CLIMATE IMPACTS OF INDUSTRIAL FOREST PRACTICES IN NORTH CAROLINA

Climate resiliency

PART II — JANUARY 2021

DOGWOOD ALLIANCE

CENTER FOR SUSTAINABLE ECONOMY
Building the DNA of the New Economy

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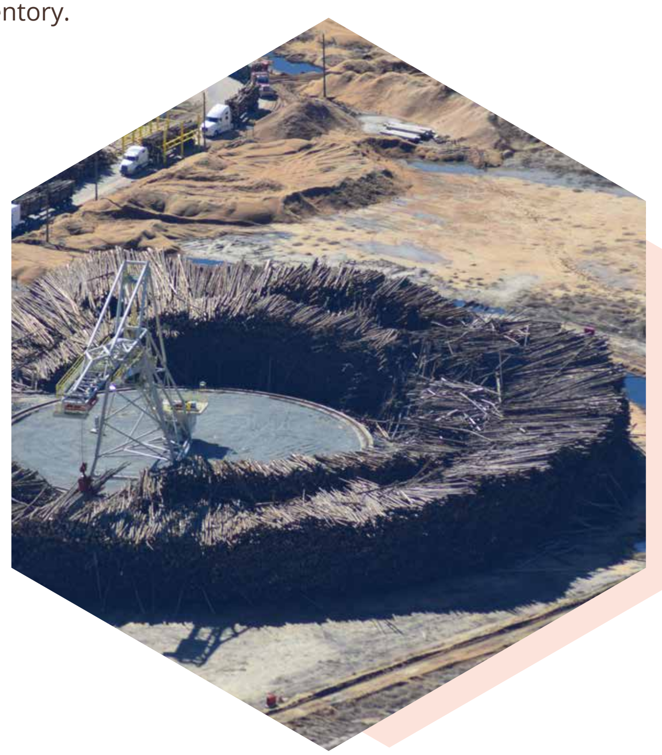
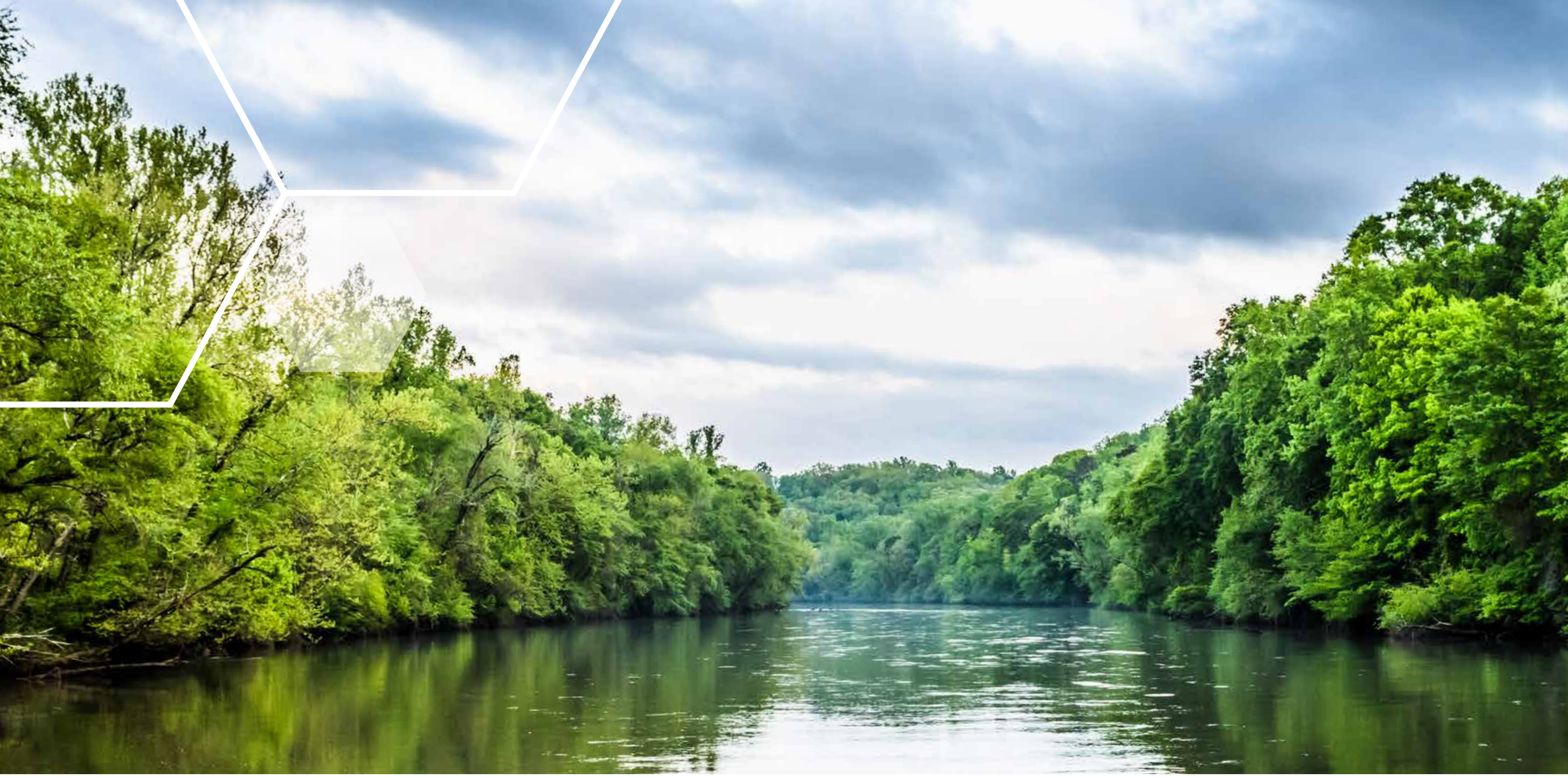
Logging destroys wildlife habitat and carbon stores.

KEY FINDINGS

Industrial logging activities are making North Carolina more susceptible to the effects of climate change.

- The logging and wood products sector in North Carolina is very carbon intensive and is likely the third largest source of greenhouse gas emissions despite being excluded in the state's official greenhouse gas inventory.
- This sector is also making North Carolina's rural landscape more vulnerable to climate change by amplifying risks that are already on the rise.
- In particular, clearcutting, short rotation timber plantations, dense logging road networks, liberal application of pesticides and fertilizers and other industrial forest practices are making the landscape more susceptible to wildfires, floods, landslides, storms, insects and disease, water shortages, nutrient pollution and harmful algae blooms.





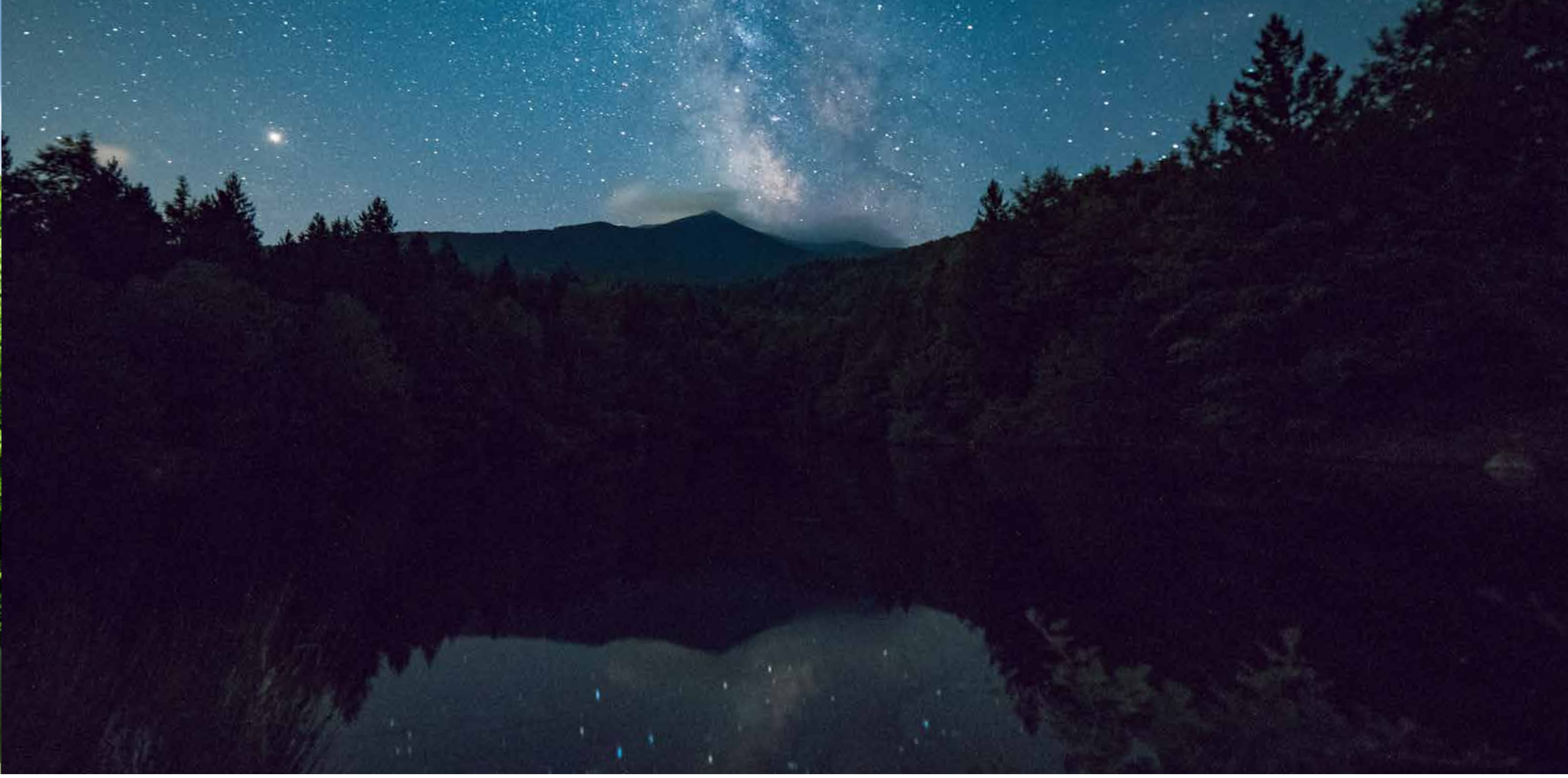
FOREWORD

Healthy standing forests buffer the worst impacts of natural disasters, providing vital natural flood control, removing carbon dioxide and other pollutants from the air, naturally filtering drinking water and helping regulate temperature. Protecting forests is essential to our ability to avoid climate chaos while simultaneously building climate resilience in rural communities as climate change worsens. Yet, with the near constant pressures of natural resource extraction, the South is clearcutting away one of its best solutions to climate change: our forests.

