and falls into a stream, for instance, will become hiding and spawning cover for salmon and other aquatic organisms. The post-spawning death of salmon, in return, exchanges nutrients (N, Ca) via decomposition that is then taken up by large trees within mature riparian areas that also support high concentrations of foraging eagles, bears, wolves, and numerous other carcass scavengers. In other words, large trees provide the keystone structure (foraging perches, nest sites) and salmon the keystone species in this exchange of resources among terrestrial, riverine, and marine ecosystems. The balance in this relation is upset when MOG is logged, which, in turn, has contributed to the demise of salmonids in the Pacific Northwest and streams depauperate in nutrient exchange.

Forest biodiversity in general is scale dependent and must be viewed within the context of the surroundings. This too can be described from large to fine scale processes.

Bioregion/ecoregion classifications –bioregional classifications are commonly used to place forests broadly into boreal, temperate, and tropical biomes based largely on consistent climatic and landform associations that result in predictable major forest groups at very large spatial scales. Within biomes are finer ecoregional classifications based on similarities in vegetation composition, landforms, and natural disturbance elements, and within ecoregions are major forest groups and so on. For instance, the biodiversity of ecoregions within the mature coastal temperate rainforest biome is much different than that of mature temperate forests in drier locales. Mature eastern hardwood forests differ from those in the Great Lakes, Rockies, Southwest, and Pacific Northwest. However, all of these forest types share in common an affinity for the initial startup of old-growth characteristics at around 80 years or so that is associated with the buildup of carbon stocks, biodiversity, and hydrological functions maintained best by maturing forests.

Context–biodiversity is strongly influenced by the quality of the surroundings via source-sink relations at landscape or watershed scales. For instance, a particular MOG stand might be the only one in the entire drainage that is sustaining older-forest associated species and microclimatic conditions and that takes on added conservation significance. An additional example is the biodiversity of a particular national park or other protected area is negatively impacted by human developments in nearby surroundings (e.g., clearcuts on the western boundary of Yellowstone National Park) that produce inhospitable conditions for species and expansive edge effects that disrupt the MOG interior. In this fashion, a local MOG can act as vital "source area" for replenishing wildlife populations in nearby depleted areas if connected and protected, or, conversely, the degraded surroundings can act as a "sink" where animals experience increased mortality due to inhospitable conditions. Maintaining connectivity among areas of high ecological integrity (e.g., MOG) provides a much needed "bridge" or "stepping stone" for movements across inhospitable landscapes. This is another reason for why all MOG need protection from logging to allow species to migrate/move across otherwise heavily developed landscapes in an overheating world in search of refugia. The process of forest fragmentation has been widely documented in the literature and the US as well (Heilman et al. 2002).

Alpha diversity–measured by counting the number of native species (species richness) and abundance of individual species for a given MOG at the stand level. Alpha diversity tends to reach its highest level on both ends of the successional circular gradient in natural forests – that is, for complex early seral forests (e.g., MOG that severely burns and is re-establishing itself, Swanson et al. 2011) and in MOG that is undisturbed by logging. Again, the process is cyclical as MOG experience natural disturbances resetting the successional clock back to young structurally complex forests and so on. Logging retards the successional pathways between MOG and complex early seral (Donato et al. 2006; Lindenmayer et al. 2008, Thorn et al. 2018).

Beta diversity–measured by counting native species (richness) and abundance across a gradient as in juxtaposed patches. In fact, beta diversity can be highest when a MOG stand is juxtaposed with a naturally disturbed complex early seral forest (Swanson et al. 2011) and lowest when a MOG stand is juxtaposed with a simplistic clearcut (anthropogenic fragmentation). This is because natural disturbances create complex biological structures (i.e., biological legacies in complex early seral forests that originated from the MOG) while anthropogenic disturbances remove and simplify them via logging. This practice is widespread as a threat to MOG and should be recognized as such (Strittholt et al. 2006, Heilman et al. 2002). Additionally, sharp boundaries created by MOG juxtaposed with clearcuts produce edge effects that can penetrate the interior of forests creating inhospitable conditions for many old forest lichens, other plants, and interior dwelling wildlife like songbirds (e.g., eastern hardwood forests are highly fragmented and contain many wood warblers, thrushes, and other neotropical migrants that decline in fragmented systems), spotted owls, marbled murrelets, Pacific fisher, martin, red tree voles, pileated woodpeckers and many others. The logging-related fragmentation and edge effects inherent in small MOG patches need to be called out as major stressors to old-forest associates and a reason for allowing forests to mature overtime to reduce this habitat fragmentation stressor.

Gamma diversity–this is a measure of species richness and endemism (species unique to a particular area) over a large geographic area like an ecoregion. For instance, the World Wildlife Fund (WWF) and Conservation International (CI) each have developed metrics that rank ecoregions (WWFs Global 200 ecoregions, Ricketts et al. 1999) and hotspots (CI, Mittermier et al. 2005) based in part on gamma diversity.

While all regions with MOG are critical to effective climate-forest policy, some ecoregions stand out as globally significant (WWF Global 200) and as hot spots (CI), including:

