The Adventures of Carbon and Nature

February 6, 2025 12:13 PM Version Norris Whiston Earltown NS
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Hyperlinked and in color versions at NS Wild Flora Society**, and** Healthy Forest Coalition**.**
Other materials found at Inverness Orin**,** Hike Nova Scotia**,** Nova Scotia Forest Notes**, and elsewhere.**

Large toothed aspen, *Populus grandidentata*, using light's photon energy to break apart atmospheric carbon dioxide. Earltown Mountain

PREFACE, SUMMARY, AND DIRECTIONS.

PREFACE:

"The Adventures of Carbon and Nature" is about some of the journeys carbon's various forms take through Earth's mediums.

At Earth's birth, 4.567 billion years ago, atmospheric carbon dioxide is believed to have been about 100,000 times its current level. Earth was a very hot place. Over Earth's first 4 billion years, magnesium and calcium were crucial to drawing down Earth's atmospheric carbon dioxide. Those elements within Earth's mantle pulled out CO_2 to create carbonates. Eventually, tiny cyanobacteria used magnesium to make carbohydrates and oxygen. About 0.5 billion years ago, visible surface life, as we know it, continued to rely on calcium's and magnesium's attraction for CO_2, creating both life's body structures and its source of energy. Carbon in its various forms has been beneficial to diverse forms of life.

Though unnoticed, one of Earth's best assistants in removing atmospheric CO_2 since around 500 million years ago is the various mycorrhizal fungi. Fungi bring nutrient water from afar for plants, and, after trading and using those carbohydrates, stores carbon harmlessly away below the soil's surface. Also best friends to safely storing earth's carbon, are the listed soil covers of chapter 4.

Material in this booklet originates from peer-reviewed articles written by credentialed scientists. The articles from which excerpts are taken, are found at reputable science, news, and journal sources. In each excerpt following a colon, all the writing, except those in brackets, are found in the footnoted article or referenced text. This author greatly admires each scientist for her/his tremendous resolve and the amount of work as herein footnoted in their biography, Google Scholar and Researchgate lists. If using this booklet for one's own writings, please make attributions to those scientists.

Though most pictures were taken by the author within Nova Scotia, such plant, forest, and deforestation examples are found worldwide.

SUMMARY:

Chapter 1 was the most difficult to organize. Photosynthesis is a complicated process. In this process, atmospheric carbon dioxide and water are reconfigured by different types of chlorophyll into carbohydrates and oxygen. The process uses enzymes, portions or assistance of 13 or more elements, incredibly tiny specialists in the living world, including bacteria, and the power of photons. Like in baking, ingredients had to be gathered, which was the job of roots, porous leaves and stems, and fungi. Certain materials are living catalysts, like yeast is in baking. Other materials supply the energy to make this process happen, like a stove or microwave, and, for plants, photons. Finally, all ingredients are preprocessed and combined uniquely within the tiniest of places.

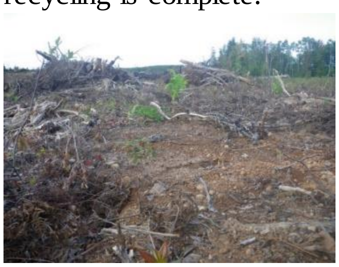
Some earth and atmospheric ingredients are more necessary than others for chlorophyll production, its photosynthesis processing, and enzyme creation than others. Water, magnesium, nitrates, phosphorus, calcium, and potassium are among those ingredients. Produce packaging labels and herbal food books provide hints about each plant's slightly different but significant biochemical creations. Animal kingdoms appreciate the oxygen, carbohydrates, and biochemicals.




Chapter 2. After plants in forest's layers reconfigure carbon dioxide and water into carbohydrates, oxygen, and biochemicals, those creations are left in leaves or sent in various directions within the plant to protect against later occurring pathogens, weather emergencies or seasonal changes. Beyond those places, studies in Sweden and elsewhere found around 50% and more of the carbohydrates are sent as trade goods to the supportive mycorrhizal fungi for their energy needs. In the end, fungi disperse the new forms of carbon deep into the soil. A Finland study showed that carbon continued to accumulate in those soils.

Chapter 3. Plants are uniquely equipped for particular places within different ecosystems and climate. Certain plants have adaptations to better resist herbivores, drought, or to control wildfire. Plants monitor their environment for oncoming weather situations, including drought and winter conditions, modify themselves and store away materials in preparation. Those that can reach resources, such as water, often share with their collaborators that can't.

Chapter 4. Soil and deadwood retain nutrients, water and carbon. These materials took a long time to gather, and ecosystems know, even if some humans don't, that they are not waste. The nutrients and carbon are recycled as long as the soil or deadwood is covered by some means and remains cool and moist. Unless they are cut or sprayed, forest's canopy as well as snow, understory plants, mosses, lichens are among those natural elements providing cover until the recycling is complete.




