Center for Sustainable Economy

Climate Impacts of the Nez Perce – Clearwater Revised Land and Resource Management Plan

A preliminary analysis of impacts from logging, road building and grazing activities

Prepared for Friends of the Clearwater, May 2023

By

John Talberth, Ph.D.
Senior Economist
Center for Sustainable Economy
1322 Washington Street Box 705
Port Townsend, WA 98368
(360) 344-2080
www.sustainable-economy.org

Support for this work was provided by the Charlotte Martin Foundation, Alex C. Walker Foundation, and the Forest Carbon Coalition

Key findings:

- The policy and regulatory framework governing revision of national forest land and resource management plans requires careful consideration of how proposed management activities will amplify or mitigate the effects of climate change.

- The draft revised land and resource management plan (LRMP) and environmental impact statement (DEIS) for the Nez Perce – Clearwater National Forest fails to disclose or mitigate the climate impacts associated with logging, road building, grazing and other land-disturbing activities even though the methods and sources of information to do so are readily available.

- To demonstrate, this report provides preliminary estimates of GHG emissions associated with logging, road building, and grazing activities and reviews the many ways these management activities could make the land more vulnerable to climate change.

- Across the five alternatives considered in the DEIS, GHG emissions from these activities are likely to range between 335,000 and 1,200,000 metric tons carbon dioxide equivalent per year. At the high end of this range, this is equivalent to putting 250,000 new passenger vehicles on the road.

- Logging, road construction and grazing activities are also likely to amplify the effects of climate change by making the land more susceptible to heat waves, droughts, water shortages, wildfires, wind damage, landslides, floods, warming waters, harmful algae blooms, insects, disease, exotic species, and biodiversity loss.

- To comply with recent National Environmental Policy Act guidance and other climate policy directives, the LRMP and DEIS should be supplemented to incorporate this information and minimize climate impacts.

I: Overview

The Nez Perce – Clearwater National Forest (NPC) encompasses nearly 4 million acres of forests, rangelands, mountains and canyons in north central Idaho. It is bounded by the Salmon River to the South, the State of Montana to the east, Oregon to the west, and the Idaho Panhandle National Forest to the North. Its watersheds include all major tributaries of the Clearwater. Portions of the Bitterroot and Clearwater ranges lie at the headwaters. Major ecological regions include the Idaho Batholith, Northern Rockies and Blue Mountains.[1]

[1] McGrath C.L., Woods A.J., Omernik, J.M., Bryce, S.A., Edmondson, M., Nesser, J.A., Shelden, J., Crawford, R.C., Comstock, J.A., and Plocher, M.D., 2002, Ecoregions of Idaho (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,350,000).

In June of 2018, the Forest Service released a draft revised land and resource management plan (LRMP) that will guide management activities for the next 15 to 20 years once adopted.[2] A draft environmental impact statement (DEIS) has also been published. Both are expected to be finalized in the summer of 2023. As the world's most urgent environmental concern, it is important to understand the climate impacts of proposed management activities and how these impacts vary among alternatives considered in the DEIS. As a contribution to that analysis, this report provides a preliminary analysis and discussion of the climate impacts of three proposed management activities – logging, road construction and livestock grazing. Neither the LRMP nor the DEIS contain any information about the climate impacts of these activities.

II: Regulatory Framework

The duty to address how climate change will affect the NPC and how management activities will exacerbate or mitigate climate change is firmly ensconced in the regulatory framework governing the NPC LRMP. The LRMP itself follows the detailed guidance contained in the Forest Service's 2012 planning rule, which recognizes the necessity of integrating climate change considerations into all aspects of NPC management to allow the Forest Service to adapt.[3] Forest planning regulations specifically call for assessments of climate change as a system driver, baseline carbon stocks, and the effects of planning alternatives on carbon storage as an ecosystem service.[4]

Folding climate change considerations into LRMP revisions was also the subject of Forest Service guidance published in 2010. That guidance included a set of principles, such as a best available science standard, as well as more detailed direction about how to discuss and disclose climate change impacts. In particular, and as noted above, the two overriding considerations must include information about "[h]ow climate change is likely to modify conditions on the planning unit" and "[h]ow management of the planning unit may influence levels of global greenhouse gases and thus climate change."[5]

In addition, President Biden's Executive Orders 14008 and 14072 as well as the Glasgow Leaders Declaration on Forests and Land Use also have direct bearing on LRMP revision process since they call on federal agencies with jurisdiction over forests to promote climate smart forestry as an alternative to conventional practices, conserve mature and old growth forests for their climate benefits, and end deforestation and forest degradation by 2030.

Finally, consideration of climate impacts is a fundamental requirement of the National Environmental Policy Act (NEPA) and thus must be part of any EIS prepared at the programmatic or project level. The most recent interim CEQ guidance requires all federal agencies to:

---

[2] The DEIS, LRMP and supporting materials are available online here: https://www.fs.usda.gov/detail/nezperceclearwater/landmanagement/planning/?cid=fseprd682962.
[3] 36 CFR § 219.5(a).
[4] 36 CFR § 219.6(b)3,4; 36 CFR § 219.19
[5] USDA Forest Service, 2010. Climate Change Considerations in Land Management Plan Revisions. January 20th, 2010. Washington, D.C.: USDA Forest Service. Available online at: https://www.fs.usda.gov/emc/nepa/climate_change/index.shtml.

(1) quantify the reasonably foreseeable GHG emissions (including direct and indirect emissions) of a proposed action, the no action alternative, and any reasonable alternatives;
(2) disclose and provide context for the GHG emissions and climate impacts associated with a proposed action and alternatives, including by, as relevant, monetizing climate damages using the social cost of carbon, and;
(3) analyze reasonable alternatives, including those that would reduce GHG emissions relative to baseline conditions, and identify available mitigation measures to avoid, minimize, or compensate for climate effects.[6]

III: Preliminary Climate Impacts Analysis

The climate impacts of management activities proposed by the LRMP fall into three basic categories: (a) life cycle greenhouse gas (GHG) emissions; (b) changes in carbon sequestration capacity, and (c) changes in climate resiliency. This report provides a partial analysis of these impacts under Alternatives NA, W, X, Y and Z as described in the DEIS and in accordance with methodologies drawn from the growing pool of life cycle analyses (LCA) cited below. Logging related emissions considered here include those associated with timber harvest and logging road construction, but exclude downstream emissions associated with transportation and energy use at mills – a more in-depth analysis should address these sources. Grazing related emissions include those generated by onsite grazing activities on the NPC as well as those related to downstream processing and consumption of beef.

In addition, this report provides a brief review of the literature associating logging and grazing activities with loss of climate resiliency, such as increased susceptibility to wildfires, water shortages, and heat stress. These issues, as well, merit a much deeper treatment with Idaho-specific data and case studies.

A. Emissions from logging and road building.

The life cycle emissions associated with a given year's logging and road building activities are increasingly well studied, and can generally be represented by the following equation:

[1] $GHG_{hvt}\ yr^{-1} = (REM - STOR) + DR + FS + SA + SL + MP$

Where:

- $GHG_{hvt}\ yr^{-1}$ = Average annual GHG emissions (tCO_2-e) released and committed in association with timber harvest and logging road construction.
- REM = Annual average CO_2-e removed from forestlands by logging and logging road construction.
- STOR = Weighted average share of REM retained in harvested wood products or landfills at 100 years.
- DR = Annual average CO_2-e released from decay and combustion of logging residuals.

[6] Council on Environmental Quality, 2023. National Environmental Policy Act on Consideration of Greenhouse Gas Emissions and Climate Change. Federal Register Vol. 88, No. 5, January 9th, 2023 at 1196 to 1212. The guidance is applicable to all pre-decisional NEPA documents.

- FS = Forgone sequestration associated with logging roads and clearcut units.
- SA = Annual average GHG emissions associated with silviculture activities.
- SL = Annual average GHG emissions associated with soil loss and degradation.
- MP = Annual average GHG emissions associated with downstream processing at mills.

