WILD
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January 10, 2025

Re: Tongass Land Management Plan Revision #64039 (submitted via https://cara.fs2c.usda.gov/Public/CommentInput?Project=64039)

Please accept these comments on the TLMP draft revision assessments as part of the public record. We submit these comments as feedback on the assessment drafts, note several places where factual corrections are needed, additional datasources, and published studies (hyperlinked herein) need to be included in the final integrated TLMP revision assessment.

Wild Heritage has been involved on the Tongass since our seminal breeding and winter bird studies (DellaSala et al. 1996), repeated by the US Fish & Wildlife Service in 2012 (Matsuoka et al. 2012). At the time, those studies underscored the importance of Tongass old-growth for bird communities and how thinning and canopy gap creation in second growth was not having much of a beneficial effect on old-growth associated bird species. Tongass old growth importance and its unique global significance via relative intactness and carbon density estimates have been updated and highlighted throughout our comments.

Notably, DellaSala (2011) published the first global assessment of temperate and boreal rainforests of the world that placed the Tongass in a global context of conservation importance as "*one of the world's last remaining relatively intact* temperate rainforests" (emphasis added). While Tongass intactness is globally significant, Canada's Great Bear rainforest, the Valdivia temperate rainforests of Chile/Argentina, and the temperate and hemi-boreal rainforests of Southern Siberia and the Russian Far East need to be also referenced in context as these rainforests eclipse the Tongass in total forested area and relative intactness, particularly given the amount of high-grade logging of Tongass high-volume old growth prior to the Tongass Timber Reform Act (Albert and Schoen 2013), which especially targeted Prince of Wales Island. This correction of proper context needs to be acknowledged in the terrestrial assessment along with the impact of high-grade logging that degraded high carbon dense, biodiverse old growth replacing it with impoverished plantations. While the total "productive" old growth on the Tongass is still impressive (~5 million acres, 89% of historic, DellaSala et al. 2022), most of the high-volume old growth was eliminated decades ago and this should be acknowledged for historical content (Albert and Schoen 2013). Further, the Tongass also contains low volume ("unproductive") old growth such as muskegs that should not be discounted in terms of their conservation significance as intact areas of high ecological integrity. Shoen and Albert (2007) conducted a conservation assessment of priority areas in southeast Alaska that included most of the

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Tongass old growth and intact areas and this should be recognized in the terrestrial assessment.

Recent studies on the Tongass, not cited in the carbon assessment section, need proper recognition along with climate related studies that are published and peer reviewed (DellaSala et al 2015, Vynne et al. 2021). The reference to Halofsky as an unpublished "draft" should be referred to only when available to the public. Importantly, when Halofsky is published it will be a General Technical Report not subject to independent peer review and thus these other published studies take on important regional significance and should have been included.

Draft Carbon Stocks Assessment Misses Several Important Studies and Does Not Provide an Appropriate Carbon Life Cycle Analysis of Logging Related Carbon Losses

The Tongass has globally important carbon stocks representing up to 20% of the total stock on the national forests (DellaSala et al. 2022) and more than the 10% acknowledged in the draft carbon assessment. While we appreciate mention of our prior publication, there is a lot more in our study that should be referenced. For instance, most (96%) of the Tongass carbon is tied up in old growth and roadless areas (DellaSala et al. 2022) with very little (4%) stock in second growth. The 10% carbon stock cited in the draft carbon assessment is only for the live tree biomass component (see Law et al. 2023 cited in the assessment) and does not include dead biomass or below-ground carbon stocks that were reported in DellaSala's percentages as noted in their figure herein.

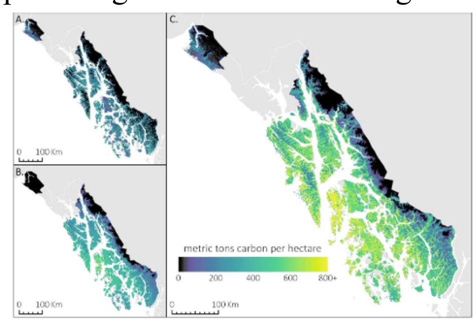

Figure 2. Spatial distribution of carbon (metric tons ha^{-1}) stored in (**A**) woody plant biomass (carbon pools include trees, roots, woody debris, seedlings/saplings, snags, and understory vegetation), (**B**) soil organic matter (top 1 m of mineral soil plus surface organic horizons), and (**C**) the sum of biomass and soil in the Tongass National Forest.

