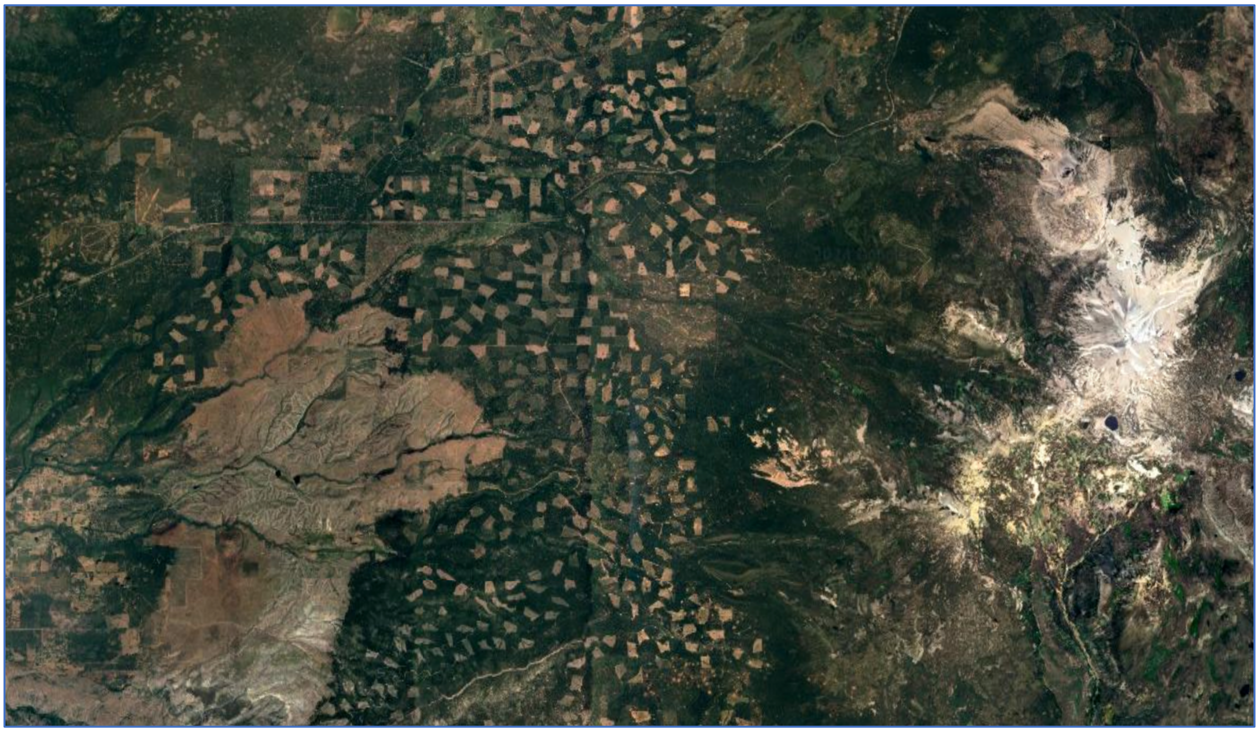

Extensive clearcutting (~20-acre patches) on the western slopes of Mt. Lassen. Image from Google Earth.

Climate Impacts of Logging and Wood Products in Shasta and Siskiyou Counties, California

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By

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Key findings:

- Despite its stated intention to achieve carbon neutrality by 2045 and growing support for climate restoration the State of California does not report or regulate greenhouse gas (GHG) emissions from industrial logging activities. This is because logging-related emissions are simply assumed to be climate neutral – offset by forest growth elsewhere or in the future or by substitution of wood products for more carbon intensive goods.

- Both assumptions are inconsistent with science and climate policy. Compared to the natural forests they have replaced, landscapes dominated by clearcuts, logging roads and timber plantations store and sequester less and emit far more carbon. As such, GHG emissions associated with intensive logging activities play a key role in keeping GHG concentrations in the atmosphere far above pre-industrial levels.

- Compared with pre-industrial forests, emissions from logging are new to the landscape, forest growth has always been there and has, in fact, been greatly reduced by logging. Moreover, replanting is the law and not some voluntary action. Therefore, granting the logging and wood products industry an effective offset for forest growth elsewhere or in newly established plantations violates the additionality requirements in California and other states' emissions trading programs, which require the timber industry to improve on nature's carbon balance and go beyond mere compliance with existing laws to earn offsets.

- Counting CO_2 captured by growth of trees eventually put on the chopping block also violates the criteria of permanence.

- And while wood products may be less carbon intensive than some substitutes, they are more carbon intensive than many others like bamboo, hemp, carbon negative concrete, wind and solar energy.

- The State of California and its counties have many methods and sources of information that can be relied upon to monitor and report the climate impacts of logging on an annual basis. To demonstrate, this report provides preliminary estimates of GHG emissions associated with logging and road building in Shasta and Siskiyou counties based on peer reviewed methodologies and also reviews ways these activities could make the land more vulnerable to climate change by increasing risks associated with wildfires, floods, heat waves and other climate stressors.