See Talberth and Carlson (2023), Hudiburg et al. (2019), Law et al. (2018), Talberth and Davis (2019), Talberth (2017) and Harris et al. (2016) for more details of these entries. For purposes of this analysis, all of these entries except for MP are presented in a preliminary fashion with the expectation that subsequent analysis by the Forest Service to comply with new NEPA guidance will include a more detailed treatment. This would include an estimate of MP based on Idaho-specific data on mill efficiencies, energy use and wood product transportation related emissions. Find below details on the line items included in the analysis.

CO_2-e removals (REM)

The most ubiquitous and accessible source of information for this adjustment is the USDA's Forest Inventory and Analysis (FIA) program, which relies on a hexagonal network of inventory plots located on US forestlands at a density of roughly one plot per 6,000 acres (Brand et al., 2000). Each state has an inventory cycle that completes roughly every five years. For our analysis, we used FIA's web-based application *EVALIDator* to extract information on annual growth, mortality, and harvest removals on from Idaho's forestlands over a 20-year period (USDA Forest Service 2023). Data is expressed in short tons, so to calculate REM, we multiplied average dry short ton removals by 0.5 (carbon content), by 0.9072 to convert short to metric tons, and then by 3.67 to convert carbon to metric tons CO_2-e. This statewide REM was then divided by Idaho's average timber volume cut (2016 – 2021) according to the Bureau of Business and Economic Research (2023) to yield the average carbon dioxide content of each thousand board foot (MBF) harvested. The result (4.92 tCO_2-e per MBF) was then applied to the MBF estimated by each alternative to calculate REM.

Long term storage in wood products and landfills (STOR)

This adjustment calculates the share of REM likely to be stored long term (100 years) in both wood products in use and landfills. For a given state, this process first involves distributing annual timber harvest (tons) into four distinct product classes based on periodic timber output profiles: (a) softwood long-lived wood products (SW-LL); (b) softwood short-lived wood products (SW-SL); (c) hardwood long-lived wood products (HW-LL), and (d) hardwood short lived wood products (HW-SL). REM is then allocated to each product class based on these shares and then multiplied by long term storage factors published in convenient look-up tables by Smith et al. (2006), which, despite refinements in several states, remain the most ubiquitously used data for estimating STOR. According to state product profiles, about 91% of Idaho's annual timber harvest is allocated to SW-LL and about 9% to SW-SL (Berg et al. 2016). Applying the Smith et al. (2006) figures, this implies that, on average, Idaho wood products lose about 76% of the original tree carbon after the standard 100-year carbon footprint period and store the rest (34%) in end use products and landfills.

Decay of logging residuals (DR)

Net ecosystem productivity (NEP) is the most accurate measure of carbon sequestration. A ubiquitous finding from the literature for almost all forest ecosystem types across the US is that for a period of 10-15 years after logging, NEP goes negative indicating that the GHG emissions associated with decay and combustion of logging residuals outpaces what is sequestered by new growth. Cutover forestlands flip from a carbon sink to a carbon source, and this effect can and should be measured as a consequence of proposed logging and road building activities in the DEIS. Regional studies of post-harvest NEP can be used as a basis. NEP is typically expressed in grams carbon per square meter per year and remains negative (a source of emissions) for a period of time that varies with species, stand age, and type of harvest. For this analysis, we incorporated values from Turner et al., (2004), who estimated DR to be about -1.1 tCO_2 per acre per year for 13 years after harvest in their western Oregon study area. To estimate DR associated with proposed logging activities under the LRMP, this figure was applied to the annual number of acres proposed for even aged harvest treatments under each management alternative, which range from a low of 4,074 acres under Alternative NA to 14,238 acres under alternative X.

Forgone sequestration (FS)

This represents the carbon opportunity cost of logging, in other words, the amount of carbon that would have been removed from the atmosphere but for a given year's logging and road building activities. FS has an identical effect on raising atmospheric GHG concentrations as a direct emission (i.e. burning an equivalent amount of fuel) and so is often regarded as an indirect emission that should be included in the analysis of proposed actions that result in deforestation, temporary or permanent. While the Forest Service could base FS on such modeled differentials over harvest cycles – i.e. if an 50 year old stand is cut down how much less carbon is being sequestered if that stand is allowed to grow another 50 years – a more tractable, and conservative approach is to limit the calculation to the period of negative NEP adopted for DR, and thus do away with the need for longer-term growth and mortality projections. This was the method adopted here.

Pre-harvest NEP was estimated from a combination of local studies and FIA data. Idaho forests currently have very low rates of net carbon sequestration, so the effect here is relatively small compared with other forestlands, amounting to about 0.2 tCO2-e per acre per year. For harvest activities, FS is simply the product of this figure and the presumed period of zero net carbon accumulation, or 13 years for this study, on each acre of land affected by even aged logging. For road building, we followed protocols inherent to offset markets and modeled FS over a 100-year period after converting linear miles of new road construction to acreage.[7]

Silvicultural activities (SA)

The US GHG inventory has begun to segregate emissions from energy consumed by on-farm operations from the broader energy sector in order to help direct policy instruments towards

[7] As an interim step to this calculation, recent timber sale prospectuses were reviewed to estimate miles of new road per MBF harvested. NPC data indicate that this value is about .0022 miles per MBF. In addition, it is assumed that each new mile of road affects about 2 acres of land.

promoting regenerative and other low-carbon practices. Likewise, it is appropriate to tally and regulate fossil fuel emissions from silviculture activities (SA), which include harvesting, chemical and fertilizer applications, replanting, thinning, and road maintenance, in order to promote climate smart alternatives. The data to do so is quite accessible. For this analysis, and after converting to a per-acre basis, we applied an emissions factor from Sonne (2006) – 8.6 tCO2-e/ha for each hectare harvested – to annual even aged harvest acres under each alternative to derive SA. Even though SA is pegged to harvest acres, it includes all other activities (i.e. replanting, thinning, herbicides, etc.) past or future, associated with final harvests.

Emissions from soil loss and degradation (SL)

While data on soil organic carbon (SOC) loss from timber harvesting is quite extensive and consistent, the fate of this carbon remains quite uncertain. However, it is widely accepted that a significant portion is emitted, while the rest redistributed over the land, in channels, or at sea. As a placeholder value, we used SOC loss factors of 22% from Nave et al. (2010) and Achat et al. (2015) as well as a lower bound emissions estimate of 15% of SOC from Lal (2020). Data on pre-harvest SOC stocks (about 18 tons carbon per acre) was extracted via *EVALIDator*.

Results

Table 1 reports results of this analysis. For alternatives considered in the DEIS, proposed logging and road construction activities are likely to generate between 275,266 and 1,157,963 metric tons CO_2-e each year under the new LRMP. To put this into perspective, the higher end of this range is equivalent to putting over 250,000 new cars on the road.[8] Releases associated with alternatives W and X would be the greatest, while emissions associated with the no action alternative (i.e. business as usual) would represent the least. The greatest source of emissions (64 – 70% across all alternatives) will be associated with the removal of CO_2 now stored in trees from the landscape and its eventual escape into the atmosphere as wood products are produced, used, and then discarded. Post-harvest releases from the decay and combustion of logging residuals are likely to be the second greatest source (17 – 22%), while forgone sequestration, silviculture activities, and soil loss and degradation are likely to contribute 8 – 20% of the total.

Table 1: GHG emissions from proposed logging and logging road construction

Logging emissions component	Management alternative				
	NA	W	X	Y	Z
Removals (REM)	270,829	1,137,480	1,235,963	640,140	344,691
Long term wood products storage (STOR)	-92,301	-387,665	-421,229	-218,166	-117,474
Decay and combustion of logging residuals (DR)	58,260	201,064	203,604	129,577	76,804
Forgone sequestration (FS)	15,412	56,798	59,012	34,950	20,098
Silviculture activities (SA)	14,185	48,955	49,574	31,550	18,700
Soil loss and degradation (SL)	8,881	30,651	31,039	19,754	11,708
Total GHG released and committed (tCO2-e/yr)	**275,266**	**1,087,285**	**1,157,963**	**637,805**	**354,527**

[8] According to the EPA, a typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year.