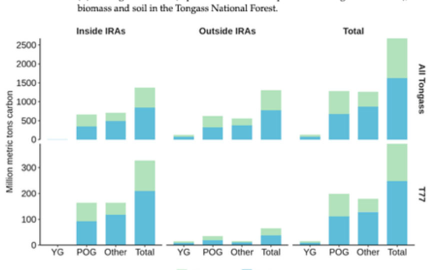

Figure 3. Carbon (million metric tons) stored in woody plant biomass and soil by forest age class (YG = young growth; POG = productive old growth) both inside and outside of Inventoried Roadless Areas (IRAs) and inside Tongass 77 watersheds (T77; bottom row) on the Tongass National Forest (top).

That omission needs to be corrected in the draft assessment. Further, your FIA based carbon assessment is missing wilderness areas (35% of the Tongass which includes old growth). DellaSala et al (2022) included all Tongass LUDs and their figures should be better cited. We request you include these data and related information in the carbon assessment from DellaSala et al. (2022) as noted herein from their published study.

It cannot be overstated how import carbon stocks in old-growth forests and roadless areas are to the Tongass' globally important carbon sink properties. The stock change from logging that peaked in the 1980s has resulted in a great deal of atmospheric emissions that in no way are made up for by natural regeneration in young stands nor the minor amount of carbon tied up in much shorter-lived wood product pools. The harvested wood product pool pales in comparison to stocks retained for centuries in old-growth forests and they should never be compared to biogenic

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carbon in forests in a carbon assessment as harvest wood product pools come with a substantial cost to the climate because most of the carbon was released at some point post logging. Notably, on the Tongass, as much if not more than 50% of the biomass in an old-growth forest is left on site as slash, stumps, and tree trunks as "fall down" (DellaSala et al. 2022). That is a serious omission in the draft carbon assessment that lacks a proper life cycle analysis (Hudiburg et al. 2019) that needs to include all sector emissions from forest floor carbon losses to transport and distribution of wood products as emissions.

Here, we summarize the logging simulation analysis from DellaSala et al. (2022) that should be referenced in the draft carbon assessment in terms of emissions already released by historic logging and what would be released under alternative scenarios (the Forest Service should conduct an updated analysis based on TLMP alternatives using a similar approach).

3.5. Estimated Carbon Emissions

Our estimates of committed 100-year carbon dioxide emissions attributable to HWP (1910–2013) exhibit strong agreement with previous estimates [33] for the USFS Alaska Region (Tongass and Chugach National Forests combined; Figure S4). On the TNF, over the period 1909–2100, committed 100-year emissions track annual logging levels, rising sharply from the 1950s and peaking in the 1970s, followed by a decreasing trend into the 21st century (Figure 5). During this period (pulp era, 1952–2000), committed 100-year emissions average >900,000 t CO_2 yr^{-1}, the most of any period (Table 4). By the transition era (2016–2021), average committed emissions dropped more than 90% to 60,449 t CO_2 yr^{-1} (Table 4). With logging levels projected to rise into the future, committed emissions are anticipated to more than double to approximately 128,374 t CO_2 yr^{-1} between 2022 and 2031 and then more than double again to 273,492 t CO_2 yr^{-1} from 2032 onward (Table 4). Despite the expected increases, projected emissions should remain far below the peak emissions of the 1970s (Figure 5B, Table 4). Following a similar trend, annual realized emissions peaked during the pulp era (1952–2000), averaging >750,000 t CO_2 yr^{-1} followed by a drop to <250,000 t CO_2 yr^{-1} by the present day (Figure 5B, Table 4). Cumulative realized emissions show the fastest increase during the second half of the 20th century (Figure 5B), and over the full period of the analysis (1909–2100), we estimated 69.5 Mt CO_2 of cumulative emissions from HWP (Table S2).

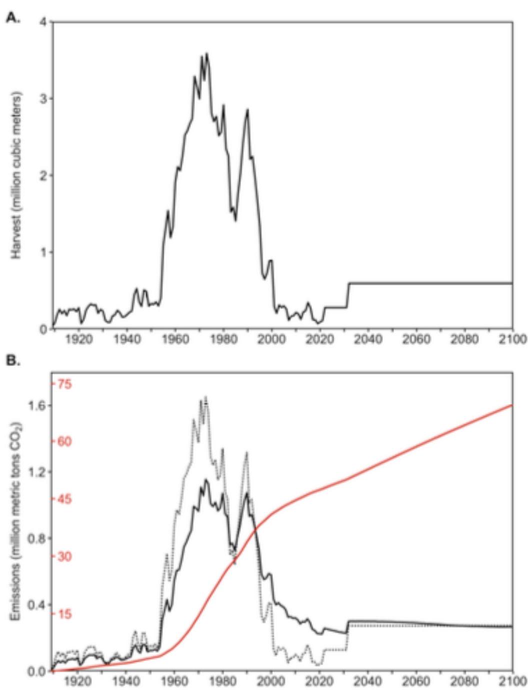

Figure 5. **(A)** Historic (1909–2021) and projected (2022–2100) annual harvest volumes (million cubic meters) for the Tongass National Forest. **(B)** Estimated 100-yr emissions from harvested wood products