- Using a life-cycle carbon footprint method, this report estimates that GHG emissions associated with logging and logging roads in Shasta and Siskiyou counties averages over 4 million metric tons CO_2 equivalent per year (4.06 MMT CO_2-e/yr). This is equivalent to annual emissions from 883,000 gas-powered passenger vehicles. In Shasta County, the annual emissions estimate of 2.07 MMT CO_2-e/yr exceeds those associated with building energy use, transportation, solid waste, water use and agriculture combined.

- Emissions factors found by this research (9.4 – 11.4 CO_2-e/mbf) fall squarely within the range reported in previous studies from both temperate and tropical forests worldwide.

Applied to California timber harvests in total suggests that the logging and wood product sector is responsible for at least 16.8 MMT CO_2-e per year.

- The results suggest that these activities are likely to generate between $487 million and $1.4 billion dollars in climate damages each year, an amount far more than any revenues generated by logging and wood products.

I: Overview

Center for Sustainable Economy (CSE) is an environmental economics think tank with expertise in forest carbon accounting and climate impacts analysis. Battle Creek Alliance (BCA) is dedicated to protecting the public trust resources of water, air, soil and wildlife, protecting diversity and raising public awareness through education throughout the inland counties of northern California.

This report, commissioned by BCA, provides an estimate of the greenhouse gas (GHG) emissions associated with logging and logging road construction in Shasta and Siskiyou Counties using publicly available forest carbon data from 2012 to 2022. Since GHG emissions associated with industrial logging activities are presently excluded from California's climate action agenda the goal of this research is to present an accounting system that can be used reliably to monitor and eventually regulate such emissions through market-based or regulatory mechanisms.

II: Why California Needs to Track and Regulate GHG Emissions from Logging

The State of California is often regarded as a leader in the fight against climate change. In 2022, California became the world's first major jurisdiction to pledge carbon neutrality by 2045 by drastically reducing greenhouse gas (GHG) emissions and scaling up carbon removed from the atmosphere by forests, farmlands, and natural landscapes (CARB 2022). There is also growing support for climate restoration – drawing down enough CO_2 from the atmosphere to take atmospheric carbon dioxide down to a safe level below 300 parts per million.[1]

Ostensibly, reducing all sources of GHG emissions are part of the solution. But there is a conspicuous hole in this climate action framework – the greenhouse gas emissions associated with industrial logging activities. While GHG emissions from growing food crops is monitored and regulated, GHG emissions from tree cropping and other forms of industrial logging are entirely absent. The state's GHG inventory chronically lists methods to track emissions from wood products as "under development"[2] even though methods to estimate life-cycle emissions have been available for decades.

Trees are half carbon by weight, and when they are cut down and processed into two by fours, paper products, or wood pellets, the majority of this biogenic carbon is released into the atmosphere over time, most of it during the first few years after logging (Smith et al. 2006). In

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[1] California Legislative Information, 2023. SR-34 (2023-2024). Bill text available online at: https://legiscan.com/CA/text/SR34/id/2832828.
[2] California's Greenhouse Gas Inventory by Sector & Activity. 2023 Edition: 2000 to 2021 - Last updated on 12/14/2023. Available online at: https://ww2.arb.ca.gov/ghg-inventory-data.

addition, intensively logged areas emit rather than sequester carbon for 10-15 years after logging as slash, needles, roots and stumps decay and as soil disturbance and changes in hydrology release CO_2 and other GHGs (Turner et al. 2004; Vestin et al. 2020). Forests logged to make way for subdivisions, highways, infrastructure or commercial development eliminate carbon sequestration permanently, while logging roads do the same as long as they are left open and kept clear of vegetation. In addition, industrial logging activities generate significant fossil fuel related GHGs associated with construction of logging roads, operation of logging equipment, fertilizer and pesticide applications, milling and manufacturing, transport of logs and end use products, and disposal of wood products in landfills. CO_2, CH_4 and N_2O are emitted by these processes (Hudiburg 2019; Law et al. 2018; Miner and Perez-Garcia 2017).

In contrast with the natural forest carbon cycle, which catches and stores carbon both above and below ground continuously for thousands of years (Paciorek et al. 2022), the whole industrial logging process can be thought of as a "catch and release" forest carbon regime that on balance takes little or no carbon out of the atmosphere (Figure 1). Carbon accumulation on the land all but ceases. As such, California's commitment to net zero and climate restoration require measures to monitor and reduce GHGs from logging activities.