B. GHG emissions from cattle grazing activities.

According to the latest analysis by the Food and Agriculture Organization of the UN, livestock production accounts for roughly 15% of global GHG emissions.[9] This estimate includes the methane released by cattle themselves as well as the fossil fuel energy consumed by feeding operations, transport, downstream processing, distribution of meat to retailers and restaurants, and disposal and decay of waste products. As with logging, there are an increasing number of studies quantifying GHG emissions associated with livestock operations of various kinds, including pasture-fed livestock that graze on public lands.

For on-site grazing activities, the most salient analysis – and the one incorporated here – was recently published by Kauffman et al. (2022) which, conveniently, includes estimates of GHG emissions associated with livestock grazing on US public lands on an animal use month (AUM) basis. The estimate, about 875 kg CO_2-e per AUM, includes emissions associated with enteric fermentation and manure deposition. LRMPs typically project AUMs into the future, so it is relatively straightforward to estimate these emissions. For this analysis and based on conversations with grazing staff on the NPC, AUMs are almost never fully utilized. Utilization rates on the NPC range from 35 – 55%. Using the midpoint (45%) and using AUM figures reported in the DEIS (28,535 AUMs across all alternatives) implies that annual GHG emissions associated with on-site grazing activities exceed 11,000 tCO_2-e.

For downstream emissions, data from Asem-Hiablie et al. (2018) was incorporated. That study broke out GHG emissions associated with various points along the life cycle of cattle production. Since Kauffman (2022) was used for on-site activities, the Asem-Hiablie et al. (2018) data was used for just the post cow-calf phases. To do this, an estimate of annual cattle production (7,134 head) was taken from the DEIS and conversations with NPC staff. A national average weight per head of 575 kg was assumed. The Asem-Hiablie et al. (2018) GHG emissions factor of .0125 kg/kg was then applied to yield an estimate of 7.19 tCO2-e per head, which translates into over 51,000 tCO_2-e annually.

Results

Table 2 combines both on-site and downstream GHG emissions associated with annual grazing activities on the NPC. The results suggest that grazing activities are likely to generate at least 62,551 tCO_2-e on an annual basis. Since AUMs do not vary by alternative, this value is common to all of them.

[9] FAO, 2023. By the numbers, GHG emissions by livestock. Available online at: https://www.fao.org/news/story/en/item/197623/icode/.

Table 2: GHG emissions associated with cattle grazing on the Nez Perce – Clearwater National Forest

(*Common to all alternatives)*

Emissions on site (all alternatives)	
AUMs	28,535
AUMs utilized (at 45%)	0.45
Emissions per AUM (tCO2-e/AUM)	0.875
Emissions subtotal (tCO2-e/yr)	11,236
Emissions downstream (all alternatives)	
Head sent for processing (#/yr)	7,134
LCA (tCO2-e) per kg (post cow-calf phase)	0.0125
LCA per head at 575 kg average	7.19
tCO2-e/yr	51,315
Total GHG impact grazing (tCO2-e/yr)	**62,551**

C. Loss of climate resiliency

In addition to generating significant amounts of GHG pollution, logging, road building, and grazing activities are making the land more susceptible to climate change by amplifying risks associated with a variety of climate stressors. For example, Talberth and Olson (2019) and CSE at al. (2023) compiled an extensive review in their analyses of the climate impacts of the Department of Natural Resources logging program in Washington State and industrial forest practices across all ownerships in North Carolina. Relevant excerpts from these publications are attached as Exhibits A and B.

As documented in these records, logging and road building – including the conversion of natural forests to tree plantations – has been shown to amplify the effects climate change by increasing the land's susceptibility to heat waves, droughts, water shortages, wildfires, wind damage, landslides, floods, warming waters, harmful algae blooms, insects, disease, exotic species, biodiversity loss. Public lands grazing activities have similar effects. For example, and as noted by Kauffman et al. (2022), public lands grazing defoliates native plants, tramples vegetation and soils, accelerates the spread of exotic species, shifts the landscape from a carbon sink to a source of greenhouse gases and exacerbates the effects of climate change on ecosystems by creating warmer and drier conditions. To comply with NEPA and the 2012 planning regulations the DEIS should be supplemented to describe if and to what extent these synergistic effects of climate change + logging, grazing, and roadbuilding on the NPC exist and how the LRMP plans to mitigate them.

D. Social cost of GHG emissions

One of the big omissions from the analysis of economic sustainability in the DEIS (Chapter 3.8.1) is any mention let alone quantification of externalized economic damages associated with logging, road construction, and grazing activities. These activities generate both market and nonmarket externalized damages, for example, to water supplies (both quality and flow), other forest uses (i.e. tourism and recreation), adjacent landowners (i.e. loss of scenery) and communities downstream (i.e. increased fire risk). To be complete, the DEIS should be supplemented to discuss and quantify these impacts.

One of the most significant externalities is, of course, related to climate change. To enable decision makers to estimate the magnitude of this externality, the Environmental Protection Agency (EPA) publishes estimates of the social cost of carbon (SCC) than can be applied by federal agencies in the NEPA context along with data on GHG emissions anticipated by proposed federal actions (EPA 2022). The latest SCC estimates range from $120 to $340 per metric ton of CO_2 equivalent for different interest rates. Table 3 applies these rates to the GHG emissions from logging, road building, and grazing estimated for each alternative. The results suggest that these activities are likely to generate between $40 and $415 million dollars in climate damages each year, an amount far in excess of income earned from resource extraction activities.

Table 3: Social costs of GHG emissions associated with logging, road building, and grazing activities under the proposed Nez Perce – Clearwater LRMP

Emissions and social costs	Management altenative				
Emissions (tCO2-e/yr)	NA	W	X	Y	Z
Logging and road building	275,266	1,087,285	1,157,963	637,805	354,527
Grazing	62,551	62,551	62,551	62,551	62,551
Total:	337,816	1,149,835	1,220,514	700,355	417,078
Social costs ($ millions)					
Social cost of carbon at $120 tCO2-e	$40.54	$137.98	$146.46	$84.04	$50.05
Social cost of carbon at 190 tCO2-e	$64.19	$218.47	$231.90	$133.07	$79.24
Social cost of carbon at $340 tCO2-e	$114.86	$390.94	$414.97	$238.12	$141.81

IV: Conclusions

As the USDA Forest Service progresses through its regular schedule of forest plan revisions, providing meaningful information about the climate consequences of management activities is imperative if the agency is going to play a leading role in promoting climate smart alternatives to conventional practices. This analysis demonstrates that the agency has all the information and methods needed to do so. GHG emissions associated with almost all major land management activities including grazing, logging, road building, oil and gas leasing and mineral extraction can be estimated by using the agency's own forest carbon data and published life cycle analyses. Using easily accessible data and LCAs, this analysis suggests that GHG emissions associated with logging, road building, and grazing under the NPC LRMP could exceed 1.2 million metric tons CO_2 equivalent per year at a social cost that could exceed $415 million dollars.

Effects of management activities on climate resiliency can also be informed by an increasingly rich set of scientific literature. As documented by Exhibits A and B, logging, road building, and grazing can amplify climate stressors such as heat waves, droughts, water shortages, wildfires, wind damage, landslides, floods, warming waters, harmful algae blooms, insects, disease, exotic species, and biodiversity loss. Given the legal and policy mandate to track and reduce GHG emissions as well as other climate impacts, the Nez Perce – Clearwater LRMP and DEIS cannot be legally sufficient without this additional information.

