April 1, 2020

Ken Tu, Interdisciplinary Team Leader
Alaska Roadless Rule
USDA Forest Service, Alaska Region
Ecosystem Planning and Budget Staff
P.O. Box 21628
Juneau, Alaska 99802-1628
(kktu@fs.fed.us)

Re: Supplemental Comment on Alaska Roadless Rule Draft EIS Concerning New Information on Tongass National Forest Carbon Sink

Dear Mr. Tu:

Please accept these supplemental comments on the Alaska Roadless Rule draft environmental impact statement (DEIS) that are based on significant new information that became available after the DEIS comment period closed and of which the DEIS did not properly analyze.

This new information, developed by the Forest Service's own scientists, supports analysis by DellaSala and Buma (submitted to the Forest Service on December 16, 2019, Exhibit 1) that the DEIS did not use the best available scientific information as required by the National Forest Management Act[1], the National Environmental Policy Act, and the Data Quality Act in failing to properly analyze the substantial carbon stores in unlogged forests and emissions consequences to the environment, the climate, and public health from entering roadless areas to construct roads and clearcut "economic" old growth stands that are disproportionately carbon-intensive. Specifically, the March 2020 issue "Science Findings" of the Forest Service's Pacific Northwest (PNW) Research Station reports on new information on forest carbon not analyzed in the DEIS. The Science Findings are attached as Exhibit 2 and summarized herein.

The PNW Research Station findings reports that:

(1) Alaska's temperate coastal forests absorb more carbon from the atmosphere than they release. They function as carbon "sinks" in part because cool temperatures slow decomposition and lead to an accumulation of carbon in woody debris and soils.
(2) Tongass dense coastal forests annually sequester 3.4 to 7.8 tetragrams (11-15% of Alaska's total sequestration rate).
(3) The amount of carbon annually sequestered by Alaska ecosystems is projected to increase by 22.5 to 70.0 teragrams over the remainder of this century.
(4) Young-growth forests rapidly accumulate carbon, making them carbon hotspots and a focus for management. Precommercial thinning reduces the maximum amount of carbon stored on a site, which may persist 100 years after treatment.
(5) Soils in the coastal temperate rainforest store large amounts of carbon, estimated at 4.5 petagrams of carbon, which is even more than the vast aboveground pools.

[1]Section 2, subsection (4) "the new knowledge derived from coordinated public and private research programs will promote a sound technical and ecological base for effective management, use, and protection of the Nation's renewable resources."

(6) Forest management activities have long-term effects on maximum amount of carbon a site can sequester.

Overall, the PNW Research Station's findings bolster the conclusions of DellaSala and Buma (2019, Exhibit 1). Specifically, the preferred alternative will substantially diminish the carbon stores of roadless areas by releasing most of that carbon to the atmosphere. These emissions would come at a crucial time when the Intergovernmental Panel on Climate Change (IPCC) and numerous scientists (cited in DellaSala and Buma) are urging countries to drastically cut fossil fuel emissions and avoid additional emissions from deforestation and forest degradation especially in areas with nationally significant carbon stores like the Tongass.

The PNW Research Station's findings aptly note that: "In 2007, President George W. Bush signed the Energy Independence and Security Act, which mandated that the Department of the Interior conduct an assessment on the potential for ecosystems in the United States to sequester carbon." However, the DEIS does not contain a scientifically rigorous analysis of carbon stocks and flows, and instead minimizes emissions by comparing them to the entire US energy sector. Thus, the DEIS is not based on best available science or high-quality information required by NEPA and the Data Quality Act.

The PNW Research Station finding concludes that "the big take home message of this assessment is that some level of mitigation and controlling the rise of atmospheric carbon dioxide in the atmosphere would decrease the potential for Alaska's ecosystems to become carbon sources." It also aptly notes that Alaska's forests play "a crucial role in the global carbon cycle." But in violation of NEPA[2], the DEIS fails to analyze an appropriate range of alternatives and measures contributing to that needed mitigation. Instead, the difference in emissions among alternatives is treated as insignificant.

Further, the PNW Research Station concludes that:

- Knowing the magnitude of the carbon loss in managed forest stands can help decision-makers evaluate carbon sequestration goals in relation to other goals, such as enhancing wildlife habitat or timber management.
- Information about carbon cycling is necessary for land management plans, which the U.S. Forest Service's 2012 Planning Rule requires to include carbon assessment[3].
- Information about forest carbon sequestration rates informs state and international goals for reducing greenhouse-gas emissions.

In conclusion, a subsequently prepared NEPA analysis for the Alaska Roadless Rule must consider this new information[4] from the PNW Research Station by now providing an assessment of average and potential maximum stocks and flows for each alternative and the specific effects of roadless entry on the Tongass carbon sink. This would allow the public to fully assess impacts to the regional environment, human health (from emissions), and the climate. The Forest Service will need to inform the public as to why it is choosing an alternative that maximizes carbon flux to the atmosphere when the IPCC and scientific community are calling for drastic cuts in

[2] 42 U.S.C. § 4332; 40 C.F.R. § 1502.14 (alternatives); 40 C.F.R. §1502.16 (environmental consequences).
[3] For instance, see 36 C.F.R. § 219.6 (b)(4), 77 Fed. Reg. 21260, 21263 (April 9, 2012).
[4] 40 C.F.R. §1502.9(c)(2).

emissions and for storing more carbon in ecosystems in response to the global climate and biodiversity emergencies (e.g., see Leighty et al. 2006, Harmon 2019, Ripple et al. 2017, 2019, Moomaw 2019 cited in DellaSala and Buma).

Thank you for your attention to this issue. We urge the Forest Service to ensure that a subsequently prepared NEPA document addresses this science.

Sincerely,

Dominick A. DellaSala, Ph.D.
Chief Scientist (lead signer)
Geos Institute, 84-4th St
Ashland, OR, 97520

Osprey Orielle Lake
Executive Director
Women's Earth and Climate Action Network
San Francisco Bay Area, CA

Sally Schlichting
Environmental Policy Analyst
Southeast Alaska Conservation Council
Juneau, AK

Edward B. Zukoski
Senior Attorney
Center for Biological Diversity
Denver, CO

Amy Moas, Ph.D.
Senior Forest Campaigner
Greenpeace USA, Oakland, CA

Kate Glover, Staff Attorney
Earth Justice, Juneau, AK

Nathaniel Lawrence, Alaska Director/Senior Attorney
Nature Program, Natural Resources Defense Council
Olympia, WA

Cc: Chris French, Deputy Chief, U.S. Forest Service (chris.french@usda.gov)

Photo- D. DellaSala

Analysis of Carbon Storage in Roadless Areas of the Tongass National Forest

Prepared by Dominick A. DellaSala, Ph. D, in consultation with Brian Buma, Ph. D

December 16, 2019

We have reviewed the Draft Environmental Impact Statement (DEIS) for the proposed Alaska Roadless Rulemaking and, in particular, its analysis of carbon storage in the inventoried roadless areas of the Tongass National Forest. The DEIS substantially undervalues the global and national importance of old-growth trees on the Tongass for carbon storage. Research shows, for example, that primary (unlogged) forests on the Tongass store much more carbon than logged forests because of the relatively high percentage of old growth and long stable residence times of carbon stored in these forests. The DEIS incorrectly assumes the carbon emitted from logging represents a zero-sum game with carbon recapture in wood product pools and reforestation – this argument is completely false (see below).

- The Tongass is part of a global network of temperate rainforests that make up ~2.5% of the world's total forest coverage but these rainforests have exceptional carbon stores for their relatively small spatial extent and are critically important in climate regulation collectively and individually.[1]

- The Tongass is one of only 4 other temperate rainforests world-wide that is still largely intact, which is a value of global importance grossly undervalued in the DEIS.[2]

- The Tongass occurs within the Pacific Coastal Temperate Rainforest bioregion (extends from Coast Redwoods to Alaska) that includes temperate rainforest ecoregions and climatically distinguishable subregions (subpolar, perhumid, seasonal, warm temperate) considered globally outstanding for their biodiversity and that collectively comprise over one-third of the world's entire temperate rainforest biome based on latest rainforest mapping that should be cited and elevated in importance in the DEIS.[3]

- Tongass carbon stores are substantially greater than any other national forest in the US and are irreplaceable as carbon sinks.[4]

- Primary (unlogged) forests on the Tongass store much more carbon than logged forests because of the relatively high percentage of old growth and long stable residence times of carbon stored in these forests, and in fact old growth forests are accruing biomass at a rate of approximately a Teragram a year.[5] The DEIS incorrectly assumes the carbon emitted from logging represents a zero sum game with carbon recapture in wood product pools and reforestation – this is completely false (see below).

- The Tongass may function as a climate refuge for species facing more extreme climatic conditions in the interior of Alaska and coastal rainforests further south if managed to protect old-growth forests and roadless areas, based on climate envelope modeling and downscaled climate projections for the region.[6]

- Globally, wilderness and intact areas have been declining at an accelerated rate, contain irreplaceable biodiversity and carbon stores, and these losses can be attributed to the "degazetting" (removal of protection status) globally – while roadless areas are not designated wilderness per se – the DEIS continues the alarming global trend of degazetting wild, irreplaceable places.[7] Instead, maintaining and restoring the integrity of intact forests and wild places is an urgent global priority for conservation and

---

[1] DellaSala et al. 2011.

[2] DellaSala et al. 2011.

[3] DellaSala et al. 2011.

[4] Leighty et al. 2006; Keith et al. 2009; Buma and Thompson 2019. Also, using the dataset in Krankina et al. 2014, the Tongass is a national carbon champion.

[5] *See* Leighty et al. 2006; Keith et al. 2009; Buma and Barrett 2015

[6] DellaSala et al. 2015.

[7] Watson et al. 2016a.

sustainability efforts designed to halt the biodiversity and climate crises.[8] Intact areas are also much more likely to retain their native biodiversity than fragmented areas in a rapidly changing climate.[9]

- Large, old growth trees are critically important globally and scientists are calling for protecting places like the Tongass where large trees are especially concentrated to help avoid a biodiversity crisis.[10]

- Because of the global importance of primary (unlogged) forests and high concentration of old-growth forests on the Tongass, scientists are calling on governments to manage these forests to reach their maximum carbon potential via "proforestation" (nature-based climate solutions that allow forests to mature) in order to mitigate climate change.[11]

- The best option for storing carbon long term on public lands is the "no harvest option" for the Tongass and all US public timberlands.[12] Forgoing timber harvest in these areas is projected to result in a net increase of 43% in carbon stores nation-wide, for instance, and an increase in sequestration potential on the national forests such as the Tongass[12]. The DEIS needs to reflect these published estimates and provide a science-based assessment of carbon stored by old forests and estimated emissions from proposed logging given the national and global significance of the Tongass.

In sum, the Forest Service is responsible for stewarding arguably the most important national forest in the nation and has an ethical-moral and legal obligation to maintain remaining untrammeled areas on the Tongass as irreplaceable assets within the national forest system (as noted by 234 scientists in an October 2019 letter calling on land managers to leave the Roadless Rule in place in Alaska). These irreplaceable values need to be fully acknowledged and protected for their national and global significance.