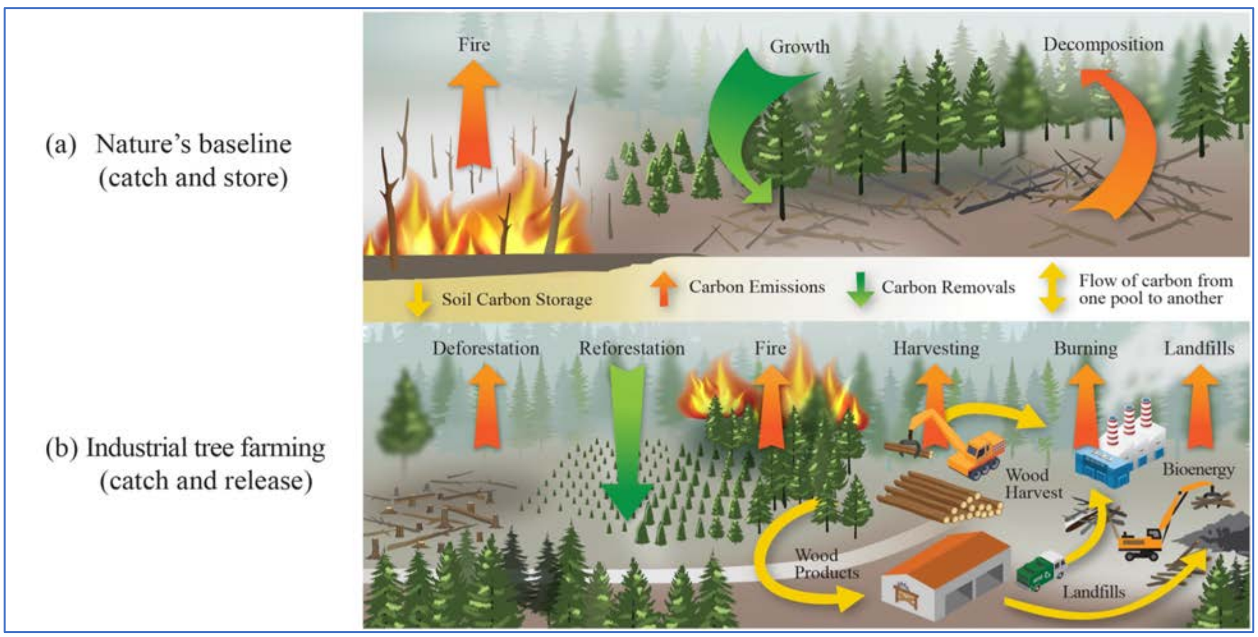

Figure 1 Compared with natural forest conditions, industrial tree farming emits more carbon, stores less, and sequesters less on an annual basis. The two regimes can be thought of as carbon catch and store vs. catch and release (Talberth and Carlson 2024).

Despite the well-known climate consequences of industrial logging activities, California does not monitor GHG emissions from the logging and wood products sector and has no plans to do so. Instead, the state has adopted a number of unwarranted GHG accounting conventions and assumptions about the carbon neutrality of this sector. In particular:

⇒ **Creating a fictitious "forest" sector and declaring it a carbon sink.**

As noted above, the economic activity of logging, road building, and wood products production and disposal releases significant quantities of both biogenic and fossil fuel-related GHGs through many life cycle channels. Entities in this sector include industrial forestland owners, logging and log hauling operators, mills and manufacturing facilities, wholesale and retail sellers of wood, and wood waste disposal outfits.

Rather than grouping these entities and their economic activities into a logging and wood products sector and using emissions factors (i.e. GHGs released per volume of wood harvested) to estimate annual GHGs released, California and other states have created a fictitious sector called "forests" and then compare carbon removed from the land by logging with carbon sequestered by forests not subject to logging each year. Since forests not logged each year always take in more carbon than is removed by logging, the entire sector is declared a carbon sink and not included in annual GHG inventories. As noted by AB 1504 (2009) "the forest sector is the only sector included in the scoping plan that provides a net sequestration of greenhouse gas emissions."[3] In this way, entities responsible for significant GHG emissions from logging fly under the climate policy radar screen.

This type of erroneous grouping is not done for agriculture. No one has suggested removing agriculture as a GHG sector because of carbon absorbed by growing crops or by native grasslands and rangelands. It is also irrational. A useful analogy is an analyst from the Bureau of Ocean Energy Management creating a sector called "oceans" and then concluding that oil and gas drilling is carbon neutral since the ocean absorbs more carbon than that released by new drilling. As a remedy, California should revise its regulated sectors to include "logging and wood products," a sector that includes all entities responsible for clearing forests for wood products or development and focus on monitoring and reducing GHG emissions from these sources.

⇒ **Declaring that biogenic releases of GHGs from logging are offset by future growth.**

This assertion invokes the projected future growth of plantation trees as an offset to logging-related emissions. By doing this, the carbon emissions associated with timber harvest plans (THPs) are often deemed negative (i.e. result in a net increase in carbon sequestration) if the sum of carbon stored in wood products and captured by future plantations is larger than the carbon removed from the land by logging.[4] But for any other sector to claim such an offset, strict criteria have to be followed including additionality and permanence (CARB 2013). Under California's offset protocols, future growth is not additional in a legal sense because replanting is required by law. Nor is it additional in an ecological sense. Nothing is being added to nature's carbon sequestration capacity. Replanting is, at best, only a partial replacement for the natural carbon

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[3] AB 1504 (2009), Section 2(b).