References

Achat, D.L., Fortin, M., Landmann, G., Ringeval, B., Augusto, L., 2015. Forest soil carbon is threatened by intensive biomass harvesting. Sci Rep 5, 15991 (2015). Doi: 10.1038/srep15991.

Asem-Hiablie, S., Battagliese, T., Stackhouse-Lawson, K.R., Rotz, C.A., 2019. A life cycle assessment of the environmental impacts of a beef system in the USA. Int J Life Cycle Assess (2019) 24: 441-455.

Berg, E., Morgan, T., Simmons, E., 2016. Timber Products Output (TPO) for Idaho. Missoula, MT: University of Montana, Bureau of Business and Economic Research.

Brand, G.J., Nelson, M.D., Wendt, D.G., Nimerfro, K.K., 2000. The hexagon/panel system for selecting FIA plots under an annual inventory. In Proceedings of the first annual forest inventory and analysis symposium, (R.E. McRoberts, G.A. Reams, P.C. Van Deusen, Eds.), Gen. Tech. Rep. NC-213 U.S. Department of agriculture, Forest Service, North Central Research Station, St. Paul, MN, pp. 8-13.

Bureau of Business and Economic Research, 2023. Idaho Timber Harvest 2002 – 2022. Missoula, MT: University of Montana, BBER.

Environmental Protection Agency (EPA), 2022. Report on the Social Cost of Greenhouse Gases: Estimates incorporating recent scientific advances. Washington, DC: National Center for Environmental Economics, Office of Policy, EPA.

Harris, N.L., Hagen, S.C., Saatchi, S.S., Pearson, T.R.H., Woodall, C.W., Domke, G.M., Braswell, B.H., Walters, B.F., Brown, S., Salas, W., Fore, A., Yu, Y., 2016. Attribution of net carbon change by disturbance type across forest lands of the conterminous United States. Carbon Balance and Management 11 (24).

Hudiburg, T.W., Law, B.E., Moomaw, W.E., Harmon, M.E., Stenzel, J.E., 2019. Meeting GHG reduction targets requires accounting for all forest sector emissions Environ. Res. Lett. 14: 095005.

Kaufmann, J.B., Beschta, R.L., Lacy, P.M., Liverman, M., 2022. Livestock use on public lands in the western USA Exacerbates climate change: implications for climate change mitigation and adaptation. Environmental Management (2022) 69:1137-1152. https://doi.org/10.1007/s00267-022-01633-8.

Lal, R., 2020. Soil erosion and gaseous emissions. Appl. Sci. 2020,10, 2784; doi:10.3390/app10082784.

Law, B.E., Hudiburg, T.W., Berner, L.T., Kent, J.J., Buotte, P.C., Harmon, M.E., 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. PNAS April 3, 2018 115 (14) 3663-3668.

Nave, L.E., Vance, E.D., Swanston, C.W., Curtis. P.S., 2010. Harvest impacts on soil carbon storage in temperate forests. Forest Ecology and Management 259: 857-866.

Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A., 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. Gen Tech. Rpt. NE-343. Morgantown, WV: USDA Forest Service, Northeastern Research Station.

Sonne, E., 2006. Greenhouse gas emissions from forestry operations. Journal of Environmental Quality 35(4): 1439-1450.

Talberth, J., Carlson, E., 2023. Forest carbon tax and reward: regulating greenhouse gas emissions from industrial logging activities. Ecological Economics (in review).

Talberth, J., Olson, L., 2021. Climate Impacts of Industrial Forest Practices in North Carolina – Part 2, Climate Resiliency. Asheville, NC: Dogwood Alliance.

Talberth, J., Davis, S., Olson, L., 2019. Climate Impacts of Industrial Forest Practices in North Carolina – Part 1. Asheville, NC: Dogwood Alliance.

Talberth, J., 2017. Oregon Forest Carbon Policy: Technical brief to guide legislative intervention. Portland, OR: Center for Sustainable Economy.

Turner, D.P, Guzy, M., Lefsy, M.A., Ritts, W.D., Van Tuyl, S., Law, B.E., 2004. Monitoring forest carbon sequestration with remote sensing and carbon cycle modeling. Environmental Management 33(4): 457-466. DOI: 10.1007/s00267-003-9103-8.

USDA Forest Service, Forest Inventory and Analysis Program, 2023. Forest Inventory EVALIDator web-application Version 2.0.4. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: http://apps.fs.usda.gov/Evalidator/evalidator.jsp]

Exhibit A

Source:

- Center for Sustainable Economy, Save the Olympic Peninsula, Legacy Forest Defense Coalition, 2023. SEPA comments on the proposed Juneau timber sale. Port Townsend, WA: CSE.

Climate resiliency impacts – logging and road building

In addition to generating significant quantities of GHG emissions, the Juneau timber sale, by deforesting 160 acres through clearcutting or other intensive practices, building, reconstructing, or maintaining nearly 45,000 feet of logging roads, and implementing harmful post-harvest regeneration activities (burning, spraying, etc.) will amplify the deleterious effects of climate change by making the land more susceptible to its effects. In particular, the Juneau timber sale in combination with similar logging projects on federal, state, and private lands in the region can be expected to amplify risks associated with:

- Depleted water supplies. Dry season stream flows are today dramatically depleted across the Pacific Northwest as a consequence of extensive logging and the rapid regrowth of water-hungry young vegetation after logging.[10] For example, long-term experiments in Coastal Oregon indicate that the conversion of mature and old growth conifer forests to homogenous plantations of Douglas fir produced a persistent summer streamflow deficit of 50 percent in plantations aged 25 to 45 years relative to intact, older forests.[11] Climate change will make matters worse by further reducing dry season flows thereby straining "the ability of existing infrastructure and operations to meet many and varied water needs."[12]

- Warming waters. As the climate warms and dries in the summer, Washington waterways will also warm. This thermal pollution is intensified by intensive logging. In Oregon, Department of Forestry modeling concludes that a typical clearcut compliant with the Oregon Forest Practices Act on average, boosts water temperatures by 2.6 degrees Fahrenheit on top of any background increase due to climate change.[13] According to multiple federal agencies, "the evidence is . . . overwhelming that forest practices contribute to widespread stream temperature problems."[14] Warmer water, in turn, will

[10] Perry, T. D., Jones, J.A., 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. Ecohydrology. 1-13.

[11] Segura, C., Bladon, K., Hatten, J., Jones, J., Hale, C., Ice, G., 2020. Long-term effects of forest harvesting on summer low flow deficits in the Coast Range of Oregon, Journal of Hydrology, Volume 585, article id. 124749.

[12] Dalton, M.M., K.D. Dello, L. Hawkins, P.W. Mote, and D.E. Rupp, 2017 *The Third Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Winston, OR, page 18.

[13] Oregon Department of Forestry (ODF), 2015. Detailed analysis: predicted temperature change results. Agenda Item 7, Attachment 3 to the meeting packet prepared for the Board of Forestry, June 3rd, 2015. Salem, OR: ODF.