Additionally, the Forest Service is taking unacceptable climate and biodiversity risks at a time when thousands of scientists have been calling for stricter protections as climate mitigation/adaptation strategies due to the global biodiversity and climate crises we now face.[13] The best alternative for storing carbon long term on public lands is a "no harvest option" for the Tongass and all US public timberlands.[14] Forgoing timber harvest in these areas is projected to result in a net increase of 43% in carbon stores nation-wide, for instance, and an increase in sequestration potential on national forests such as the Tongass. The DEIS needs to reflect these

---

8 Watson et al. 2017; Ripple et al. 2019.

9 Watson et al. 2016b.

10 Keith et al. 2009; Lindenmayer et al. 2012, 2013; Krankina et al. 2014.

11 Mackey et al. 2014; Moomaw 2019.

12 Leighty et al. 2006; Depro et al. 2008

13 Watson et al. 2016a,b; Ripple et al. 2017; Ripple et al. 2019.

14 Leighty et al. 2006; Depro et al. 2008.

published estimates and provide a science-based assessment of carbon stored by old forests and emitted from proposed logging given the national and global significance of the Tongass and in relation to these cited studies.

A. THE DEIS UNDERVALUES FOREST CARBON AND GROSSLY UNDERESTIMATES EMISSIONS ATTRIBUTABLE TO LOGGING.

NEPA regulations state that:

> NEPA procedures must insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken. The information must be of high quality. Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA.[15]

To ensure that the agency has taken the required "hard look," courts hold that the agency must utilize "public comment and the best available scientific information"[16] or open themselves up to lawsuits.

Further, NEPA requires agencies to explain opposing viewpoints and their rationale for choosing one viewpoint over the other.[17] Federal courts have set aside NEPA analysis where the agency failed to respond to scientific analysis that calls into question the agency's assumptions or conclusions.[18]

---

15 40 C.F.R. § 1500.1(b).

16 *Biodiversity Cons. Alliance v. Jiron*, 762 F.3d 1036, 1086 (10th Cir. 2014) (internal citation omitted). Regulations implementing the planning provisions of National Forest Management Act (NFMA) also require the use of the best available scientific information (BASI). 36 C.F.R. § 219.3. As noted above, the proposed action includes adding 185,000 acres to the suitable timber base, which requires that the Forest Service amend the Tongass Forest Plan. The Forest Service's planning regulations apply to Forest Plan amendments. 36 C.F.R. § 219.1. Even if they do not apply, they establish sound agency practice and comport with NEPA's mandates regarding best available scientific information and high quality data.

17 40 C.F.R. § 1502.9(b) (requiring agencies to disclose, discuss, and respond to "any responsible opposing view").

18 *See Ctr. for Biological Diversity v. U.S. Forest Serv.*, 349 F.3d 1157, 1168 (9th Cir. 2003) (finding Forest Service's failure to disclose and respond to evidence and opinions challenging EIS's scientific assumptions violated NEPA); *Seattle Audubon Soc'y v. Moseley,* 798 F. Supp. 1473, 1482 (W.D. Wash. 1992) ("The agency's explanation is insufficient under NEPA – not because experts disagree, but because the FEIS lacks reasoned discussion of major scientific objections."), *aff'd sub nom. Seattle Audubon Soc'y v. Espy,* 998 F.2d 699, 704 (9th Cir. 1993) ("[i]t would not further NEPA's aims for environmental protection to allow the Forest Service to ignore reputable scientific criticisms that have surfaced"); *High Country Conservation Advocates v. Forest Service*, 52 F. Supp. 3d 1174, 1198 (D. Colo. 2014) (finding Forest Service violated NEPA by failing to mention or respond to expert report on climate impacts).

The DEIS does not present or consider the best available scientific information about the impact of the proposed action on forest carbon. The DEIS presents a contradictory, scientifically flawed, inappropriately scaled and biased accounting of forest carbon losses associated with suspending the national roadless conservation rule on the Tongass. Not a single forest carbon life cycle analysis is presented, yet, the Forest Service draws sweeping conclusions that undervalue the global importance of carbon stored in old growth and roadless areas (IRAs) on the Tongass, while inappropriately minimizing the emissions footprint from roadless entry at a time when overwhelming scientific consensus urges governments to avoid additional emissions from forest degradation and to store more carbon in forest ecosystems.[19] Because agencies and academics have quantified and compared the carbon emissions of alternative logging proposals, the Forest Service cannot fail to undertake a similar analysis on the basis that it is too complex or complicated. Dr. DellaSala's 2016 report addressed carbon stores from wood products and concluded that logging Tongass old-growth forest under the 2016 Forest Plan would result in net annual CO2 emissions totaling between 4.2 million tons and 4.4 million tons, depending on the time horizon chosen.[20] The Bureau of Land Management a decade ago completed an EIS for its Western Oregon Resource Management Plan in which that agency also predicted and quantified the net carbon emissions from its forest and other resource management programs.[21]

Opening up roadless areas and logging in old-growth forests, as the proposed rule would do, conflicts with published research showing the most effective/efficient means to maintain the enormous Tongass carbon sink is to protect all remaining old-growth forests from logging.[22] The DEIS carbon assessment does not present the best scientific information, particularly in reference to the global climate emergency[23] or the importance of keeping carbon tied up in Tongass forests as recommended by scientists.[24] In fact, the DEIS goes as far as to boldly proclaim, without a single published scientific reference, that "the management mechanisms applied in all alternatives are consistent with internationally recognized climate change adaptation and mitigation practices identified by the IPCC (IPCC 2000, 2007)."[25] To the contrary, the IPCC (2018)[26] does not endorse roadless development as an appropriate climate mitigation/adaptation

---

[19] Mackey et al. 2013, Mackey 2014, Mackey et al. 2016a,b, Griscom et al. 2017, Law et al. 2018, Ripple et al. 2019, Moomaw 2019.

[20] D. DellaSala, *The Tongass Rainforest as Alaska's First Line of Climate Change Defense and Importance to the Paris Climate Change Agreements* (2016) at 14, and available at https://forestlegacies.org/wp-content/uploads/2016/01/tongass-report-emissions-2016-01.pdf (last viewed Dec. 13, 2019).

[21] *See* Bureau of Land Management, Western Oregon Proposed RMP Final EIS (2009) at 165-181, excerpts attached.

[22] Leighty et al. 2006.

[23] Ripple et al. 2019.

[24] Leighty et al. 2006, DellaSala et al. 2011, Moomaw 2019.

[25] DEIS at 3-128.

[26] Given the large size of this report and the fact that the IPCC report is readily available online, we have provided only the only link and not the full pdf - https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf.

strategy. Rather, the IPCC has repeatedly recommended storing more carbon in ecosystems by avoiding additional emissions in the land sector.[27] The same is true for the published sources cited in these comments. We are unaware of any other research that supports the DEIS assertion that clearcutting old-growth rainforests and building roads into intact watersheds is consistent with adaptation and mitigation strategies.

Based on the recent IPCC assessment (2019), an estimated 23% of total anthropogenic greenhouse gas emissions (2007-2016) derive from agriculture, forestry, and other land use. Thus, IPCC recommends avoiding additional emissions from these sectors.

Notably from the IPCC (2019)

> "Achieving land degradation neutrality will involve a balance of measures that avoid and reduce land degradation, through adoption of sustainable land management, and measures to reverse degradation through rehabilitation and restoration of degraded land. Many interventions to achieve land degradation neutrality commonly also deliver climate change adaptation and mitigation benefits. The pursuit of land degradation neutrality provides impetus to address land degradation and climate change simultaneously (high confidence)."

There are at least two fundamental flaws (inherent *biases*) in the DEIS carbon assessment: (1) undervaluing long-term carbon stored in intact watersheds and old-growth forests compared to logged areas; and (2) understating cumulative emissions from logging and road building by using an inappropriate analysis scale and by overstating wood product stores that do not comport with recent published estimates (discussed below).

The DEIS also does not sufficiently meet the Forest Service's substantive obligation to protect Tongass resources because it: (1) proposes to enter intact watersheds that are acting as irreplaceable strongholds for fish and wildlife populations in a changing climate;[28] and (2) degrades intact areas containing nationally recognized carbon sinks at a time when scientists recommend avoiding entry into intact areas as critical to preventing the escalating climate and biodiversity crises underway globally.[29] Specifically, the DEIS should continue *to protect, preserve, manage, and restore* natural systems (roadless, old growth) on the Tongass, rather than degrade them by development, and then expecting them to somehow be miraculously restored and recovered with all emissions offset by regrowth and wood product stores – an assumption directly contradicted by the best available science (see below).

---

27 *See also* Griscom et al. 2017, Moomaw 2019.

28

See DellaSala et al. 2011, DellaSala et al. 2015, Watson et al. 2016a,b; 2017.

29 Watson et al. 2016a,b; 2017; Ripple et al. 2019.

To assess properly the impacts of the proposed exemption on carbon emissions and sequestration, the agency must address the following key elements and information not now considered in the DEIS.

Trees accumulate carbon over their entire lifespan. While growth efficiency declines as the tree matures, corresponding increases in a tree's total leaf area overcome this slow down as the **whole-tree carbon accumulation rate increases with age and tree size** (Figure 1 – the figure below and some of the text in this section was modified from materials sent to DellaSala by M.G. Anderson, pers. comm). A study of 673,046 trees across six countries and 403 species found that at the extreme, a large old tree may sequester as much carbon in one year as growing an entire medium size tree.[30] At one site, large trees comprised 6 percent of the trees but 33 percent of the annual forest growth. More recent studies show the largest 1% of trees in old-growth forests worldwide store ~50% of the total stand level carbon.[31] In the Tongass, old growth forests continue to accrue biomass and carbon at an amazing rate[32]. In sum, young trees grow fast, but old trees store a disproportionate amount of carbon over time given the larger leaf surface area for absorption and massive tree trunks and root wads that represent centuries of accumulated carbon.