[4] For example, with respect to concerns over the climate impacts of the Redwood Empire Sawmills THP 1-20-00084-1, CalFire concludes "this THP demonstrates a net sequestration of carbon, not a net emission of carbon." The THP GHG calculator tool estimates "[t]he estimated quantity of carbon sequestration is determined from the estimated growth of trees onsite and from carbon stored in wood products and landfills."

cycle damaged by logging. Nor is future growth permanent. Tree plantations not now on the harvest block are simply emissions in waiting.

⇒ **Assuming that wood products are always less carbon intensive than wood substitutes.**

This simple assertion is based on one important assumption: that biogenic releases of carbon don't matter. In terms of fossil energy use, wood products generally do release less per ton of product than some substitutes, like conventional concrete or steel. But if biogenic releases are included, the situation reverses. It takes 2 or more tons of harvested wood to produce a ton of lumber (Pramreiter et al. 2023). The ton lost in the process results in a GHG emission of 1.8 tons CO_2-e.[5] So, a ton of lumber has a biogenic carbon intensity of at least 1.8 tons CO_2-e just from efficiency losses in the production process. And this is just one GHG source in a life cycle with many others. In contrast, one ton of cement has a carbon intensity of 0.8 to 0.9 tons of CO_2 per ton of product.[6] And many other wood substitutes such as carbon negative concrete, bamboo, brick, hemp are among alternative sources of fiber or building materials with much lower carbon footprints. Producers of these materials are put at a competitive disadvantage by California's market interventions that promote wood products over these substitutes and declare wood products to be sustainable.

⇒ **Assuming that wood products are better at storing carbon than forests.**

Left undisturbed by logging, forest ecosystems will accumulate carbon indefinitely. One study found that forests of the upper Midwest accumulated carbon for at least 8,500 years, only to have most of that lost in just 150 years as industrial logging activities (for wood and for agricultural expansion) commenced (Paciorek et al., 2022). In California, the timber industry asserts that logging is necessary to store carbon in wood products that would otherwise be lost to the atmosphere through fire and disease. But this makes no sense since dead and dying trees, including those scorched by fire, keep most of their carbon on the land and in soils (Harmon et al. 2022) and because for every ton of carbon stored in wood products many more tons are released into the atmosphere throughout the wood products life cycle. Because of this, there is no net carbon storage in wood products.

Because each of these claims is contested by science or inconsistent with established climate policy, continuing to exempt logging and wood products emissions from California's GHG inventory is at odds with the state's aspirations to be a leader in the fight against global warming. Instead, California should be developing a system to monitor and eventually regulate such emissions through its emissions trading scheme or other market-based mechanisms such as a forest carbon tax and reward program.

In early 2024, CSE published research in the journal *Environment, Development and Sustainability* on how states can operationalize a forest carbon tax and reward program (Talberth and Carlson

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[5] Trees are half carbon by weight so the lost ton is equivalent to 0.5 tons carbon. This is multiplied by 3.67 to convert carbon to carbon dioxide (0.5 * 3.67 = 1.835).

[6] See, e.g. Kullman, J., 2023. Curbing concrete's carbon emissions with innovations in cement manufacturing. ASU News, October 17, 2023.

2024). It would require tracking the portion of logging-related GHG emissions not now included in the state's GHG inventory and implementing a system of exemptions and credits for climate smart practices to reduce such emissions over time.

To demonstrate what that GHG accounting framework would look like in California, CSE has replicated the methodology in the EDS study to create a preliminary tally of GHG emissions from logging in Shasta and Siskiyou counties that could be suitable as a basis for a forest carbon tax and reward program implemented at the state or county level. The GHG accounting framework presented here can also be used as a basis for calculating the emissions associated with THPs in order to comply with California Environmental Quality Act (CEQA) project level GHG requirements.[7]

III: Preliminary Climate Impacts Analysis for Shasta and Siskiyou Counties

The climate impacts of industrial logging activities fall into three basic categories: (a) life cycle greenhouse gas (GHG) emissions; (b) loss of carbon sequestration capacity, and (c) loss of climate resiliency. This section provides a partial analysis of GHG emissions and loss of carbon sequestration capacity associated with logging and logging road construction in Shasta and Siskiyou counties between 2001 and the present. Where noted, estimates are preliminary pending compilation of more detailed, site-specific information. In addition, this section provides a brief review of the literature associating logging and logging road construction with loss of climate resiliency, such as increased susceptibility to wildfires, water shortages, and heat stress. The bulk of this review is contained in Exhibits A and B. Finally, this section calculates the social costs of GHG emissions associated with logging and road building activities in Shasta and Siskiyou counties using EPA's most recent estimates for the social costs of carbon.

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

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.
- FS = Forgone sequestration associated with logging roads and clearcut units.
- SA = Annual average GHG emissions associated with silviculture activities.