Climate change is happening - now - and the impacts are becoming increasingly apparent across the United States and the world. To truly address climate change, we must focus on strategies that not only align with leading-edge climate science, but also advance equitable solutions that reverse historical patterns of systemic racial and environmental injustices that have put low-income and people of color at greatest risk of suffering the worst impacts.

The South is on track, as projected, to be the region worst impacted by climate change in the United States. In fact, profound and widespread impacts from extreme weather events tied to climate change

are already occurring: from extreme flooding, to drought-related forest fires, to heat waves, dying forests, and more. While we are all impacted by climate change, low-income communities with high populations of Black, Indigenous and People of Color (BIPOC) are disproportionately impacted. Throughout the Southern coastal floodplain, rural communities are being hit especially hard. People are losing their homes, jobs, and businesses. Lives have been lost. A concentration of heavily polluting industries and industrial logging in these economically struggling rural areas makes individuals even more vulnerable to the economic and health-related hardships of repeated devastating flooding from hurricanes and other extreme weather events. The COVID-19 pandemic adds to the health and economic vulnerability that these communities face.



The Southern Coastal Floodplain is the global hub for industrial logging and wood product manufacturing, with logging rates that are among the highest on Earth. A long history of wealth and land inequity persists throughout these rural areas, where BIPOC make up a substantial part of the population but own only a tiny fraction of the forest land. The recent expansion of the wood pellet industry has put these communities at even greater risk from pollution and ecological destruction.

Overall, Black Americans are exposed to 38% more polluted air than white Americans. 71% of Black Americans live in counties that are in violation of clean-air standards. The recent expansion in the wood pellet export industry has brought these issues to light across the South. In North Carolina, every single wood pellet biomass facility is located in an environmental justice community, adding to the air pollution and ecological destruction that places these communities at greater risk as climate change intensifies.

Embracing forest solutions that ensure equity and that specifically address these racial and environmental injustices is necessary to fully address the climate crisis. This means advancing solutions that create equitable opportunities for social mobility and creating intergenerational wealth, including ownership of land. It also means reducing pollution, forest destruction, and other risks to human health, and creating equitable access to natural areas and recreational opportunities. This requires a willingness to center BIPOC voices and champion community-led climate solutions, including in the forest sector.

At a time when we should be scaling up forest protection as a critical climate and community resiliency solution, the exact opposite is happening -- logging and pollution are increasing, and high-carbon wetland forests that protect communities from dangerous flooding are specifically being impacted. This report describes the synergistic impacts of climate change and industrial logging and identifies a range of 'climate smart' forest practices that can help turn things around. We hope that this report will give our readers an understanding of how critical standing forests are to building climate resilient, healthy rural communities and preventing the worst impacts of climate change from coming to fruition.

Danna Smith, Executive Director
Dogwood Alliance

BACKGROUND

In another report, CSE and Dogwood Alliance document the greenhouse gas emissions associated with the logging and wood products sector in North Carolina. Despite being excluded from the state's official greenhouse gas (GHG) inventory, emissions from the release of carbon in biomass and wood products, forgone sequestration capacity, decay of logging residuals, and fertilizers likely top 44 million metric tons of carbon dioxide (MMT CO2-e/yr) each year, making this sector the third most carbon intensive in the state.[1] Ongoing improvements in the GHG accounting methodology will eventually help fold emissions from this sector into national and state inventories and thereby help policy makers more directly incorporate this sector into climate action plans.[2] But emissions are only one dimension of how this sector is jeopardizing climate goals.

As we discuss in this report, replacement of native forests with intensively managed lands also represents a significant reduction in the land's ability to withstand the effects of climate change. North Carolina is not alone in this respect. A rapidly growing body of research and monitoring data has shown that wherever the natural forest carbon cycle (nature's baseline) has been disrupted by industrial forest practices forestlands and the ecosystem services they provide are more at risk from a wide range of stressors such as flooding, drought, heat stress, insects, disease, fire and loss of biological diversity. This is because natural checks and balances against these threats are maximized in forests that are allowed to grow to be expansive, old, and diverse.[3]

As such, managing more of North Carolina's forestlands for biomass, paper, or other products of young, small diameter timber plantations presents a host of public health and safety threats that exacerbate those already anticipated from climate change. What is needed instead is a rapid transformation away from industrial logging practices and towards climate smart alternatives that are capable of replenishing forest carbon stocks, ecosystem services, and biological diversity while making the state more resilient to climate change.

[1] Talberth, J., L. Olson and S. Davis, 2019. Climate Impacts of Industrial Forest Practices in North Carolina. Synthesis of best available science and implications for forest carbon policy. Part I. Asheville, NC: Dogwood Alliance.

[2] See, e.g. Pearson, T., E. Swails, S. Brown, 2012. Wood Product Accounting and Climate Change Mitigation Projects Involving Tropical Timber. Winrock International report to the International Tropical Timber Organization; Sierra Club BC. 2019. Hidden, Ignored and Growing https://sierraclub.bc.ca/wp-content/uploads/SCBC-Forest-Emissions-Report-Jan-19.pdf.

[3] 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.

[4] Kunkel, K.E., D.R. Easterling, S. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. Dissen, G.M. Lackmann, R.A. Luettich, Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart and A.J. Terando, 2020. North Carolina Climate Science Report. North Carolina Institute for Climate Studies, 233 pp. Available online at: http://ncics.org/nccsr.

WHAT CLIMATE CHANGE WILL BRING TO NORTH CAROLINA

Global warming has already brought profound changes to North Carolina's natural ecosystems and human communities. Such changes will continue to amplify unless drastic actions are undertaken to stabilize and then reverse atmospheric CO_2 concentrations back toward the 350 parts per million upper limit safe zone suggested by climate scientists. The range of current and anticipated effects is well documented in the literature. Here, we highlight some of the most significant changes that have bearing on forest policy in North Carolina and ones that are particularly worrisome from the standpoint of public health and safety.

Heat stress

Like most other places in the world, North Carolina is getting hotter. According to the latest North Carolina Climate Science Report, by 2050, models project that the annual average temperature in North Carolina will increase anywhere from 2°F to 5°F compared to the average temperature for 1996-2015.[4] By 2100, the average temperature is projected to increase by 2°F to 10°F compared to the average temperature for 1996–2015. The range of values represents different assumptions about future greenhouse gas emissions (GHG) with the highest values associated with a business as usual scenario whereby GHG emissions increase through the end of this century and the lower values associated with a scenario in which emissions increase at a slower rate, peak around the middle of this century, and then begin to decrease.

[5] NCDHHS, 2015. North Carolina Climate and Health Profile. Raleigh, NC: North Carolina Department of Health and Human Services, Division of Public Health.

[6] Rhea, S., A. Ising, A.T. Fleischauer, L. Deyneka, H. Vaughn-Batten, A. Waller, 2012. Using near real-time morbidity data to identify heat-related illness prevention strategies in North Carolina. *Journal of Community Health* 37:495-500. DOI 10.1007/s10900-011-9469-0.

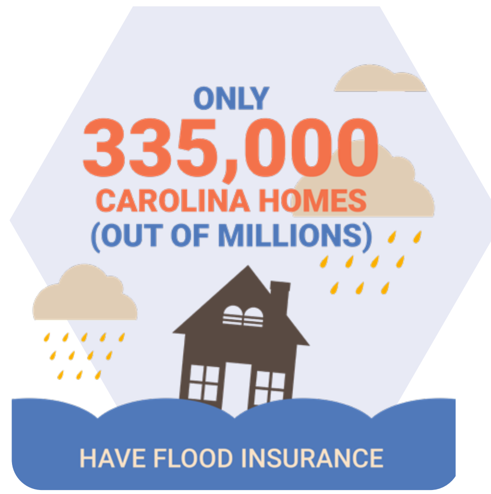
[7] Luginbuhl, R.C., L.L. Jackson, D.N. Castillo, K.A. Loringer, 2008. Heat-related deaths among crop workers, United States, 1992-2006. *Morbidity and Mortality Weekly Report*. 2008; 57:649-653.

[8] Lippmann, S.J.,et al., 2013. Ambient temperature and emergency department visits for heat-related illness in North Carolina, 2007–2008. *Environ. Res*.(2013) http://dx.doi.org/10.1016/j.envres.2013.03.009i.

[9] North Carolina Flood Insurance.org. Statewide Flood Facts. To Better Understand Why Flood Insurance is Important in North Carolina. Available online at: https://northcarolinafloodinsurance.org/flood-facts.