Quoting directly from the abstract in Lutz et al. (2018):

> Main conclusions: 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 services.[33]

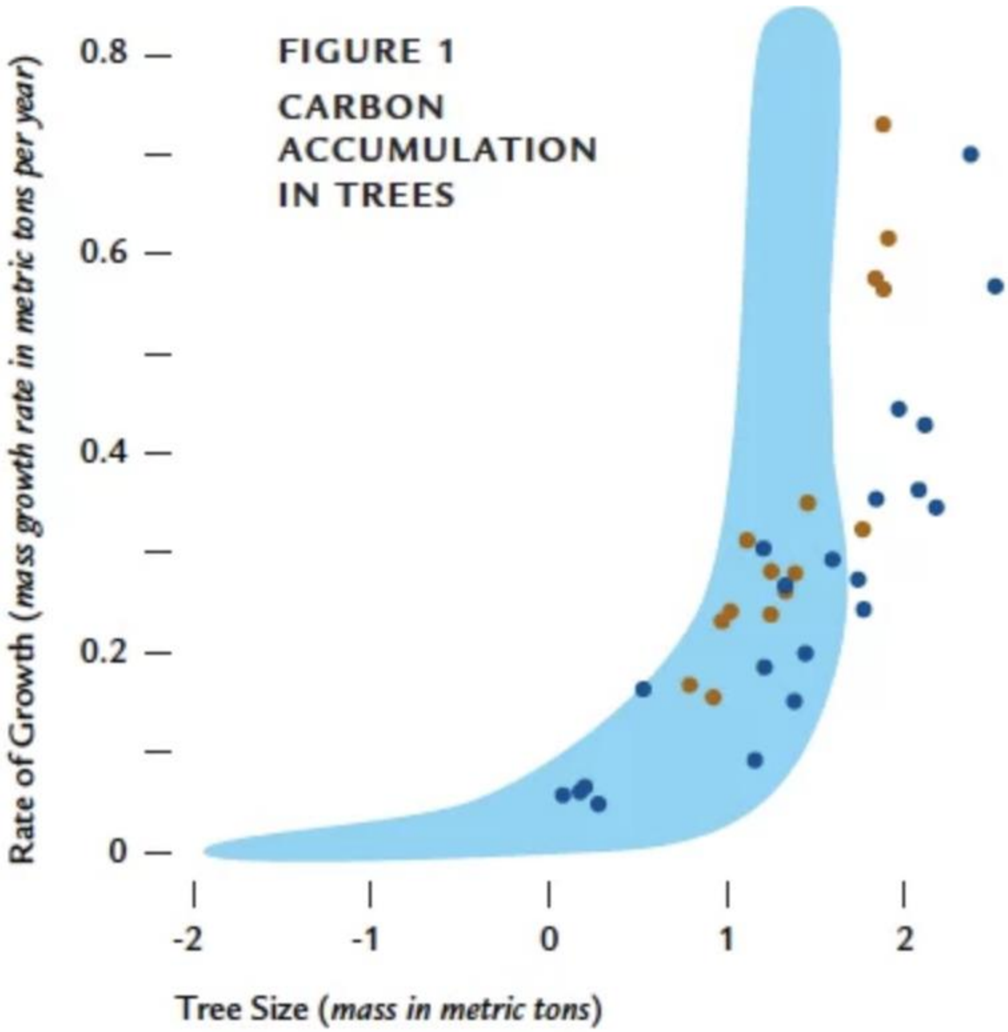
---

30 Stephenson et al. 2014.

31 Lutz et al. 2018.

32 Buma and Barrett 2015

33 Lutz et al. 2018



Aboveground mass growth rates for 58 species (shaded area) juxtaposed with two of the most massive tree species on earth: Swamp Gum (*Eucalyptus regnans*—brown dots) and Coast Redwood (*Sequoia sempervirens*—blue dots). Mass growth rate equals the total mass accumulated each year after accounting for respiration. The mass of a tree is primarily carbon, so the figure shows that annual carbon accumulation increases with the size of the tree. (Adapted from Stephenson et al. 2014.)

Old forests accumulate carbon and contain vast quantities of it. Although individual trees experience an increasing rate of carbon sequestration, forest stands experience an "S-curve" of net sequestration rates (e.g. slow, rapid, slow).[32] The expected decline in older stands is due to

---

Lutz et al. 2018.

tree growth balanced by mortality and decomposition. For instance, an international team of scientists reviewed 519 published forest carbon-flux estimates from stands 15 to 800 years old and found that, in fact, net carbon storage was positive for 75 percent of the stands over 180 years old and the chance of finding an old-growth forest that was carbon neutral was less than 1 in 10.[33] They concluded that old-growth forests are substantial carbon sinks, steadily accumulating carbon over centuries and containing vast quantities of it in relatively stable form.

Old forests accumulate carbon in soils. Soil organic carbon levels in old forests are generally thought to be in a steady state. However, as Alaska's climate increasingly overheats (twice the rate of the rest of the US), soils will be exposed to increased drying and reduced snowpack, and this will lead to methane release. Notably, Tongass soils store >50% of the carbon in the already incredibly dense ecosystem[33]. Moreover, protecting remaining unlogged forests provides for more stable microclimates (with less desiccation and lower temperatures). In fact, recent research shows that old-growth forests may act as a climate buffer as studies comparing logged vs. old growth in the Oregon Cascades found that old growth reduced maximum spring and summer air temperatures as much as 2.5 degrees C.[34] Thus, scientists have repeatedly acknowledged the superior climate benefits inherent to old-growth forests that are irreplaceable in human lifetimes.

Forests share carbon among tree species. Trees compete for sunlight and soil resources, and competition for resources is commonly considered the predominant tree species interactions in forests. However, recent research on carbon isotope labeling has shown that trees interact in more complex ways, including substantial exchange and sharing of carbon below ground. Aided by mycorrhiza networks, interspecific transfer among trees accounts for 40% of the fine root carbon: totally ~280 kg ha-1 per year tree-to-tree transfer.[35] Morrien et al. (2017), found that mycorrhiza soil networks become more connected and take up more carbon as forest succession progresses even without major changes in dominant species composition. Notably, old-growth forests compared to young growth contain more complex below-ground processes that connect trees at the subsurface level.[36] Thus, the Forest Service needs to provide information on the impacts of logging on soil microbial and mycorrhizae carbon exchange before concluding it is insignificant. Failure to include such information would violate NEPA's hard look and BASI mandates.

Primary forest carbon can help slow climate change. Griscom et al. (2017) systematically evaluated 20 conservation, restoration, and improved land management actions that increase carbon storage and avoid greenhouse gas emissions. They found that the maximum potential of natural climate solutions was ~2.4 Pg of carbon per-year while safeguarding food security and

---

l. 2018

[33] McNicol et al. 2019

[33] Luyssaert et al. 2014.

[34] Frey et al. 2016.

[35] Klein et al. 2016.

[36] Morrien et al. 2017.

biodiversity.[37] To put the Tongass in this perspective – total Tongass stores = 2.8 Pg carbon with 16%-23% of that in IRAs – additionally, by maximizing carbon in IRAs and old growth (the scientifically recommended climate strategy) – the entire national forest benefits through the maintenance of linked ecosystem services and biodiversity (i.e., multifunctionality of forests maintained via carbon management).[38] New research (see below) suggests this strategy is the most cost-feasible option by a large margin[39] (also see below) and it should receive highest priority as a policy consideration[40] especially on the Tongass.[41] In addition to carbon, old forests also build soil, cycle nutrients, mitigate pollution, purify water, release oxygen, and provide habitat for wildlife at levels far superior than logged forests.[42]

Primary (unlogged) forests are far superior to logged forests in climate mitigation and biodiversity benefits. Globally, primary forests store 30-50% more carbon than logged forests (which is similar to the estimates provided in the DEIS on mature vs. logged Tongass forest stores[43]) and up to half of the carbon stored in a forest is represented by the largest/oldest 1% of trees at the stand level as noted.[44] As stated, logging primary forests results in a net carbon debt and other irreplaceable losses that are not made up for via reforestation or wood product stores as the carbon present in primary forests and soils takes centuries to accumulate compared to much shorter-lived wood products that represent only a fraction of the original forest store.

In part because the DEIS analysis fails adequately to account for this basic scientific information relevant to an assessment of the impact of the proposed exemption on carbon and climate impacts, the DEIS is flawed in at least the specific ways described herein.

Tongass carbon stores need to be prioritized as globally and nationally significant climate mitigation/adaptation strategies to be protected, preserved, and managed as unique ecological communities. Old-growth forests, in general, store massive amounts of carbon in trees, foliage, and soils. Pacific coastal rainforests, in particular, are global champions in this regard.[45] Of relevance, temperate rainforests in Alaska store >2.8 Petagrams (Pg) C (1 Pg = 1 billion tonnes) in biomass and soils, the equivalent of >8% of the carbon in all contiguous US forests, most of which is on the Tongass.[46] Based on FIA datasets, Tongass roadless areas represent ~16% to 23% of total carbon on the Tongass forest depending on categories used

---

37 Griscom et al. 2017.

38 *See* Brandt et al. 2014.

39 Moomaw et al. 2019.

40 McKinley et al. 2011.

41 Leighty et al. 2006; Buma and Thompson 2019

42 Mackey et al. 2014, Brandt et al. 2014.

43 DEIS at 3-124.

44 Lutz et al. 2018.

45 Leighty et al. 2006, Keith et al. 2009, Krankina et al. 2014.

46 Leighty et al. 2006; Buma and Thompson 2019; McNicol et al. 2019

(Table 1, 2). Thus, roadless areas – especially those with old-growth forests – are uniquely valuable as a long-term stable carbon sink compared to logged areas that emit most of their carbon (see below).

The Tongass stores a massive amount of carbon--the total carbon stored in Tongass roadless areas are equivalent to annual emissions of ~128, 550-watt coal-fired power plants.[47] Keeping carbon in forests is a fundamental climate mitigation strategy directly responsive to the climate emergency[48] and essential to offsetting some of the emissions from the energy sector. The Tongass stores a massive amount of carbon in its old growth forests, at levels that if emitted into the atmosphere would approach the emission equivalents of coal-fired power plants. At a time when the world is looking for leadership on cutting emissions at all scales, removing protection for this carbon storage is unsupportable. Table 1 provides a breakdown of Tongass old-growth roadless carbon values (including congressionally withdrawn areas), Table 2 just the IRA carbon values, and Figure 1 shows the spatial distribution of carbon stores on Tongass IRAs. Table 3 shows that Alternative 6 will place at risk 71.5% of the carbon stored in old-growth forests and soils, with most of that carbon emitted to the atmosphere (see Leighty et al. 2006). Table 4 provides an economic estimate of the carbon value at risk to logging on the Tongass under Alternative 6 (>$234 million), which may far exceed timber values. Additionally, if the Forest Service enters all roadless areas in this century >$2.2 billion in carbon assets will be squandered away, should an offset market develop. All these data were available to the Forest Service (Forest Inventory Assessment - FIA) and they need to be fully analyzed in the DEIS to provide reliable estimates of carbon assets and their relative (to timber), tradeoffs involved, and the economic importance on the Tongass of carbon, along with reliable estimates of emissions from logging. Disclosing these tradeoffs is especially relevant at a time when the IPCC (2018, 2019) and other reports (Ripple et al. 2017, 2019) have warned that we have about 10 years before severe climate impacts are locked in with irreversible consequences to biodiversity and the planet's life-giving systems.

[47] https://www.oregonlive.com/business/2010/12/pges_coal-fired_boardman_plant.html.

[48] *See* Moomaw 2019, Ripple et al. 2019.

Table 1. Estimated carbon biomass in old-growth forest among categories of roadless areas on the Tongass NF						
OwnerType_2019	USDA FOREST SERVICE					
POG	OG Only					
	low estimate	high estimate	Total area		Estimate C in OG forest biomass	
Row Labels	Average of Carbon_ratio 58	Average of Carbon_ratio 46	Sum of GIS_Hectares		(low estimage in Mg)	(high est. in Mg)
Roadless in 2001 Rule	264.7	333.7	999,179		264,443,913	333,444,106
Lg. Roadless Areas not in	257.1	324.1	76,166		19,580,156	24,689,023
Small Rdls Areas	242.4	305.6	58,329		14,139,031	17,828,070
Roaded-Roadless	249.3	314.4	14,357		3,579,634	4,513,860
Roaded Areas	263.3	332	156,023		41,076,507	51,794,893
Wilderness or NM	247.7	312.3	662,496		164,101,837	206,915,638
Non-USFS Lands	261.5	329.8	4,171		1,090,861	1,375,453
Unknown	187.5	236.5	982		184,209	232,273
Grand Total	**255.6**	**322.3**	**1,971,704**		**503,969,209**	**635,467,036**

Table 2. Carbon stored in roadless area categories on the Tongass.