Chapters 5, 6, and 7. Without those covers, temperature changes what soil's microbes do with soil's chemically bonded carbon and moisture. Eddy covariance systems, satellites and other means, over time, measure and analyze atmospheric gases which leave the exposed soil, deadwood, exposed (and so) warmed fragmented forests, wood products, and burning biomass. Dr. Andrew Black, U. British Columbia, "Even 15 years after harvest, the middle-aged stand was still a net carbon source, releasing up to 5 tonnes of CO_2, [per hectare] per year." Based on the losses of carbon in the next chapter, in the analyzed soils, it would appear that steady lowering losses continue until between 30 and 40 years. Relative to those warmed fragmented forests "Canada accounts for 21% of the global [forest] degradation."

Chapter 8. Also over time, soil remains are measured by scientists for quantities of carbon and essential nutrients. Nitrates, phosphorus, and other essential elements have endured losses. Soils were found to contain their lowest mineral carbon contents after 30-40 years. Studies found that soils, after clearcutting, don't return to their previous levels of carbon for over 80 years.

Chapter 9 and 10. Measuring tree growth and other things, scientists have learned what best collects / removes atmospheric CO_2 and other atmospheric gases. A study conducted by 38 forestry experts throughout the world on 670,000 trees of 403 species found the oldest trees work best to pull atmospheric carbon dioxide out, and those oldest trees never stop growing. Among important forest characteristics for CO_2 sequestering are more broadleaved trees than darker heat-absorbing conifer trees, early nitrogen-fixing capabilities, high biodiversity including old large slow-growing trees mixed with fast growing trees, large trees, and, in particular, structurally layered, and complex vegetation. Utilizing those qualities, Prof. Tom Crowther, ETH-Zurich University, Switzerland, "This new quantitative evaluation shows restoration isn't just one of our climate change solutions, it is overwhelmingly the top one."

Chapter 11 examines the atmospheric conditions found in the Keeling Curve results. These worldwide reports identify what portion of earth's atmospheric condition is attributable to deforestation. Logging, it turns out, plays a far larger role in earth's atmospheric carbon situation than what people have been led to believe. An Oregon State University and University of Idaho study reports that logging's carbon emissions in Oregon are one and a half times more than transportation's or energy's emissions. There are many studies listed.

DIRECTIONS: A MERE READING OF THE TABLE OF CONTENTS ALLOWS ONE TO PARTIALLY UNDERSTAND WHAT IS IN EACH REFERENCED PIECE OF THE TEXT. To learn more details, tap the item or its tiny picture to see the selected quotes. The full referenced articles and their primary authors' institution(s), biography, contact, and published works are hyperlinked within the footnotes. Tap 'home' to return to the table of contents.

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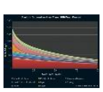
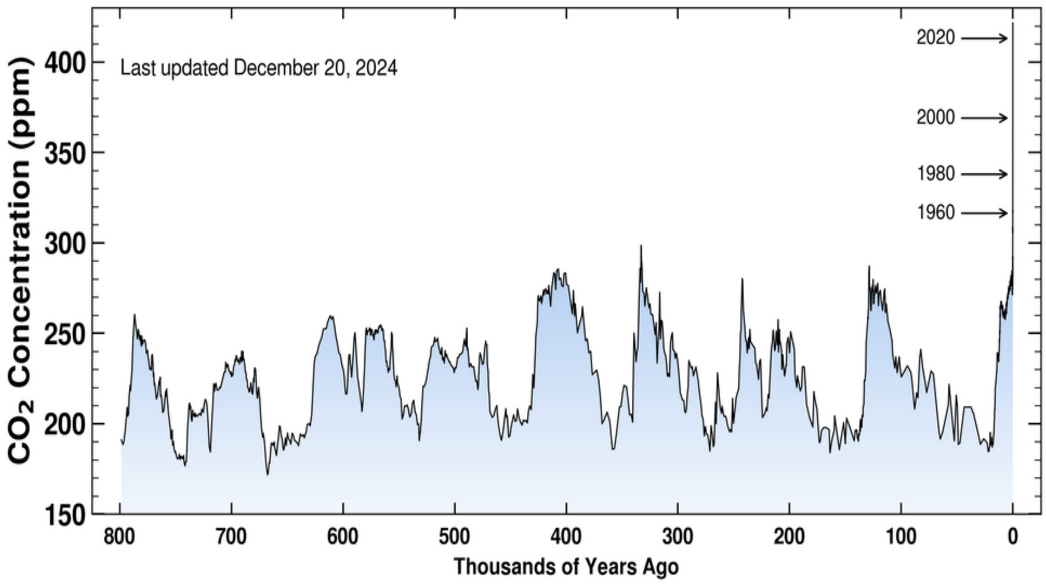


SECTION A. - CARBOHYDRATE AND BIOCHEMICAL CREATION.

1a. Carbohydrate Ingredients, Atmospheric Carbon. From the Keeling graph, one can see there is plenty!



In Earth's biogeochemical history, reaching the interglacial ages (the high parts and peaks in CO_2 on this graph), after they set for relatively brief times, caused massive changes in climate, ocean levels, and forced nature into huge adaptations, migrations, or extinctions. As a part of nature, various hominids have lived through all those above periods and they also either had to adapt, migrate, or, in many areas of the world, go extinct. The only hominid, who barely made it through, was Homo sapiens. What happened during some of those interglacial (warm) and glacial (ice ages) periods is linked below. [1]

1b. Carbohydrate Ingredients - Atmospheric Carbon's location. Prof. Jesse Kroll, "But this is not the case, the CO_2 emitted by cars, factories, and other sources mixes thoroughly into the atmosphere."