While these statewide average figures are cause for concern, they mask the more worrisome trends in extreme heat events, which can have major public health consequences in the form of heat-related deaths, hospitalizations, and emergency department visits.[5] **In North Carolina, the number of heat-related visits to the emergency department increases by 15.8 for every 1°F increase in temperature from 98°F to 100°F, particularly among vulnerable groups.[6] One of those groups is outdoor agriculture and forestry workers.** A 2008 study found that North Carolina had the highest rate of heat-related deaths among crop workers in the country.[7] While many heat-stress studies focus on the vulnerability of urban populations, in North Carolina, it is the rural populations that may be most vulnerable.[8]

Flooding



According to flood insurance data, flooding is North Carolina's second-most common natural hazard, occurring on average every seven and a half days.[9] **A recent New York Times investigation found that millions of homes in the Carolinas are at risk of flooding and only 335,000 have flood insurance.**[10] Insurance coverage is the spottiest in rural areas. In some places, less than 1 percent of homes are insured.

With climate change, the incidence of coastal and inland flooding is on the rise and with it an increase in the loss of life and property. Sea level rise and storm surges from increasingly powerful and slow-moving hurricanes and coastal storms is an increasingly important driver of coastal flooding. North Carolina's coast has experienced three extreme tropical cyclone-driven flood events since 1999, causing catastrophic human impacts from flooding and leading to major impacts to water quality, biogeochemistry, and ecological conditions.[11] Researchers have suggested that this trend represents a recent "regime shift" with major ramifications for hydrology, carbon and nutrient cycling, water and habitat quality.

The inland flooding threat is also related to these storms but also an increase in extreme, shorter lived precipitation events such as severe thunderstorms. Extreme precipitation events are defined as days which rainfall exceeds 3 inches. The number of such events has been highly variable throughout the historical record, however, there has been a statistically significant upward trend, with the highest number of extreme events occurring over the past several years (2015 – 2018).[12]

Climate modeling suggests that most areas in North Carolina will see an increase in the number of extreme precipitation days and associated flooding – up to a 100% increase in some areas of the Western Mountains under the business as usual scenario.[13] Even in non-extreme, but heavy rainfall events, flooding threats are on the rise as typical rainstorms are becoming more intense. According to the EPA, "[s]ince 1958, the amount of precipitation during heavy rainstorms has increased by 27 percent in the Southeast, and the trend toward increasingly heavy rainstorms is likely to continue."[14]

[10] Walsh, M.W., 2018. Millions of Carolina Homes are at Risk of Flooding. Only 335,000 Have Flood Insurance. New York Times September 19th, 2018. Available online at: https://www.nytimes.com/2018/09/19/business/flood-insurance-florence.html.

[11] Paerl, H.W., N.S. Hall, A.G. Hounshell, R.A. Luettich Jr., K.L. Rossignol, C.L. Osburn, J. Bales, 2019. Recent increase in catastrophic tropical cyclone flooding in coastal North Carolina, USA: Long term observations suggest a regime shift. *Sci Rep 9*, 10620 (2019). https://doi.org/10.1038/s41598-019-46928-9.

[12] Kunkel et al., 2020, note 4.

[13] Id.

[14] EPA, 2016. What Climate Change Means for North Carolina. Fact sheet: EPA 430-F-16-035. Washington, D.C.: US Environmental Protection Agency.

[15] Kunkel et al., 2020, note 4.

Droughts and water shortages

While droughts are a natural occurrence in North Carolina their incidence and severity are likely to rise with climate change. Scientists have expressed high confidence in scenarios where future droughts are warmer than historical events and that these warmer conditions will lead to more rapid drying through increases in evaporation from surfaces and transpiration by vegetation (evapotranspiration, or ET).[15] Forest water use will rise. As noted by the US Forest Service, "[w]arming air temperatures likely will increase regional drying through increased forest water use via evapotranspiration regardless of changes in precipitation."[16]

In addition, and during summertime months, the position of the Bermuda High is a key driver of drought cycles in North Carolina. Climate model simulations indicate that extension of the Bermuda High northwestward will occur more frequently in the future.[17] Thus, it is likely that future droughts will be more severe in terms of soil moisture deficits and the impacts on rainfed agriculture and natural vegetation.

Warmer, more frequent droughts mean less water for downstream uses. Decreases in forest water yield and decreased low flows during droughts are expected.[18] As such, water shortages in North Carolina and other southeast states are expected to increase and reduce the availability of clean water for drinking as well as water for agriculture and industrial uses.[19]

Water pollution

Climate change threatens the quality of water flowing through North Carolina's streams, rivers, and marine environments. During heavy rain events, North Carolina already experiences major nutrient contamination episodes as runoff from hog farms, fields rich in fertilizers and farm chemicals and impervious surfaces is flushed into sensitive aquatic ecosystems. Floodwaters from Hurricanes Floyd, Matthew and Florence led to a major expansion in hypoxic 'dead' zones in the Albemarle-Pamlico estuary, as well as massive pulses of carbon overflowing into coastal waters – all visible from space.[20] An increase in droughts and hotter weather also elevates the risk of nutrient pollution because water in streams and rivers flows slower and warmer thus degrading streams' natural ability to dilute and filter out pollutants.[21]

Outbreaks of harmful algae blooms (HABs) become more likely in these degraded water bodies as well. HABs in North Carolina are closely related to high temperatures and reduced precipitation during droughts. According to North Carolina's Division of Public Health, "[d]uring droughts, more harmful algal blooms occur, increasing the potential for exposure to HAB toxins, via ingestion, especially by vulnerable groups such as children and family

[16] 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.

[17] Li, L., W. Li, and Y. Kushnir, 2012: Variation of the north Atlantic subtropical high western ridge and its implication to southeastern US summer precipitation. *Climate Dynamics*, 39 (6), 1401–1412. http://dx.doi.org/10.1007/s00382-011-1214-y.

[18] Kunkel et al., 2020, note 4.

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

[20] Rich, B., 2019. More flooding, damage likely, report finds. Cateret County News Times, August 10th. Available online at: https://www.carolinacoastonline.com/news_times/article_86a19128-bbae-11e9-b31f-9bd014d35386.html.

[21] North Carolina Forest Service, 2012. North Carolina's Emerging Forest Threats. Management Options for Healthy Forests. Raleigh, NC: North Carolina Forest Service.

pets."[22] HAB contamination, in turn, is highly disruptive to local economic uses of clean water such as recreation, domestic water supply and subsistence fishing.

In addition to nutrient pollution and elevated HAB risk, climate change risks North Carolina's streams and rivers with more sediment pollution. Increases in heavy downpours and more intense hurricanes can lead to greater erosion and more sedimentation in waterways.[23] Thermal pollution is an increasing threat as well, and, coupled with other stressors, is putting many of North Carolina's sensitive aquatic species at greater risk – especially cool water species like brook trout. Eighty-three fish, forty-three mussels, twenty-one crayfish and ten snail species identified as priorities for conservation by the North Carolina's Wildlife Action Plan are already at risk from pollution, hydrological alteration, physical habitat manipulation, and introduction of non-indigenous species.[24] All of these risks are on the rise due to climate change.

Wildfires

Although most attention to the increasing wildfire threat is focused on western states, the reality is that North Carolina and other southeast states have more wildfires already than anywhere else in the country. This region has the largest annual average number of wildfires in the continental US.[25] In North Carolina, increased temperatures and drought and reduced fuel moisture will contribute to increased fire frequency and intensity, total burned area, and longer fire seasons.[26] In North Carolina, the number of weeks with conditions conducive to very large fires is projected to increase more than 300% for the Coastal Plain by the mid-21st century under the business as usual climate change scenario. Increases of 50% to 100% are projected for the Western Mountains.[27]

With this elevated wildfire risk comes elevated risks to lives, homes, and infrastructure. Smoke inhalation far from burned areas will also rise, contributing to an increase in the severity of respiratory illness as wildfires made worse by drought conditions contribute more smoke and particulate matter to the air. For example, the 2008 and 2011 wildfires in Dare County resulted in an increase in respiratory and cardiovascular-related emergency department visits in surrounding areas. The 2008 wildfire saw an increase in these types of visits by 42% - 66%.[28]

[22] NCDHHS, 2015, note 5.

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

[24] 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.

[25] Kunkel et al., 2020, note 4.

[26] McNulty et al. 2013, note 5.

[27] Id.

[28] NCDHHS, 2015, note 5.

Hurricanes and other extreme wind events

Climate change will bring more powerful hurricanes, tornadoes, severe thunderstorms and other extreme wind events that can destroy forests, crops, and buildings. The frequency of hurricanes and tropical storms with direct impacts on North Carolina has increased since 1985, with the highest 5-year total occurring during the 2000-2004 period. While some models predict fewer, but more intense storms, others predict an increase in both frequency and intensity.

On balance, however, the intensity of the strongest hurricanes is likely to increase with warming, and this could result in stronger hurricanes impacting North Carolina.[29] In addition to catastrophic flood threats (discussed earlier), the strongest hurricanes (Category 3 and higher) can result in massive economic damage from wind to forests along their paths. Spectacular levels of damage were incurred along the Gulf Coast where Hurricanes Katrina and Michael made landfall. Winds from Katrina damaged 22 million cubic meters of timber estimated at a value of $1.4 – $2.4 billion.[30] Michael blew down or damaged over 3.5 million acres of trees with an estimated value of $1 billion in Florida alone.[31]

An increase in severe thunderstorms and tornadoes is highly likely. The frequency of days with large numbers of tornadoes – tornado outbreaks – is on the rise as is the length of the season over which such tornado activity occurs.[32] High winds and wind gusts from non-tornadic storms are likely to increase as well.[33] Bomb cyclones – coastal storms that strengthen explosively – are likely to have significantly stronger winds as well as climate change unfolds.[34]

[29] Kunkel et al., 2020, note 4.

[30] McNulty et al., 2013, note 5.