Large Roadless Areas Average Mg per ha	Total Mg Carbon	"Roaded Roadless" Average Mg per ha	Total Mg Carbon	Small Rdls Areas Average Mg per ha	Total Mg Carbon	Roaded Areas Average Mg per ha	Total Mg Carbon	Protected by Congress Average Mg per ha	Total Mg Carbon	Non-USFS Lands Average Mg per ha	Total Mg Carbon	Total Average Mg per ha	Total Total Mg Carbon
242.58	**47,208,021**	**274.78**	**98,058**	**313.89**	**1,867,886**	**361.48**	**10,026,227**	**207.71**	**66,457,805**	**263.80**	**5,436,143**	**260.64**	**131,094,140**
245.92	2,081,610					317.13	83,671	224.49	36,976,406	205.86	248,378	224.82	39,390,064
224.39	7,939,491	248.04	7,679	361.21	317,926	374.39	1,469,914	179.03	2,579,177	277.13	198,836	277.09	12,513,023
255.70	18,610,022	295.11	85,792	305.53	1,322,520	356.44	6,423,528	210.15	11,972,020	286.92	3,550,567	278.05	41,964,449
231.40	17,172,289	226.63	4,587	304.03	227,439	371.92	2,025,237	144.80	7,123,632	252.95	1,407,175	261.84	27,960,360
190.38	1,404,610					234.51	23,876	185.47	7,806,570	228.97	31,187	192.89	9,266,244
232.20	**58,182,471**	**262.79**	**1,429,232**	**261.26**	**4,248,583**	**303.66**	**15,895,643**	**196.32**	**22,381,595**	**253.61**	**11,984,173**	**249.11**	**114,121,697**
236.71	9,363,695	232.25	279,800	213.54	756,243	291.33	3,979,300	167.72	2,705,767	252.31	1,048,227	244.24	18,133,031
248.42	4,621,788			282.27	61,790	345.31	264,235	231.39	6,290,381	200.47	149,533	246.54	11,387,728

201.63	14,044,010	240.78	675,871	236.58	1,737,670	276.70	4,000,336	199.16	2,694,688	216.69	3,418,960	225.90	26,571,535
289.39	4,013,721	317.04	8,473	337.44	1,008,771	340.32	3,176,035	284.31	1,032,343	291.65	521,090	311.71	9,760,434
237.96	26,139,257	301.06	465,088	286.21	684,109	320.59	4,475,736	177.93	9,658,416	268.36	6,846,362	254.25	48,268,969
229.96	**31,318,111**	**247.66**	**892,278**	**238.48**	**2,941,262**	**290.26**	**16,874,911**	**239.86**	**16,293,468**	**268.92**	**21,060,394**	**255.37**	**89,380,425**
264.73	5,634,563			226.80	397	356.33	2,846			265.96	3,679,426	266.56	9,317,233
219.88	15,720,049	244.81	775,492	234.97	2,586,253	287.67	15,078,975	258.07	7,425,974	261.59	14,491,136	252.13	56,077,879
281.10	2,088,047	230.67	21,443	251.59	236,829	294.96	1,465,398	196.99	4,999,443	315.98	468,652	278.44	9,279,811
231.49	7,875,451	293.14	95,343	284.60	117,783	322.67	327,692	192.56	3,868,051	296.39	2,421,180	256.94	14,705,501
186.13	**53,884,796**	**336.78**	**287,412**	**333.72**	**595,565**	**312.46**	**2,942,711**	**149.44**	**66,534,550**	**259.89**	**5,757,139**	**213.28**	**130,002,173**
192.56	11,619,409	369.34	120,627	327.18	275,972	313.76	861,295	118.57	3,208,927	268.13	1,822,554	235.07	17,908,784
62.94	1,228,345			368.10	96,490	136.68	78,974	159.84	18,154,192	284.05	46,875	168.06	19,604,876
						123.88	45	181.02	31,003,210	148.94	170	179.52	31,003,425
187.62	21,671,798	288.49	136,481	309.91	31,943	325.86	1,478,419	118.41	7,974,912	260.51	721,358	212.07	32,014,912
192.02	19,365,243	314.33	30,304	440.91	191,161	322.72	523,978	118.67	6,193,309	251.30	3,166,182	215.24	29,470,176
225.32	**190,593,399**	**264.38**	**2,706,980**	**265.82**	**9,653,295**	**312.40**	**45,739,492**	**196.09**	**171,667,419**	**263.11**	**44,237,849**	**247.37**	**464,598,434**

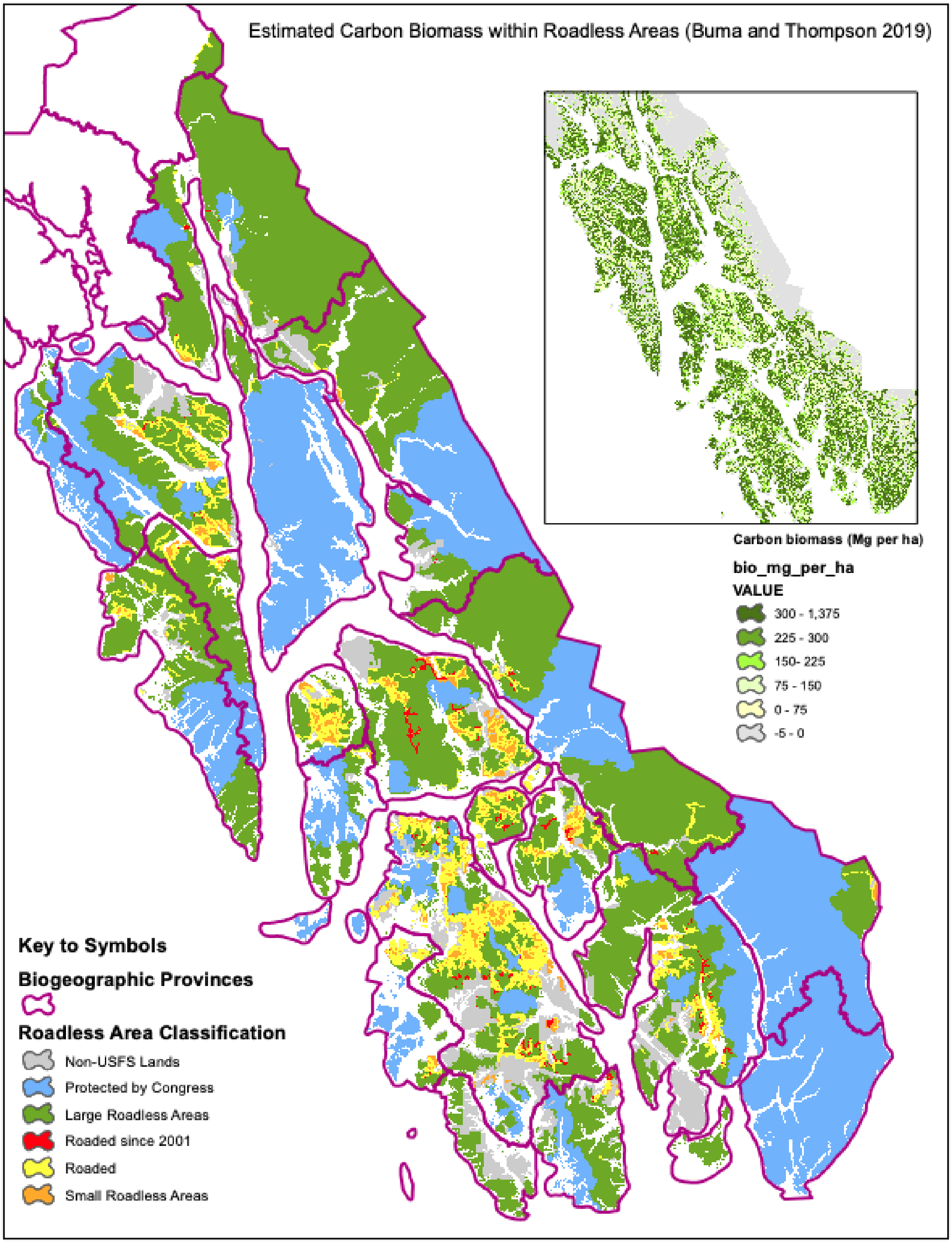

Estimated Carbon Biomass within Roadless Areas (Buma and Thompson 2019)
Carbon biomass (Mg per ha)
bio_mg_per_ha
VALUE
300 - 1,375
225 - 300
150- 225
75 - 150
0 - 75
-5 - 0
Key to Symbols
Biogeographic Provinces
Roadless Area Classification
Non-USFS Lands
Protected by Congress
Large Roadless Areas
Roaded since 2001
Roaded
Small Roadless Areas

Table 3. Estimated Mg of forest and soil carbon on lands suitable for old-growth logging under DEIS Alternatives

	Alternatives					
Forest & Soil Carbon Estimates	**1**	**2**	**3**	**4**	**5**	**6**
Suitable Acres (with Data)	229,564	249,888	307,778	387,941	394,997	394,997
Net Change from Alt 1 (acres)	0	20,325	78,214	158,377	165,433	165,433
Suitable Hectares (w/data)	92,901	101,126	124,554	156,994	159,850	159,850
Net Change from Alt 1 (hectares)	0	8,225	31,652	64,093	66,948	66,948
Total Forest C (low est)	23,625,799	25,643,535	31,591,558	39,655,731	40,508,557	40,508,557
% Increase from Alt 1 (low est)	0.0%	8.5%	33.7%	67.8%	71.5%	71.5%
Total Forest C (high est)	29,790,661	32,334,884	39,834,901	50,003,261	51,078,589	51,078,589
% Increase from Alt 1 (high est)	0.0%	8.5%	33.7%	67.8%	71.5%	71.5%
Total Soil C	34,284,875	37,153,086	45,699,226	56,497,163	57,468,262	57,468,262
% increase from Alt 1 (soil)	0.0%	8.4%	33.3%	64.8%	67.6%	67.6%
Forest + Soil C (low)	57,910,675	62,796,621	77,290,783	96,152,894	97,976,819	97,976,819
Forest + Soil C (high)	64,075,536	69,487,970	85,534,126	106,500,424	108,546,851	108,546,851

% Increase from Alt 1 (high)	0.0%	8.4%	33.5%	66.2%	69.4%	69.4%

Table 4. Economic value of at-risk carbon (Alternative 6 plus all suitable)

	Alt 6 suitable timber at-risk	All suitable timber at-risk
Acres	42,500	394,997
Low est total carbon	40,508,577	40,508,577
CO_2 (carbon x 3.67)	148,666,478	148,666,478
Value of CO_2 at-risk in suitable timber base* at $15/ton CO_2	$240,839,694 40% logged in first decade = $96.3 million	$2.2 billion

*Suitable timber base = 10.8% of at-risk carbon under Alt 6, 100% at risk under all suitable acres

Carbon emissions assessment by the Forest Service provides a misleading comparison to other emissions and fails to include a social cost analysis. The DEIS is woefully inadequate as it compares emissions (prior and current logging) on the Tongass to gross emissions from the **entire US electric power sector in 2012** and **all US emissions in 2017**.[49] Federal courts have rejected this kind of skewed comparisons.[50] This arbitrary baseline ignores the incremental nature of carbon emissions and impacts and is inconsistent with recommendations of the IPCC (2018) to avoid additional emissions, and with the broader scientific consensus of fully protecting carbon sinks like the Tongass.[51] To comply with NEPA, the Forest Service must, at a minimum, explain why it is choosing to ignore these expert conclusions. The global community also has signaled its intent to protect carbon sinks under Article 5 of the Paris Climate

49 DEIS at 3-124.

50 *See High Country*, 52 F. Supp. 3d at 1190 ("Beyond quantifying the amount of emissions relative to state and national emissions and giving general discussion to the impacts of global climate change, [the agencies] did not discuss the impacts caused by these emissions."); *Mont. Envtl. Info. Ctr. v. U.S. Office of Surface Mining*, 274 F. Supp. 3d 1074, 1096–99 (D. Mont. 2017) (rejecting the argument that the agency "reasonably considered the impact of greenhouse gas emissions by quantifying the emissions which would be released if the [coal] mine expansion is approved, and comparing that amount to the net emissions of the United States"); *WildEarth Guardians v. Zinke*, 368 F. Supp. 3d 41, 76-78 (D.D.C. 2019) (holding BLM's conclusion that the emissions from oil and gas leases "represent an incremental contribution to the total regional and global GHG emissions level" was arbitrary and capricious because it was not supported by any data).