[14] EPA-FWS-NMFS, 2/28/01 Stream Temperature Sufficiency Analysis Letter to ODF and ODEQ.

cause "harmful algal blooms to occur more often, in more waterbodies and to be more intense."[15]

- Increased wildfire risk. Timber plantations and other intensively managed forestlands burn hotter and faster than natural forests. This is because they lack the moisture content and structural complexity needed to keep wildfires in check. Decades of monitoring by firefighters and researchers show that fires burning in complex natural forests create a mosaic of intensely burned and relatively untouched areas. On the other hand, fires burning in homogenous tree plantations are more likely to be uniformly severe.[16] New research that examined burn severity after Oregon's historic wildfires in 2020 concluded that "[e]arly-seral forests primarily concentrated on private lands, burned more severely than their older and taller counterparts, over the entire megafire event regardless of topography."[17] This should be a wakeup call to DNR that the practice of replacing structurally complex, mature forests, such as those in the Juneau timber sale with monoculture plantations is a practice that exposes nearby communities to increased wildfire risk. Two recent court decisions have flagged the connections between clearcut-style logging and increased fire hazard and further underscored the need for re-consideration of clearcut style management in areas near communities.[18]

- Heat waves. Mature forests in the Juneau timber sale area now act as temperature refuges, helping to keep the land and waters within and adjacent to the sale area cool during both routine and extreme heat wave events. During heatwaves, which are becoming more frequent and extreme, surface temperatures in open clearcuts can exceed 130 degrees Fahrenheit while under the shaded forest canopy temperatures are often 40 to 50 degrees cooler (AR REC-016904). A recent analysis by CSE and OSU researcher Christopher Still reviewed data from NEON tower sites in plantations and undisturbed old growth forests in southwest Washington and found that the degraded plantation site was hotter (+4.5 ºC), lost more water, was less efficient at photosynthesis, and experienced a more dramatic impact to carbon cycling, flipping from a sink to a source during the heat dome event.[19] All of these impacts can be expected as a result of the Juneau timber sale.

- Increased incidence and severity of landslides. The vast network of clearcuts and logging roads permeating industrial timber plantations and heavily logged DNR lands present a

[15] US Environmental Protection Agency, "Climate change and harmful algae blooms," available online at: https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms.
[16] *See, e.g.,* Stone, C., Hudak, A., Morgan, P., 2008. Forest harvest can increase subsequent forest fire severity. In Proceedings of the Second International Symposium on Fire Economics, Planning and Policy: A Global View. Armando González-Cabán**,** ed. Riverside, CA: USDA Forest Service, Pacific Southwest Research Station.
[17] Evers, C., Holz, A., Busby, S., Nielsen-Pincus, M., 2022. Burn severity in seasonal temperate rainforests under record fuel aridity. Fire 5(2), 41. https://doi.org/10.3390/fire5020041.
[18] Cascadia Wildlands; and Oregon Wild v. Bureau of Land Management; and Seneca Sawmill Company 6:19-cv-00247-MC. United States District Court of Oregon. 2019; and Bark; et al. v. United Stated Forest Service; and High Cascade Inc. No. 19-35665 D.C. No. 3:18-cv-01645-MO. United States Court of Appeals, Ninth Circuit. 2020.
[19] Still, C., Talberth, J., 2022. Deforestation, forest degradation, heat waves and drought. Evidence from the Pacific Northwest heat dome of 2021. Port Townsend, WA: Center for Sustainable Economy. Available online at: https://www.sustainable-economy.org/deforestation-and-forest-degradation-are-making-heat-waves-and-drought-more-intense-evidence-from-the-pacific-northwest-heat-dome.

significant risk of landslides, especially during extreme precipitation events, such as the 1996 floods. Under almost all climate change scenarios for the Northwest, the frequency of these events will increase. Maintenance of strong root systems is an important factor in stabilizing soils during these events. Clearcutting (including areas within variable retention harvest units) reduces the strength of root systems dramatically, and thus is a major factor in increased landslide risk.[20] Logging roads channel water runoff and cause debris torrents that can travel many miles downstream, pick up momentum, and become heavily destructive.[21] Studies indicate that clearcuts exhibit landslide rates up to 20 times higher than background rates. Near logging roads, landslide rates are up to 300 times higher than in forested areas.[22]

- <u>Increased risk of flooding</u>. Research has demonstrated that heavily logged watersheds are at a much higher risk of flooding than those maintained in natural forest conditions. For example, Jones and Grant found that logging increased peak discharges by as much as 50% in small basins and 100% in large basins over a 50-year study period.[23] A 2008 Forest Service science synthesis confirmed the detrimental impacts of logging and logging roads on peak flows across western Oregon and Washington.[24]

- <u>Enhanced habitat for invasive species and organisms that put public health at risk</u>. Invasive species find few barriers in monoculture tree plantations and other heavily logged sites since key natural processes that keep such species in check have been removed. As succinctly stated by Norse, "in monocultures, without barriers to dispersal, insects and pathogens find unlimited resources in all directions."[25] As Washington's climate changes, a wide variety of non-native plants, insects, and disease-causing organisms, such as viruses, bacteria, prions, fungi, protozoans, and internal (roundworms, tapeworms) and external (lice, ticks) parasites will spread, adversely affecting the health of humans, livestock, and pets in addition to fish and wildlife. A recent Forest Service assessment concluded "[e]vidence suggests that future climate change will further increase the likelihood of invasion of forests and rangelands by nonnative plant species that do not normally occur there (invasive plants), and that the consequences of those invasions may be magnified."[26]

---

[20] Schmidt, K.M, J. J. Roering, J.D. Stock, W.E. Dietrich, D.R. Montgomery, Schaub, T. 2001. The variability of root cohesion as an influence on shallow landslide susceptibility in the Oregon Coast Range. *Can. Geotech. J* (38): 995-1024.

[21] Swanson, F. J., J. L. Clayton, W. F. Megahan, Bush, G., 1989. Erosional processes and long-term site productivity, pp. 67-81 in *Maintaining the Long-Term Productivity of Pacific Northwest Forest Ecosystems*. D. A. Perry, R. Meurisse, B. Thomas, R. Miller, J. Boyle, J. Means, C.R. Perry, R. F. Powers, eds. Portland, Oregon: Timber Press.

[22] Heiken, D., 2007. Landslides and Clearcuts: What Does the Science Really Say? Eugene, OR: Oregon Wild.

[23] Jones, J., Grant, G.E., 1996. Peak flow responses to clearcutting and roadbuilding in small and large basins, western Cascades, Oregon. Water Resources Research 32(4): 959 – 974.

[24] Grant, G.E., Lewis, S.L., Swanson, F.J., Cissel, J.H., McDonnell, J.J. 2008. Effect of Forest Practices on Peak Flows and Consequent Channel Response: A State-of-Science Report for Western Oregon and Washington. PNW-GTR-760. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

[25] Norse, E., 1990. Ancient Forests of the Pacific Northwest. Washington, DC: The Wilderness Society.

[26] Kerns, B., Guo, Q., 2012. Climate Change and Invasive Plants in Forests and Rangelands. U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. Available online at: https://www.fs.usda.gov/ccrc/topics/climate-change-and-invasive-plants-forests-and-rangelands.

- Elevated risk of harmful algae blooms. Harmful algal blooms (HAB) are an urgent concern statewide as climate change unfolds. Industrial forest practices greatly amplify this risk through three channels: (a) by warming waters; (b) by decreasing natural flow rates, and (c) by contaminating water supplies with glyphosate and urea, along with other chemicals and fertilizers that enhance HAB growth. With the presence of glyphosate and urea in streams, nontoxic algae growth is inhibited and HABs dominate without competition.[27] Modern drinking water treatment costs increase significantly when more rigorous treatment is needed to cleanse contaminated source water. Managing land to prevent source water contamination may be more cost-effective and may better protect human health than treating water after it has been contaminated. [28]

---

[27] Glibert, P. M., Harrison, J., Heil, C., & Seitzinger, S., 2006. Escalating worldwide use of urea–a global change contributing to coastal eutrophication. Biogeochemistry, 77(3): 441-463.

[28] Dissmeyer, George E., ed. 2000. Drinking water from forests and grasslands, a synthesis of the scientific literature. USDA Forest Service. Southern Research Station, General Technical Report SRS-39.

Exhibit B

Source:

- Talberth, J., Olson, L., 2019. The Climate Impacts of Industrial Forest Practices in North Carolina. Part II: Climate resiliency and policy interventions. Asheville, NC: Dogwood Alliance.