[31] Engle, J., 2019. Analysis of a natural disaster: Hurricane Michael's lasting impacts on Florida's timber inventory. Forests2Market.com, blog. Available online at: https://www.forest2market.com/blog/analysis-of-a-natural-disaster-hurricane-michaels-lasting-impacts-on-floridas-timber-inventory.

[32] Kunkel et al., 2020, note 4.

[33] Cheng, C.S., G. Li, Q. Li, 2012. Possible impacts of climate change on wind gusts under downscaled future climate conditions over Ontario, Canada. *Journal of Climate* 25: 3390-3408.

[34] Martinez-Alvarado, O., S.L. Gray, N.C.G. Hart, P.A. Clark, K. Hodges, M.J. Roberts, 2018. Increased wind risk from sting-jet windstorms with climate change. *Environ. Res. Lett*. 13: 04402.

[35] Pye, J., T.P. Holmes, J.P. Prestemon, D.N. Wear. Economic Impacts of the Southern Pine Beetle. Chapter 14 in Coulson, R. and K.D. Klepzig, eds., 2011: Southern Pine Beetle II. GTR-SRS-140. Asheville, NC: USDA Forest Service Southern Research Station.

Insects, disease, and invasive species

Insects and diseases that threaten agricultural and forest lands are likely to expand under most climate change scenarios. Of most concern for foresters is the southern pine beetle (SPB) which has caused over $1.5 billion in damages since the mid-eighties at a rate of about $43 million per year. Higher air temperatures are expected to increase over-wintering beetle larva survival rate and allow the beetles to produce more generations per year.[36]

The mountain pine beetle is another species of concern. Historically, its range has been limited by cold temperatures at higher altitudes and latitudes that prevent the beetle from completing its life cycle in a single season. However, warmer temperatures in recent years have allowed the beetle to complete its life cycle in a single season. The resulting expansion in the beetle's range has infected new tree species and produced epidemic breakouts in existing and new environments.[37] While these two species are of special concern, bark beetles in general will be better able to take advantage of forests stressed by more frequent drought.[38]

Climate change will also complicate North Carolina's fight against destructive invasive species. As explained by Defenders of Wildlife:

> *Invasive species compete with native species for resources, decrease forage quality, alter community structure and ecosystem processes such as nutrient cycling and fire regimes, cause genetic hybridization, increase predation, cause mortality through disease and pest outbreaks, foul and clog waterways, and impact human health as well as economic well-being.*[39]

Under climate change, climatic constraints that limit some species' ability to spread will be relaxed such that previously benign non-native or current invasive species may pose new or altered threats. These constraints include growing season duration, temperature requirements that trigger dormancy, or moisture tolerances.[40] Species tolerant of heat, drought or more frequent disturbances may thrive in places where they are now held in check. As one example, populations of the Great Lakes common reed (*Phragmites australis*) – recognized as a severe threat in North Carolina – have already expanded with higher than average temperatures and reductions in water levels.[41] As another example, Kudzu, a major invasive species on forestlands is expected to increase dramatically as its "range and tolerance of harsh conditions will allow it to rapidly move into new areas."[42]

[36] Ayres, M., M. Lombardero. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. The Science of the Total Environment 262 (3): 263-286.

[37] DeWan et al., 2010, note 24.

[38] North Carolina Forest Service, 2012, note 21.

[39] DeWan et al., 2010, note 24.

[40] Hellmann, J. J., J. E. Byers, B. G. Bierwagen, J. S. Dukes, 2008. Five potential consequences of climate change for invasive species. *Conservation Biology* 22: 534-543.

[41] Wilcox, K.L., S.A. Petrie, L.A. Maynard, S.W. Meyer, 2003. Historical distribution and abundance of Phragmites australis at Long Point, Lake Erie, Ontario. *J. Great Lakes Res*. 29(4): 664-680.

[42] North Carolina Forest Service, 2012, note 20.

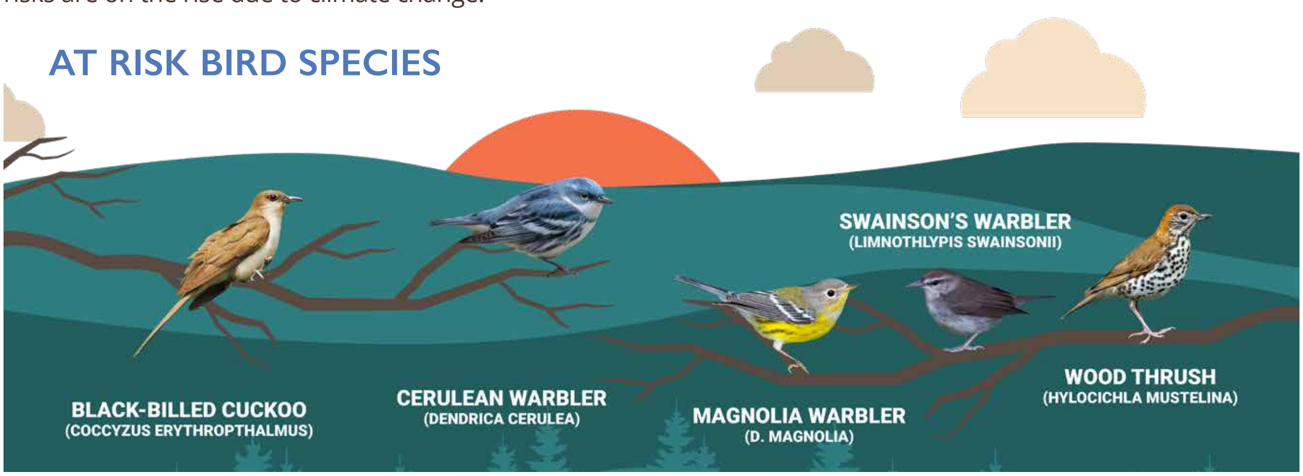
Loss of native fish, wildlife, and plants

Because of shifts in the suitable land base for certain ecosystem types, increasing temperatures, and an increase in natural and human caused disturbances many of North Carolina's native wildlife, fish and plants are at greater risk of extirpation or extinction due to climate change. Certain high elevation forest types and coastal ecosystems – like red spruce-Fraser fir and tidal forests – may disappear entirely due to higher temperatures and rising sea levels.[43]

Forests that do persist will become more fragmented and degraded by an increase in wind damage, insects, disease, wildfires, floods and heat stress. This poses special risks to species that need large, interior blocks of forest to survive as well as those with restricted ability to migrate through hostile terrain (i.e. clearcuts, urban areas, agricultural lands) as corridors will become smaller and more disturbed. These include a number of forest interior dwelling species, such as black-billed cuckoo (*Coccyzus erythropthalmus*), cerulean warbler (*Dendrica cerulea*), magnolia warbler (*D. magnolia*), Swainson's warbler (*Limnothlypis swainsonii*), and wood thrush (*Hylocichla mustelina*).

Protected areas may lose their ability to provide important refugia for native wildlife. Because they are relatively small and isolated, current protected areas only capture a narrow range of environmental conditions across the wide range of habitat types in North Carolina. With climate change, these areas may no longer provide temperature, precipitation, or hydrologic conditions within the historic natural range of variation for these habitat types.[44]

Floods, droughts, and changes in hydrology will have big impacts on aquatic species already under stress from intensive land uses. Eighty-three fish, forty-three mussels, twenty-one crayfish and ten snail species identified as priorities for conservation by the North Carolina's Wildlife Action Plan are already at risk from pollution, hydrological alteration, physical habitat manipulation, and introduction of non-indigenous species.[45] All of these risks are on the rise due to climate change.



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

[44] Pyke, C., D.T. Fischer, 2005. Selection of bioclimatically representative biological reserve systems under climate change. *Biological Conservation* 121: 429-441.

[45] DeWan et al., 2010, note 24.

[46] Gilbert, N., 2010. More species means less disease. Nature (2010). Available online at: https://www.nature.com/articles/news.2010.644.

[47] Keesing, F., L. Belden, P. Daszak, et al. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature* 468, 647–652 (2010). https://doi.org/10.1038/nature09575.

Exposure to novel diseases

The global COVID-19 pandemic is a stark reminder about the increasing risks humanity faces from novel viruses that are, in part, caused by human intrusion into wild areas and biological impoverishment of native ecosystems, which degrades the ability of these ecosystems to regulate pathogens of all types. More species means less disease.[46] Conversely, when biodiversity is lost, diseases can spread far more effectively. In a review of 12 global health threats, including West Nile fever and Lyme disease, researchers found that in every case, the diseases became more prevalent as biodiversity was lost. For example, three studies showed that a decreased diversity of small mammals in an area causes the prevalence of hantaviruses — which induce fatal lung infections in humans — in host animals to rise, thereby increasing the risk to humans.[47] And so as climate change accelerates biodiversity loss, so too will it accelerate the risks of global pandemics such as we are now facing.

In addition to the indirect effects via biodiversity loss, climate change will increase human health risks in a more direct fashion. Numerous studies have documented the connection between rising rates of warming on the geographic expansion of pathogen-based diseases.[48] In addition, an increasing frequency of extreme weather events exposes affected populations to a host of post-disaster conditions optimal for the spread of disease. Extreme weather events may not only trigger major spread of diseases through the increased growth of vectors, pathogens, viruses, and transmission routes, but can also "cause a breakdown of public health infrastructure, loss of sanitation and hygiene, shortage of drinking water supply, and increased concentration of people."[49]

North Carolina's Division of Health is on alert to these emerging threats. Bacterial, viral and parasitic diseases that are transmitted by mosquitoes, ticks and fleas – known as vector-borne diseases – are of most concern. These include diseases such as spotted fever Rickettsiosis, LaCrosse encephalitis, West Nile virus, eastern equine encephalitis, and Q fever. Most of these diseases can cause serious illness or even death. Vector-borne diseases may become newly established in a vector population or endemic diseases may increase in incidence as a result of changing climatic patterns, including warming and an increase in extreme weather events.[50] For example, mosquito populations can skyrocket after hurricanes or periods of intense precipitation. Following Hurricane Irene in 2011, "mosquito landings on a person in one minute became 'too numerous to count' in some coastal counties."[51]

New diseases may also be introduced and find suitable habitat as the climate warms. Imported cases of Chikungunya and Dengue have been identified in residents from North Carolina and other states, returning from areas where it is endemic. In late 2013, the first local transmission of Chikungunya in the Americas was reported on islands in the Caribbean. Local transmission of Chikungunya has not been documented in the continental U.S. but is possible because a "competent vector mosquito (Aedes albopictus), an aggressive day-time biter, is found throughout North Carolina."[52]

[48] Khan, M.D., H.H.T. Vu, Q.T. Lai, J.W. Ahn, 2019. Aggravation of human diseases and climate change nexus. *Int J Environ Res Public Health* 16(15): 2799. Doi: https://dx.doi.org/10.3390%2Fijerph16152799.