Prof. Jesse Kroll, MIT, "If the carbon dioxide (CO_2) in Earth's atmosphere were clustered in certain spots, then it might be easier to remove CO_2 from the air by building machines that capture CO_2 in those places. But this is not the case, the CO_2 emitted by cars, factories, and other sources mixes thoroughly into the atmosphere, so the amount of CO_2 in the air is more or less consistent around the world. There will be some [variations] depending on how close you are to sources or sinks."

[Howard Herzog, Senior Research Engineer, MIT Energy Initiative, at MIT:] However, using DAC [Direct Air Capture] to combat climate change would require the technology to capture billions of tons of CO_2 annually. That is about a million times more than what the few currently operational pilot projects can capture. [2]

 1c. Carbohydrate Ingredients - Nutrient Water. Prof. Tom Wessels, Antioch U., N.H., "Any plant that interacts with mycorrhizal fungus can increase nutrient water uptake up to tenfold."

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[1] Current atmospheric carbon dioxide levels are found at Keelingcurve.ucsd.edu. The method for finding current results is at "How Scientists Measure Carbon Dioxide in the Air." Youtube 2:24 Video. The method used for finding the ancient results is found at British Antarctic Survey. The Earth's activities during the interglacial and glacial periods are found at Nova Scotia Wild Flora Society site within "Keeling Curve II – CO_2 in Context." Humanity and all of nature should expect the same.

[2] Andrew Moseman, Ask MIT reporter, March 22, 2021. "Is there a place in the atmosphere where carbon dioxide is concentrated, and if so, can we remove it?" AUDIO 3:19 *Ask MIT*. From: Interviews of: Dr. Jesse Kroll, civil and environmental engineering, MIT. Biography and Contact; Google Scholar; Researchgate. Howard Herzog, a Senior Research Engineer in the MIT Energy Initiative Video; Biography and Contact; Researchgate.

Prof. Tom Wessels, Antioch U., N.H., "For certain groups of our plants, they're so co-evolved they have to interact with mycorrhizae."
A roadside park, Lake Anslie, Cape Breton, NS

Prof. Tom Wessels (Antioch U., N.H.): [12:44] "Because of their extensive mycelium that goes through the soil, any plant that interacts with mycorrhizal fungus can increase nutrient water uptake up to tenfold. And, for certain groups of our plants, they're so co-evolved they have to interact with mycorrhizae." [12:58] "So, all of our regional coniferous trees [pine, spruce, fir, hemlock, tamarack, etc.], like the hemlock here, has to act with mycorrhizal fungi [ectomycorrhizal fungi]. All the members of the heath family, like the mountain laurel or blueberries or cranberries [with huckleberries, Labrador tea, rhodora, rhododendron, and azalea], have to interact with mycorrhizae fungi [Ericoid mycorrhizal fungi]. And, finally also, all of our orchids [including lady slippers and ladies tresses] have to interact with mycorrhizal fungi [orchidaceous mycorrhizal fungi]. Because these three groups have become so co-evolved they can't make it on their own." [3]

1d. Sun's Photons. Dr. Diana Beresford-Kroeger, "Its photons of energy can remain trapped in the sun's sphere for 100,000 years."

Dr. Diana Beresford-Kroeger (botanist, medical biochemist) partially narrated by Gordon Pinsent: [0:00] "The sun, the life force of our solar system, its photons of energy can remain trapped in the sun's sphere for 100,000 years. And, when finally they are released, it will take the photons 8 minutes to travel from the surface of the sun to the surface on a leaf on planet earth."

[0:39] "A leaf is a marvel of evolution. It transforms the photons into food for planet earth, creating a foundation for all life. And it begins with a tree. It's time to look again at that tree outside your door." [2:14] Diana Beresford-Kroeger: "We've just started to understand that we've missed the big picture where forests are concerned. They [the trees] have a bigger genome than we have. They have more complex chemistry. And now the forests are coming down, but we have missed the essentials of what a tree is all about." [4]

[3] Prof. Tom Wessels. July 3, 2019 "The Ecology of Coevolved Species" Youtube 35:10 New England Forests.} At [11:48] Prof. Wessels begins his talk about fungi. There is a full, mostly correct, transcript at the Youtube site. Prof. Tom Wessels (landscape ecology, Antioch University), Biography and Contact , Wikipedia, Researchgate. Another of his many videos on Youtube.

[4] Dr. Diana Beresford-Kroeger & Gordon Pinsent Aug. 15, 2017 "Call of the Forest: The Forgotten Wisdom of Trees" VIDEO 52:10 placed on Youtube June 8, 2023. By Sept. 4, 2024 only 2,544 views.) TVO Today and TVO Youtube gives a transcript and the ability to go back & forth typing J, K, or L. Dr. Diana Beresford-Kroeger lives in Merrickville, Ontario, Website and Contact, Wikipedia and Researchgate at Carlton U., Ottawa and other places.