- Klamath-Siskiyou (northwest California, southern Oregon) – considered one of the world’s most biodiverse temperate conifer forest ecoregions with exceptional richness of mollusks (many endemics), plants (many endemics), conifers (among the greatest richness), and other highly rich taxa (WWF Global 200 ecoregion, CI hotspot). This ecoregion is considered endangered due to logging, roads, and other developments with much of its old growth gone and the vast majority of what’s left on federal lands (Strittholt et al. 2006).
- Sierra Nevada Conifer Forests and Hawaiian Islands (combined) – exceptional number of endemic plants and high rates of logging in both regions along with extensive logging of old trees in the Sierra and invasive species problems in Hawaii impacting endangered endemic birds.
- North Pacific Coastal Forests (includes the Tongass and Chugach national forests) – from the redwoods to Prince William Sound contains several globally outstanding ecoregions using the WWF classification (most old growth is gone in the southern extent (coast redwoods) considered endangered from logging). Globally significant carbon stocks are present in older forests, especially the redwoods and coastal temperate rainforests (Krankina et al. 2014). The Tongass and Chugach, in particular, include the greatest concentration of carbon stocks in the national forest system (DellaSala et al. 2022).
- Long-leaf pine wiregrass forests – are one of the most biodiverse temperate forests (mainly the understory) in the world. Only some 2% remain and this forest type is highly endangered and on federal lands mostly. Please note the FIA inappropriately groups long-leaf with loblolly pine and this obscures the rarity of the former and its endangered status.
- Blue Ridge Mountains and Appalachia Mixed Mesophytic Forests (combined WWF Global 200 ecoregions) – exceptional diversity of amphibians, neotropical migratory birds, plant species – highly altered by logging and development (endangered) with forests maturing from past logging but now threatened by ramped up logging of mature forests on the Nantahala and Pisgah National Forests.

Threatened and endangered species safe haven – finally, many threatened and endangered species find irreplaceable habitat in MOG, whether on state or federal species lists as imperiled (DellaSala et al. in review). Federal MOG contain high concentrations of federally and state-listed species and imperiled ecosystems based on the IUCN dataset of "red listed" species and ecosystems (DellaSala et al. in review). This needs to be acknowledged as the main reason these species and ecosystems are imperiled is because of logging.

Mature/Old Growth Forests are Nature's Wellsprings for Clean Water

Forests play a pivotal role in the hydrological cycle that includes the continuous circulation of water between the biosphere and the atmosphere. Forests do this essential service by via uptake of water in roots and release of water back to the atmosphere via evapotranspiration through leaf pores. Simply put, forests can be thought of as giant water towers for water storage and gradual release. 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 little influence on the relation between leaf area and site water balance, while tree size matters most. In other words, larger trees have more leaf area and greater water balance (Grier and Running 1977).

Mature forests also help reduce flooding by buffering streams from peak high flows – that is – they may impede excessive runoff through absorption and slow release of water. And they provide shade along streams by keeping stream and ambient temperatures from overheating. The older and larger the trees, the greater these 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 (Wokosin and Harris 2018). In the temperate zone, logging large, canopy trees, results in drier understories, whereby the amount of sunlight and heat reaching the ground causes more evaporative losses and higher surrounding temperatures (Wheeling et al. 2019)[4]. 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 interconnected with streams and marine ecosystems. Logging and development are known to produce downwind continental interiors with declining rainfall and water availability that heighten drought and wildfire risks (Ellison et al. 2021). This top logging threat needs to be recognized in any MOG assessment.

In sum, MOG are essential for maintaining water balance in forested watersheds (Perry and Jones 2017). Specifically, uncut watersheds with MOG and dense riparian vegetation are more hydrologically stable with higher levels of terrestrial and aquatic biodiversity as follows.

- 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

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[4] Also https://eos.org/research-spotlights/how-forest-structure-influences-the-water-cycle

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 (Perry and Jones 2016).

- 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 (Pypker et al. 2006). 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 (Crampe et al. 2021). 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 (Harmon and Sexton 1995). Additionally, dense riparian vegetation helps regulate the amount of sediment that reaches streams, depending on geomorphology.

- 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 (Murphy and Koski 2011)

- 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 (Wondzell 2001).

- 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 (Ham 1982). 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 southeast, logging resulted in increased stream sediment and nutrients, more variable flow, altered fish and wildlife habitat of stream and riparian communities, and increased risk of human health effects (floods) (Nagy 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.

- In the southern Appalachian Highlands of the Central Hardwood Region, landslides commonly occur in logged areas (Wooten et al. 2016). 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, will likely exacerbate this effect.

- In the Mid-Atlantic and northeastern states, traditional stream restoration efforts have limited success because many fluvial systems remain in a degraded state after a century of widespread logging (Schaberg and Abt 2004). 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 nationwide also tend to be at the headwaters of streams with the cleanest drinking water source areas (DellaSala et al. 2011).

Finally, the issue of tree cutting for water yield is politically charged, particularly in western and other drought-stricken regions (Furniss et al. 2010). 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 (Rhodes and Frissell 2015). 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 served by keeping watersheds in mature forest and intact condition.

HOW CAN A DEFINITION BE DURABLE BUT ALSO ACCOMMODATE AND REFLECT CHANGES IN CLIMATE AND FOREST COMPOSITION?

First, the definition should begin with a reference age of 80 for mature that is needed to restore deficient old-growth areas nationwide.

Additionally, it would be prudent to adopt a hybrid approach that includes both spatially explicit high-resolution mapping of old forest proxies (e.g., DellaSala et al. in review, Mackey et al. in review) and bottom up FIA plots. The combined approach is scientifically defensible and would provide direction for all national forests and BLM districts on how to proceed with the MOG inventory.

As to durability, one of the biggest concerns is policy durability – i.e., standing the test of time as administration’s change priorities requires stacking protective policies making them difficult to overturn. **Consequently, this EO process needs to link the two presidential**

EOs (14008 and 14072) to ensure policy stability. That is, the inventory and protection parts of each EO need to be conjoined in setting forest-climate policies.

Regarding changes in climate and forest composition, the single most important step is to recognize MOG will change overtime via natural and climate-enabled disturbance events but those areas still need to be protected from logging. As mentioned, all forests are dynamic and what you do to a forest post-disturbance will affect its entire successional trajectory. Thus, we request you extend protections across the successional gradient of MOG given the circularity of successional processes noted. Further, it is widely recognized that MOG represent potential climate refugia (DellaSala et al. 2015; also see DeFrenne et al. 2013) and are most likely to present a buffering of climatic conditions compared to inhospitable and hotter/drier logged surroundings (Betts et al. 2017). Finally, climate resilience strategies involve giving ecosystems their best shot at adapting to climate related shifts. If landscapes are connected and anthropogenic disturbances minimized in frequency and intensity that would provide forests with more time and less stressors to adapt to climate change. Land-use disturbances (e.g., roads, logging, mining, grazing, ORVs, energy development) accumulate across space and time and can flip ecosystems to novel states (Paine et al. 1998, Lindenmayer et al. 2011).