[49] Id.

[50] NCDHHS, 2015, note 5.

[51] Id.

[52] Id.

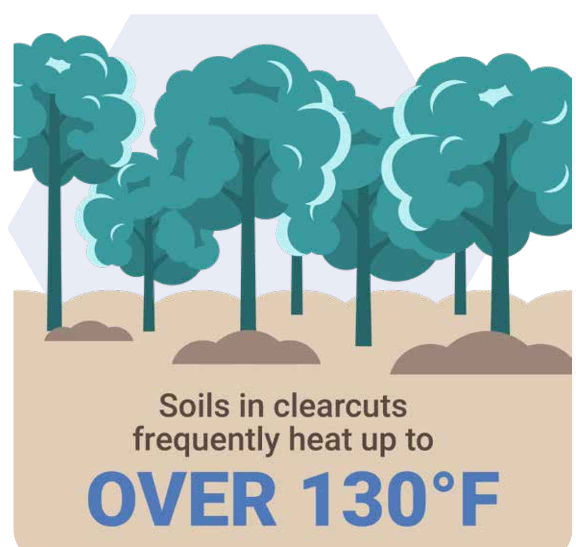
Plantations offer just a fraction of the ecosystem services that real, natural forests do.

HOW INDUSTRIAL LOGGING PRACTICES ARE MAKING MATTERS WORSE

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.[53] 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.[54] 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



[53] Thom et al., 2019, note 3.

[54] 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.

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.[55] 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 pre-industrial times to today, deforestation accounts for one third of the increase in temperature of the average hottest day of the year.[56]

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 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. 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."[58]

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.[59] 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 peak flow rates increase 14–15% and stormflow volume increased 10% after logging.[60]

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

[55] 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.

[56] 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.

[57] 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.

[58] 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.

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

[60] 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.

major component of industrial forest landscapes, and have potentially longer effects if not properly located, constructed, maintained, and closed.[61]

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.[62] 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.[63] This can reduce growing season low flows by as much as 20%.[64] 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.[65]

[61] 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.

[62] 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.

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

[64] 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.

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

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 A). 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.[66]

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.[67] The effects of logging in North Carolina and other southeast states on sedimentation

TABLE A

POST-LOGGING IMPACTS ON WATER QUALITY: GOSHEN SWAMP AND SIX RUNS CREEK

PARAMETER	GOLDEN SWAMP		SIX RUNS CREEK	
	PRE-HARVEST	POST-HARVEST	PRE-HARVEST	POST-HARVEST
Temperature	15.9 ± 5.8	19.0 ± 7.7	16.0 ± 5.8	19.1 ± 6.4
Dissolved oxygen (mg/L)	6.3 ± 2.9	4.7 ± 4.1[b]	7.3 ± 2.1	7.1 ± 2.0
Specific conductance (μS/cm)	143 ± 45[a]	200 ± 56[b]	98 ± 39	104 ± 12
pH	6.6 ± 0.5	6.2 ± 0.34	6.7 ± 0.41	6.2 ± 0.48
Turbidity (NTU)	6 ± 8	14 ± 27	7 ± 6	9 ± 9
Total suspended solids (mg/L)	3 ± 2	10 ± 12[b]	3 ± 4	2 ± 3
Total nitrogen (μg/L)	1349 ± 348	1584 ± 902[b]	1486 ± 431	979 ± 332
Nitrate-N (μg/L)	287 ± 294[a]	56 ± 135[b]	524 ± 280	389 ± 285
Total Kjeldahl-N (μg/L)	1058 ± 408	1531 ± 942[b]	962 ± 417	590 ± 180
Ammonium-N (μg/L)	71 ± 75	184 ± 256	72 ± 50	121 ± 128
Total phosphorus (μg/L)	116 ± 72	240 ± 187[b]	113 ± 48	119 ± 41
Molar N : P	40 ± 54	20 ± 11	35 ± 22	22 ± 15
Orthophosphate-P (μg/L)	30 ± 17	112 ± 185	35 ± 17	43 ± 22
Chlorophyll a (μg/L)	3.9 ± 5.9[a]	28.0 ± 47.8[b]	1.1 ± 1.1	0.5 ± 0.3
Fecal coliform bacteria (col/100 mL)	116 ± 103	1993 ± 5986[b]	143 ± 268	244 ± 768

[a] Indicates a significant difference ($p < 0.05$) between Goshen Swamp and Six Runs Creek pre-harvest data.
[a] Indicates a significant difference ($p < 0.05$) between Goshen Swamp and Six Runs Creek post-harvest data.

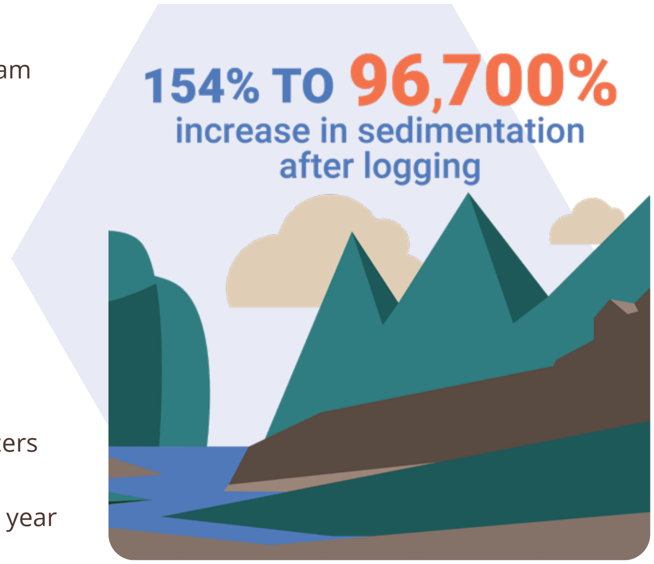
Source: Ensign, S.H., M.A Mallin, 2001. Stream water quality changes following timber harvest in coastal plan swamp forest. *Wat. Res.* 35(14): 3381-3390

[66] 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.

[67] 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.

rates is well documented. Table B 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.[68]

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.[69]



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

TABLE B

SEDIMENTATION AND CLEARCUT LOGGING IN THE SOUTHEAST

			SEDIMENT INCREASE	
FOREST TYPE AND ACTIVITIES	**STUDY SITE**	**TREATMENT**	**% INCREASE**	**Mg Ha/yr**
LOGGING ALONE				
Loblolly pine	South Carolina	Clearcut	655	0.131
Mixed hardwoods	Georgia	Clearcut	154	0.103
Upload hardwoods	Tennessee	Clearcut	2,020	10.6
Loblolly pine	Arkansas	Clearcut	1,875	0.225
Loblolly/shortleaf pine	Arkansas	Clearcut	6,500	0.26
LOGGING AND SITE PREPARATION				
Loblolly pine	Mississippi	Clearcut, bed	2,198	13.63
Slash pine	Florida	Clearcut, windrow	1,100	0.033
Loblolly pine	North Carolina	Clearcut, blade	1,939	9.695
Loblolly pine	Arkansas	Clearcut, shear	653	0.464
Shortleaf pine	Arkansas	Clearcut, windrow	1,926	0.578
Loblolly pine	Texas	Clearcut, shear	750	0.175
LOGGING ROADS				
Mixed hardwoods	North Carolina	Road construction	11,900	1.19
Loblolly pine	Georgia	Road construction	96,700	3.868

Source: TK

[68] 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.

[69] 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.

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".[70]

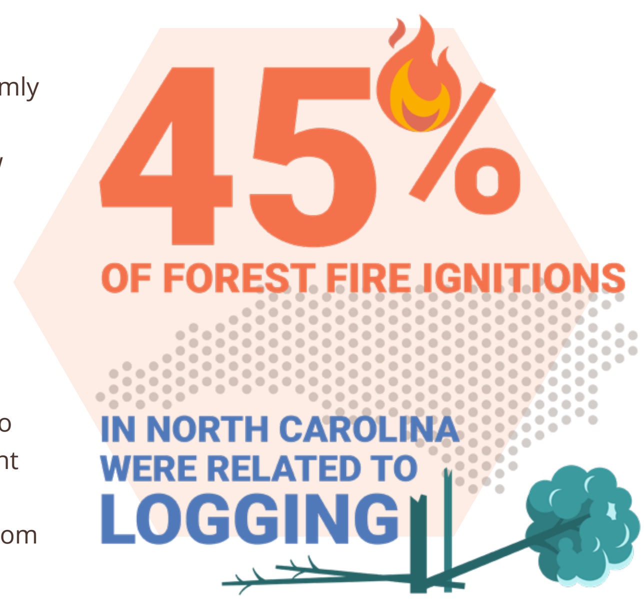
Chemical herbicides used to control weedy competition with plantation seedlings is another serious, and growing, water quality threat. Glyphosate is one of the most commonly used on North Carolina's forestlands for both conifer and hardwood plantations.[71] When this chemical enters water bodies, it 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.[72]

Wildfires

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."[73]

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."[74]

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.[75]



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

[70] http://www.carolinacoastonline.com/news_times/article_86a19128-bbae-11e9-b31f-9bd014d35386.html.