 1e. Sun's Photons Making Carbohydrate & Oxygen. Dr. Diana Beresford-Kroeger, "These green machines have a quantum grab where they can pull the sun's energy out of the photon and place it into a chlorophyll electron."

Dr. Diana Beresford-Kroeger, "From the backscatter dance of a free photon on the surface of a leaf, the power of photosynthesis arises."
Sunshine's photons hitting a leaf of a mountain maple, *Acer spicatum*, Shubie Park, NS

Dr. Diana Beresford-Kroeger (botanist, medical biochemist Merrickville Ont.): [PHOTOSYNTHESIS] These green machines [cyanobacteria, mosses, plants, & trees] have a quantum grab [rubisco - Ribulose biphosphate $C_5H_{12}O_{11}P_{12}$] where they can pull the sun's energy out of the photon [light] and place it into a chlorophyll [$C_{55}H_{72}O_5N_4Mg$] electron. From the backscatter dance of a free photon on the surface of a leaf, the power of photosynthesis arises. [5]

1f. Materials - Photosynthesis Assistance of Magnesium. Susan Patterson, of Gardening Knowledge, "Magnesium is the powerhouse behind photosynthesis in plants."

Susan Patterson, of Gardening Knowledge: Technically, magnesium is a metallic chemical element which is vital for human and plant life. Magnesium is one of thirteen mineral nutrients that come from soil, and when dissolved in water, is absorbed through the plant's roots. Magnesium is the powerhouse behind photosynthesis [$6\ CO_2 + 6\ H_2O > C_6H_{12}O_6 + 6O_2$] in plants. Without magnesium, chlorophyll cannot capture sun energy needed for photosynthesis. Magnesium in plants is located in the enzymes, in the heart of chlorophyll molecule [$C_{55}H_{72}O_5N_4Mg$]. Magnesium is also used for metabolism of carbohydrates and cell membrane stabilization. The role of magnesium is vital to plant growth and health. Magnesium deficiency in plants is common where soil is not rich in organic matter or is very light. Heavy rains can cause a deficiency to occur by leaching magnesium out of sandy or acidic soil. In addition, if soil contains high amounts of potassium, plants may absorb this instead of magnesium, leading to a deficiency. [6]

1g. Materials - Photosynthesis Assistance of Nitrogen. Ferris Jabr, author of Becoming Earth, "Although nitrogen is abundant on Earth, comprising 78 percent of the atmosphere, it is largely inaccessible to most [life] in its gaseous form."

Ferris Jabr, author of Becoming Earth: All life requires nitrogen, a primary component of genes, proteins, and enzymes. Although nitrogen is abundant on Earth, comprising 78 percent of the atmosphere, it is largely inaccessible to most in its gaseous form. Pairs of nitrogen atoms in the atmosphere are linked by one of the strongest molecular bonds in existence. Lightning is one of the few physical phenomena powerful enough to split that bond. Because gaseous nitrogen is so difficult to break apart and mix into new molecules, it is useless to most living creatures. {Jabr54}

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[5] Dr. Diana Beresford-Kroeger (botanist and medical biochemist) 1 April 2016. "Green Machines." New Internationalist. Diana Beresford-Kroeger (botanist and medical biochemist, Merrickville Ont.) Wikipedia Researchgate at Carlton U., Ottawa and other places.

[6] Susan Patterson, Master Gardener. Seen 3 July 2019. "Fixing Magnesium Deficiency in Plants: How Magnesium Affects Plant Growth." *Gardening Know How*. Susan Patterson, Gardening Knowhow. Articles and Contact; Publications.

Microbes are critical to this cycle: bacteria and other microbes are the only organisms that have evolved enzymes with the ability to cleave atmospheric nitrogen and turn it into biologically useful molecules, such as ammonia, nitrite and nitrate. Some of these nitrogen-fixing microbes, as they're known, live symbiotically on the roots of peas, beans, and other legumes, whereas others live independently in soil and water. {Jabr55} [7]

1h. Materials - Photosynthesis Assistance of Nitrogen and Phosphorus. Stanford University Ed.: "But as carbon dioxide concentrations rise, trees will need extra nitrogen and phosphorus to balance their diet."

Tree jelly lichen, *Collema subflaccidum* (left), and lungwort lichen, *Lobaria pulmonaria*, assisted by *Nostoc* nitrogen-fixing bacteria living within, sharing nitrates with an old sugar maple, *Acer saccharum*, when it rains. [Certain nitrogen-fixing support doesn't occur until the forests get older.] Earltown Village, Nova Scotia [See also CO2 collectors]

Stanford University Ed.: Like the eponymous character in Shel Silverstein's classic children's tale, trees are generous with their gifts, cleaning the air we breathe and slowing the ravages of global warming by absorbing about a quarter of all human-caused carbon dioxide emissions. But this generosity likely can't last forever in the face of unabated fossil fuel consumption and deforestation.

[Dr. César Terrer, Earth, Energy & Environmental Sciences, Stanford U:] "Keeping fossil fuels in the ground is the best way to limit further warming. But stopping deforestation and preserving forests so they can grow more is our next-best solution."