WHAT, IF ANY, FOREST CHARACTERISTICS SHOULD A DEFINITION EXCLUDE?

Any definition needs to start with the reference age set at 80 and then compile the indices associated with mature and old-growth characteristics that overlap. That should also allow for change to happen and not include logging in any of the applications. Importantly, if MOG has experienced a naturally severe disturbance it needs to go through the successional restart unaided by logging and tree planting. Thus, the definition of MOG needs to include natural dynamism as part of the constant development of forests from MOG to young and back again. So, this comment is more of one of inclusion than exclusion aside for prohibiting post-disturbance logging that retards forest succession.

Additionally, it is vital that the definition of MOG include carbon stocks as carbon is specifically mentioned in the EO (see box below). Again, the recommendation of some scientists to excluded carbon in the definition is ill-founded, inconsistent with the EO, and lacks a thorough understanding of accumulated stores in mature forests and large trees and soils. As mentioned, in a climate emergency, keeping additional emissions out of the atmosphere by allowing forests to mature and build carbon stock is far more important than net sequestration, planting trees, or storing a small portion of carbon in harvested wood product pools. We recommend that you exclude recommendations that do not recognize carbon stock relevance in MOG pursuant to the EO.

Carbon as Called Out in EO 14072

"Globally, forests represent some of the most biodiverse parts of our planet and play an irreplaceable role in reaching net-zero greenhouse gas emissions. Terrestrial carbon sinks absorb around 30 percent of the carbon dioxide emitted by human activities each year. Here at home, America's forests absorb more than 10 percent of annual United States economy-wide greenhouse gas emissions. Conserving old-growth and mature forests on Federal lands while supporting and advancing climate-smart forestry and sustainable forest products is critical to protecting these and other ecosystem services provided by those forests."

Even more importantly, the primary sentence in the order, at the very beginning of the key Section 2, setting out the duties of federal agencies highlights carbon storage as a core duty, listed second overall, and above fire mitigation:

"My Administration will manage forests on Federal lands, which include many mature and old-growth forests, to promote their continued health and resilience; retain and enhance carbon storage; conserve biodiversity; mitigate the risk of wildfires; enhance climate resilience; enable subsistence and cultural uses; provide outdoor recreational opportunities; and promote sustainable local economic development."

Finally, we recommend that you classify all MOG as endangered under the Red-listed ecosystem criteria (Bland et al. 2016). Importantly, any ecosystem identified as endangered would need to go through a recovery period that responds to the root causes of degradation (i.e. such as logging in this case), and then develops a strategy for stabilizing and recovering the population of interest (in this case MOG). A federal recovery effort for MOG would not exclude recognition of the key factor involved (logging) in the decline and would not ignore the importance of prohibiting logging so the at-risk ecosystem can recover.

CLOSING RECOMMENDATIONS ON CLIMATE SMART MANAGEMENT

The president's executive order on MOG lays the ground work for protecting at-risk MOG from logging via proposed national rulemaking and especially if this executive order is linked to the 30 x 30 executive order. While the inventory process per se does not establish policy, we request that a parallel rulemaking be set up that is based on a purpose and need to protect from logging all MOG and large trees (≥80 years) on federal lands and allow the old-growth ecosystem and all its climate and biodiversity benefits sufficient time to recover naturally. We also note that while many land managers claim that thinning for fuels reduction should not include large fire-resistant trees, this is seldom met in practice as large trees are most often removed to pay for the cost of thinning (DellaSala et al. 2022b – also see footnote#1 on p.2). Thus, any restoration and climate resilience planning involving mechanical treatments should instead target a portion of the small trees as needed and not the large, fire-resistant ones with accumulated carbon stores and complex structures regardless of tree species composition. This also means restoring protections to large (>21 in dbh) trees in places where there is an historical deficit such as the dry pine and mixed conifer forests of eastern Oregon and Washington (i.e., the Eastside screens – DellaSala and Baker 2020). Those large trees are what remains of complex structures, have substantial carbon stores (Mildrexler et al. 2021), and they are needed to restore old growth, regardless of compositional differences (i.e., whether they are firs or pines is irrelevant to their complex structures, wildlife habitat, and carbon stores present, see DellaSala and Baker 2020).

In sum, subsequent or parallel national rulemaking as a preferred policy option must meet the following conditions:

1 – Protect from logging the accumulated and accumulating carbon stocks in MOG and large trees as carbon sinks and reservoirs regardless of region or species composition (if it's mature and large it's important) – every time trees are removed from the forest via logging, carbon is emitted to the atmosphere. What matters most in a climate emergency is avoiding gross emissions, not net sequestration (Mackey et al. 2013, Law et al. 2018, Moomaw et al. 2019, Buotte et al. 2020). Thus, the best chance for enacting effective forest-climate policies centered on climate smart management is to avoid putting more emissions into the atmosphere from logging. Consider, ~ 80% of the carbon in a forest is emitted to the atmosphere and winds up in a landfill within a century of logging (Hudiburg et al. 2019). The carbon debt is not made up for by storing carbon in harvested wood product pools or planting trees given most wood products are short lived, young trees do not contain the carbon stores that older trees have built up over decades-centuries (Luyassert et al. 2009, Keith et al. 2009, Mackey et al. 2013, Stephenson et al. 2014, Mildrexler et al. 2020), and timber harvest rotations are on short return cycles. Additionally, clearcuts act as carbon sequestration "dead zones" for at least a decade until trees are established and carbon begins to accumulate. This is why many scientists are calling on governments to not only protect carbon sinks but the carbon stocks and reservoirs present in unlogged and MOG (Zoltan et al. 2021).