While the draft carbon assessment aptly notes that "harvest is the dominant disturbance," it is incorrect to assume this has had "minimal impacts to carbon density." This is an incorrect and highly subjective statement given that carbon density is highest in old-growth forests (DellaSala et al. 2022) and logging in these forests type converted them to low-carbon density second growth (~400,000 acres) at the expense of atmospheric emissions that you did not account for. While "on average, harvest affected 0.04 percent of the total forested area per year," this is the wrong scale of analysis. What's most important is how harvest targeted first and foremost the most carbon dense old-growth forests on the Tongass and then type converted them to diminished stocks that resulted in most of the carbon emitted.

Thus, in a nutshell, your carbon assessment is not based on best available science, needs to incorporate published studies that estimated stock reduction from

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logging (DellaSala et al. 2022), acknowledge how little is stored in wood product pools (Law et al. 2018, Hudiburg et al. 2019, Harmon 2019), and conduct a proper carbon life cycle analysis of the impacts of timber harvest (past, current, projected) on carbon stocks and how harvest targeted the most carbon dense forests on the Tongass. That is – the percentage of the land base logged on average is hiding the ball (trivializing) on how impactful logging has been aimed at the most productive, carbon dense old-growth forests. Harvest wood product pools are nearly always overestimated by the Forest Service and timber industry (Harmon et al. 2019) as is the case in the draft carbon assessment.

Terrestrial Assessment and Species of Conservation Concern

Ecological Integrity Problems are Incorrectly Portrayed as Primarily a Natural Disturbance Problem - the draft terrestrial assessment – as well as other Forest Service assessments like the national old growth threat assessment – inappropriately blames natural disturbances for declines in ecological integrity even though there are clearcut differences between logging-related forest disturbances vs. natural disturbances that are often associated with high levels of ecological integrity (DellaSala et al. 2025). We request that you specify clearly how ecosystems respond differently to cumulative logging and road building (degradation) vs. natural disturbances like blowdown, wildfires, insects and disease that in most cases are beneficial ecologically (DellaSala et al. 2022, 2025).

Species of Conservation Concern Draft List Is Missing Important Taxa - Yellow cedar is aptly noted in the draft terrestrial assessment for climate-change induced losses related to declining snowpack regionally. However, yellow cedar should have been selected as a species of conservation concern (SCC) in the SCC assessment given its widely documented decline. In addition, DellaSala et al. (1996) recommended the inclusion of the Pacific Slope Flycatcher (using difference criteria at the time) because of its tight association with old-growth forests and its lower abundance in second growth. We also appreciate the attention to bryophytes, fungi, and lichens as potential SCC mainly because these taxa tend to be very sensitive to subtle changes in forest microclimates that can be induced by edge effects from logging and road building. This is especially importance given the Tongass has world-class levels of lichen richness, for instance (DellaSala 2011). Additionally, we request that you query published datasets on endemic subspecies known to be distributed – and perhaps even isolated – across the Tongass archipelago, especially in karst areas (e.g., Androski et al. 2024).

Transition to Young/Second Growth Needs to Speed Up and Eliminated all Old Growth Harvesting aside from micro-site removals for Indigenous Uses - we fully support the Southeast Alaska Sustainability Strategy emphasis on transitioning the Tongass out of old-growth logging as demonstrated in our published studies (DellaSala and Furnish 2020, pdf attached). Tongass second growth can meet the Tongass timber targets entirely without the need for even 5 mm bd ft of old growth annually (DellaSala and Furnish 2020). The Forest Service's own analysis supports this request to transition fully into second growth.

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Inadequate Climate Change Assessment – the draft terrestrial assessment refers to Halofsky et al. (draft) yet that is not provided to the public nor will it be subjected to independent peer review standards compared to the peer reviewed publications that were not cited and are available herein. There are several published reports and studies that need to be cited on the importance of the Tongass as potential climate refugia (DellaSala et al. 2015, 2022; Law et al. 2023, Vynne et al. 2023 – all hyperlinked above).