Carbon dioxide—the dominant greenhouse gas warming the earth—is food for trees and plants. Combined with nutrients like nitrogen and phosphorus, it helps trees grow and thrive. But as carbon dioxide concentrations rise, trees will need extra nitrogen and phosphorus to balance their diet. The question of how much extra carbon dioxide trees can take up, given limitations of these other nutrients, is a critical uncertainty in predicting global warming.

[Prof. Rob Jackson, Earth System Science at Stanford U.,] "Planting or restoring trees is like putting money in the bank." [8]

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[7] Jabr = page in Ferris Jabr "Becoming Earth How Our Earth Came to Life" New York: Random House 2024 pp. 273. Ferris Jabr Biography and Contact

[8] Stanford University. 12 August 2019. "Study gauges trees' potential to slow global warming in the future." *Phys.org News*. Based upon Dr. César Terrer (Earth, Energy & Environmental Sciences, at Stanford U. now at MIT), Robert B. Jackson, and 32 authors & Oskar Franklin. 12 August 2019. "Nitrogen and phosphorus constrain the CO_2 fertilization of global plant biomass." *Nature Climate Change*. (2019). Dr. César Terrer, Stanford U. now at MIT Biography and Contact; Google Scholar; Researchgate. Dr. Robert B. Jackson, School of Sustainability, Stanford U. Biography and Contact; Google Scholar; Researchgate.

 1i. Materials - Photosynthesis Assistance of Nitrogen and Phosphorus. Lawrence Berkeley National Laboratory, "The more abundant nutrients are, the more plants can take advantage of increasing atmospheric carbon dioxide."

Schreber's moss, tree socks, or big red stem, *Pleurozium schreberi,* assisted by free-living nitrogen-fixing *Nostoc* bacteria, sharing nitrates with an old hemlock woods.

Sandy Cope Trail, Earltown, NS

Lawrence Berkeley National Laboratory: Plants' ability to take in carbon dioxide is limited by the availability of soil nutrients, especially nitrogen and phosphorous. The more abundant nutrients are, the more plants can take advantage of increasing atmospheric carbon dioxide. Microbes in the soil are a factor too because they compete with plants for nutrients.

They found that a significant portion of nutrient uptake takes place in the absence of photosynthesis as plants and microbes compete for nutrients.

Microbes, in fact, play an important role in the carbon cycle, and interactions between plants, soil, and microbes are complex, presenting a challenge to climate scientists. Most climate models assume that plants compete for nutrients in the soil only when they're demanding it for photosynthesis, and not, for example, at night or in non-growing seasons.

[QUOTE Dr. William J. Riley, Dept. of Energy's Lawrence Berkeley Nat. Lab.] "What most climate models have ignored is this pretty robust observational literature showing plants acquire nitrogen from soil even when they're not photosynthesizing." [9]

1j. Carbohydrate and Oxygen Creation (Photosynthesis) by Plants. Dr. Suzanne Simard, U of British Columbia, "The leaves were the source of the chemical energy, the engines of life."

Dr. Suzanne Simard: Water [and its soluble nutrient contents] taken up by the roots from the soil would travel up the XYLEM – the innermost vascular tissue linking roots to foliage. {Si146}

Their [the leaves'] stomata – the tiny holes that draw in carbon dioxide to join with water to make sugar and pure oxygen – pumped fresh air for me to gulp. {Si7-8}.

I thought back to my plant physiology classes, imagining a birch leaf photosynthesizing – converting light energy to chemical energy (sugar) by combining carbon dioxide from the air with water from the soil. Because of their ability to photosynthesize, the leaves were the source of the chemical energy, the engines of life. {Si146} [10]

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[9] Lawrence Berkeley National Laboratory 29 October 2018. "Improving climate models to account for plant behavior yields 'goodish' news." *Phys.org News*. Based upon William. J. Riley, (Dept. of Energy's Lawrence Berkeley Nat. Lab.) et al (+2 others), Weaker land–climate feedbacks from nutrient uptake during photosynthesis-inactive periods, *Nature Climate Change* (2018). Dr. William J. Riley Dept. of Energy's Lawrence Berkeley Nat. Lab. Biography and Contact Google Scholar, Researchgate. Dr. Qing Zhu, Dept. of Energy's Lawrence Berkeley Nat. Lab. Biography and Contact; Google Scholar; Researchgate.

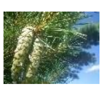
[10] Si = page number within Dr. Suzanne Simard, *Finding the Mother Tree*. Canada: Allen Lane 2021. pp. 350. Dr. Suzanne Simard (U. of British Columbia) *Website*, *Biography and contact*, Wikipedia; *Researchgate* , *Google Scholar*.

 1k. Carbohydrate and Oxygen Creation by Mosses. Dr. Ruth Wall Kimmerer, ""The type of chlorophyll in their [the mosses'] leaves differs from their sun-loving counterparts, and is fine-tuned to absorb the wavelengths of light that filter through the forest canopy." [Many other plants living under the forest canopy also have fine-tuned chlorophyll, giving structurally complex forests a significant advantage in collecting atmospheric CO_2.]