2 – Work with independent scientists to fill information gaps in spatially explicit datasets on MOG that supplement the FIA datasets via a hybrid approach. Many relevant GIS mapping projects have been published by researchers using new analysis tools (e.g., Carroll et al. 2021, carbon mapping by Dr. Bev Law of Oregon State University, forest carbon assessments at Woodwell Research Center, and DellaSala et al. in review). USDA/DOI should take this information under advisement and continue collaboration with independent scientists in meeting the MOG EO emphasis on best science. For example, carbon dense forest mapping has already occurred in the Pacific Northwest where federal lands have more carbon per acre than the tropics (Krankina et al. 2012, Krankina et al. 2014, Law et al. 2022), on the Tongass that stores up to 20% of all carbon on the national forest system (DellaSala et al. 2022a), for large trees east of the Cascades in Oregon and Washington (Mildrexler et al. 2020), and for the nation (DellaSala et al. in review). These studies can help provide the scientific foundation for national rulemaking to protect all MOG and large carbon-storing trees in addition to allowing mature forests affected by stand replacing natural disturbances time to regrow and recapture diminished carbon stocks (proforestation, Moomaw et al. 2019). Our estimates (DellaSala et al. in peer review and attached to our comments) indicate ~ 50 million acres of federal lands MOG are at-risk from logging (GAP3 designations) that could instead become the purpose and need for rulemaking. Such forest set-asides would contribute to the 30 x 30 targets for both the Forest Service and BLM unprotected MOG.

3 – Restore landscape connectivity by reducing stressors from logging and other land-use disturbances– this means in MOG areas removing some roads (which are a source of human-caused fire ignitions and fish and wildlife habitat degradation); upgrading culverts for handling storm surge; re-introducing imperiled species; re-introducing beavers for floodplain stability; removing invasive weeds and livestock grazing, especially from streams and wetlands, as livestock are a top threat on public lands to forest, rangeland, riparian, and wetland biodiversity and climate mitigation (Beschta et al. 2012); and reconnecting the landscape and floodplain to facilitate wildlife movements and water storage/flood protection in a rapidly changing climate (Haber et al. 2015).

4 – Biofuels from forests are not a climate smart strategy and this needs to be acknowledged as a key stressor of MOG – the burning of "feed stock" from forests will contribute emissions on par with burning coal (Hudiburg et al. 2011, Schlesinger 2018). Biofuel (pellets) in the southeastern US for instance have been the main driver of complete forest type conversions at the expense of MOG and are associated with social injustice problems as many polluting pellet processing plants are located near BIPOC and economically disadvantaged communities. At a minimum, this needs to be identified as a key stressor that is expanding nationally and internationally.

5 – Preoccupation with expansive "fuels reduction" in MOG as a climate resilience strategy will damage forest functions (particularly carbon stores), and put more emissions into the atmosphere than natural disturbances in those forests, thus, Infrastructure funding needs to be redirected to home hardening, defensible space, and ecological restoration in already highly degraded areas (DellaSala et al. 2022b) – Fire suppression spending has skyrocketed while acres burning have increased mainly because of climate change and not because of a lack of forest treatments (DellaSala et al. 2022b). Logging (thinning) to reduce wildfire intensity degrades ecosystem integrity, reduces carbon stocks, can downgrade imperiled species habitat, and produces far more emissions over a comparable area compared to wildfire and other natural disturbances combined (Harris et al. 2016). Logging also requires an expansive road system for access that represent cumulative damages that need to be addressed (DellaSala et al. 2022b). In addition, based on empirical evidence, while the Forest Service treats thousands of acres per year using "thinning," the likelihood of a fire encountering a treated stand is <1% (Schoennagel et al. 2017). Increasing the scale and pace of logging will not change those odds appreciably and even if it could the tradeoffs would be increased carbon emissions, diminished carbon stocks, loss of wildlife habitat, impaired aquatic ecosystems, and removal of large-fire resistant trees that nearly always happens in timber sales to pay for costs of treatments. This is why many scientists are now requesting that land managers focus strategically on reducing flammable vegetation nearest towns and homes and not by removing large trees in the backcountry (Moritz et al. 2014, Schoennagel et al. 2017, Law et al. 2022). The agency needs to be more surgical with thinning by targeting flammable tree plantations and leaving large trees in place. In areas, where regrowth of fire intolerant trees has come in, some of the large trees could be girdled or tipped into streams in order to maintain their ecological functions and keep carbon in dead tree pools and soils (decomposition slowly emits carbon but that takes decades while new growth recaptures carbon). Finally, in a comprehensive national and regional analysis of emissions, scientists found emissions from logging eclipsed by five-fold that of disturbances from wildfires, insects, and wind combined (see Harris et al. 2016, Law et al. 2018).

6 – Preoccupation with wildfire as "catastrophic" and to be prevented by logging is harming ecological integrity and comes at the expense of large trees and MOG –federal agencies would benefit from including the latest research showing the ecological integrity benefits of large fires of mixed severity in dry pine and mixed conifer forests of the West (DellaSala and Hanson 2015). The preoccupation with reducing fire intensity even as acres burning continue to rise due to extreme fire weather caused by climate change and industrial logging (e.g., Zald and Dunn 2018) runs counter to ecosystem integrity principles and effective climate mitigation policies (DellaSala et al. 2022b). In particular, the preoccupation with "megafires" and large high severity fire patches most often proclaimed as problematic to forest renewal, means the bigger climate problem of removing large trees and their extensive carbon stocks are being ignored by federal agencies. Even in the largest patches of high severity burns (thousands of acres), researchers documented sufficient conifer establishment within the core of the largest high severity patches (DellaSala and Hanson 2019). Additionally, it makes no ecological or climate sense to remove large trees post-fire or post-insect disturbance (for reviews see Lindenmayer et al. 2008, Thorn et al. 2018) as post-disturbance (salvage) logging is destructive to complex early seral forests, an early seral stage with levels of biodiversity comparable to that of old-growth forests (Swanson et al. 2011, DellaSala et al. 2014, DellaSala and Hanson 2015, DellaSala et al. 2017, DellaSala 2019). The Forest Service and BLM need to acknowledge how large fires of mixed severity under safe conditions can reduce flammable vegetation over large areas more quickly and cost effectively than any landscape thinning or suppression. Suppression should strategically focus on protecting homes and towns while keeping firefighters out of harms' way. Additionally, fires tend to burn uncharacteristically severe in logged landscapes compared to protected areas (Bradley et al. 2016, Zald and Dunn 2018).