51 Keith et al. 2009, DellaSala et al. 2011, Stephenson et al. 2014, Mackey et al. 2014, Law et al. 2018, Moomaw et al. 2019.

Agreement. While the US is irresponsibly withdrawing from the agreement, it is also irresponsible for the Forest Service to downplay the substantial regional emissions from Tongass roadless and old growth logging when the rest of the world is looking for ways to reduce and avoid emissions **at all scales**. Instead, the agency should choose the alternative with the least emissions – no action – and compare alternatives against no action with respect to reliable and accurate direct, indirect, and cumulative emissions. This also needs to be expressed in carbon dioxide equivalents to estimate the socio-economic cost of carbon. Additionally, the emissions need to be expressed at an appropriate **regionally specific scale**, as for instance, coal-fired power plant equivalents as mentioned above so that the public understands the true regional climate consequences of opening roadless areas to logging and development.

Further, the DEIS falsely asserts that "it is difficult and highly uncertain to ascertain the indirect effects of emissions resulting from these alternatives on global climate."[52] The Forest Service could easily express the indirect impacts of climate emissions by quantifying or estimating climate pollution volumes by alternative (as noted above in our analysis) and then using the social cost of carbon (SCC) to assess and compare the significance of the effects on global climate. The very purpose of the SCC is to assist decisionmakers in (conservatively) estimating the marginal damages from each additional ton of greenhouse gas emissions. To avoid this analysis irresponsibly kicks the emissions can down the road.

The DEIS incorrectly states that most of the carbon in trees after logging will be recovered via reforestation and stored in wood products for buildings instead of stored in forest ecosystems and this is completely false. As noted, a substantial portion of the total forest carbon is contained in foliage, branches and bark, root wads and soils.[53] Because much of the carbon in logs hauled to mills becomes waste, only a relatively minor portion of the total tree carbon ultimately ends up in wood products.[54] Up to 40% of the harvested material does not become forest products and is burned or decomposes quickly on site, and a majority of manufacturing waste is burned for heat. One study found that 65% of the carbon from West Coast forests logged over the past 100 years is still in the atmosphere with just 19% stored in long-lived products; the remainder is in landfills.[55] Additionally, Leighty et al. (2006) reported that a century of Tongass logging has emitted 6.4-17.2 Tg C that is still in the atmosphere (again – it matters most what the atmosphere "sees" more than what is stored in wood products). Further, Hudiburg et al. (2019) note that state and federal reporting of emissions has erroneously excluded some product-related emissions, resulting in 25-55% underestimation of total CO2 emissions from logging. Thus, the Forest Service needs to fully disclose and provide reliable estimates on how much carbon is emitted by clearcutting given the substantial fall down and problems with underestimating emissions as noted. Large amounts of logs, stumps, root wads and slash are left on the ground after clearcutting and soils are noticeably disturbed by heavy equipment. This cannot be simply dismissed as an insignificant impact in the DEIS.

---

52 DEIS at 3-127

53 Campbell et al. 2007.

54 *See, e.g.*, Harmon et al. 1990, Harmon et al. 1996, Ingerson 2008, Law et al. 2018, Harmon 2019.

55 Hudiburg et al. 2019.

It is also wrong for the Forest Service to assert that carbon stored in Tongass saw logs (wood product pools) compensates for carbon emitted by logging long-lived (hundreds of years) trees in the Tongass old-growth carbon sink.[56] The carbon debt created by expansive clearcut logging (past, present, future) must be calculated using reliable and accurate estimates via a carbon life cycle analysis that accounts for how long carbon remains in the atmosphere (after all, it's what the atmosphere "sees" that matters most in the long run). Thus, at a minimum, NEPA requires that the Forest Service conduct a carbon life cycle analysis using published sources and the Forest Service should use FIA/timber stand data on estimated carbon uptake and stores in old growth vs. young growth to calculate age-related differences in carbon stores and associated emissions from logging (e.g., using the carbon values for Tongass old growth and IRAs in our comments) at the regional scale. The following analysis components should be included in the DEIS:

- In-boundary emissions – at the stand and landscape level, this includes carbon entering the atmosphere from the substantial "fall down" and defect of uneconomical logs, slash, and stumps – based on Tongass timber stand inventory data (2016-18) fall down alone (uneconomical material) may be as high as 70% of felled trees (carbon emitted directly to the atmosphere) with old-growth defect at least 30%.

- Out-of-boundary emissions – this includes: (1) carbon emitted via wood processing waste at the mill (see Law et al. 2018 for example); (2) fossil fuels used in transport and manufacture of wood products, including emissions from log exports sent to China and then exported for distribution as products, the lower 48 states and elsewhere (note - transport emissions are easily obtained from the Alaska Department of Environmental Conservation Division of Air Quality (greenhouse gas emission inventory[57]; and (3) estimated emissions from road building.[58]

- Use more recent studies on wood product substitution estimates – Harmon (2019), for instance, re-examined substitution assumptions questioning their *reliability* in life cycle analysis and concluding that any benefits depend on duration of fossil carbon displacement, longevity of buildings being assumed, and nature of the forest supplying building materials (also see below):

  "Substitution of wood for more fossil carbon intensive building materials has been projected to result in major climate mitigation benefits often exceeding those of the forests themselves. A reexamination of the fundamental assumptions underlying these projections indicates long-term mitigation benefits related to product substitution may have been overestimated *2- to 100-fold (emphasis added)*. This suggests that while

[56] *See, e.g.*, DEIS at 3-127.

[57] *See* https://dec.alaska.gov/air/anpms/projects-reports/greenhouse-gas-inventory)

[58] *See* Loeffler et al. 2008 for how to estimate this -note – this is a Forest Service publication easily accessible to the agency.

product substitution has limited climate mitigation benefits, to be effective the value and duration of the fossil carbon displacement, the longevity of buildings, and the nature of the forest supplying building materials must be considered."[59] Failure to address this scientific study would violate NEPA's and NFMA's mandate that the Forest Service use the best available science and that the agency explain why its approach differs from that of experts.

- The need for reliable published references to estimate wood product stores– Researchers report most carbon is emitted to the atmosphere when old trees are logged, accounting for wood product stores is only a fraction of the carbon pool (e.g., ~35% of the live carbon is rapidly emitted when an old-growth forest is logged with another 30% emitted at the mill and even more in transportation).[60]

- The reference to an albedo effect in the DEIS (at 3-123) is unreliable, cannot be verified, is inconsistent with the BASI requirement, and should be dropped. The DEIS provides no citation or support for its unsubstantiated albedo assumption, which likely was extrapolated from the boreal regions where albedo has been reported as having a potential cooling affect because of the reflectance properties of snow. The Forest Service cannot make this same claim for the Tongass given that low-elevation temperate rainforests experience relatively little snow (and therefore have low albedo/reflectance properties), especially in a changing climate (as noted in the DEIS). Without a life cycle analysis that first estimates logging emissions and then compares emissions to whatever insignificant albedo effect is anticipated in temperate regions with little snow, the albedo cooling assumption is falsified and cannot be used for disclosing climate impacts of Tongass logging. In sum, large regional and ecosystem type variations have been observed in albedo and one cannot compare albedo from one region to another or one forest type to another.

In this regard, the DEIS echoes unsupportable claims and assumptions by the wood products industry that substituting wood for concrete and steel reduces the overall carbon footprint of buildings and thus is unreliable and inaccurate. The agencies' wood production substitution claim has been refuted by recent analyses that reveal forest industries have been using unrealistic and erroneous assumptions in their models, overestimating the long-term mitigation benefits of substitution by 2- to 100-fold.[61] An additional recent analysis concluded that the carbon footprint of wood is 6% higher than concrete (Stiebert et al. 2019), and that assessment did not include the reduced forest carbon sequestration and storage caused by forest losses as discussed. Importantly, a very recent breakthrough in solar energy production will soon make it possible to dramatically reduce the carbon footprint of concrete and steel even further.[62] Additionally,

59 Harmon 2019. –

60 *See* Harmon et al. 1990, Harmon et al. 1996, Law et al. 2018, Harmon 2019.

61 As discussed, Law et al. 2018, Harmon 2019.

62 https://www.cnn.com/2019/11/19/business/heliogen-solar-energy-bill-gates/index.html.

regarding the noted problems with exaggerated wood substitution benefits,[63] there is no assurance that concrete and steel replaced by wood will not be used in application somewhere else (i.e., leakage from using steel/concrete used elsewhere). For the substitution benefit to accrue, an equivalent amount of concrete or steel would need to not be produced and used in construction; otherwise, substitution is purely speculative (not best science) and unreliable. Further, the DEIS did not account for the high recycled content in most steel or recent/future anticipated advances in reducing the carbon footprint of concrete. For instance, changing manufacturing methods impact embodied energy, as for example, if fly ash is added to concreate it could yield 22-38% reductions in embodied energy required in manufacturing processes, thereby reducing the displacement value of wood.[64] Using clean, renewable energy instead of coal in concrete and steel manufacturing also can lower the substitution value and is part of the mix of energy sources being expand upon by the global community (i.e., over the next few decades new energy sources and processing efficiencies will emerge to reduce concrete/steel emissions and this needs to be factored into a "best case scenario" for energy efficiency upgrades in the DEIS). This change is already underway.[65]

To construct a proper life cycle analysis that provides a science-based assessment of carbon stocks and flows on the Tongass, the DEIS should adopt a method similar to the approach used by Hudiburg et al. in their 2019 life cycle analysis of emissions from logging. The following abstract summarizes their methodologies:

> Abstract
> Atmospheric greenhouse gases (GHGs) must be reduced to avoid an unsustainable climate. Because carbon dioxide is removed from the atmosphere and sequestered in forests and wood products, mitigation strategies to sustain and increase forest carbon sequestration are being developed. These strategies require full accounting of forest sector GHG budgets. Here, we describe a rigorous approach using over one million observations from forest inventory data and a regionally calibrated life-cycle assessment for calculating cradle-to-grave forest sector emissions and sequestration. We find that Western US forests are net sinks because there is a positive net balance of forest carbon uptake exceeding losses due to harvesting, wood product use, and combustion by wildfire. However, over 100 years of wood product usage is reducing the potential annual sink by an average of 21%, suggesting forest carbon storage can become more effective in climate mitigation through reduction in harvest, longer rotations, or more efficient wood product usage (emphasis added). Of the~10,700 million metric tonnes of carbon dioxide equivalents removed from west coast forests since 1900, 81% of it has been returned to the atmosphere or deposited in landfills (emphasis added). Moreover, state

63 *See* DEIS at 3-123.