Dr. Ruth Wall Kimmerer, "One consequence of being small is that competing for sunlight is simply not possible – the trees will always win. So mosses are usually limited to life in the shade, and they flourish there."
Filtered sunlight on a broom moss, *Dicranum scoparium*, beside a sugar maple, *Acer saccharum*, Rogart Trail, Earltown, Nova Scotia

Dr. Ruth Wall Kimmerer (College of Environmental Science and Forestry, Syracuse, New York): Trees stand tall and rigid because of their vascular tissue, the network of xylem, thick-walled tubular cells that conduct water with the plant like wooden plumbing. Mosses are the most primitive of plants and lack any such vascular tissue. Their slender stems [unless surrounded by water] couldn't support their weight if they were any taller. This lack of xylem means they can't conduct water from the soil to leaves at the top of the shoot. A plant more than a few centimeters high can't keep itself hydrated. {Ki14}

[SUNLIGHT] One consequence of being small is that competing for sunlight is simply not possible – the trees will always win. So mosses are usually limited to life in the shade, and they flourish there. The type of chlorophyll in their leaves differs from their sun-loving counterparts, and is fine-tuned to absorb the wavelengths of light that filter through the forest canopy. {Ki15}[11]

 1l. Biochemical Production. Dr. Diana Beresford-Kroeger, "The greater biodiversity in the forest the more varied is the biochemistry and the more interactive the synergy between the released chemicals."

Dr. Diana Beresford-Kroeger, "Pines all produce alpha and beta pinenesa, aerosols which protect the body against cancer by boosting the immune system." [White pine *Pinus strobus* (left). Willow *Salix* (middle), meadowsweet *Spiraea latifolia* (right), quaking aspen, large toothed aspen, balsam poplar *Populus* contain the immuno stimulant *Salicylic acid* (ASA) $C_7H_6O_3$.
ASA (aspirin) has served certain nearby plants, animals, humans, and, I believe I read, dinosaurs.]

[11] Ki = Dr. Robin Wall Kimmerer. Gathering Moss – A Natural and Cultural History of Mosses. Oregon State University Press 2003 pp. 169. Dr. Robin Wall Kimmerer, College of Environmental Science and Forestry, State University of New York, Syracuse, NY, and lives in Fabius, NY [Biography, videos, and contact](), [Wikipedia]() and [Researchgate](), [The Serviceberry an Economy of Abundance](). (Thanks Bev.)

Dr. Diana Beresford-Kroeger, Carleton U.: Photosynthesis feeds many biochemical pathways within the tree. Some are used to produce amino acids, proteins and hormones. Others are chained together to make the three essential fatty acids for embryogenesis (reproduction).

Each species of tree has its own chemical identity that is always true to its own genome. The greater the diversity within the forest, the more varied is the biochemistry and the more interactive the synergy between the released chemicals.

Sometimes the aerosols are released under pressure like a landmine. More often it is the physics of the sun's heating that drives the release. Other times the aerosols require carrier compounds to aid in their lift.

[ECOSYSTEM DEFENSE] Aerosols have a unique ecofunction in the atmosphere. Aerosols can include 'scrubber' compounds, like detergent. Their aseptic character helps clean the air. Some harbour hallucinogens or have gentle anaesthetic characteristics. Many are antiviral, antifungal and antibiotic.

There are also complex, anti-cancer biochemicals that become airborne, like those of the pine family. Pines all produce alpha and beta pinenesa, aerosols which protect the body against cancer by boosting the immune system. Cypress produce taxodione aerosols strong tumour-inhibiting properties. Yew trees produce paclitaxel used routinely in the treatment of breast cancer. [12]

SECTION B. CARBON DISPERSAL TO SOIL ECOSYSTEMS, DROUGHT SURVIVAL & FIRES, AND COVERING OF SOIL'S CARBON STORES.

2. DISPERSING CARBOHYDRATES (PHOTOSYNTHATE) & CARBON STORAGE.

2a. Dispersing Carbohydrates (Photosynthate). Dr. Suzanne Simard, U. British Columbia, "From the leaves, the sugar would travel into the conducting cells of the PHLOEM."

Simard, "The sugar would accumulate in the cells of the leaves and the sap then load into the leaf veins like blood being pumped into arteries."
Yellow birch *Betula alleghaniensis* Earltown Lakes Trail, Nova Scotia

Dr. Suzanne Simard, UBC: The sugar – carbon rings bonded with hydrogen and oxygen would accumulate in the cells of the leaves and the sap then load into the leaf veins like blood being pumped into arteries. From the leaves, the sugar would travel into the conducting cells of the PHLOEM – the blanket of tissue encircling the birch trunk under the bark and forming a pathway from leaves to the root tips. {Si146}

[CARBON STORAGE] While leaves are the source of photosynthate, roots are sinks. {Si146}

The sugar train in my imagination didn't stop at the roots. I'd read that photosynthate was unloaded from the root tips into mycorrhizal fungal partners, like freight unloaded off boxcars onto trucks. {Si147} [13]

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[12] Dr. Diana Beresford-Kroeger (botanist and medical biochemist) 1 April 2016. "Green Machines." New Internationalist. Dr. Diana Beresford-Kroeger (botanist and medical biochemist, Merrickville Ont.) Wikipedia Researchgate at Carlton U., Ottawa and other places.