In closing, the best way for forestry to become climate smart is to protect the stores in carbon dense MOG and large trees (≥80 years) and allow mature forests sufficient time to grow back carbon and old growth characteristics. Globally, deforestation and forest degradation result in more carbon emissions (20% of global total) then the entire transportation network and in the US emissions from logging are up to 5x greater than natural disturbances combined (Harris et al. 2016, Law et al. 2018). Avoiding additional logging emissions can best be accomplished by prohibiting logging of carbon dense MOG and large trees (≥80 years) and by acknowledging logging as a principal threat to MOG that requires national rulemaking. Older forests from the coast redwoods and Tongass rainforest to the eastern hardwoods and southern cypress swamps store massive amounts of carbon that if protected from logging would make an essential contribution to the US National Determined Contribution to the Paris Climate Agreement (Article 5.1). Further, this MOG assessment should be aligned with 30 x 30 targets in the presidents' related executive order (14008). Emphasizing carbon in forest planning comes with co-benefits including clean water, biodiversity, recreation, and ecosystem integrity (Brandt et al. 2014, Buotte et al. 2020). Finally, national rulemaking would direct all forest plans to choose alternatives that protect MOG from logging and minimize logging emissions. To reiterate, avoiding additional emissions from logging is a far superior climate mitigation benefit than planting 1 billion trees and because tree planting is nearly always coupled to logging – leave the tree planting for urban areas. There is simply no better alternative than to protect the carbon stocks in MOG and large trees from logging via national rulemaking that responds to the global biodiversity and climate crises aptly noted in presidential executive orders.

Literature Cited (including links to publications)

Albert, D.M.; Schoen, J.W. Use of Historical Logging Patterns to Identify Disproportionately Logged Ecosystems within Temperate Rainforests of Southeastern Alaska. Conserv. Biol. 2013, 27, 774–784 https://pubmed.ncbi.nlm.nih.gov/23866037/

Beschta, R.L., D. A. DellaSala et al. 2012. Adapting to climate change on western public lands: addressing the impacts of domestic, wild and feral ungulates. Environmental Management DOI 10.1007/s00267-012-9964-9 https://www.researchgate.net/publication/233418604_Adapting_to_Climate_Change_on_Western_Public_Lands_Addressing_the_Ecological_Effects_of_Domestic_Wild_and_Feral_Ungulates

Betts, M.G., Phalan, B, Rousseau, J.S., Yang, Z. (2017). Old-growth forests buffer climate-sensitive bird populations from warming. Diversity and Distribution 24:439-447 https://onlinelibrary.wiley.com/doi/full/10.1111/ddi.12688

Bilby, R.E., Ward, J.W. 2011. Characteristics and function of large woody debris in streams draining old-growth, clearcut, and second-growth forests in southwestern Washington. Canadian J. Fisheries and Aquatic Sciences https://doi.org/10.1139/f91-291; https://cdnsciencepub.com/doi/abs/10.1139/f91-291

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P. (eds.) (2016). Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, Version 1.0. Gland, Switzerland: IUCN. ix + 94pp https://portals.iucn.org/library/sites/library/files/documents/2016-010.pdf

Bradley, C.M., C.T. Hanson, and D.A. DellaSala. 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7: Ecosphere 7:1-13 https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/ecs2.1492

Brandt, P. et al. 2014. Multifunctionality and biodiversity: Ecosystem services in temperate rainforests of the Pacific Northwest, USA. Biological Conservation 169: 362–371 https://www.oregon.gov/odf/ForestBenefits/Documents/Forest%20Carbon%20Study/Reference-biological-conservation.pdf

Buotte, P.C., et al. 2019. Carbon sequestration and biodiversity co-benefits of preserving forests in the western United States. Ecological Applications, 30(2), 2020, e02039 https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/eap.2039

Carleton, T.J. (2003). Old growth in the Great Lakes forest. Environment Reviews 11 https://doi.org/10.1139/a03-00.

Carroll, C, and J.C. Ray. 2021. Maximizing the effectiveness of national commitments to protected area expansion for conserving biodiversity and ecosystem carbon under climate change. SocArXiv preprint doi: https://doi.org/10.31235/osf.io/snk95; https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15645

Crampe, E.A., Segura, C., Jones, J.A. Fifty years of runoff response to conversion of old-growth forest to planted forest in the H.J. Andrews Forest, Oregon, USA. Hydrological Processes https://doi.org/10.1002/hyp.14168

Davis, M.B. (ed.). (1996). Eastern old-growth forests. Prospects for rediscovery and recovery. Island Press: Washington, D.C. https://islandpress.org/books/eastern-old-growth-forests

DeFreene, P. multiple authors. 2013. Microclimate moderates plant responses to macroclimate warming. PNAS https://www.pnas.org/doi/suppl/10.1073/pnas.1311190110

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 https://www.researchgate.net/profile/Dominick-Dellasala/publication/264975754_Roadless_areas_and_clean_water/links/547e22a40cf2de80e7cc52f7/Roadless-areas-and-clean-water.pdf