Climate resiliency impacts – industrial forest practices

In North Carolina and other US states with productive forestlands, industrial logging practices are exacerbating the stressors already being experienced as a result of climate change and thereby undermining efforts to adapt. Common industrial forest practices include clearcutting, short rotation timber plantations, slash burning, dense networks of logging roads and liberal application of fertilizers and pesticides. These practices have greatly compromised the ability of North Carolina's forestlands to supply clean water, provide cool microclimates in summer, control floods, and support native species, like wild pollinators, fish and game that benefit human communities nearby. Native forests, being more structurally and functionally complex, are far more productive in supplying these services and buffering against the harmful effects of climate change.[29] Their loss and replacement by landscapes dominated by industrial forest practices amplifies almost all of the major climate change threats predicted for North Carolina. In particular:

<u>Heat stress</u>

Deforestation is a major contributor to hotter temperatures experienced by communities and workers in forest-dependent regions. Ambient air temperatures are far higher in recently clearcut lands as are water and soil temperatures. In the Pacific Northwest, one recent study found that during the growing season ambient temperatures in clearcuts were on average ten degrees hotter than stands with at least fifty percent canopy closure.[30] Soil temperature increases are the most dramatic and can be lethal for temperature sensitive species. For example, research has shown that after clearcutting in the Southern Appalachians in North Carolina new plants are exposed to soil temperatures that are occasionally in excess of 140°F and frequently over 130°F.[31] As climate change unfolds and background temperatures soar, these open, clearcut lands can become dangerously hot.

The 'rural heat islands' caused by deforestation are so important that recent researchers have concluded that in temperate regions where at least 15% of forest cover has been removed from

[29] Thom et al., 2019, note 3.
[30] Davis, K.T., S.Z. Dobrowski, Z.A. Holden, P.E. Higuera, J.T. Abatzoglou, 2019. Microclimatic buffering in forests of the future: the role of local water balance. *Ecography* 42:1-11.
[31] McGee, C.E., 1976. Maximum soil temperatures on clearcut forest land in western North Carolina. USDA Forest Service Research Note SE – 237. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station.

pre-industrial times to today, deforestation accounts for one third of the increase in temperature of the average hottest day of the year.[32]

All of this is bad news for outdoor workers, especially those in the agriculture and forestry sectors. One study from the tropics is illustrative. Compared to those who worked in areas with a relatively intact forest canopy, outdoor workers in deforested areas deforested spent significantly more time with core body temperatures exceeding 38.5°C (101.3°F) after adjustment for age, sex, body mass index, and experiment start time, with a larger difference among those who began the experiment after 12 noon.[33] As such, deforestation is a significant factor in elevated risks of heat stroke and heat exhaustion, ailments already on the rise in North Carolina.

Flooding

Industrial forest practices increase the risk of flooding. As succinctly summarized in a 2017 letter to Governor Cooper from the scientific community "[n]atural forests increase the resiliency of low-lying and flood-prone areas, whereas forest degradation, clearcut logging, and conversion of natural forests to pine plantations significantly decrease flood protection benefits to surrounding communities."[34]

This fact has been established by decades of careful research on the hydrological impacts of logging in North Carolina. For example, a 1983 study found that discharge immediately below an Appalachian logging operation increased 30-45 percent, resulting in a 55-percent annual increase in stormflow erosivity during the 4-year cycle of harvesting, site preparation, and machine planting.[35] As another example, a 2001 analysis of hydrological responses to clearcutting mixed hardwoods in the southern Appalachians found that, on an average, initial flow rate and peakflow rates increase 14–15% and stormflow volume increased 10% after logging.[36]

The greatest potential logging operations have for amplifying extreme peak flows (up to 330% above natural rates) is through routing of runoff via road systems or stream channel modification. Roads systems are a major component of industrial forest landscapes, and have potentially longer effects if not properly located, constructed, maintained, and closed.[37]

---

[32] Lejeune, Q., E.L. Davin, L. Gudmundsson, J.W. Winckler, S.I. Seneviratne, 2018. Historical deforestation locally increased the intensity of hot days in northern mid-latitudes. Nature Climate Change 8: 386-390.

[33] Suter, M.K., K.A. Miller, I. Anggraeni, K.L. Ebi, E.T. Game, J. Krenz, Y.J. Masuda, L. Sheppard, N.H. Wolff, J.T. Spector, 2019. Association between work in deforested compared to forested areas and hukan heat strain: An experimental study in a rural tropical environment. *Environ Res Lett.* 14(8): 084012.

[34] A copy of the letter can be accessed here: https://www.dogwoodalliance.org/wp-content/uploads/2017/11/Scientist-Letter-to-Governor-Cooper_11-15_2017.pdf.

[35] Hewlett, J.D., R. Doss, 1984. Forests, floods and erosion: A watershed experiment in the southeastern piedmont. Forest Science 30(2): 424-434.

[36] Swank, W.T., K.J. Elliott, J.M. Vose, 2001. Long-term hydrologic and water quality responses following commercial clearcutting of mixed hardwoods on a southern Appalachian catchment. *Forest Ecology and Management* 142(1-3): 163-178.

[37] Eisenbies, M.H., W.M. Aust, J.A. Burger, M.B. Adams, 2007. Forest operations, extreme flooding events, and considerations for hydrological modeling in the Appalachians – A review. *Forest Ecology and Management* 242: 77-98.

Droughts and water shortages

Clearcut logging operations amplify the natural cycles not only of flooding, but of drought as well. During heavy precipitation events, flood risks are greater but during low flow times of year industrial forest landscapes often produce less water. In Oregon, for example, two paired watershed studies came to the same conclusion: watersheds dominated by industrial tree plantations reduced dry season flows by an average of 50% relative to the amount of water produced by watersheds dominated by old growth forests.[38] These streamflow deficits were found to persist over the entire six-month dry season.

This same effect has been found in southeastern forests, as well. Watershed experiments indicate that conversion of hardwoods to pine plantations substantially reduce monthly and annual streamflow.[39] This can reduce growing season low flows by as much as 20%.[40] One reason for this is that plantations have a greater canopy area blocking precipitation from the soil and greater transpiration within the canopy. Another reason is the fact that pine monocultures use far more soil water than natural stands.[41]

Water pollution

Industrial logging practices have wide ranging impacts on water quality. For example, in a detailed study of logging related impacts after clearcutting near the Goshen Swamp researchers found significantly higher suspended solids, total nitrogen, total phosphorus, total Kjeldahl nitrogen, fecal coliform bacteria, and significantly lower dissolved oxygen over a 15-month period relative to an unlogged, control stream (Figure XX). Longer-term deleterious effects included recurrent nuisance algal blooms that had not been present during the 212 years before the clearcut. Although a 10-meter uncut buffer zone was left streamside, this was insufficient to prevent the above impacts to stream water quality.[42]

Sedimentation, thermal pollution, and pollution associated with nutrients and chemicals are of particular concern as climate change unfolds. Alone and in combination, these stressors optimize habitat for HABs and water borne disease.[43] The effects of logging in North Carolina and other

---

[38] Perry, T. D., J.A. Jones, 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. *Ecohydrology.* 1-13; Segura, C., K.D. Blandon, J.A. Hatten, J.A. Jones, V.C. Hale, G.G. Ice, 2020. Long term effects of forest harvesting on summer low flow deficits in the Coast Range of Oregon. *Journal of Hydrology* 585: 124749. https://doi.org/10.1016/j.jhydrol.2020.124749.

[39] Swank, W.T., J.E. Douglass, 1974. Streamflow greatly reduced by converting deciduous hardwood stands to pine. *Science* 185(4154): 857-859.

[40] Kelly, C.N., K.J. McGuire, C.F. Miniat, J.M. Vose, Streamflow response to increasing precipitation extremes altered by forest management, *Geophys. Res. Lett.*, 43: 3727–3736, doi:10.1002/ 2016GL068058.

[41] McNulty et al. 2013, note 16.

[42] Ensign, S.H., M.A. Mallin, 2001. Stream water quality changes following timber harvest in a coastal plain swamp forest. *Wat. Res*. 35(14): 3381-3390.