[7] Cal. Code Regs. tit. 14 § 15064.4

- SL = Annual average GHG emissions associated with soil loss and degradation.
- TMP = Annual average GHG emissions associated with transportation of logs to mills and 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 TMP are presented in a preliminary fashion with the expectation that emerging research and sources of data can be used to fill in holes or gaps or make estimates more site specific. This would include an estimate of TMP based on Shasta/Siskiyou-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 from Shasta and Siskiyou counties between 2012 and the present (USDA Forest Service 2023). The data are broken out into four aggregate ownership categories including national forest, other federal, state and private. In both counties, federal and private logging activities make up the vast majority of removals. Data is expressed in dry 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.

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 the latest California timber product output profile,[8] about 96.5% of California's annual timber harvest is softwood species more or less evenly distributed between long-lived (46.6%) and short lived (49.9%) products. Short lived hardwood products account for the remainder (3.5%). Applying the Smith et al. (2006) figures, this implies that, on average, California wood products lose about 79% of the original tree carbon after the standard 100-year carbon footprint period and store the rest (21%) in end use products and landfills.

[8] USDA Forest Service, Timber Product Output Interactive Reporting Tool. Available online at: https://research.fs.usda.gov/products/dataandtools/tools/timber-products-output-tpo-interactive-reporting-tool.

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. 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 logging and road building activities, we applied this value to the average annual acreage of even-aged harvesting activity in Shasta and Siskiyou counties between 2001 and the present. To determine this acreage, we used the interactive World Resources Institute Global Forest Watch database,[9] which tracks the loss and gain of forest cover annually since 2001. In particular, the annual average acreage of forest cover loss (reducing a stand below 30% canopy closure) minus acreage of forest cover loss due to wildfire and road construction (considered separately below)[10] was used to estimate the annual even-aged harvesting acreage for all logging-related purposes.[11] In Shasta County, the estimate is 15,123 annual acres. In Siskiyou County, it is 32,234 acres.

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

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[9] World Resources Institute, Global Forest Watch interactive map tool is available online at: https://www.globalforestwatch.org/map/.

[10] To back out acreage associated with new logging road construction, a sample of recent timber harvest plans (THPs) for both counties was reviewed. Data on right-of-way acreage plus logging road length (which is convertible to acreage) from these THPs was used to calculate an average road acreage factor per thousand board feet (mbf) logged. Annual logging road acreage was then estimated by multiplying annual MBF harvested in each county by these factors.

[11] Under California's timber harvest regulations, logging of dead and dying timber that does not remove more than 10% of the volume per acre is exempt from timber harvest plan requirements. However, such operations can contribute to forest cover loss. In both Shasta and Siskiyou counties, the annual acreage affected is significant: 81,375 acres (Shasta) and 26,773 acres (Siskiyou).

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. Due to high losses from mortality, Shasta and Siskiyou County forests currently have very low rates of net carbon sequestration, so the effect here is relatively small compared with other forestlands, and ranges from 0.34 – 1.02 tCO2-e per acre per year. For harvest activities, FS is simply the product of these figures 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. See note 10 for the process used to convert annual volume logged in each county to estimates of new logging road acreage.

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 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 in each county 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 50 tons carbon per acre) was extracted via *EVALIDator*.

Results

Table 1 reports results of this analysis. Based on forest carbon data, data from THPs, and data on forest cover loss, logging and logging road construction activities in Shasta and Siskiyou counties likely generate at least 4.06 MMT CO2-e per year. This represents GHGs released or committed over a 100-year period from both biogenic and fossil fuel sources and includes carbon sequestration forgone by even aged harvest units and new logging roads. To put this into perspective, this is equivalent to annual emissions from 883,000 gas-powered passenger vehicles.[12]

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

Across the two counties, the greatest source of these life-cycle emissions (61 – 68%) is 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 (13 – 24%), while forgone sequestration, silviculture activities, and soil loss and degradation are likely to contribute 15 – 20% of the total.

In both counties, almost all GHG emissions were associated with logging and road building activities on private and national forest lands. Together, these ownerships accounted for about 99% of the total. In Shasta County, national forest logging accounts for 10% of the total, while private land logging accounts for 89%. In Siskiyou County, national forest logging accounts for 43% of the total while private lands logging accounts for 57%.

According to data from the Bureau of Business and Economic Research at the University of Montana (BBER 2023), logging in Shasta County has produced an average of 181,688 thousand board feet (mbf) each year over the past two decades while in Siskiyou County, that figure is 210,579 mbf. As noted in Table 1, this translates into emissions factors of 9.44 – 11.40 tCO_2-e/mbf harvested, which fits squarely within the range found by previous research (Talberth and Carlson 2024). According to the FIA data retrieved for this analysis, a dry short ton of wood removed averages about 0.17 mbf and thus implies a life-cycle carbon intensity of 2.15 tCO2-e per metric ton of finished product. In Siskiyou County, a dry short ton removed averages about 0.23 mbf and thus implies a life cycle carbon intensity of 2.8 tCO2-e per metric ton of finished product.[13] As noted previously (see page 6) these figures are significantly higher than those commonly cited for cement (0.8 to 0.9 tCO2-e per ton of product) and undermine claims about the carbon superiority of wood products over common substitutes.