[71] 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.

[72] 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.

[73] 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.

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

[75] 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.

fire. Longleaf tolerates fire better when that sheath of needles wraps around the bud. Loblolly do not have that adaptation."[76]

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.[77] 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.[78] 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.[79] With existing data, it is not possible to refine these figures further, but the connection between industrial logging operations and wildfire starts has been well established for many decades.[80] 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.[81] Nearly 5,000 acres were burned.

Hurricanes and other extreme wind events

Extensively clearcut 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.[82] Foresters have recommended smaller clearcut sizes and increased riparian buffers to counteract this threat.[83]

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 events. Recent thinning is an additional risk factor in these forests.[84]

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

77 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/.

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

79 North Carolina Forest Service, Fire Statistics: Fires by Cause, available online at: https://www.ncforestservice.gov/fire_control/fc_statisticsCause.htm.

80 See, e.g. Moore, H.E., 1980. Industrial Operations Fire Prevention Field Guide. San Francisco, CA: USDA Forest Service Pacific Southwest Region.

81 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.

82 McNulty et al., 2008, note 16.

83 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.

84 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.

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%).[85]

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 homogeneous 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 land ownership patterns, and "resistance by forest managers to change current practices."[86]

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.[87] 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."[88]

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.[89] 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.[90]

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.[91] As a result, many of North Carolina's sensitive species that depend on complex native, interior, and older forests are at risk.

[85] McNulty et al., 2008, note 16.

[86] 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.

[87] Weinberg, A., 2012. Retaining Working Forests: Eastern North Carolina. New York, NY: Open Space Institute.

[88] 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.

[89] DeWan et al., 2010, note 24.

[90] 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.

[91] DeWan et al., 2010, note 24.

For example, while 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.[92] 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.[93]

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."[94]

Exposure to novel diseases

As noted earlier, biodiversity protects ecosystems against the spread of infectious disease.[95] 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.[96] 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.[97] 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.

[92] 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.

[93] 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.

[94] Hickman, C., 2007. TIMOs and REITs. Situation in brief. Washington, DC: USDA Forest Service, Research and Development.

[95] Gilbert, N., 2010, note 46.

[96] 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.

[97] 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 Sciences* 100: 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

Rebuilding permanent carbon storage is one of the few realistic pathways to reducing $CO_{2.}$

CLIMATE SMART PRACTICES OFFER A SOLUTION

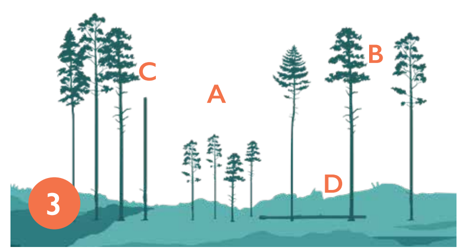
The adverse climate impacts of industrial forest practices in North Carolina can be dramatically reduced by transforming these practices into climate smart alternatives. While the term 'climate smart' is a concept in need of further refinement, it nonetheless is a useful one that can be applied to a number of specific practices that simultaneously reduce timber harvest emissions, increase landscape-level sequestration, increase permanent carbon storage on the land, and improve forest resiliency to the effects of climate change (Figure E). Rebuilding permanent carbon storage is key since it represents one of the few realistic pathways to reducing CO_2 concentrations in the atmosphere back to the 350-ppm scientific safe zone. There are several general categories of climate smart practices that can accomplish these goals.

FIGURE E

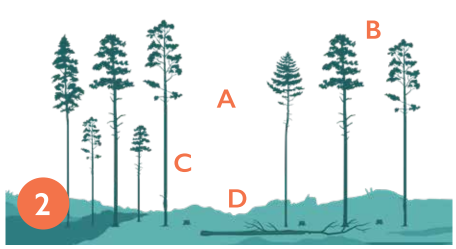
HOW TO GET OLD-GROWTH CHARACTERISTICS IN FORESTS

OLD GROWTH STRUCTURAL CHARACTERISTIC	MANAGEMENT PRACTICE
Increase the diversity of tree sizes and ages	Harvest single trees or small groups of trees, creating gaps up to 1/4 acre; repeat to create multi-aged stands
Increase the number of snags—large standing dead trees	Girdle (i.e., cut several rings of bark/cambium around the stem to deliberately kill the tree) selected medium- to large-sized trees, including cull trees
Increase number and volume of downed logs	Fell and leave on the ground selected medium- to large-sized trees, including cull trees, which can improve the growth of residual trees
Provide for future snags and downed logs	Reserve permanent "legacy trees" within harvested areas
Increase number of large living trees	Thin woods by removing competing, low-quality trees adjacent to largest, most vigorous trees

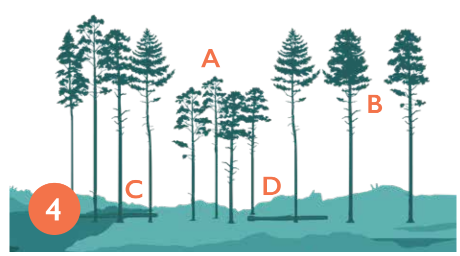
Woodlot before old-growth restoration practices.



15 years after harvest. (A) A 1/4-acre gap is regenerated, diversifying tree sizes and ages. (B) Thinned trees grow larger. (C) Girdled tree is now a snag. (D) Large downed log shows signs of decay.



Immediately following a harvest using old-growth restoration practices. (A) Trees are cut and removed to create a 1/4-acre gap. (B) Full crowned canopy trees are thinned to increase their size. (C) Poor quality tree girdled to create standing dead tree. (D) Tree felled to the ground and left in the woods to provide large downed logs.



30 years after harvest. (A) Gap is no sapling and pole-sized trees. (B) Thinned trees designated with "L" for legacy tree, are large with big crowns. (C) Snag has fallen to the ground and now provides a new large downed log. (D) Large downed log is well decomposed.

Adapted from: D'Amato, A., P. Catanzaro, 2007. *Restoring Old Growth Characteristics*. Amherst, MA: University of Massachusetts Extension.

Forest carbon reserves and proforestation

One of the best options for protecting and restoring high density forest carbon stocks is through a system of forest carbon reserves off limits to most forms of commercial resource extraction. Proforestation would be the predominant form of management on these lands. Proforestation is a term used to describe the practice of purposefully growing an existing forest intact toward its full ecological potential, including its maximum potential to capture and store carbon.[98] This means letting forests grow big, and old.

Public forest lands managed by federal, state, and county agencies are the most important lands for designation of these reserves. These are the only places where managers have the option of focusing on ecosystem services that benefit all North Carolinians rather than on providing timber supplies for mills and biomass facilities. Within the public lands matrix, all late successional/old growth forests (LSOG) should be protected immediately since these represent the most important existing forest carbon stocks and since these forests provide blueprints for restoring a climate resilient landscape across the state.

Presently, LSOG forests in North Carolina are seriously depleted relative to their natural extent. LSOG forests are defined as forests that meet certain age, size, and structural characteristics.[99] In general, forests must be natural (not replanted) at least 100 years old to be considered as candidates. Such forests represent less than two percent of North Carolina's forestlands, so the potential for replenishment is significant.[100] Unfortunately, older forests continue to be lost.

Any climate policy designed to maintain and rebuild high density carbon stocks must halt any further loss and protect all remaining late successional and old growth forests from logging and other forms of anthropogenic disturbance. Forest carbon reserves should also include younger, highly productive forests that are likely to capture and store carbon rapidly while evolving into LSOG stands. North Carolina has some of the most productive forest lands in the nation. Over 2.3 million acres fall into the USDA's highest productivity classes, which are forestlands capable of growing at least 120 cubic feet per acre per year.[101]

Restoring old growth forest characteristics

Since carbon storage and resiliency to fires, drought, floods, and pathogens is maximized in LSOG forests, anything that can be done to put existing timber plantations and other younger forests on a trajectory to eventually develop LSOG conditions is smart climate policy. Importantly, this does not always mean excluding timber harvest. To the contrary, in existing plantations and other younger forests it may require thinning in multiple entries over several decades to accomplish and thus provide a sustainable timber supply while rebuilding carbon

[98] Moomaw, William R., S.A. Masino, E.K. Faison, 2019. Intact forests in the United States: proforestation mitigates climate change and serves the greatest good. *Frontiers in Forests and Global Change*. 2. doi:10.3389/ffgc.2019.00027.

[99] USDA Forest Service, Southern Region, 1997. Guidance for conserving and restoring old growth forest communities on national forests in the Southern Region. Report of the Region 8 Old-Growth Team. Atlanta, GA: USDA Forest Service Region 8. Brown, M., J.T. Vogt, 2015. North Carolina's Forests, 2013. Resource Bulletin SRS-205. Knoxville, TN: USDA Forest Service, Southern Research Station.

[100] Brown, M., J.T. Vogt, 2015. North Carolina's Forests, 2013. Resource Bulletin SRS-205. Knoxville, TN: USDA Forest Service, Southern Research Station.

[101] Id.

[102] D'Amato, A., Catanzaro, P., 2007. Restoring old-growth characteristics. Amherst, MA: University of Massachusetts Extension.

stocks, improving climate resiliency, and enhancing other ecosystem services like water filtration and provision of fish, game, and non-timber forest products. But of course, these benefits of ecologically-based thinning are only realized if the stand is not subsequently clearcut but instead allowed to grow and evolve in perpetuity.