DellaSala, D.A., et al. 2014. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? Natural Areas Journal 34:310-324 https://bioone.org/journals/natural-areas-journal/volume-34/issue-3/043.034.0317/Complex-Early-Seral-Forests-of-the-Sierra-Nevada--What/10.3375/043.034.0317.full

DellaSala, D.A., and C.T. Hanson. 2015 (eds). The ecological importance of mixed-severity fires: nature’s phoenix. Elsevier: Boston. https://www.elsevier.com/books/the-ecological-importance-of-mixed-severity-fires/dellasala/978-0-12-802749-3

DellaSala, D.A. et al. 2015. In the aftermath of fire: logging and related actions degrade mixed and high-severity burn areas. In, D.A. DellaSala and C.T. Hanson (eds), The ecological importance of mixed-severity fires: nature’s phoenix. Elsevier: Boston. https://www.elsevier.com/books/the-ecological-importance-of-mixed-severity-fires/dellasala/978-0-12-802749-3

DellaSala, D.A., et al. 2017. Accommodating mixed-severity fire to restore and maintain ecosystem integrity with a focus on the Sierra Nevada of California, USA. Fire Ecology 13:148-171 https://fireecology.springeropen.com/articles/10.4996/fireecology.130248173

DellaSala, D.A., T. Ingalsbee, and C.T. Hanson. 2018. Everything you wanted to know about wildland fires in forests but were afraid to ask: lessons learned, ways forward. https://wild-heritage.org/wp-content/uploads/2020/10/wildfire-report-2018.pdf

DellaSala, D.A. and C.T. Hanson. 2019. Are wildland fires increasing large patches of complex early seral forest habitat? Diversity11, 157; doi:10.3390/d11090157 https://www.mdpi.com/1424-2818/11/9/157/htm

DellaSala, D.A. 2019. Fire-mediated biological legacies in dry forested ecosystems of the Pacific Northwest, USA. Pp. 38-85, In: E.A. Beaver, S. Prange, D.A. DellaSala (eds). Disturbance Ecology and Biological Diversity. CRC Press Taylor and Francis Group, LLC: Boca Raton, FL. https://www.routledge.com/Disturbance-Ecology-and-Biological-Diversity-Scale-Context-and-Nature/Beever-Prange-DellaSala/p/book/9780367861773

DellaSala, D.A., Baker, W.L. 2020. Large trees: Oregon's bio-cultural legacy essential to wildlife, clean water, and carbon storage. https://wild-heritage.org/wp-content/uploads/2020/12/Large-Trees-Report-12.2020.pdf

DellaSala, D.A, et al. 2020a. Primary forests are undervalued in the climate emergency. Bioscience. doi:10.1093/biosci/biaa030 https://www.researchgate.net/publication/341277924_Primary_Forests_Are_Undervalued_in_the_Climate_Emergency

DellaSala et al. 2020b. A strategic natural-carbon reserve to fight climate change. Seattle Times. https://www.seattletimes.com/opinion/a-strategic-natural-carbon-reserve-to-fight-climate-change/

DellaSala, D.A. and Furnish, J. 2020. Can young-growth forests save the Tongass Rainforest in southeast Alaska? Encyclopedia of the World's Biomes, Elsevier. https://www.sciencedirect.com/science/article/pii/B9780124095489116859

DellaSala, D.A., Gorelik, S.R., Walker, W.S. 2022a. The Tongass National Forest, southeast Alaska, UA: a natural climate solution of global significance.
Land *2022*, 11:717; https://doi.org/10.3390/land11050717
https://www.researchgate.net/publication/360511060_The_Tongass_National_Forest_Southeast_Alaska_USA_A_Natural_Climate_Solution_of_Global_Significance

DellaSala, D.A., Baker, B.C., Hanson, C.T., Ruediger, L., and Baker. W. 2022b. Have western USA fire suppression and megafire active management approaches become a contemporary Sisyphus? Biological Conservation https://doi.org/10.1016/j.biocon.2022.109499

Donato, D.C., Fontaine, J.B., Campbell, J.L. Robinson, W.D., Kauffman, J.B., Law, B.E. 2006. Post-wildfire logging hinders regeneration and increases fire risk. Science 2006 Jan 20;311(5759):352.doi: 10.1126/science.1122855. Epub 2006 Jan 5. https://pubmed.ncbi.nlm.nih.gov/16400111/

Donato, D.C., Campbell, J.L., Franklin, J.F. 2011. Multiple successional pathways and precocity in forest development: can some forests be born complex? J. Vegetation Science https://doi.org/10.1111/j.1654-1103.2011.01362.x

Ducey, M.J., Whitman, A.A. Gunn, J. (2013). Late-successional and old-growth forests in the northeastern United States: structure, dynamics, and prospects for restoration. Forests 4:1055-1086 DOI:10.3390/f4041055; https://www.researchgate.net/publication/260516680_Late-Successional_and_Old-Growth_Forests_in_the_Northeastern_United_States_Structure_Dynamics_and_Prospects_for_Restoration

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

Frey, S.J.K., Hadley, A.S., Johnson, S.L., Schulze, M, Jones, J.A., Betts, M.G. (2016). Spatial models reveal the microclimatic buffering capacity of old-growth forests. Sci. Adv. 2016; 2: e1501392. https://www.fs.usda.gov/treesearch/pubs/52562

Furniss, M.J., multiple authors. 2010. Water, climate change, and forests. PNW Res Sta GTR-812 https://www.fs.fed.us/pnw/pubs/pnw_gtr812.pdf

Grier, C.G., Running, S.W. 1977. Leaf area of mature northwestern coniferous forests: relation to site water balance. Ecology https://doi.org/10.2307/1936225

Griscom, B.W., multiple authors. 2017. Natural climate solutions. PNAS https://www.pnas.org/doi/10.1073/pnas.1710465114