[13] Si = page number within Dr. Suzanne Simard, *Finding the Mother Tree*. Canada: Allen Lane 2021. pp. 350. Dr. Suzanne Simard (U. of British Columbia) *Website*, *Biography and contact*, Wikipedia; *Researchgate*; *Google Scholar*.

2b. Carbon Storage into Trees.

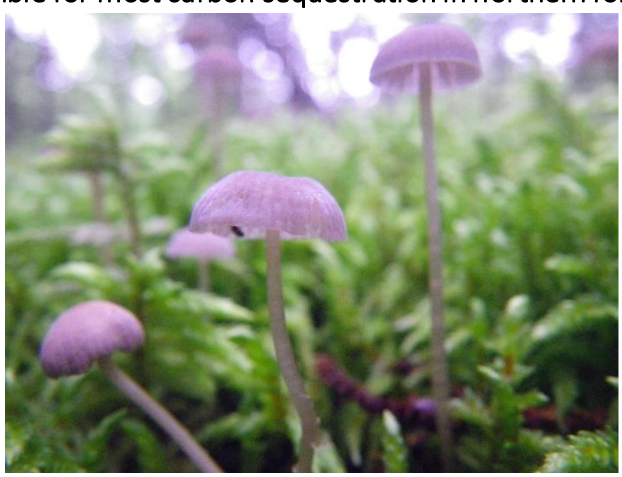
Dr. Suzanne Simard, UBC: Despite it being only a few hours before darkness, I paused at a log, a casualty of saws that had cleared the road right-of-way. The pale round face of its cut end showed age rings as fine as eyelashes. The blond-colored early wood, the spring cells pump with water, were edged by dark-brown cells of latewood formed in August when the sun is high and drought settles in. {Si8}

Some rings were wider, having grown plenty in rainy years, or perhaps in sunny years after a neighboring tree blew over, and others were almost too narrow to see, having grown slowly during a drought, a cold summer, or some other stress. {Si8}

2c. Carbon Storage into Roots, Soil, & Microbes. Dr. Dan Durall "learned that half of the carbon was shuttled and stored below ground – in roots, soils, and microbes such as mycorrhizal fungi."

Dr. Suzanne Simard, UBC: I returned to the site with university [Oregon State University - Corvallis] research associate, Dr. Dan Durall, an expert at labeling trees with carbon isotopes. He was also my next-door neighbor in Corvallis. Dan had just finished a project for the Environmental Protection Agency [HOW] where he'd labeled trees with carbon-14 and learned that half of the carbon was shuttled and stored below ground – in roots, soils, and microbes such as mycorrhizal fungi. The EPA needed this information so they could start figuring how best to store carbon in forests for mitigating climate change. {Si150} [14]

2d. Carbon Storage into Soil. Bob Yirka, Phys.org, [The Swedish U. of Agricultural Sciences] "study finds fungi, not plant matter, responsible for most carbon sequestration in northern forests."



47% to 70% of new carbon in deeper levels of the soil came about due to fungi.
Sandy Cope Trail, Earltown NS

[Agreement with afore-mentioned Durall's study] Bob Yirka: But what the trees actually do with the carbon has been a matter of debate—most have suggested that it's likely carried to needles and leaves then eventually drops to the forest floor where over time decomposition causes it to leech into the soil. If that were the case, this new team of researchers reasoned, then the newest carbon deposits should appear closest to the surface of the forest floor.

[HOW. Following ^{14}C within soil samples from 30 islands in northern Sweden, researchers' made a discovery.] But this is not what they found—instead they discovered that newer deposits were more likely to be found at deeper levels in the soil. This was because, they learned, the trees were carrying much of the carbon they pulled in down to their roots (via sugars) where it was being sequestered by a type of fungi (ectomycorrhizal, aka mycorrhizal fungi) that eats the sugars and expels the residue into the soil.

In their study they found that 47 percent of soil carbon found on large island samples came about due to fungi, as did a whopping 70 percent of carbon in small island soil samples. Thus far, the team is only able to guess why there are

[14] Dr. Dan Durall, Oregon State U. & UBC Okanagan, Biography and contact and Researchgate

such differences in the soils, but theorize it's likely due to differences in decomposition rates. Study finds fungi, not plant matter, responsible for most carbon sequestration in northern forests. [15]

 2e. Carbon Storage into Soil. Dr. Antti-Jussi Lindroos, Natural Resources Institute Finland, Helsinki, "The surface layer of mineral soil [lies] underneath the organic layer and it also accumulates carbon as forests grow older."

"The surface layer of mineral soil underneath the organic layer comprises significant carbon stocks and it also accumulates carbon as forests grow older."
Long-term research sites were monitored in 14 forest sites across Finland for more than 20 years. Photo: Erkki Oksane Luke

Natural Resources Institute Finland (Luke): The study focused on changes in carbon stocks in mineral soil forests. [HOW] Research sites were monitored in 14 forests across Finland for more than 20 years. Carbon stocks in soil were determined in 1995, 2006 and 2016 as part of the UNECE's International Cooperative Program on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests).