Table 1: GHG emissions from logging and roadbuilding activities in Shasta and Siskiyou counties (tCO2-e/yr)

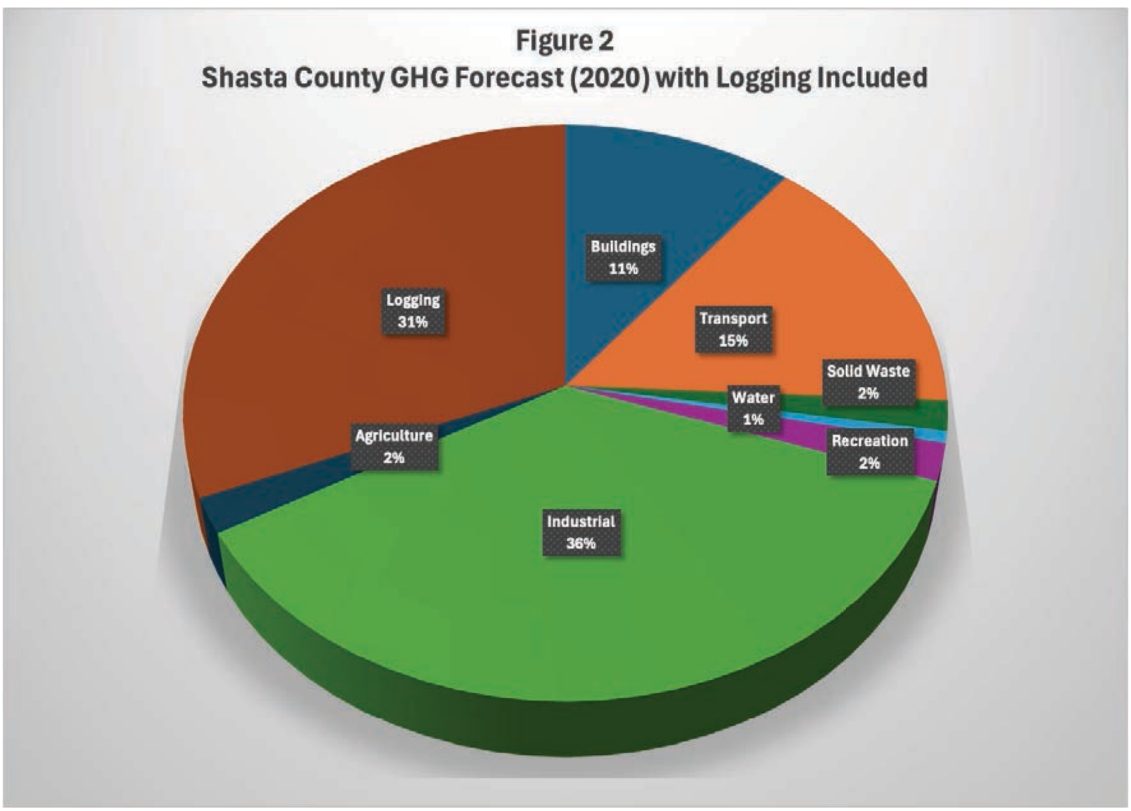
Logging emissions component	Shasta	Siskiyou
Removals (REM)	1,769,531	1,538,921
Long term wood products storage (STOR)	-371,602	-323,173
Decay and combustion of logging residuals (DR)	259,544	477,030
Forgone sequestration (FS)	241,110	148,766
Silviculture activities (SA)	64,450	52,604
Soil loss and degradation (SL)	107,697	92,953
Total GHG released and committed (tCO2-e/yr)	**2,070,731**	**1,987,100**
Emissions factors (tCO2-e/mbf)	**11.40**	**9.44**

[13] These ton to mbf conversions are consistent with US Forest Service samples from across the US. For example, in the northern region, a ton of green wood harvest embodies about 0.2174 mbf. See Winn et al. (2020).

The GHG emissions reported in Table 1 are not directly comparable to annual GHG inventories from other sources (i.e. transportation) since the basis for other sectors is real time accounting of GHGs associated with combustion of fossil fuels while the basis for Table 1 figures is life-cycle carbon footprint taking both biogenic and fossil fuel related releases into consideration. Nonetheless, since this footprint is being generated every year, from a climate policy perspective, adding logging and wood product sector emissions to annual GHG inventories seems prudent.

GHG inventories are not regularly published for either Siskiyou or Shasta Counties, however, in 2012, Shasta County completed a Shasta Regional Climate Action Plan (CAP) that tallied emissions for the unincorporated portions of the county as well as the communities of Redding, Anderson, Shasta Lake (Pang 2012).