Haber, J. et al. 2015. Planning for connectivity: a guide to connecting and conserving wildlife within and beyond America’s national forests. https://wildlandsnetwork.org/wp-content/uploads/2016/11/planning-for-connectivity.pdf

Ham, D.R. 1982. Fog drip in the Bull Run municipal watershed, Oregon. JAWR https://doi.org/10.1111/j.1752-1688.1982.tb00073.x

Hanberry, B.B., Brzuskek, R.F., Foster, H.T., and Schauwecker, F.J. (2018). Recalling open old growth forests in the southeastern mixed forest province of the United States. Ecoscience https://doi.org/10.1080/11956860.2018.1499282

Harmon, M.E., and Sexton, J. 1995. Water balance of conifer logs in early stages of decomposition *Plant and Soil* **volume 172**, pages141–152 (1995)

Harmon, M.E., 2019. Have product substitution carbon benefits been overestimated? A sensitivity analysis of key assumptions. Environmental Research https://iopscience.iop.org/article/10.1088/1748-9326/ab1e95

Harris, N.L., et al. 2016. Attribution of net carbon change by disturbance type across forest lands of the conterminous United States. Carbon Balance Manage 11:24 DOI 10.1186/s13021-016-0066-5 https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-016-0066-5

Heilman, G., Strittholt, J.R., Slosser, N.C., DellaSala, D.A. 2002. Forest fragmentation of the conterminous United States: assessing forest intactness through road density and spatial characteristics. *BioScience*, Volume 52, Issue 5, May 2002, Pages 411–422, https://doi.org/10.1641/0006-3568(2002)052[0411:FFOTCU]2.0.CO;2

Hudiburg, T.W., B.E. Law, C. Wirth, and S. Luyssaert. 2011. Regional carbon dioxide implications of forest bioenergy production. Nature Climate Change 1:419-423. https://doi.org/10.1038/nclimate1264

Hudiburg, T.W., et al. 2019. Meeting GHG reduction targets requires accounting for all forest sector emissions. Environ. Res. Letters https://doi.org/10.1088/1748-9326/ab28bb https://iopscience.iop.org/article/10.1088/1748-9326/ab28bb

IPBES. 2021. Biodiversity and climate change workshop report. IPBES and IPCC. https://ipbes.net/sites/default/files/2021-06/20210609_workshop_report_embargo_3pm_CEST_10_june_0.pdf

Intergovernmental Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis, from Working Group 1 of the IPCC 6th Assessment Report.

Intergovernmental Panel on Climate Change (IPCC). 2022. IPCC Sixth Assessment Summary for Policymakers https://www.ipcc.ch/report/ar6/wg2/

Kauffman, M.R., Binkley, D., Fule, P.Z., Johnson, M., Stephens, S.L., Swetnam, T.W. (2007). Defining old growth for fire-adapted forests of the western United States. Ecology and Society http://www.ecologyandsociety.org/vol12/iss2/art15/

Keith, H., Mackey B.G., Lindenmayer, D.B. 2009. Re-evaluation of forest biomass carbon stocks and lessons from the world’s most carbon-dense forests. PNAS https://www.pnas.org/doi/pdf/10.1073/pnas.0901970106

Krankina, O.N., M. E. Harmon, F. Schnekenburger, and C.A. Sierra. 2012. Carbon balance on federal forest lands of Western Oregon and Washington: the impact of the Northwest Forest Plan. Forest Ecology and Manage. 286:171-182 https://www.researchgate.net/publication/257198033_Carbon_balance_on_federal_forest_lands_of_Western_Oregon_and_Washington_The_impact_of_the_Northwest_Forest_Plan

Krankina, O., D.A. DellaSala, et al. 2014. High biomass forests of the Pacific Northwest: who manages them and how much is protected? Environmental Management. 54:112-121 https://pubmed.ncbi.nlm.nih.gov/24894007/

Law, B.E., Hudiburg, T.W., Berner, L.T., Harmon, M.E. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. PNAS https://www.pnas.org/doi/10.1073/pnas.1720064115

Law, B.E., multiple authors. 2022. Creating strategic reserves to protect carbon and reduce biodiversity losses in the United States. Land 2022, 11, 721. https://doi.org/10.3390/land11050721

Lawrence, D., Coe, M., Walker, W., Verchot, L., Vandecar, K. 2022. The unseen effects of deforestation: biophysical effects on climate. Frontiers for Global Change https://doi.org/10.3389/ffgc.2022.756115

Lindenmayer, D.B., P. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press: Washington D.C. https://islandpress.org/books/salvage-logging-and-its-ecological-consequences

Lindenmayer, D.B., Hobbs, R.J., Likens, G.E. 2011. Newly discovered landscape traps produce regime shifts in wet forests. PNAS 108 (38) 15887-15891 https://doi.org/10.1073/pnas.1110245108

Lindenmayer, David B., William F. Laurance, and Jerry F. Franklin. 2012. Global Decline in Large Old Trees. Science 338, no. 6112 (December 7, 2012): 1305–6. https://doi.org/10.1126/science.1231070.