Over the past two decades, climate smart practices that accelerate the development of LSOG conditions from plantations have been field tested and verified in multiple forest ecosystems across the country. For example, researchers and University of Massachusetts have published a technical guide for restoring LSOG conditions in eastern hardwood stands for private and public forestland owners.[102] Ford and Keeton (2017) found that structural complexity enhancement treatments had a beneficial effect on forest diversity and long term carbon storage in northern hardwood and conifer stands.[103] The Siuslaw National Forest has shown that thinning 30- to 35-year-old plantations to low densities and planting a mix of conifer seedlings can speed up development of old-growth characteristics in Douglas-fir forests.[104] Kerr (2012) provides a useful science synthesis on ecological restoration thinning techniques to accelerate the growth of large trees, create multiple canopy layers, increase understory plant diversity, and maintain deep crowns (branches growing well down the trunk). In moist forest plantations, he notes that “[t]he best available science concludes that [variable density thinning] VDT (leaving skips and gaps and using variable tree spacing, unlike an industrial thinning regime) can accelerate the onset of some characteristics of LSOG forests.[105]

While thinning itself produces GHG emissions and reduces carbon stocks temporarily, it also accelerates the growth of trees left behind so over the long run carbon stocks accumulate not only in large, older trees, but in snags and downed logs that recycle stored carbon into the soil. In this way timber harvest and increased carbon storage are compatible. As noted by Busing and Garman (2002), “[t]hinning from below can expedite the development of large live and dead trees, and canopy height diversity without greatly diminishing wood quantity or quality.”[106]

[103] Ford, S., W.S. Keeton, 2017. Enhanced carbon storage through management for old-growth characteristics in northern hardwood-conifer stands. Ecosphere 8(4): e01721.

[104] Chan, S.S., Larson, D.J., Maas-Hebner, K.G., Emmingham, W.H., Johnston, S.R., Mikowski, D.A., 2006. Overstory and understory development in thinned and underplanted Oregon Coast Range Douglas-fir stands. Can. J. For. Res. 36: 2696-2711.

[105] Kerr, A. 2012. Ecologically Appropriate Restoration Thinning in the Northwest Forest Plan Area. A Policy and Technical Analysis. Conservation Northwest, Geos Institute, Klamath-Siskiyou Wildlands Center, and Oregon Wild.

[106] Busing, R.T., Garman, S.L., 2002. “Promoting old-growth characteristics and long-term wood production in Douglas-fir forests.” *Forest Ecology and Management* 160 (2002): 161-175.

Alternatives to clearcutting, chemicals, and fertilizers

As discussed in Part I of this report, clearcuts are carbon sequestration dead zones for ten to fifteen years after harvest because emissions from the decay and combustion of logging residuals and losses of soil carbon outweigh any sequestration by seedlings and new growth. Moreover, the application of chemical herbicides and fertilizers used to suppress competing vegetation and enhance seedling growth in clearcuts generates additional carbon emissions above and beyond the emissions associated with timber harvest because they contain embodied carbon that is released into the atmosphere in a short period of time.[107] In addition, nitrogen-based fertilizers (urea being the most common) applied to forestlands increases atmospheric nitrous oxide, the third most harmful greenhouse gas behind methane and CO_2.

[107] See, e.g. Lal, R., 2004. "Carbon emissions from farm operations." Environment International 30 (2004): 981-990.

[108] For a profile of these foresters and their techniques, see Segerstrom, C., 2017. Slow Wood: Reimagining the value and values of timber. Eugeneweekly.com, August 3rd, 2017. Available online at: http://www.eugeneweekly.com/20170803/lead-story/slow-wood.

[109] Franklin, R., 2009. Converting Planted Loblolly (or slash) Pine to Longleaf Pine: An Opportunity. Forestry Leaflet 31. Clemson, SC: Clemson Extension.

Profitable, climate smart techniques that leave forest cover intact and obviate the need for use of chemical herbicides and fertilizers are routinely practiced by small scale, sustainable forestry operations in North Carolina and other southeastern states. Techniques include individual and group tree selection, small patch cuts, thinning, and management for a diverse mix of both hardwoods and softwoods.[108]

For example, one type of harvest system described by researchers at Clemson University puts private landowners interested in restoring native longleaf pine forests on a path to do so through thinning and small patch cuts that provide opportunities to gradually plant and restore longleaf pines while minimizing reductions in timber yield.[109] Uneven-age management is another type of harvest system where a diversity of size-age classes are maintained at all times, leaving the forest canopy intact. Most commercial pine species can be managed profitably through uneven age management. Shelterwood is another system that obviates the need for reforestation (along with the chemicals and fertilizers needed to boost the growth of newly planted stands) because larger trees are left behind to naturally reseed thinned areas. At the Turnball Creek Educational State Forest shelterwood cutting is being used to demonstrate a system for sustainable management of longleaf pines:

> *First, the stand is cleared of most trees, leaving only a few large, healthy longleaf, widely spaced, to act as "seeders." The understory is burned to remove other competitive growth, and the natural cycle of the pine takes care of the rest. Seeds fall to the ground and their buds take root in the open area. No seedlings need be purchased, and no labor is required for planting. The forest does all the work.*[110]

The common theme associated with each of these alternatives to clearcutting is that wood is removed but a forest is left behind. The practicality and ecological benefits of alternatives to conventional clearcutting have been extremely well documented.[111] The relative climate benefits of such practices are fourfold – (a) the areal extent of carbon sequestration dead zones is minimized or eliminated; (b) emissions associated with timber harvesting, chemicals, and fertilizers are reduced or eliminated; (c) the structural diversity and climate resiliency of stands improve, and (d) permanent carbon storage on the land is significantly higher.

Long rotations

Even if conventional clearcutting and even aged practices are used, significantly extending rotation lengths (time between harvests) can mitigate many adverse climate impacts and flip high emissions landscapes back into those that accumulate and store high densities of carbon.

The ecological and economic benefits of long rotations have been well researched for decades. Curtis (1997) summarized a number of key benefits, including reduced land area in recent clearcut condition, larger trees and higher quality wood, less need for herbicides, higher quality wildlife habitat, more stable hydrological regimes (lower peak flows and higher dry season flows), enhanced long-term site productivity and improved carbon storage.[112] More recently, researchers have concluded that supporting (water, soil, nutrients) and cultural (aesthetics, cultural heritage) ecosystem services would generally be affected negatively by shortened rotations and positively by extended rotations, as would most biodiversity indicators.[113]

[110] North Carolina Educational State Forests: Longleaf Pine Shelterwood Cut. Available online at: https://www.ncesf.org.

[111] See, e.g. Franklin, J.F., Berg, D.R., Thornburgh, D.A., Tappeiner, J.C., 1997. "Alternative silvicultural approaches to timber harvesting: variable retention harvest systems." Chapter 7 in Kohm, K.A., Franklin, J.F., eds. Creating a Forestry for the 21st Century. Washington, DC: Island Press.

[112] Curtis, R.O., 1997. "The role of extended rotations." Chapter 10 in Kohm, K.A., Franklin, J.F., eds. Creating a Forestry for the 21st Century. Washington, DC: Island Press.

[113] Roberge, J.M., H. Laudon, C. Bjorkman, T. Ranius, C. Sandstrom, A. Felton, A. Stens, A. Nordin, A. Granstrom, F. Widemo, J. Bergh, J. Sojnesson, J. Stenlid, T. Lundmark, 2016. Socio-ecological implications of modifying rotation lengths in forestry. Ambio 45(Suppl 2): 109-123.

In Part I of this report, we documented the importance of long rotations from a carbon sequestration standpoint. For example, on a typical industrial forest landscape, we demonstrated how extending rotation ages from 30 years to 90 years could boost annual carbon sequestration rates by over 32%.

Economically, long rotations vastly improve the standing asset value of a forest and a landowner's ability to generate income from multiple sources. In an analysis of the effects of extended rotations on timber supply and three asset value categories – carbon, conservation, and standing timber – CSE found that by extending rotation age from 40 to 240 years Oregon can boost the permanent value of state forestland in the northern Coast Range from roughly $3.9 billion to over $21 billion. Modeled carbon stocks in a 240-year rotation regime were 3.5 times greater than the 40-year rotation baseline.

Afforestation

Afforestation is the process of establishing forests where they do not presently exist because the land has been converted to other uses or because forests were not established there by natural processes. Afforestation potential in North Carolina is among the highest in the country.

In an in-depth analysis of afforestation potential throughout the US, North Carolina and other southeastern states stood out as having the highest potential for planting new forests on idle agricultural lands or lands now being used for pasture and hay (Figure F).[115] The model predicts the amount of land that would be converted into newly planted forests with adequate economic incentives targeting afforestation. Most of the afforestation potential in North Carolina was found to be in the coastal plain.

This analysis is an underestimate since it excluded from consideration lands that are now being used for cropping operations. If economic incentives were strong enough, many more acres could also be afforested. In North Carolina, more and more crops are being planted on marginal land with marginal yield capabilities, and so for these lands, even small changes in economic incentives could make a large difference.

To operationalize this, the USDA and its state-level counterparts are working with landowners to guide them through the process of establishing forest cover on their marginal farmlands as a way to diversify revenue streams. This includes directing cost-share funding their way through programs such as the Forest Stewardship Incentives Program, the Agricultural Conservation Program, Forestry Incentives Program, and Conservation Reserve Program. With such incentives, afforestation potential is much greater on existing croplands. Table F provides an estimate of afforestation potential by county in North Carolina. The data is drawn from the USDA study that estimated the amount of cropland, pastureland, and rangeland that could be converted to forest cover if incentive payments for carbon sequestration were high enough.[116] At a price of at least $50 per metric ton CO2, North Carolina has the potential to increase forest cover by nearly 9 million acres – about 3.5 million acres from existing cropland, 3.7 million acres from pastureland, and 1.8 million acres from rangeland.