Conclusions (What's Needed in Revision)

The draft assessments overall need to be substantially improved based on the best available science pertaining to: (1) the Tongass' global significant ecosystem values by recognizing its global context compared to other temperate rainforest regions in DellaSala (2011); (2) its potential as climate refugia (DellaSala et al. 2015, Vynne et al. 2023, Law et al. 2023); (3) importance of Tongass old-growth forests and roadless areas for carbon and for climate refugia (DellaSala et al. 2022); (4) how historic logging targeted the most carbon dense forests (Albert and Schoen 2013); (5) the cumulative effects of logging and road building, including fragmentation of previously intact areas (DellaSala et al. 2022); emissions from logging and how little carbon is stored in wood product pools (Hudiburg et al. 2019, Harmon 2019, DellaSala et al. 2022); and (6) published climate projections of the region in relation to the Tongass' climate refugia properties (DellaSala et al. 2015, Vynne et al. 2023, Law et al. 2023). We request that you include a time series, spatially explicit analysis of old growth logging and road building by eco-provinces that also includes road densities and impacts of roads and fragmentation on species of conservation concern. That analysis would show how certain provinces like those on Prince of Wales Island have been targeted and cumulatively impacted. Additionally, while the draft assessment refers to the Tongass wildlife conservation strategy, that strategy does not protect enough old growth habitat (Smith and Flaherty 2023). Instead, published studies request protection of Tongass old-growth and roadless areas (DellaSala et al. 2022) because of their important refugia and carbon properties (Vynne et al. 2023, Law et al. 2023) and they should be fully protected as carbon reserves in forest-climate policy (Law et al. 2022). A Tongass conservation strategy is needed in TLMP revision that protects ALL old growth and roadless areas (preferred alternative) and further enables the transition out of old growth through prior analysis (DellaSala and Furnish 2020 – below) and the agency's own young growth analysis that shows the transition is feasible, while also allowing some young growth not needed in transition volume (DellaSala and Furnish 2020) to mature and further accrue carbon stocks degraded by past logging via proforestation (Moomaw et al. 2019).

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Can Young-Growth Forests Save the Tongass Rainforest in Southeast Alaska?

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Abstract

The Tongass National Forest in southeast Alaska is one of the last relatively intact temperate rainforests in the world. Due to public controversy over old-growth logging, the USDA Forest Service finalized a plan in 2016 to transition out of old-growth logging but not until 2032 as the agency claims it needs to log ~17,000 ha of old growth as "bridge timber" until some 114,000 ha of young growth regenerating from prior clearcut logging is readily available. Transitioning out of old growth logging faster than proposed by the Forest Service would maintain fish, wildlife, and climate benefits along with timber industry needs more aligned with the limits of what the Tongass rainforest can sustain. Recent young growth (mainly 55-year old precommercially thinned stands) inventories on the Tongass suggest that the Forest Service can begin a transition out of old-growth logging within 5 years and on a much smaller (~50,000 ha) and predominately young growth land base than the agency proposes in its transition plan, if certain conditions are met.

> "The Tongass National Forest is a national treasure. Today, I am outlining a series of actions by USDA and the Forest Service that will protect the old-growth forests of the Tongass while preserving forest jobs in southeast Alaska. I am asking the Forest Service to immediately begin planning for the transition to harvesting second growth timber while reducing old-growth harvesting over time."
>
> July 3, 2013 Press Release, USDA Secretary Tom Vilsack

Tongass as a World Class Temperate Rainforest

At 6.8 million hectares, the Tongass National Forest in southeast Alaska is the largest national forest in the United States and one of the world's last relatively intact temperate rainforests (DellaSala, 2011). This national forest is hemmed in by glaciated Coast Mountains to the east and numerous near-shore islands to the west ranging from the Yakutat Forelands in the north to Prince of Wales Island south (one of the largest islands in North America) (**Fig. 1**).

Some 90% (>2 million ha) of forests on the Tongass is considered "productive" old growth, consisting of structurally complex, multilayered forests with trees >150 years (Schoen and Orians, 2013, also see **Fig. 1**). Old-growth Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) forests on the Tongass are global carbon sinks (Leighty et al., 2006) that store atmospheric carbon for centuries primarily because the maritime climate limits fire occurrence. The region's relatively intact watersheds provide ideal conditions (compared to the lower 48 states) for five species of salmonids (*Oncorhynchus* spp.), a principal food source for grizzly bears (*Ursus arctos*), wolves (*Canis lupus ligoni*, unique subspecies), and bald eagles (*Haliaeetus leucocephalus*).