[43] For an overview, see Denchak, M., M. Sturm, 2019. Freshwater Harmful Algal Blooms 101. Natural Resources Defense Council, available online at: https://www.nrdc.org/stories/freshwater-harmful-algal-blooms-101#causes; Center for Earth and Environmental Science, Indiana University. What causes algal blooms? Available online at: https://cees.iupui.edu/research/algal-toxicology/bloomfactors.

southeast states on sedimentation rates is well documented. Table XX provides a sample of studies that quantified the change in sedimentation associated with logging, site preparation, and road construction. Across the thirteen studies, sedimentation increased anywhere from 154% to 96,700% after logging of timber plantations that supply bioenergy markets.[44]

The effects of logging on water temperatures has also been well studied. Forest vegetation shades stream channels from solar radiation, thereby producing stream temperatures that are cooler and less variable than for unshaded sites. Research has shown that canopy removal or thinning can boost water temperatures in streams on southeastern forests up to 13°F over baseline conditions.[45]

As noted above, industrial logging activities also boost nutrient and chemical loads entering streams, lakes, rivers and estuaries. In Part I of this report, we documented the widespread use of urea-based fertilizers on North Carolina's forestlands and estimated annual application rates to be about 225 pounds per acre per year on an average of 128,000 acres. Runoff of these fertilizers is of great concern given the increasing threats of HABs as well as marine and other aquatic dead zones, especially in the wake of major flooding. As noted by UNC's Dr. Hans Paerl in a recent media report, "We should minimize fertilizer application during hurricane season; one 'wet' storm can lead to major losses of fertilizer to downstream nutrient sensitive waters".[46]

Chemical herbicides used to control weedy competition with plantation seedlings is another serious, and growing, water quality threat. Glyphosate is one of the most commonly used on North Carolina's forestlands for both conifer and hardwood plantations.[47] When this chemical enters water bodies, it provides fuel for HAB growth. Recently, Great Lakes researchers found glyphosate to be one of the key drivers in the toxic algal blooms that shut down Toledo's water supply in 2014.[48]

<u>Wildfires</u>

Because they are more homogenous, dense, young, and packed with ill-adapted species, timber plantations greatly elevate the risk of wildfire. Plantation fires burn hotter and faster and put firefighter's lives at greater risk compared to natural forests that have built-in mechanisms to keep wildfires in check. Native southern pines, especially as they age, are well adapted to fire. Longleaf

---

[44] Diaz-Chavez, R., G. Berndes, D. Neary, A.E. Neto, M. Fall, 2011. Water quality assessment of bioenergy production. *Biofuels, Bioprod. Bioref.* 5: 445-463.
[45] Sun, G., M. Riedel, R. Jackson, R. Kolka, A. Devendra, A Shepard, J. Shepard, Chapter 19: Influences of Management of Southern Forests on Water Quantity and Quality. In Rauscher, H.M., K. Johnsen, eds., 2004. Southern Forest Science: Past, Present and Future. Asheville, NC: USDA Southern Research Station.
[46] http://www.carolinacoastonline.com/news_times/article_86a19128-bbae-11e9-b31f-9bd014d35386.html.
[47] NC State Extension, 2017 Quick Guide to Forestry Herbicides Used for Softwood and Hardwood Site Preparation and Release. Available online at: https://content.ces.ncsu.edu/quick-guide-to-forestry-herbicides-used-for-softwood-and-hardwood-site-preparation-and-release.
[48] Saxton, M.A., E.A. Morrow, R.A. Bourbonniere, S.W. Wilhelm, 2011. Glyphosate influence on phytoplankton community structure in Lake Erie. *Journal of Great Lakes Research* 37: 683-690.

pine, for example, is the only tree species "able to cope with annual or biennial fires throughout its life span."[49]

Post-fire studies conducted in many parts of the US highlight the elevated wildfire risks of industrial tree plantations. For example, in the context of several post-fire analyses in Oregon, researchers found that timber plantations burn hotter and faster than structurally diverse high biomass forests that have not been logged or logged with low-impact methods: "[o]ur findings suggest intensive plantation forestry characterized by young forests and spatially homogenized fuels, rather than pre-fire biomass, were significant drivers of wildfire severity."[50]

In Idaho, at the Cooney Ridge fire complex, an extensively and homogeneously logged watershed burned severely and uniformly due to remaining ground slash (which had attained low fuel moisture after overstory removal) and severe fire weather (low relative humidity and strong upslope winds). This contrasted with a mosaic of burn severities in an adjacent watershed with higher fuel loads yet greater heterogeneity in fuel distribution at the stand and landscape levels[51].

In Texas, researchers found extensive damage to loblolly plantations after the severe fire season of 2011 and continue to advocate for reestablishment of more fire and drought resistant longleaf pines as a replacement: "[l]ongleaf pine has a unique growth form that protects the terminal bud most of the year from fire. Longleaf tolerates fire better when that sheath of needles wraps around the bud. Loblolly do not have that adaptation."[52]

Industrial forest practices also increase the risk of fire through slash burning, equipment use, and construction and maintenance of dense logging road networks, which provide access not only for timber but also for firewood, dispersed camping, and hunting. In North Carolina, hunting in recent clearcuts is encouraged.[53] Nationwide, abandoned campfires left by hunters and recreationists are the most common single source of human ignitions and eighty percent of wildfires started by campfires are within a quarter mile of roads.[54] More forest roads mean more wildfires.

Industrial forest practices are also a direct cause of many fire starts in North Carolina. Since 1970, forty-five percent of ignitions were related to debris burning (including logging slash) and

---

[49] Stanturf, J.A., D.D. Wade, T.A. Waldrop, D.K. Kennard, G.L. Achtemeier. Chapter 25: Background Paper: Fire in Southern Forest Landscapes. In Wear, D.N., J.G. Greis, 2002, The Southern Forest Resource Assessment. Asheville, NC: USDA Forest Service Southern Research Station.

[50] Zald, H.S.J., C. Dunn, 2018. Severe fire weather and intensive forest management increase fire severity in a multi-ownership landscape. Ecolgical Applications 28(4): 1068-1080.

[51] Stone, C., A. Hudak, P. Morgan, 2008. Forest harvest can increase subsequent forest fire severity. In Proceedings of the Second International Symposium on Fire Economics, Planning and Policy: A Global View. Armando González-Cabán**,** ed. Riverside, CA: USDA Forest Service, Pacific Southwest Research Station.

[52] Texas Longleaf Implementation Team, 2020. Asset Protection from Wildfire. Blog. Available online at: https://txlongleaf.org/blog/2020/01_january/asset-protection-from-wildfire/.

[53] Walters, A., 2020. Blog: Clearcuts: Overlooked Hunting Hotspots. Mossy Oak Properties, NC Land and Farms, available online at: https://www.nclandandfarms.com/clearcuts-overlooked-hunting-hotspots/.

[54] Evans, A., S. Berry. 2018. Increasing Wildfire Awareness and Reducing Human-Caused Ignitions in Northern New Mexico. Santa Fe, NM: Forest Stewards Guild.

machine use.[55] With existing data, it is not possible to refine these figures further, but the connection between industrial logging operations are wildfire starts has been well established for many decades.[56] In Virginia, for example, the state's longest duration fire on record – the 2008 South One Fire near the Great Dismal Swamp – was sparked by logging equipment and fueled by logging slash.[57] Nearly 5,000 acres were burned.