64 Harmon 2019.

65 *See* J. Gillis, The Steel Mill That Helped Build the American West Goes Green, The New York Times (Oct. 16, 2019) (describing Colorado steel mill's decision to manufacture steel using only renewable energy), available at https://www.nytimes.com/2019/10/16/opinion/solar-colorado-steel-mill.html (last viewed Dec. 13, 2019).

> and federal reporting have erroneously excluded some product-related emissions, resulting in 25%–55% underestimation of state total CO2 emissions. For states seeking to reach GHG reduction mandates by 2030, it is important that state CO2 budgets are effectively determined or claimed reductions will be insufficient to mitigate climate change.[66]

Logging involves transportation of trucks and machinery across long distances between the forest, the mill, and point of distribution and the DEIS needs to properly disclose these emission sources. For every ton of carbon emitted from logging, an additional ~17% is estimated from fossil fuel consumption to support transportation, extraction, and processing of wood[67], not including the significant emissions from building roads.[68] There is no indication that this was even accounted for in the DEIS.[69] As noted, the Forest Service should consult with state emissions data to obtain reliable estimates of emissions from transport and manufacturing of wood products, particularly the incredibly long hauling distances involved with exporting logs to China and the burning of fossil fuels to get them there (plus when manufactured products are shipped again to retail and distribution areas). In the Tongass this is an especially valid concern given the remote location, no road access (necessitating saltwater barges), and weather which requires extensive and long transportation chains.

The DEIS does not account for the reduction in carbon sequestration and storage potential in forests due to logging-caused soil compaction and nutrient loss. This is despite the fact that these combined impacts can reduce forest carbon storage potential contributing to an overall carbon debt not explained or assessed in the DEIS. We note that this debt is not trivial because ~60% of the carbon lost through logging since 1700s has not yet been recovered by the land sector[70] and 81% of carbon previously stored in West Coast forests has been returned to the atmosphere via logging since 1900.[71] These are centuries-long atmospheric carbon emissions coming at a time when we are in a climate emergency.[72] This is why scientists are calling for policies that avoid emissions and store more carbon in forests compared to wood product pools.[73]

---

66 Hudiburg et al. 2019.

67 Ingerson 2008.

68 *See* Loeffler et al. 2008.

69 The DEIS at 3-127 includes "transporting wood products" in a laundry list of potential cumulative impacts to consider in its climate analysis, but provides no analysis at all of the scale or nature of that impact, violating NEPA's hard look mandate.

70 McKinley et al. 2011.

71 Hudiburg et al. 2019.

72 Ripple et al. 2019.

73 Hamon et al. 1990, 1996, Leighty et al. 2006, McKinley et al. 2011, Mackey et al. 2016a,b, Law et al. 2018, Moomaw 2019.

Additionally, there are other greenhouse gas effects such as methane and nitrous oxide emissions from soil impacts that will impact the climate from logging.[74]

In sum, the DEIS fails to include peer-reviewed science on forest carbon and emissions that shows: (1) primary (unlogged) forests are far superior to logged forests at carbon uptake and storage long term; (2) trees accumulate carbon over their entire lifespan; older trees capture and store far more carbon than young trees; (3) old, primary forests accumulate far more carbon than they lose through decomposition and respiration, thus acting as net carbon sinks; (4) logged forests are an emission source for at least the first decade and never fully recapture the emitted carbon stored in the pre-logged old-growth forest due to short rotation harvests and carbon losses throughout the wood product distribution chain; and (5) the superior carbon benefits of old forests are especially evident when taking into account the role of undisturbed soils (which may contain ~50% of carbon stores[75],) and below ground carbon exchange losses from logging and climate change impacts.

B. DEIS CLAIMS ABOUT TEMPERATE RAINFORESTS AND FOREST MANAGEMENT ARE NOT BASED ON BEST AVAILABLE SCIENCE

In addition to failing to analyze important information about the Tongass and its value for climate and carbon storage, the DEIS fails to analyze important information about the value of temperate rainforests.

- **Temperate rainforest amount reported in the DEIS is incorrect** – The DEIS grossly underestimates the global importance of coastal temperate rainforests, including the Tongass, for carbon regulation (0.5% global cover; no citation given).[76] DellaSala et al. (2011) provided the first computer generated map of all the world's temperate rainforests reporting that the total area for this rainforest biome is actually 2.5% of all forests globally (5 times that reported in the DEIS). The Pacific Coastal rainforests (California Coast Redwoods to Alaska) are globally significant as they represent over one-third of all temperate rainforests world-wide and because the Tongass is one of only 4 other relatively intact temperate rainforests (Great Bear – BC; Valdivia – Chile; Russian Far East; Southern Siberia). Thus, even though the overall global footprint of this rainforest biome is relatively small, the climate regulation properties of these forests – because of their enormous carbon stores – along with their myriad biodiversity and ecosystem benefits[77] – are globally significant and irreplaceable.[78] The Forest Service therefore has a national and global responsibility to maintain the intactness of this region and opening up roadless areas will have global ramifications contributing to the pace and scale of forest degradation globally. This is why 234 scientists signed a letter urging the Forest

[74] McKinley et al. 2011.

[75] Campbell et al. 2007. McNicol et al. 2019

[76] DEIS at 3-122.

[77] Brandt et al. 2014.

[78] DellaSala et al. 2011.

Service to protect the region's roadless areas (attached). The decision to open up roadless areas therefore is not based on best available science. At an absolute minimum, the Forest Service must correct its evaluation of the global importance of the Tongass's temperate rain forests and respond to these expert reports.

- **Unsubstantiated claims are made about management activities approximating and promoting natural processes** – The Forest Service states, without a single citation, that logging and prescribed fire tend to approximate and promote natural processes and that such actions can result in long-term carbon uptake and storage that somehow increases resilience.[79] We note that prescribed fire is not even relevant on the Tongass rainforest and has no purpose in this DEIS. The statement overall also has no basis in the ecological literature, and certainly none for the Tongass's temperate rainforest, and seems to imply that forest degradation is a net gain in carbon and ecosystem processes even though the IPCC (2018, 2019) and numerous scientific studies indicate otherwise.[80] As discussed, the Forest Service needs to provide a reliable life cycle analysis and evidence-based review of the literature to back assertions that clearcut logging and road building somehow resemble natural disturbance processes – including effects on biodiversity (e.g., deer, wolves, murrelets and other old growth species). The statement, in fact, is reflective of old-school forestry ideologies long dismissed in the ecological literature and even by many foresters. Notably, given the lack of fire on the Tongass, primary disturbance agents are blow down from wind storms (canopy gap, stand, landscape level), landslides (watershed-landscape level), and tree mortality (stand level – canopy gaps – and watershed-landscape yellow cedar death from climate impacts). In no way do clearcuts, roads, mines, dams, etc. resemble any of these natural disturbances as natural disturbances leave prodigious amounts of biological legacies[81] that "life-boat" a forest through successional stages while these developments in old growth and IRAs will remove nearly all biological legacies. The long return interval of natural disturbances allows for old growth to develop over centuries, whereas, logged areas can be logged again in <100 years; this is insufficient time for forests to recoup carbon emitted from logging and to reach their maximum carbon potential.[82] We note that Public Law 113-291 (2014) allows up to 15,000 acres of young growth to be logged from 2016-2025 in stands < 95% CMAI and there is flexibility in NFMA to allow a continuation of harvesting at young ages beyond 2025 – thus, the carbon debt from re-logging these forests on a sustained yield basis is never recaptured and remains in the atmosphere for over a century at a time when we are in a climate emergency. The Forest Service needs to properly account for this carbon debt in the DEIS.

---

79 DEIS at 3-123.

80 *See e.g.*, Harmon et al. 1990, Harmon et al. 1996, Mackey et al. 2014, Law et al. 2018, Moomaw 2019.

81 DellaSala 2019; Buma et al. 2019.

82 Moomaw 2019.

United States Department of Agriculture
Forest Service

PNW
Pacific Northwest
Research Station

INSIDE

Science FINDINGS

issue two hundred twenty-five / march 2020

"Science affects the way we think together."

Lewis Thomas

Forestry as a Natural Climate Solution: The Positive Outcomes of Negative Carbon Emissions

David D'Amore

An unthinned, even-aged stand in southeast Alaska. New research on carbon sequestration in the region's coastal temperate rainforests, and how this may change over the next 80 years, is helping land managers evaluate tradeoffs among management options.

"Stones have been known to move and trees to speak."

— William Shakespeare

Forests have long been recognized for the ecological and economic services they provide. The Organic Administration Act of 1897 that authorized the creation of forest reserves, now better known as national forests, describes these forest reserves as securing "favorable conditions of water flows, and to furnish a continuous supply of timber." As efforts to mitigate climate change gain traction, forests are being appreciated for the role they play in the global carbon cycle. Through photosynthesis, trees convert sunlight, water, and atmospheric carbon dioxide into carbohydrates (energy) and oxygen. These carbohydrates contain carbon that is fixed from atmospheric carbon dioxide. This carbon is used to create woody tissue and other plant parts and is stored in these woody tissues or sequestered in its roots and soil.

Although a tree releases carbon dioxide, along with heat and excess water when consuming carbohydrates, more carbon is stored than is released into the atmosphere. This ability to sequester carbon is one reason forests are considered a natural solution to help mitigate climate change. By sequestering carbon, forests are offsetting the emissions that human activity is releasing into the atmosphere.

IN SUMMARY

Forests are considered a natural solution for mitigating climate change because they absorb and store atmospheric carbon. With Alaska boasting 129 million acres of forest, this state can play a crucial role as a carbon sink for the United States. Until recently, the volume of carbon stored in Alaska's forests was unknown, as was their future carbon sequestration capacity.

In 2007, Congress passed the Energy Independence and Security Act that directed the Department of the Interior to assess the stock and flow of carbon in all the lands and waters of the United States. In 2012, a team composed of researchers with the U.S. Geological Survey, U.S. Forest Service, and the University of Alaska assessed how much carbon Alaska's forests can sequester.

The researchers concluded that ecosystems of Alaska could be a substantial carbon sink. Carbon sequestration is estimated at 22.5 to 70.0 teragrams (Tg) of carbon per year over the remainder of this century. In particular, Alaska's dense coastal temperate forests and soils are estimated to sequester 3.4 to 7.8 Tg of carbon per year. Forest management activities were found to have long-term effects on the maximum amount of carbon a site can sequester. These findings helped inform the carbon assessment sections of Chugach and Tongass National Forests' land management plans.

However, forests release carbon too; it doesn't remain permanently sequestered. Decomposition of biomass stored in trees and soil releases carbon to the atmosphere. A portion of this carbon mixes with water and travels underground until reaching a water source that carries it to a river and out to the ocean. Once in the ocean, this carbon can fuel marine life, get jettisoned back into the atmosphere by a breaking wave, or sink to the deep ocean and remain there for millennia.