In spite of its global significance, the Tongass is the only national forest in the nation that still clearcuts (clear-fells) old growth on an industrial scale. Old-growth logging began in earnest in the 1950s with peak logging levels achieved in the 1960s–80s (**Fig. 2**). At the time, "high-grading" of the largest trees was a common practice that concentrated logging in low-elevation systems and on productive karst (limestone base) topography (Schoen and Orians, 2013).

The Tongass is now at a critical juncture regarding its status as a global carbon sink and relatively intact rainforest. Compared to the Pacific Northwest, which overcut old growth decades ago resulting in a shutdown of federal lands logging due to litigation over the imperiled Northern Spotted Owl (*Strix occidentalis caurina*), the Tongass currently has no endangered species. Therefore, there is a unique opportunity to transition out of old-growth logging to avoid future controversial listings.

In 2016, the USDA Forest Service finalized an amendment to the Tongass land use plan to transition out of old-growth logging if certain conditions were met. The transition would provide a potential means to end decades of controversy where the choices were limited to either protect some or clearcut much of the old growth (**Fig. 3**). A transition would present a third option that would eventually rely mostly on limiting logging to young forests regenerating from prior clearcut logging.

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Data sources: NACP Aboveground Biomass and Carbon Baseline Data (NBCD 2000), Aboveground forest biomass for Alaska, USDA-FS FIA & RSAC (from Data Basin by the Conservation Biology Institute

Fig. 1 Tongass National Forest, southeast Alaska. Map provided by J. Leonard, Geos Institute. Dark green shows forests exceptionally high carbon-biomass important in climate regulation and climate refugia (DellaSala, 2011).

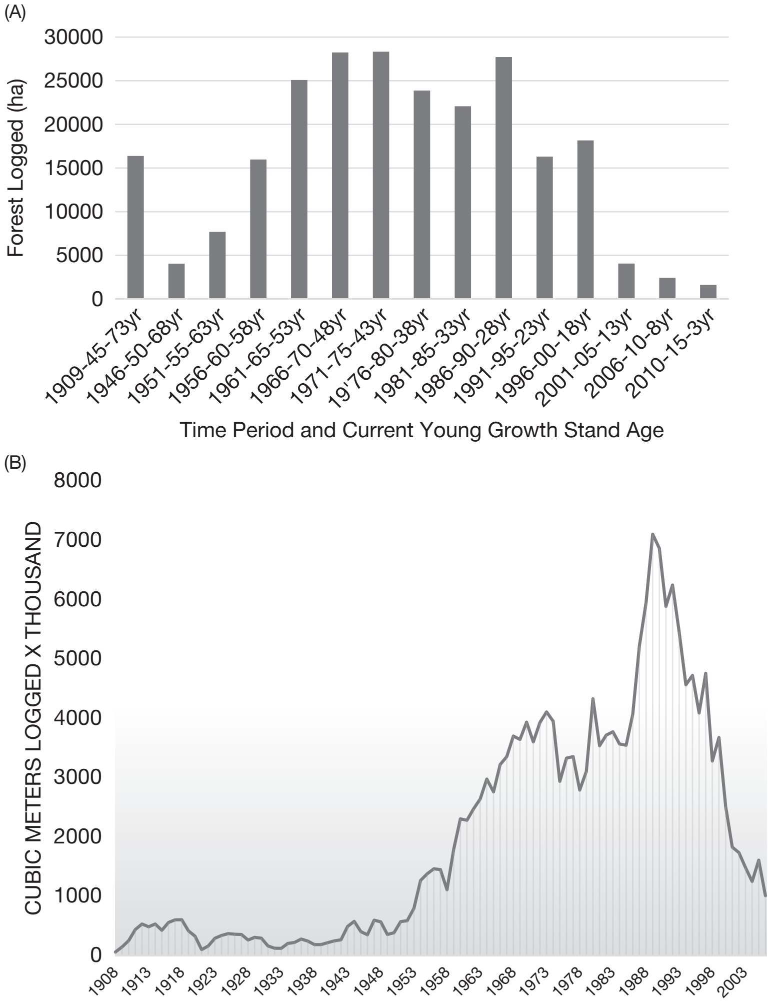

Fig. 2 (A) Tongass National Forest old-growth forest logged from 1909 to 2015 and current (2018) age of logged young stands. (B) Timber volume logged from 1908 to 2006 on the Tongass National Forest. Volume calculations (cubic meters) are based on green and rough sawn at 1 full inch containing ~2.4 cubic meters of usable material. Actual recovery of lumber is greater than estimated long log scale and therefore a conversion factor of 6.25 was used to express the data in cubic meters. Data for both figures were extracted from available timber harvest records courtesy of A. Brackley, USDA Forest Service, Pacific Northwest Research Station, Sitka, AK, United States.