Lindenmayer, D.B., multiple authors. 2013. New policies for old trees: averting a global crisis in a keystone ecological structure. Conservation Letters **https://doi.org/10.1111/conl.12013**

Lutz, J.A. et al. 2018. Global Importance of Large-Diameter Trees. Global Ecology and Biogeography 27, no. 7:849–64. https://doi.org/10.1111/geb.1274

Luyssaert S, et al. 2008. Old-growth forests as global carbon sinks. Nature 455:213–215 https://www.nature.com/articles/nature07276

Mackey, B, et al. 2013. Untangling the confusion around land carbon science and climate change mitigation policy. Nature Climate Change https://www.nature.com/articles/nclimate1804

Mackey B., D. A. DellaSala, et al. 2014. Policy options for the world's primary forests in multilateral environmental agreements. Conservation Letters 8:139-147
DOI: 10.1111/conl.12120 https://conbio.onlinelibrary.wiley.com/doi/10.1111/conl.12120

Mittermeir, R., multiple authors. 2005. Hot spots revisited. Tropical Biology and Conservation https://press.uchicago.edu/ucp/books/book/distributed/H/bo3707156.html

Mildrexler, D.J. et al. 2020. Large trees dominate carbon storage in forests east of the Cascade Crest in the United States Pacific Northwest. Frontiers in Forests and Global Change https://www.frontiersin.org/articles/10.3389/ffgc.2020.594274/full

Moomaw, William R., Susan A. Masino, and Edward K. Faison. 2019. Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good.Frontiers in Forests and Global Change 2 (2019). https://doi.org/10.3389/ffgc.2019.00027.

Moritz, M.A. et al. 2014. Learning to Coexist with Wildfire. Nature 515, no. 7525 (November 6, 2014): 58–66. https://doi.org/10.1038/nature13946.

Murphy, M.L., Koski, K.V. 2011. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American J. Fisheries Management https://doi.org/10.1577/1548-8675(1989)009<0427:IADOWD>2.3.CO;2

Nagy, R.C., Lockaby, B.G., Helms, B., Kalin, L., Stoeckel, D. 2011. Water resources and land use and cover in a humid region: the southeastern United States. J. Environmental Quality https://doi.org/10.2134/jeq2010.0365

Paine, R.T., Tegner, M.J., Johnson, E.A. 1998. Compounded perturbations yield ecological surprises. Ecosystems 1:535-545 https://link.springer.com/article/10.1007/s100219900049

Pan, Y., Chen, J.M., Birdsey, R., McCullough, K., He, L. Feng, F. 2011. Age structure and disturbance legacy of North American forests. Biogeosciences, 8, 715–732, 2011https://doi.org/10.5194/bg-8-715-2011

Perry, T.D., Jones, J.A. 2017. Sumer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. Ecohydrology 10:1-13 https://andrewsforest.oregonstate.edu/publications/4981

Pypker, T.G., Unsworth, M.H., Bond, B.J. 2016. The role of epiphytes in rainfall interception by forests in the Pacific Northwest. I. Laboratory measurements of water storage. Canadian J. Forest Research https://doi.org/10.1139/x05-298

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

Ricketts, T., multiple authors. 1999. Terrestrial ecoregions of North America. Island Press: Washington, D.C https://islandpress.org/books/terrestrial-ecoregions-north-america

Schaberg, R.H., Abt, R.C. 2004. Vulnerability of mid-Atlantic forested watersheds to timber harvest disturbance. Environmental Monitoring and Assessment 94:101-113 https://link.springer.com/article/10.1023/B:EMAS.0000016882.72472.e1

Schlesinger, W.H. 2018. Are wood pellets a green fuel? Science 359:1328-1329 https://www.science.org/doi/abs/10.1126/science.aat2305

Schoennagel, T. et al. 2017. Adapt to more wildfire in western North American forests as climate changes. PNAS https://www.pnas.org/content/114/18/4582

Shifley, S.R., Roovers, L.M., Brookshire, B.L. (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

Simard, S. 2021. Finding the mother tree. https://www.penguinrandomhouse.com/books/602589/finding-the-mother-tree-by-suzanne-simard/

Stephenson, N. L., et al. 2014. Rate of Tree Carbon Accumulation Increases Continuously with Tree Size. Nature 507, no. 7490 (March 6, 2014): 90–93. https://doi.org/10.1038/nature12914

Strittholt, J.R., DellaSala, D.A., Jiang, H. 2006. Status of mature and old-growth forests in the Pacific Northwest. Conserv Biol . 2006 Apr;20(2):363-74.doi: 10.1111/j.1523-1739.2006.00384.x; https://pubmed.ncbi.nlm.nih.gov/16903097/

Swanson, M.E. et al. 2011. The forgotten stage of forest succession: early-successional ecosystems on forested sites. Frontiers in Ecology and Environment 9:117-125 doi:10.1890/090157 https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/090157

Thorn, S., multiple authors. 2018. Impacts of salvage logging on biodiversity: a meta-analysis. J. Applied Ecology DOI: 10.1111/1365-2664.12945; https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.12945

UNFCCC. 2019. Draft text on 1/CP.25 https://unfccc.int/documents/204646

Vynne, C., multiple authors. 2021. The importance of Alaska for climate stabilization, resilience, and biodiversity conservation. Frontiers in Forests and Global Change https://doi.org/10.3389/ffgc.2021.701277

Wheeling, K. (2019). How forest structure influences the water cycle, *Eos*, 100, *https://doi.org/10.1029/2019EO134709. Published on 15 October 2019.*

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

Wondzell, S.M. 2001. The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of Eastern Oregon and Washington. Northwest Science https://hdl.handle.net/2376/989

Wooten, R.M., Witt, A.C., Miniat, C.F., Hales, T.C., Aldred, J.L. (2016). Frequency and Magnitude of Selected Historical Landslide Events in the Southern Appalachian Highlands of North Carolina and Virginia: Relationships to Rainfall, Geological and Ecohydrological Controls, and Effects. In: Greenberg, C., Collins, B. (eds) Natural Disturbances and Historic Range of Variation. Managing Forest Ecosystems, vol 32. Springer, Cham. https://doi.org/10.1007/978-3-319-21527-3_9

Zald, H.S.J., and C. Dunn. 2017. Severe fire weather and intensive forest management increase fire severity in a multi-ownership landscape. Ecological Applications 28 DOI:10.1002/eap.1710 https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.1710

Zoltan, K, D.A. DellaSala, et al. 2020. Recognising the importance of unmanaged forests to mitigate climate change. Global Change and Biology https://doi.org/10.1111/gcbb.12714