The CAP presented GHG emissions estimates for 2008 and forecasted business as usual emissions for 2020, 2035, and 2050. Figure 2, below, compares Table 1 estimates for Shasta County with the 2020 CAP projections. If Table 1 logging-related emissions were included, it would surpass the GHG emissions associated with building energy use, transportation, solid waste, water use and agriculture combined.



B. Loss of climate resiliency

In addition to generating significant amounts of GHG pollution, industrial logging and road building activities are making the land more susceptible to climate change by amplifying risks associated with a variety of climate stressors. For example, CSE et al. (2023) and Talberth and

Olson (2019) 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. While most of this research was compiled from studies in other states, it is all relevant to California since the effects of industrial forest practices are similar for every US region.

C. Social cost of GHG emissions

An important consideration in climate policy is the economic costs of GHG emissions, which are externalized onto society as a whole and presently not reflected in the prices of final goods and services. Having on hand information about these costs helps decision makers evaluate the benefits and costs of mitigation measures designed to reduce these emissions from any particular source. 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, state and local agencies when conducting environmental analysis, such as those required for timber harvest plans under CEQA. The latest SCC estimates range from $120 to $340 per metric ton of CO_2 equivalent for different discount rates (1%, 3% and 5%). Table 2 applies these rates to the GHG emissions from logging and logging road construction in both counties. The results suggest that these activities are likely to generate between $487 million and $1.4 billion dollars in climate damages each year, an amount far in excess of any revenues generated by logging and wood products.

Table 2: Social costs of GHG emissions associated with logging and road construction in Shasta and Siskiyou Counties

Emissions and social costs			
Emissions (tCO2-e/yr)	Shasta	Siskiyou	Total
Logging and road building	2,070,731	1,987,100	4,057,831
Social costs ($ millions)			
Social cost of carbon at $120 tCO2-e	$248.49	$238.45	$486.94
Social cost of carbon at 190 tCO2-e	$393.44	$377.55	$770.99
Social cost of carbon at $340 tCO2-e	$704.05	$675.61	$1,379.66

IV: Conclusions

For Shasta and Siskiyou counties to have a robust climate action agenda, the climate impacts of logging activities, whether for timber or to clear the way for development, should be understood, monitored and eventually regulated through market-based or other policy mechanisms. This analysis demonstrates that both counties have ample access to data sources and methods to do so. GHG emissions associated with logging activities can be estimated by using forest carbon data generated by the USDA's Forest Inventory and Analysis (FIA) program coupled with information from a rapidly growing pool of peer reviewed research. This preliminary analysis suggests that GHG emissions associated with logging and logging road construction in both counties exceeds 4 million metric tons CO_2 equivalent per year at a social cost of at least $487 million dollars.

Effects of logging activities on climate resiliency can also be informed by an increasingly rich set of scientific literature. As documented by Exhibits A and B, logging and road building 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 California's commitments to carbon neutrality by 2045 and to minimize the impacts of climate change on the state, a more detailed analysis of logging related emissions and adverse effects on climate resiliency is urgently needed.

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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:

- <u>Depleted water supplies</u>. 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.[1] 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.[2] 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."[3]

- <u>Warming waters</u>. 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.[4] According to multiple federal agencies, "the evidence is . . . overwhelming that forest practices contribute to widespread stream temperature problems."[5] Warmer water, in turn, will

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[1] Perry, T. D., Jones, J.A., 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. Ecohydrology. 1-13.
[2] 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.
[3] 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.
[4] 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.
[5] 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."[6]

- 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.[7] 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."[8] 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.[9]

- 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.[10] 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

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[6] US Environmental Protection Agency, "Climate change and harmful algae blooms," available online at: https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms.

[7] *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.

[8] 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.

[9] 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.

[10] 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.[11] Logging roads channel water runoff and cause debris torrents that can travel many miles downstream, pick up momentum, and become heavily destructive.[12] 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.[13]

- Increased risk of flooding. 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.[14] A 2008 Forest Service science synthesis confirmed the detrimental impacts of logging and logging roads on peak flows across western Oregon and Washington.[15]

- Enhanced habitat for invasive species and organisms that put public health at risk. 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."[16] 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."[17]

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[11] 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.
[12] 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.
[13] Heiken, D., 2007. Landslides and Clearcuts: What Does the Science Really Say? Eugene, OR: Oregon Wild.
[14] 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.
[15] 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.
[16] Norse, E., 1990. Ancient Forests of the Pacific Northwest. Washington, DC: The Wilderness Society.
[17] 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.[18] 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. [19]

[18] 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.
[19] 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.[1] 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:

Heat stress

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.[2] 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.[3] 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

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[1] Thom, D., M. Golivets, L. Edling, G. Meigs, D. Gourevitch, L.J. Sonter, G.L. Galford, W.S. Keeton, 2019. The climate sensitivity of carbon, timber, and species richness covaries with forest age in boreal-temperate North America. Glob Change Biol 25: 2446-2458.
[2] 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.
[3] 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.[4]

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.[5] As such, deforestation is a significant factor in elevated risks of heat stroke and heat exhaustion, ailments already on the rise in North Carolina.