To achieve its transition, the Forest Service specified that it would need to log another ~17,000 ha of old growth during the next 16 years (presumably to 2032) before getting to ~114,000 ha of young growth needed to sustain industry over a 100-year period at a projected volume of 287.5 million cubic meters annually.

Setting a Transition Timeline: Young Growth Volume

Determining when to transition out of old growth centers on how much young growth is available now and into the future and the commercial viability of young trees (i.e., can industry make a profit?). Only the volume necessary to meet a transition timeline is estimated herein. More detailed timber volume estimates and a study of economic value of young growth trees are currently in progress.

Adjusting Cumulative Mean Annual Increment (CMAI)—young growth stands on the Tongass must reach 95% of CMAI, generally the time at which annual growth of trees begins to level off before a regeneration (clearcut) harvest is attempted (~80–90 years, pers. commun. A. Brackley). However, the Forest Service can relax this requirement if logging is deemed consistent with other plan components of its land management plan, which, in this case, is a transition out of old-growth logging. Shorter rotation ages allow capture of timber volume in younger age stands. We argue that a rotation age of 55-years can be used to achieve transition quickly, as this age class corresponds to the oldest young growth stands currently available on the Tongass (Fig. 2) and the average quartile mean diameter-at-breast-height of 28 cm, which is currently being exported on private lands in the region.

Fig. 3 Three choices on the Tongass rainforest: (A) protect some of the old growth for ecological, cultural, and climate benefits; (B) log most of the accessible old growth and convert it to commercially producing plantations; and (C) transition into previously logged and now regenerated young growth (D. DellaSala). Note on the Tongass, regeneration following clearcut logging is via natural seed source. No planting is necessary.

Ecological and Operability Constraints on Young Growth Logging—Based on Forest Service inventories, the Tongass has over 173,000 ha of young growth of varying ages (mostly <50 years; Fig. 2); 71% of this is within roaded and development land-use designations and technically within the timber base (USDA Forest Service 2014). Notably, the Forest Service uses the most current and complete data available on young growth, which provided a foundation for a faster transition (http://databasin.org/maps/d4ee7a0d9662463289b17bf429f6a0ff/active).

For this estimate, we included young stands (55 years) within 240 m of operable roads that were either precommercially thinned (PCT) or commercially thinned (CT), on slopes $<72\%$ (based on prior Forest Service analysis), and not within ecologically sensitive areas (Table 1). Precommercial thinning on the Tongass is designed to reduce competition among densely packed young trees (speeding up growth rates) and usually occurs 15–30 years after stand initiation. A second entry via commercial thinning typically occurs at ~ 60 years with extraction of commercial product.

Young Growth Timber Volume Projections—Based on the logging constraints proposed, sufficient young growth timber volume would be readily available on the Tongass to meet transition requirements (~ 287 million cubic meters annually) beginning as soon as 2020 (Table 2). Obtaining young growth volume from these stands would reduce the timber land base by $>60\%$ of the Forest Service's transition footprint. In sum, $\sim 50,000$ ha of predominately young growth PCT and CT stands within five Ranger Districts closest to milling operations could support a more rapid transition with reduced insert "environmental" conflicts.

Young Growth Economics: The Bottom Line

Determining the market potential of young growth on the Tongass is in early stages but initial results are promising (Fig. 4). For instance, a commercial thinning project ("Dragon Point commercial thin") in 70-year old young growth offered by the Forest Service yielded 28.1 million cubic meters with an appraised value of $440,035. All four timber sale bids received by the agency were above appraised value and one was 81% above appraisal (http://sitkawild.org/2014/06/dargon-point-timber-sale-local-wood-local-benefits/). The private sector (mainly Sealaska Native Corporation) also exports Sitka spruce round logs from 50 to 70-year-old young growth in the region.