Research over the past decade has answered questions about the rates at which trees of different ages and forests of different types sequester carbon. We now know that middle-aged forests (about 50 to 100 years old) sequester carbon at a faster rate than older forests, but older forests store more carbon because over time, they have sequestered more carbon into the trees and soils. Management activities and natural disturbances also affect the volume of carbon sequestered in a forest. When trees are harvested, the disturbed soil releases carbon to the atmosphere. Regenerating small young trees won't immediately store as much carbon as the larger, older harvested trees did. Similarly, a bark beetle outbreak or wildfire can result in dying trees releasing carbon into the atmosphere and a decrease in carbon being stored on the landscape.

Why is it necessary to understand the carbon cycle at this fine level of detail? The United Nations Framework on Climate Change, which was passed in 1992, seeks to stabilize the concentration of greenhouse gasses, such as carbon dioxide, in the atmosphere. The United States is a signatory to the agreement, and the Environmental Protection Agency is charged with compiling an annual report on the nation's annual carbon flux or carbon budget: the volume of carbon released into the atmosphere minus the volume of carbon sequestered by landscapes.

KEY FINDINGS

- Alaska's temperate coastal forests absorb more carbon from the atmosphere than they release. They function as carbon "sinks" in part because cool temperatures slow decomposition and lead to an accumulation of carbon in woody debris and soils.
- The amount of carbon sequestered by Alaska ecosystems is projected to increase by 22.5 to 70.0 teragrams of carbon per year over the remainder of this century. This increase is in part due to vegetation growth in the temperate forests in the southeast portion of the state.
- Young-growth forests rapidly accumulate carbon, making them carbon hotspots and a focus for management initiatives. Precommercial thinning, however, reduces the maximum amount of carbon stored on a site. This reduction may persist 100 years after treatment.
- Soils in the coastal temperate rainforest store large amounts of carbon, estimated at 4.5 petagrams of carbon, which is even more than the vast aboveground pools. However, soil carbon storage is susceptible to a warming climate; warmer temperatures could increase biomass accumulation while also increasing decomposition.

Tracking Carbon Through Forests and Streams

With Alaska's 129 million acres of forest, the state plays a crucial role in the global carbon cycle. The coastal temperate rainforests in southeast and south-central Alaska are particularly valuable as carbon sinks because they grow rapidly and do not experience frequent disturbances, such as wildfire or bark beetle outbreaks. Dave D'Amore, a research soil scientist with the U.S. Forest Service Pacific Northwest Research Station, focuses on understanding the carbon cycle, specifically, within the terrestrial landscapes in southeast Alaska.

Maintaining this research focus over the past 25 years hasn't always been easy, D'Amore admits. "Carbon cycle science wasn't a high priority for research in the past because you have to balance work related to current research questions with work addressing

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

PNW Science Findings is published monthly by:

Pacific Northwest Research Station
USDA Forest Service
P.O. Box 3890
Portland, Oregon 97208

Send new subscription and change of address information to:

SM.FS.pnw_pnwpubs@usda.gov

Rhonda Mazza, editor; rhonda.mazza@usda.gov

Jason Blake, layout; jason.p.blake@usda.gov

To find Science Findings online, visit https://www.fs.usda.gov/pnw/ and click on **Publications**.

Become a digital subscriber here: https://www.fs.usda.gov/pnw/publications/subscriptions.shtml

USDA United States Department of Agriculture
Forest Service

U.S. Forest Service

A thinned, 50-year-old stand in southeast Alaska. Thinning enables more sunlight to reach the forest floor, resulting in a more diverse understory and wildlife habitat, and increases growth rate of remaining trees. In a forest model simulation, the volume of carbon stored aboveground in a thinned stand was less than in an unthinned stand 100 years after treatment.

potential future needs and questions," he explains. "It is often difficult to anticipate future information needs and initiate research in advance of their importance"

Now, however, carbon cycle research is a priority, and according to D'Amore, "it's an important research issue worldwide."

In 2001, D'Amore and his colleagues realized that basic knowledge was needed on how dissolved organic carbon moved through southeast Alaska's watersheds. "We recognized that the lateral flux could be a big part of the carbon budget," he says. "We lose a portion of the carbon by a pathway that wasn't accounted for traditionally in carbon balance equations."

Carbon is a fundamental component of organic acids, which influence aquatic productivity as a source of nutrients and energy. The high volume of rainfall and perennial streamflow that is common in coastal forests carries large amounts of carbon from the soil and into the streams. "These streams are dark brown because they're chock-full of organic carbon," D'Amore explains.

After publishing several papers on carbon cycling and confirming that there is a significant volume of carbon leaving watersheds through aquatic pathways, D'Amore shifted his focus to the terrestrial side of the carbon cycle. He wanted to pursue both the basic questions and the applied questions that forest managers needed answered. Specifically, on the Tongass National Forest, management was transitioning from harvesting old-growth stands to young-growth stands. "A key question was how much carbon is accumulating in those young stands and what happens when you thin them?" D'Amore says.

The accepted belief among land managers was that thinning young stands, which was done to increase the growth rate of the remaining trees and improve wildlife habitat, increased carbon sequestration. D'Amore recalls thinking, "No, I don't think it works that way."

To test this hypothesis, D'Amore's team used two datasets containing growth-and-yield measurements of young-growth forests in southeast Alaska. One dataset dating back to the 1920s included measurements of 12 unthinned plots, while the other dataset contained measurements from 272 thinned and unthinned plots. The scientists used these data to build a forest model that simulated carbon storage and accumulation over 100 years across three different thinning treatments (a 47, 60, and 73 percent reduction in basal area) and a nonthinned treatment. The model was run through 100 years because that was the timespan of the observations.

The results revealed that thinning the forest reduced the overall volume of carbon being sequestered—100 years later, a thinned stand did not achieve the same volume of sequestered carbon as an unthinned stand. However, the rate of carbon accumulation in the thinned stands was similar to that of the unthinned stands if decomposition of cut trees in the thinned stands was not included in the equation.

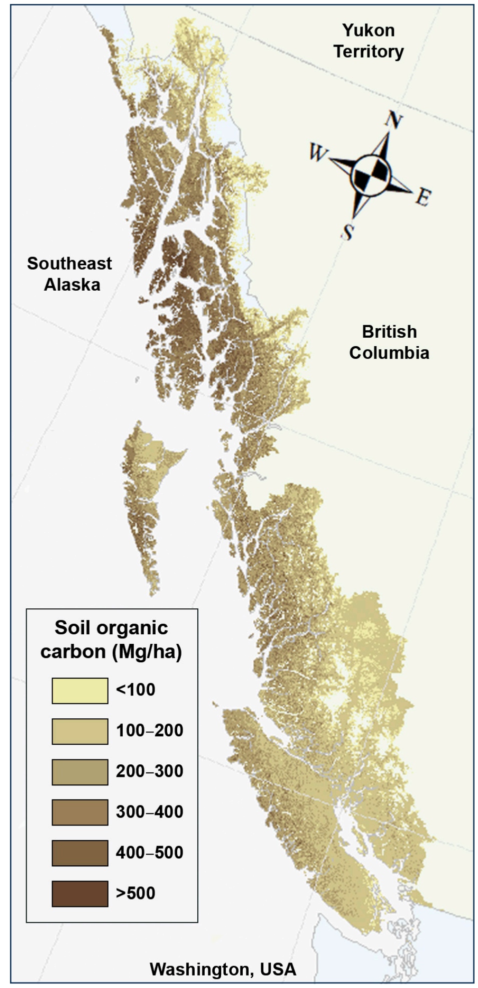
While the findings validated D'Amore's hunch, he cautions that these results don't suggest that reducing the carbon sequestering potential of a forest is good or bad. "We're just answering a key question related to the carbon cycle so managers can make a more informed decision," he explains. "There might be another reason for thinning, such as to enhance wildlife habitat, and there is a value judgement that needs to be made. There are a lot of tradeoffs."

Mapping Carbon in Soil

With the role of the aboveground forests in the carbon cycle quantified, the next piece was quantifying the volume stored in the soil across the region. A regional map of soil-stored carbon is needed, says D'Amore, because "soil has traditionally not been included in carbon budget calculations because people view soil as stable and not changing very fast. Yet small changes over large areas, or even short periods of time, can impact the carbon budget."

To create this map, D'Amore collaborated with colleagues throughout Alaska and British Columbia. Gavin McNicol led the research team as a postdoctorate with the Alaska Coastal Rainforest Center—a hub of collaborative research founded by the University of Alaska Southeast and U.S. Forest Service.

A researcher collects soil samples from volcanic-derived soil in the Heén Latinee Experimental Forest within the Tongass National Forest. These samples were later analyzed to determine the carbon content.



Soil organic carbon stock predictions to 1 m (Mg C ha−1) at 90.5 m resolution for small watersheds within coastal temperate rainforest across British Columbia and southeast Alaska. This effort to map soil carbon revealed that an estimated 22 percent of carbon in this coastal temperate rainforest is stored in the top 1 m of soil. Adapted from McNicol et al. (2019).

McNicol employed a new technique called digital soil mapping. He created a model that used data collected from 800 plots spanning from southeast Alaska to Vancouver Island to estimate the soil carbon stored in areas without plot data. With the compiled soil database, McNicol used measurements such as the amount of rainfall, temperature, topography, and other variables to predict soil type at the local level as these factors can affect the amount of carbon that soils sequester.

The modeling effort provided maps of regional carbon patterns, and estimated the total carbon stored within the coastal forest region at 4.5 petagrams—about 4.5 billion tons, or 2.2 trillion pounds—with 22 percent of the carbon stored in the organic soil layers.

"McNicol's work is a model-based estimate," cautions D'Amore. "But there's a lot more confidence in the estimated carbon values because of the large amount of information that was used to predict the stock at each location."

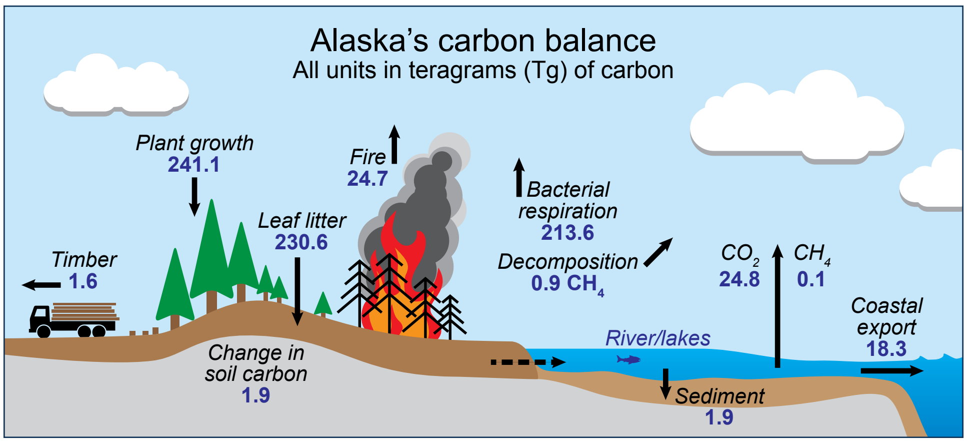
Alaska Land Carbon Project

In 2013, D'Amore received a message from A. David McGuire, an ecologist with the U.S. Geological Survey (USGS) stationed at the University of Alaska in the Cooperative Fish and Wildlife Research Unit. McGuire was the lead scientist charged with overseeing the Alaska Carbon Cycle Assessment. In 2007, President George W. Bush signed the Energy Independence and Security Act, which mandated that the Department of the Interior conduct an assessment on the potential for ecosystems in the United States to sequester carbon. The USGS was assigned the task of conducting the nationwide assessment. After conducting assessments for the regions in the lower 48 states, it was Hawaii and Alaska's turn in 2012.