Hurricanes and other extreme wind events

Extensively clearcuts landscapes in North Carolina increase susceptibility of adjacent forests to wind damage, which is already on the rise from more intense hurricanes, tornadoes, and thunderstorms associated with climate change. Clearcuts create exposed edges where wind damage can penetrate an otherwise healthy forest and create severe damage.[58] Foresters have recommended smaller clearcut sizes and increased riparian buffers to counteract this threat.[59]

The homogeneity and composition of timber plantations is also an issue. Canopy evenness – a trait of short rotation timber plantations – is a significant risk factor. Researchers have found that, although trees in dense, uniform canopied stands may experience relatively less wind loading while the canopy is intact, the high degree of uniformity in crown size and stem form can lead to a substantial propagation of damage from newly exposed stand edges during extreme wind event. Recent thinning is an additional risk factors in these forests.[60]

The species mix in timber plantations is also a concern. Common plantations species are less resilient to wind damage than the natural, longleaf pines they have replaced. For example, following Hurricane Katrina, researchers found that long leaf pine suffered less mortality (7%) than loblolly pine (26%).[61]

Insects, disease and invasive species

Industrial logging operations spread many types of forest pathogens and invasive species that are already on the rise due to climate change. Southern pine beetles (SPB) – the most conspicuous forest insect threatening southern forests – thrives in the homogenous timber plantations associated with industrial forest practices. Diverse and complex stand structures are more resistant to the beetle, but many industrial forestland owners do not follow guidelines for creating more beetle resistant conditions for a variety of reasons including lack of or conflicting

---

[55] North Carolina Forest Service, Fire Statistics: Fires by Cause, available online at: https://www.ncforestservice.gov/fire_control/fc_statisticsCause.htm.
[56] See, e.g. Moore, H.E., 1980. Industrial Operations Fire Prevention Field Guide. San Franscisco, CA: USDA Forest Service Pacific Southwest Region.
[57] US Fish and Wildlife Service, 2008. Longest Burning Fire in Virginia Finally Out. Available online at:: https://www.fws.gov/fire/news/va/southone_final.shtml.
[58] McNulty et al., 2008, note 16.
[59] Rowan, C.A., S.J. Mitchell, H. Temesgen, 2002. Effectiveness of clearcut edge windfirming treatments in coastal British Columbia. *Forestry* 76(1). DOI: 10.1093/forestry/76.1.55.
[60] Mitchell, S.J., 2012. Wind as a natural disturbance agent in forests: a synthesis. *Forestry* 86(2): 147-157. https://doi.org/10.1093/forestry/cps058.
[61] McNulty et al., 2008, note 16.

management objectives, rapid changes in landownership patterns, and "resistance by forest managers to change current practices."[62]

Timber Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs) are among forestland managers and owners with the most rapid changes in landownership and conflicting management objectives given their focus on short term returns to investors. Over the past fifteen years, TIMOs and REITs have acquired major holdings of forestland throughout the southeast, including North Carolina. At least nineteen percent (1.1 million acres) of forestlands in North Carolina's coastal plain are managed by these investor-driven entities.[63] As stated succinctly by the Texas Forest Service, "[t]hese new owners are likely to lack the experience, trained manpower, and equipment that the forest industries had developed over many decades to address SPB outbreaks."[64]

Industrial logging operations are also a critical factor in the spread of invasive species. As summarized by Defenders of Wildlife, the stages of invasion include species transport, colonization, establishment, and landscape spread.[65] Logging practices contribute to each. The constant traffic of log trucks, skidding equipment, and logs being moved in and out of a site as well as the process of moving equipment from one site to another not only disturbs sites and creates habitat for invasive species but spreads seeds and plant parts to other areas where invaders can get started and thrive.[66]

<u>Loss of native fish, wildlife and plants</u>

Industrial forest practices are a major threat to biodiversity in North Carolina. The fragmented landscape of clearcuts, young timber plantations, and dense logging road networks that sustain these practices do not support many of the fish, wildlife and plants that depend on large contiguous tracks of native and old growth forests. Habitat fragmentation is also taking its toll because it provides vectors for invasive species and barriers to migration of species that may need to shift ranges due to climate change.[67] As a result, many of North Carolina's sensitive species that depend on complex native, interior, and older forests are at risk.

For example, while biomass plantations may benefit more common species that inhabit openings and shrublands they are replacing mature hardwoods, floodplain forests and longleaf pine ecosystems that are biodiversity hotspots for rare and sensitive native species like prothonotary warbler, Kentucky warbler and wood thrushes.[68] In a 2002 assessment, researchers found that

---

[62] Nowak, J., C. Asaro, K. Klepzig, R. Billings. 2007. The Southern Pine Beetle prevention initiative: Working for healthier forests. *Journal of Forestry*, July/August 2008.
[63] Weinberg, A., 2012. Retaining Working Forests: Eastern North Carolina. New York, NY: Open Space Institute.
[64] Billings, R. Mechanical Control of Southern Pine Beetle Infestations. Chapter 27 in Coulson, R. and K.D. Klepzig, eds., 2011: Southern Pine Beetle II. GTR-SRS-140. Asheville, NC: USDA Forest Service Southern Research Station.
[65] DeWan et al., 2010, note 24.
[66] Ledoux, C., D.K. Martin, 2012. Proposed BMPs for Invasive Plant Mitigation during Timber Harvesting Operations. Gen. Tech. Rpt. NRS-118. Newton Square, PA: USDA Forest Service, Northern Research Station.
[67] DeWan et al., 2010, note 24.
[68] Tarr, N.M, M.J. Rubino, J.K. Costanza, A.J. McKerrow, J.A. Collazo, R.C. Abt, 2016. Projected gains and losses of wildlife habitat from bioenergy-induced landscape change. Bioenergy 9(5): 909-923.

less than one percent of both hardwood and pine trees in the Piedmont measured were nineteen inches or greater in diameter – a stark measure of mature forest depletion in this region.[69]

Forest conversion is another concern related to industrial forest management because many of the corporations involved are organized as Real Estate Investment Trusts (REITs) and Timber Investment Management Organizations (TIMOs) that are more likely to sell off their lands for development than traditional forest products companies. As Forest Service researchers note, "it's not uncommon for TIMOs and REITs to have a staff, or subsidiary, that is specifically tasked with handling the sale of lands that have been determined to have some 'higher and better use' than continued timber production."[70]

Exposure to novel diseases

As noted earlier, biodiversity protects ecosystems against the spread of infectious disease.[71] So when native forests with rich inherent biodiversity are converted into simplified tree plantations forest ecosystems lose their internal control mechanisms to keep harmful organisms in check. Researchers have shown that deforestation and habitat fragmentation or modification, and the accompanying loss of structural diversity, can lead to changes in human contact rates with a variety of pathogens and disease vectors.[72] Changes in the diversity or composition of animal hosts may be closely associated with the incidence of zoonotic diseases such as Lyme disease or West Nile virus (WNV) in humans.[73] Given this, the spread of industrial tree plantations for biomass and small diameter wood products represents a strategy of biological impoverishment at the exact moment in history when we need to rebuild species richness to combat the growing threats of novel viruses like SARS-CoV-2, the virus that causes COVID-19.

---

[69] Brown, M.J. and R.M. Sheffield. 2003. Forest statistics for the Piedmont of North Carolina, 2002. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. Resource Bulletin SRS- 86.
[70] Hickman, C., 2007. TIMOs and REITs. Situation in brief. Washington, DC: USDA Forest Service, Research and Development.
[71] Gilbert, N., 2010, note 46.
[72] Vittor A.Y., R.H. Gilman, J. Tielsch, G. Glass, T.I.M Shields, W.S. Lozano, V. Pinedo-Cancino,J.A. Patz, 2006. The effect of deforestation on the human-biting rate of *Anopheles darlingi*, the primary vector of falciparum malaria in the Peruvian Amazon. *American Journal of Tropical Medicine and Hygiene* 74: 3–11.
[73] LoGiudice K., R.S. Ostfeld, K.A. Schmidt, F. Keesing, 2003. The ecology of infectious disease: Effects of host diversity and community composition on Lyme disease risk. Proceedings of the National Academy of Sciences100: 567–571; Ezenwa, V.O., L.E. Milheim, M.F. Coffey, M.S. Godsey, R.J. King, S.C. Guptill, 2007. Land cover variation and West Nile virus prevalence: Patterns, processes, and implications for disease control. Vector-Borne and Zoonotic Diseases 7: 173–180