Table 1 Ecological and operability constraints for a 55-year old young growth timber base within five Tongass Ranger Districts (Thorne Bay, Craig, Petersburg, Wrangell, Ketchikan) closet to timber mills

	Importance
Ecological constraint	
Karst topography	Known to be highly productive and likely to become future old growth via restoration (also the terrain tends to be unstable due to physical and chemical weathering of the bedrock geology
Wilderness, land-use II designations, national monuments, inventoried roadless areas	High ecological values, mostly old growth, mostly off-limits to logging (out of the timber base)
Beach fringe, riparian buffers	Highly productive ecotones for salmon, bears, eagles, and other wildlife and where logging is restricted via forest plan standards and guidelines
Slopes $>72\%$	Unstable and erosive
Natural disturbances	To allow for development of complex early seral forests and succession to old growth
Not in the suitable harvest base	Already restricted due to environmental concerns
Operability constraint	
5 Ranger districts with prior log sourcing	Hauling distance
Precommercially thinned within 240 m of operable roads (as determined by the Forest Service)	Already productive with road access
Precommercially thinned with at least partial overlap with a 240-m road access buffer	May have access problems given part of the stand lies outside the 240-m buffer
Commercially thinned stands within 240 m of road access	Additional young growth sites for volume estimates

Table 2 Timber volume scenarios within five Tongass ranger districts (Craig, Wrangell, Ketchikan, Thorne Bay, Petersburg) projected over a six-decade period using precommercially thinned (PCT) stands within $\sim$240 m of operable roads. Carryover volumes are based on harvest levels remaining consistent for each of the scenarios with the carryover from prior periods being used to supplement the harvest base such that there are no rolling green outs

Time period	*Annual cubic meters × thousand*	*Annual carryover/deficit cubic meters × thousand*	*Additive annual carryover/deficit cubic meters × thousand*
2015–19	142,512	−4362	
2020–24	524,968	290,594	290,593
2025–29	520,119	285,744	576,338
2030–34	475,569	241,194	817,531
2035–39	394,338	159,962	977,494
2040–44	299,850	65,475	1,042,969
2045–49	205,206	−29,169	1,013,800
2050–54	42,881	−191,494	822,306
2055–59	194	−234,181	588,125
2060–64	0	−234,375	353,750
2065–69	0	−234,375	119,375
2070–74[a]	142,512	−91,862	27,521
2075–79	524,969	290,594	318,106

[a]Re-harvest of 2015–19 units begins.

As an important next step to securing a rapid transition, an economic study is needed to determine lumber grade of 55-year old logs, in consultation with experts from the timber industry and Forest Service. Recently proposed on the Tongass, a wood products study would allow mills to sort young growth by "value-added" lumber and determine market response, securing the best possible information on young growth log and lumber recovery, young growth value-added grade recovery, and market response to young-growth wood products.

Climate Benefits of a Rapid Transition

Tongass rainforests not only store more carbon than any national forest in the United States, but also may function as a critically important climate refuge (i.e., first line of defense) given maritime influences that moderate more extreme climate events anticipated for interior Alaska and temperate regions further south (DellaSala et al., 2017). Relatively intact watersheds also provide refuge for old-growth dependent species (including many that are important to subsistence needs), while buffering salmon from cumulative effects of climate change and more extensive logging in the surroundings (especially on private lands) (Watson et al., 2013).

Notably, prior estimates of carbon flux from logging scenarios on the Tongass indicate that *only a no-logging scenario* maintains carbon stores over time. Carbon also has future economic value in terms of avoided costs from global warming pollution and development of carbon-offset markets. For instance, if carbon were stored long-term in old-growth forests instead of being released to the atmosphere by logging, estimated annual economic value of stored carbon would be comparable to revenue generated from Tongass timber sales should carbon markets mature (Leighty et al., 2006). Importantly, an Interagency Working Group on Social Cost of Carbon estimated that the costs of carbon from global warming effects would be $27–221 per ton by 2050. Recent evidence suggests the costs may be much higher, including large demographic displacements of human settlements along coastlines (Pizer et al., 2014).

Soon after logging old growth, carbon is emitted to the atmosphere via decomposition of logging slash, fossil-fuel emissions from transport and wood processing (e.g., up to 50% of Tongass logs can be shipped overseas), and decay or combustion (within 40–50 years) of forest products in landfills. Planting or growing young trees or storing carbon in wood products does not make up for emissions released from a logged forest, especially one on short timber rotations (< 100 years compared to old-growth forests that store carbon for centuries). Indeed, after an old forest is clearcut, the young forest remains a net CO_2 emitter for 5–50 years, depending on site productivity (see Harmon et al., 1990; Law and Harmon, 2011) (**Fig. 5**).