[114] Talberth, J., 2015. Testimony of Dr. John Talberth before the Oregon Board of Forestry. Subcommittee on alternative forest management plans for northwest state forests. October 19th, 2015. Lake Oswego, OR: Center for Sustainable Economy.

[115] Wade, C.M., J.S. Baker, G. Latta, S.B. Ohrel, J. Allpress, 2019. Projecting the spatial distribution of possible planted forest expansion in the United States. Journal of Forestry 117(6): 560-578.

[116] Nielsen, A.S.E, A.J. Plantinga, R.J. Alig, 2014. New Cost Estimates for Carbon Sequestration Through Afforestation in the United States. PNW-GTR-888. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

FIGURE F

AFFORESTATION POTENTIAL BY COUNTY IN NORTH CAROLINA

COUNTY	CROP ACREAGE	PASTURE ACREAGE	RANGE ACREAGE	IC A
Alamance County	3,660	81,500	13,210	98,370
Alexander County	1,000	51,130	5,580	57,710
Alleghany County	550	50,170	1,530	52,250
Anson County	7,320	49,700	30,780	87,800
Ashe County	950	50,790	2,840	54,580
Avery County	380	12,130	2,070	14,580
Beaufort County	123,770	3,640	36,650	164,090
Bertie County	86,080	33,570	30	119.680
Bladen County	103,500	3,050	53,560	172,130
Brunswick County	46,670	2,330	56,840	103,840
Buncombe County	2,540	59,170	4,930	66,610
Burke County	1,300	38,100	8,940	43,340
Cabarrus County	1,930	67,750	14,810	76,500
Caldwell County	1,150	39,090	5,960	46,200
Camden County	28,170	28,520	0	56,690
Carteret County	49,290	1,130	15,250	65,640
Caswell County	3,240	66,340	17,310	75,890
Catawba County	1,230	79,020	11,500	91,750
Chatham County	4,120	50,950	19,350	104,480
Cherokee County	540	14,170	2,960	17,970
Chowan County	36,220	20,070	0	56,290
Clay County	390	9,900	1,560	11,850
Cleveland County	2,130	112,510	8,170	122.,610
Columbus County	138,250	5,140	78,240	221,630
Craven County	71,220	3,460	36,220	110,900
Cumberland County	62,390	13,280	48,710	124,380
Currituck County	26,320	21,150	0	47,470
Dare County	1,930	450	1,610	4,020
Davidson County	2,790	89,310	22,620	114,720
Davie County	1,420	68,310	8,970	68,700
Duplin County	174,310	5,570	48,990	228,870
Durham County	1,260	16,830	6,890	24,980
Edgecombe County	113,460	11,840	31,740	159,049
Forsyth County	1,470	44,680	10,230	56,380
Franklin County	17,260	67,260	15,940	100,460
Gaston County	560	45,490	7,430	53,780
Gates County	37,010	21,330	0	58,340
Graham County	280	3,370	520	4,170
Granville County	3,850	56,910	25,230	87,990
Greene County	71,470	8,510	15,120	95,108
Guilford County	5,390	133,660	9,250	118,300
Halifax County	109,570	29,800	34,060	173,430
Harnett County	65,390	28,370	62,070	155,830
Haywood County	2,330	34,370	1,540	37,940
Henderson County	5,630	37,750	3,450	46,530
Hertford County	48,630	21,430	0	70,060
Hoke County	41,200	6,230	21,590	69,020
Hyde County	65,700	1,330	16,800	83,830
Iredell County	2,260	133,000	17,060	152,320
Jackson County	370	13,820	2,010	16,200

COUNTY	CROP ACREAGE	PASTURE ACREAGE	RANGE ACREAGE	IC A
Johnston County	134,260	52,800	50,900	237,950
Jones County	56,860	1,150	20,360	78,390
Lee County	7,540	20,490	16,070	44,100
Lenoir County	95,190	8,100	23,420	126,710
Lincoln County	1,580	67,510	9,220	78,310
McDowell County	1,260	24,340	5,590	31,190
Macon County	560	20,830	3,260	26,650
Madison County	790	32,020	3,060	35,870
Martin County	88,190	2,780	13,730	104,700
Mecklenburg County	840	30,910	8,810	40,560
Mitchell County	110	11,350	1,610	13,070
Montgomery County	6,530	23,050	22,730	52,310
Moore County	21,900	34,790	56,820	112,510
Nash County	81,070	36,470	23,220	140,760
New Hanover County	4,900	430	7,800	13,130
Northampton County	98,160	32,400	1,210	131,770
Onslow County	59,400	2,390	29,270	91,060
Orange County	2,400	54,410	8,130	64,940
Pamlico County	35,560	840	19,260	55,960
Pasquotank County	35,260	41,230	0	76,460
Pender County	60,420	2,220	55,530	118,140
Perquimans County	43,370	42,150	0	87,520
Person County	4,670	56,720	16,640	78,030
Pitt County	143,310	12,550	38,850	194,710
Polk County	200	19,290	9,240	23,736
Randolph County	4,790	130,740	16,340	151,870
Richmond County	20,650	11,850	37,470	70,000
Robeson County	208,310	18,150	63,050	289,540
Rockingham County	4,390	65,230	16,830	106,420
Rowan County	2,410	104,160	20,230	126,800
Rutherford County	170	59,110	26,820	86,100
Sampson County	213,930	5,730	59,440	279,070
Scotland County	39,590	6,670	21,640	68,200
Stanly County	3,960	89,840	14,090	107,880
Stokes County	1,700	56,320	13,940	71,960
Surry County	2,130	90,620	11,600	106,350
Swain County	120	3,750	810	4,710
Transylvania County	1,470	13,640	870	15,986
Tyrrell County	52,590	1,340	8,220	62,150
Union County	9,550	169,620	10,690	189,860
Vance County	3,450	26,520	11,750	41,720
Wake County	26,420	61,350	32,390	120,195
Warren County	3,730	39,800	15,250	58,790
Washington County	79,570	3000	12,290	96,800
Watauga County	400	24,950	1,540	26,900
Wayne County	133,950	18,590	35,590	193,130
Wilkes County	2,590	87,410	7,530	97,530
Wilson County	85,680	13,720	21,420	120,820
Yadkin County	2,380	52,520	9,890	94,790
Yancey County	460	16,190	1,660	18,310
TOTALS	**3,480,450**	**3,668560**	**1,765, 190**	8,914,200

Wade, C.M., J.S. Baker, G. Latta, S.B. Ohrel, J. Allpress, 2019. Projecting the spatial distribution of possible planted forest expansion in the United States. Journal of Forestry 117(6): 560-578.

Wetland forests are some of the best forest types for carbon storage and retention.

PHOTO: WINIFRED HELTON-HARMON

CONCLUDING THOUGHTS

In North Carolina and other forested states, the serious climate impacts of the logging and wood products sector has been ignored and excluded from evolving climate action agendas. Instead, the entire focus for state climate policy has been grounded on the false perceptions that this sector is not only climate neutral but a net positive regardless of practices on the ground. This false perception has, in turn, provided decision makers with ties to this sector with opportunities to advocate for increased logging and consumption of biomass energy and wood products as a climate solution.

As an example, in June 2020 the state released a first draft of its Natural and Working Lands (NWL) Action Plan – an important component of the state's overall climate action agenda being developed in response to Governor Cooper's Executive Order 80. With respect to forestlands, the NWL Action Plan states that "[w]ood products from well-managed forests store forest carbon and offer lifecycle emissions benefits compared to alternative products that are more fossil-fuel intensive."

But as set forth in Parts I and II of this report, the logging and wood products sector has been shown not only to be one of the most carbon intensive in the state but a major threat to the state's ability to adapt to climate change by making the land more susceptible to wildfires, heat waves, droughts, water shortages, water pollution, flooding, wind damage and human exposure to novel diseases. The life-cycle emissions associated with this sector likely top 44 million metric tons CO_2 per year, making it the third most carbon intensive. And there are many less carbon intensive substitutes for wood - like wind and solar energy for biomass and bamboo and other fibers for paper.

Rather than promoting increased logging and consumption of wood products as a climate solution, the state should firmly embrace a diversity of policy tools for reducing consumption, replenishing the land with real forests rather than high risk timber plantations, and scaling up climate smart forestry solutions capable of delivering steady supplies of high quality wood products while leaving a climate resilient forest behind. Climate smart forestry means letting as many trees as possible grow big and old (proforestation), restoring landscapes scarred by clearcuts, logging roads, and monoculture tree plantations, and using low impact harvesting techniques like variable density thinning.

By reducing the scale of industrial forest practices and making climate smart forestry solutions the law, North Carolina has the potential to significantly enhance the ability of the state's forestlands to capture and permanently store enough atmospheric CO_2 to make a substantial contribution to the fight against global warming. Dogwood Alliance and its partners look forward to working with Governor Cooper, the legislature, state agencies and other public institutions to take full advantage of this opportunity.

[117] North Carolina DEQ, 2020. North Carolina Natural and Working Lands Action Plan: DRAFT. Raleigh, NC: North Carolina DEQ, North Carolina Forest Service, North Carolina Department of Agriculture, North Carolina Wildlife Resources Commission, and North Carolina Department of Natural and Cultural Resources.

ABOUT DOGWOOD ALLIANCE • Dogwood Alliance advances environmental justice and climate action by mobilizing diverse voices to protect Southern forests and communities from industrial logging. For over 25 years, Dogwood Alliance has worked with diverse communities, partner organizations and decision-makers to protect Southern forests across 14 states. They do this through community and grassroots organizing, holding corporations and governments accountable and working to conserve millions of acres of Southern forests.

About Center for Sustainable Economy: CSE advances solutions that protect and restore the diversity of life. They work with partners to accelerate the transition to a sustainable and just society.

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