<u>Flooding</u>

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."[6]

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.[7] 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.[8]

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. Road systems are a major component of industrial forest landscapes, and have potentially longer effects if not properly located, constructed, maintained, and closed.[9]

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[4] 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.

[5] 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.

[6] 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.

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

[8] 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.

[9] 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.[10] 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.[11] This can reduce growing season low flows by as much as 20%.[12] 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.[13]

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. Longer-term deleterious effects included recurrent nuisance algal blooms that had not been present during the 2½ 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.[14]

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.[15] The effects of logging in North Carolina and other

[10] 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.
[11] Swank, W.T., J.E. Douglass, 1974. Streamflow greatly reduced by converting deciduous hardwood stands to pine. *Science* 185(4154): 857-859.
[12] 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.
[13] McNulty, S., P. Caldwell, T.W. Doyle, K. Johnsen, Y. Liu, J. Mohan, J. Prestermon, G. Sun, Forests and Climate Change in the Southeast USA, Chapter 8 In: Ingram, K.; K. Dow, L. Carter, J. Anderson, eds. 2013. Climate of the Southeast United States: Variability, change, impacts, and vulnerability. Washington, DC: Island Press. 165-189.
[14] 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.
[15] 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. A meta-analysis of 13 studies found that sedimentation increased anywhere from 154% to 96,700% after logging of timber plantations that supply bioenergy markets.[16]

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.[17]

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".[18]

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.[19] 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.[20]

<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 pine, for example, is the only tree species "able to cope with annual or biennial fires throughout its life span."[21]

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[16] 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.
[17] 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.
[18] http://www.carolinacoastonline.com/news_times/article_86a19128-bbae-11e9-b31f-9bd014d35386.html.
[19] 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.
[20] 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.
[21] 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.

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."[22]

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[23].

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."[24]

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.[25] 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.[26] 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 machine use.[27] 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.[28] In Virginia, for example, the state's longest duration fire on record – the 2008

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[22] 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.
[23] 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.
[24] Texas Longleaf Implementation Team, 2020. Asset Protection from Wildfire. Blog. Available online at: https://txlongleaf.org/blog/2020/01_january/asset-protection-from-wildfire/.
[25] 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/.
[26] Evans, A., S. Berry. 2018. Increasing Wildfire Awareness and Reducing Human-Caused Ignitions in Northern New Mexico. Santa Fe, NM: Forest Stewards Guild.
[27] North Carolina Forest Service, Fire Statistics: Fires by Cause, available online at: https://www.ncforestservice.gov/fire_control/fc_statisticsCause.htm.
[28] See, e.g. Moore, H.E., 1980. Industrial Operations Fire Prevention Field Guide. San Franscisco, CA: USDA Forest Service Pacific Southwest Region.

South One Fire near the Great Dismal Swamp – was sparked by logging equipment and fueled by logging slash.[29] 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.[30] Foresters have recommended smaller clearcut sizes and increased riparian buffers to counteract this threat.[31]

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.[32]

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%).[33]

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 management objectives, rapid changes in landownership patterns, and "resistance by forest managers to change current practices."[34]

Timber Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITs) are among forestland managers and owners with the most rapid changes in

[29] 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.
[30] McNulty et al., 2013, note 13.
[31] 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.
[32] 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.
[33] Johnsen, K.H., Butnor, J.R., Kush, J.S., Scmidtling, R.C., 2009. Hurricane Katrina winds damaged longleaf pine less than loblolly pine. Southern Journal of Applied Forestry 33(4): 178-181. Doi: http://dx.doi.org/10.1093/sjaf/33.4.178.
[34] 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.

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.[35] 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."[36]

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.[37] 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.[38]

Loss of native fish, wildlife and plants

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.[39] 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.[40] In a 2002 assessment, researchers found that 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.[41]

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

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[35] Weinberg, A., 2012. Retaining Working Forests: Eastern North Carolina. New York, NY: Open Space Institute.
[36] 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.
[37] DeWan, A., N. Dubois, K. Theoharides, J. Boshhoven, 2010. Understanding the impacts of climate change on fish and wildlife in North Carolina. Washington, DC: Defenders of Wildlife..
[38] 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.
[39] DeWan et al., 2010, note 37.
[40] 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.
[41] 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.

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."[42]

Exposure to novel diseases

As noted earlier, biodiversity protects ecosystems against the spread of infectious disease.[43] 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.[44] 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.[45] 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.

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[42] Hickman, C., 2007. TIMOs and REITs. Situation in brief. Washington, DC: USDA Forest Service, Research and Development.
[43] Gilbert, N., 2010. More species means less disease. Nature (2010). Available online at: https://www.nature.com/articles/news.2010.644.
[44] 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.
[45] 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