Globally, deforestation (8%–15%) and forest degradation (6%–13%) contribute more greenhouse gas pollution than the world's entire transportation network (Estimates are conservative as they were mainly derived from the tropics where the majority

Fig. 4 (A) Young trees on a log deck awaiting processing. (B) Milled beams processed by local Alaskan mill (D. DellaSala).

Fig. 5 Logging on the Tongass National Forest contributes greenhouse gas emissions while depleting fish and wildlife habitat (D. DellaSala).

of forest losses occur—boreal and temperate losses are not available at this time (Intergovernmental Panel on Climate Change, 2007; Houghton et al., 2012). Recognizing the importance of unlogged forests as carbon sinks, scientists have repeatedly called for protecting carbon stored in primary forests as integral to stabilizing global climate change (Mackey et al., 2014), which is why countries have committed to reducing emissions and protecting forest sinks (COP 21 climate agreements).

Tongass Climate Change Refuge: Uncertainties and Risks

Follow Up Research and Monitoring—reliably estimating carbon flux under different transition scenarios requires comprehensive carbon assessment tools. Without the benefit of such analysis, however, the Forest Service claims that logging old-growth forests "could result in *either a net loss or gain* of carbon" (emphasis added) depending on logging practices used even though clearcut logging (a substantial emissions source) is the method of choice on the Tongass (some young tree retentions and small (<4 ha) clearcuts are proposed in young forests within Old Growth Reserves and Beach buffers by the agency). Follow up work, ideally conducted by the Forest Service, in consultation with carbon scientists, is needed to determine logging emissions; however, in prior simulations (as noted), only a no-logging alternative results in continued long-term carbon storage (Leighty et al., 2006).

Climate Shift Happens—effects of climate change on forest productivity represent significant and costly risks to the Tongass' global status. As the climate warms, other vegetation types may replace carbon-dense conifer forests on the Tongass that evolved during a cooler climate (DellaSala et al., 2017). For instance, during the Miocene millions of years ago, Alaska was a much warmer place dominated by hardwood forests. As current climate change accelerates, it could lower carbon storage potential of conifer forests as hardwoods gradually replaces conifers and some conifers die off (thereby emitting CO_2 as is currently happening with an extensive die-off of Alaska yellow cedar *Cupressus nootkatensis*; Hennon et al., 2012). However, the maritime climate of the Tongass also might ameliorate some of climate-mediated impacts compared to more extreme changes for interior Alaska and temperate rainforests to the south, but only if old-growth forests are intact (DellaSala et al., 2017) (**Fig. 6**).

In sum, the Tongass is a global carbon sink; however, this sink may increasingly become an emissions source due to old-growth logging (DellaSala, 2011). Choosing a climate responsible and rapid transition for the Tongass would better safeguard Alaska's climate, comply with the COP 21 Paris climate change agreements and the global pledge by governments and entities to end global deforestation.

"We share the vision of slowing, halting, and reversing global forest loss while simultaneously enhancing food security for all. Reducing emissions from deforestation and increasing forest restoration will be extremely important in limiting global warming to 2°C." United Nations Climate Summit New York Declaration on Forests (agreed to by 157 governments, including the United States, indigenous groups, corporations, NGOs, and others).

Fig. 6 Relatively intact forest landscape (potential climate refuge) within Mendenhall Glacier National Park near Juneau, Alaska (A. DellaSala).

Conclusions

The Tongass is one of the last places on Earth where primary forests (unlogged) are still relatively abundant but declining. This critically important rainforest provides Alaskans with unparalleled economic (e.g., recreation and tourism economies greatly exceed logging related jobs and revenue), ecological, and climate benefits (Schoen and Orians, 2013). Using Forest Service inventories, a rapid transition could (1) begin in 2020 as 55-year stands become increasingly available compared to the agency's 2032 transition that relies mostly on old growth logging to get to a transition stage; (2) achieved on a much smaller land base ($\sim$50,000 ha of young growth vs. a mix of 114,000 ha of young growth and 17,000 ha of old growth); and (3) result in substantially less carbon emissions along with ecological and cultural benefits sustained over time. Under a rapid transition, logging would occur within areas of relatively low controversy, reducing litigation costs and uncertainty of timber supply to local mills. An economic assessment of young growth is needed to fully assess viability of young trees.

The Tongass is the only national forest still clear cutting old growth on an industrial scale. Other national forests such as the Siuslaw in Oregon are generating young growth timber volume as part of a 1990s-transition due to policy reforms enacted. The time for the Tongass to make a transition is rapidly approaching if the Forest Service will act while there is still significant old growth remaining to conserve and without the controversy of future endangered species listings and ongoing timber wars.

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