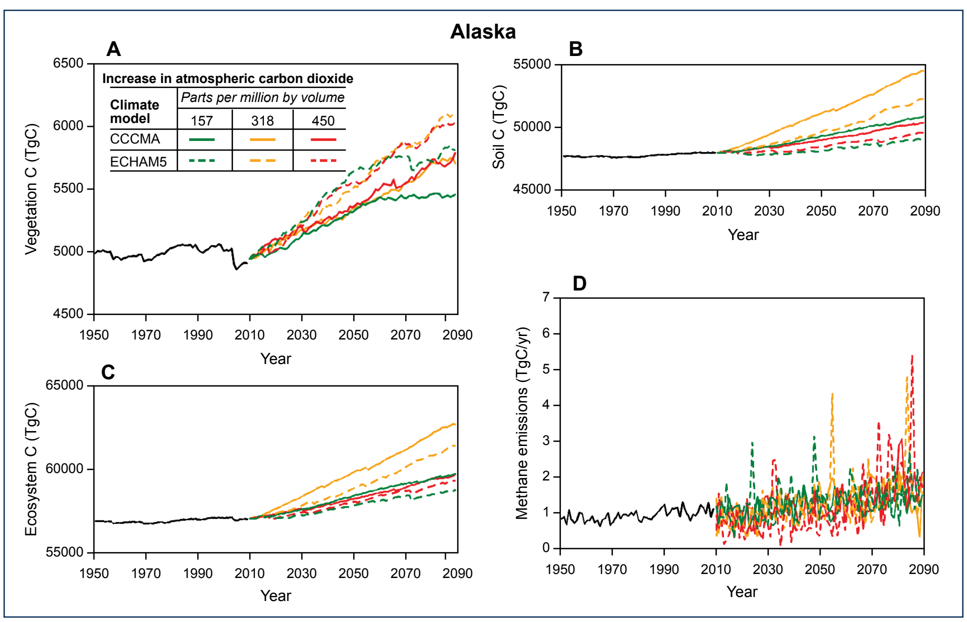
"I reached out to D'Amore because my group had a lot of experience with Alaska's boreal and tundra ecosystems but limited experience with southeast Alaska," McGuire says.

D'Amore welcomed the invitation to help with the carbon cycle assessment. "When you look at where the carbon is on the federal lands, it's mostly held by the Forest Service," he explains. As it turns out, not only was D'Amore's carbon sequestration work on young-growth forests relevant, but his earlier watershed carbon budget research was incorporated into the assessment.

To model the present and future carbon cycle for Alaska, McGuire and the team used datasets containing data on landscape characteristics that would affect carbon sequestration, such as soil texture, fire disturbance, historical climate, and future forest management. "We tried to pull together as much information as we could to create a baseline picture from 1960 through 2010," he explains.



Estimated carbon balance of Alaska in teragrams of carbon (10^{12} C) per year from 1950 to 2009 for terrestrial (upland and wetland) and inland aquatic ecosystem components. Adapted from McGuire et al. (2018).



Time series of statewide carbon dynamics for Alaska for the historical (1950–2009) and projected (2010–2099) for (a) vegetation carbon, (b) soil carbon, (c) total ecosystem carbon, and (d) net methane emissions to the atmosphere. These projections were developed using the Canadian Coupled Global Climate Model and European Centre Hamburg Model; the models were run under different emission scenarios. Adapted from McGuire et al. (2018).

A major finding of the assessment was that during the baseline historical period, the state was nearly carbon neutral because the release of carbon in the boreal forest region of Alaska due to wildfires was offset by the rest of the state sequestering carbon. However, it was estimated that from 2010 to 2099 the state would sequester carbon at the rate of 22.5 to 70.0 teragrams (Tg) of carbon per year. Although wildfires and the subsequent release of carbon into the atmosphere is expected to increase, the volume of vegetative biomass and longer growing seasons is estimated to result in higher volumes of carbon being sequestered. In particular, the study estimates that the forested ecosystems of coastal Alaska will sequester 3.4 to 7.8 Tg of carbon per year.

However, McGuire says that while Alaska is projected to be a sink for the remaining decades of this century, "we expect this pattern to reverse itself and lose carbon based on other modeling studies we've conducted. Because of warming, we shouldn't count on Alaska being a long-term carbon sink; it will likely turn into a [carbon] source." After 2100, permafrost thaw will likely release a substantial volume of carbon into the atmosphere, which may more than offset the carbon being sequestered by Alaska's other ecosystems through photosynthesis.

"The big take-home message of this assessment is that some level of mitigation and controlling the rise of atmospheric carbon dioxide in the atmosphere would decrease the potential for Alaska's ecosystems to become carbon sources," McGuire says.

What's Next in Carbon Cycle Research

Producing the comprehensive carbon assessment, *Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of Alaska*, was significant. However, both D'Amore and McGuire say the report does not definitively quantify the volume of carbon expected to be sequestered by Alaska's ecosystems in the future; instead, it is important for reducing uncertainties that can help inform land managers.

"We've certainly said it's not the final word on projections in carbon cycling," explains McGuire, "but that it's a benchmark for future assessments to have in terms of moving forward and trying to do better assessments in the future."

"That's what I view these days as my carbon cycle science job," D'Amore adds, "to reduce the uncertainty in the terrestrial carbon sink because it plays a big role in any greenhouse-gas mitigation strategy."

The tension that D'Amore described earlier between conducting basic and applied research may also be abating when it comes to carbon cycle research. The 2012 Forest Service Planning Rule requires updated forest management plans to include a section on the effects of climate change; basic research is now becoming applied science.

Greg Hayward is a wildlife ecologist with the Forest Service who worked on climate change vulnerability assessments that were incorporated into the forest management plans for the Chugach and Tongass National Forests. He describes his role as helping staff craft the climate plan components, as well as evaluating the potential effects of climate change.

"These assessments looked at the potential consequences, both positive and negative, of a changing climate on the array of resources that the Forest Service pays attention to," he explains, "but also the social, economic, and cultural consequences of those changes in the ecology of the system and changes in resource delivery."

Writing these assessments brought together more than 30 collaborators, one of which was D'Amore. Coincidentally, as the Chugach forest management plan was being updated, the Alaska Land Carbon Project was underway.

"Because of the relationship we have with the researchers, we often benefited from discussions with the scientists regarding preliminary data analysis and results," Hayward says. "The incorporation of science into our work not only includes looking at published research but having access to the scientists for discussions."

The Chugach forest management plan, which was finalized in August 2019, incorporates the latest carbon cycle science. Similarly, as the Tongass National Forest works through the National Environmental Policy Act process to implement its forest management plan, D'Amore's research on the implications of thinning second-growth forests and carbon sequestration will be used in the climate change analysis.

If a tree dies,
plant another in its place.

—Linnaeus [Carl von Linné], Swedish botanist

Land Management Implications

- Knowing the magnitude of the carbon loss in managed forest stands can help decision-makers evaluate carbon sequestration goals in relation to other goals, such as enhancing wildlife habitat or timber management.
- Information about carbon cycling is necessary for land management plans, which the U.S. Forest Service's 2012 Planning Rule requires to include carbon assessments. In Alaska, both the Chugach and Tongass National Forests have adopted a climate strategy.
- Information about forest carbon sequestration rates informs state and international goals for reducing greenhouse-gas emissions.

Dave D'Amore

Soil scientists collect soil samples from a hillslope dominated by large, mature conifers in southeast Alaska.

Writer's Profile

Andrea Watts is a freelance science writer who specializes in covering natural resources topics. Her portfolio is available at https//:www.wattswritings.wordpress.com and she can be reached at andwatts@live.com.

For Further Reading

D'Amore, D.V.; Biles, F.E.; Nay, S.M.; Rupp, T.S. 2016. Watershed carbon budgets in the southeastern Alaskan coastal forest region. In: Zhu, Z.; McGuire, A.D., eds. Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of Alaska. Chap. 4. U.S. Geological Survey Professional paper 1826. 196 p. https://pubs.er.usgs.gov/publication/pp1826.

D'Amore, D.V.; Oken, K.L.; Herendeen, P.A., [et al.]. 2015. Carbon accretion in natural and thinned young-growth stands of the Alaskan perhumid coastal temperate rainforest. Carbon Balance and Management. 10: 25. https://doi.org/10.1186/s13021-015-0035-4.

Genet, H.; He, Y.; McGuire, A.D. [et al.]. 2018. The role of driving factors in historical and projected carbon dynamics of upland ecosystems in Alaska. Ecological Applications. 28: 5-27. https://doi.org/10.1002/eap.1641.

McGuire, A.D.; Genet, H.; Lyu, Z. [et al.]. 2018. Assessing historical and projected carbon balance of Alaska: a synthesis of results and policy/management implications. Ecological Applications. 28: 1396-1412. https://doi.org/10.1002/eap.1768.

McNicol, G.; Bulmer, C.; D'Amore, D. [et al.]. 2019. Large, climate-sensitive carbon stocks mapped with pedology-informed machine learning in the North Pacific coastal temperate rainforest. Environmental Research Letters. https://doi.org/10.1088/1748-9326/aaed52.

Science FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW Third Avenue
P.O. Box 3890
Portland, OR 97208-3890

Official Business
Penalty for Private Use, $300

PRSRT STD
US POSTAGE
PAID
PORTLAND OR
PERMIT N0 G-40

Scientist Profiles

DAVID D'AMORE is a research soil scientist with the Pacific Northwest Research Station. His current research focus is developing carbon cycle budgets that incorporate both long-term terrestrial stocks and the gaseous and dissolved carbon fluxes within them. D'Amore received his M.S. from Oregon State University and his Ph.D. from the University of Alaska Fairbanks.

D'Amore can be reached at:

USDA Forest Service
Pacific Northwest Research Station
11175 Auke Lake Way
Juneau, AK 99801-8791

Phone: (907) 586-9755
E-mail: david.v.damore@usda.gov

A. DAVID MCGUIRE is a retired ecologist with the U. S. Geological Survey. His research interests include operation of ecological processes at large spatial scales, ecological modeling, and global change biology. McGuire received his Ph.D. from the University of Alaska.

McGuire can be reached at:

Alaska Cooperative Fish and Wildlife Research Unit
PO Box 757020
University of Alaska Fairbanks
Fairbanks, AK 99775-7020

Phone: (907) 474-6242
E-mail: admcguire@alaska.edu

Collaborators

Frances Biles, E. Ashley Steel, Paul Hennon, and Mark Nay, U.S. Forest Service Pacific Northwest Research Station

Kiva Oken, University of Washington

Dave Harris, U.S. Forest Service Alaska Region

Gavin McNicol, Stanford University

Scott Rupp and Helene Genet, University of Alaska Fairbanks

Zhilang Zhu, U.S. Geological Survey