"According to one of our new and interesting findings, the surface layer of mineral soil underneath the organic layer comprises significant carbon stocks and it also accumulates carbon as forests grow older." says senior scientist [Natural Resources Institute Finland, Helsinki] Antti-Jussi Lindroos.

Carbon stocks in forest soil decreased in two spruce-dominated sites in which natural damage and resulting harvesting operations reduced the growing stock. [16]

[15] Bob Yirka, Phys.org March 29, 2013 "Study finds fungi, not plant matter, responsible for most carbon sequestration in northern forests." LINKS Phys.org News. From {Karina Engelbrecht Clemmensen (North European Forest Mycologists) et al. (+9 others) 29 March 2013 "Roots and Associated Fungi Drive Long-Term Carbon Sequestration in Boreal Forest" *Science*. Vol. 339 no. 6127 pp. 1615-1618. Karina Engelbrecht Clemmensen, North European Forest Mycologists, Swedish U. of Agricultural Sciences, Biography and contact and Researchgate

[16] Natural Resources Institute Finland (Luke) Nov. 10, 2022 "Mineral soil in forests accumulates carbon as trees grow." Luke.fi en & *Phys.org News*. From: Dr. Antti-Jussi Lindroos (Natural Resources Institute Finland, Helsinki) et al (+2 others), Soil carbon stock changes over 21 years in intensively monitored boreal forest stands in Finland, *Ecological Indicators* Vol. 144 Nov. 2022 109551. *Science Direct*. Dr. Antti-Jussi Lindroos, Natural Resources Institute Finland, Helsinki. Biography and Contact; Google Scholar; Researchgate.

3. WATER, DROUGHT, AND FIRES.

3a. Drought Survival - Moss. Dr. Robin Wall Kimmerer, State U. of New York, "Profound changes in the shape [of mosses' leaves] occur as water is pulled back to the atmosphere."

"Most importantly, enzymes of cell repair are synthesized and stored for future access. All growth and activity is suspended in drought-sleep." White tipped moss, *Hedwigia ciliate*, on rock, showing leafs' reaction to a dry period. Rogart Mountain Trail, Earltown, NS

Dr. Robin Wall Kimmerer, State U. of New York, at Syracuse, NY: The essential functions are carefully shut down and packed away. Most importantly, enzymes of cell repair are synthesized and stored for future access. All growth and activity is suspended in drought-sleep. {Ki35}[17]

The mosses begin their time of waiting. It may be only a matter of days before dew returns, or it may be months of patient desiccation. Acceptance is their way of being. They earn their freedom from the pain of change by total surrender to the ways of rain. {Ki35}

What art of waiting is practiced by the mosses, crisped and baking on the summer oak? They curl inward upon themselves, as if suspended in daydreams. And if mosses dream, I suspect they dream of rain. {Ki36}

Profound changes in the shape [of mosses' leaves] occur as water is pulled back to the atmosphere. Some mosses begin to fold their leaves or roll them inward. This reduces the exposed surface area of leaf and helps the plant cling to the last bits of surface water. {Ki42}[18]

3b. Drought Survival - Plants. Peter Wohlleben, author of The Power of Trees, "In dry summers, the most important condition roots actively monitor is, of course, moisture."

Peter Wohlleben, forest ranger, lecturer at Forest Academy & Eberswalde University: The roots are probably the most important part of the tree. Cells at the root tips work together to function a bit like a plant brain. The tips test the ground as the roots grow in darkness continuously monitoring at least twenty parameters, including moisture, of course, but much more than that. The root tips also take note of gravity – after all, the tender tissues need to remain in the soil and not grow up and out of the ground. Light sensors also prevent this from happening. {Woh16}

In dry summers, the most important condition roots actively monitor is, of course, moisture. When this is in short supply, the roots immediately send signals up the trunk and along the branches, telling the leaves to shut their small, mouthlike openings [stomata]. This puts sugar production - and therefore water use – on hold. [HOW] Swiss researchers have discovered how this works. They were studying young beeches in the laboratory and had simulated drought conditions in a test setup. The scientists observed that it is indeed the roots that regulate the behavior of the leaves. As the ground dries up, the roots reduce their consumption of sugar – and just when it becomes impossible for them to pump more water up to the leaves, they no longer need to do so: when the roots shut down their intake of sugary liquid from the leaves, sugar supplies back up, which causes the leaves to stop making food. {Woh17}

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[17] This shut down is similar to what deciduous trees' leaves do in the fall or during severe droughts in the summer, when they too send future needs to their trunks and roots. NMW

[18] Ki = Dr. Robin Wall Kimmerer. Gathering Moss – A Natural and Cultural History of Mosses. Oregon State University Press 2003 pp. 169. Dr. Robin Wall Kimmerer, College of Environmental Science and Forestry, State University of New York, Syracuse, NY, and lives in Fabius, NY Biography, videos, and contact, Wikipedia and Researchgate.

When trees close the openings in their leaves and stop producing sugar, they switch to their stored supply of food to keep themselves alive. To process their food, the trees need to take in oxygen like we do when we breathe. They are now absorbing oxygen and releasing carbon dioxide, and as a result, a drought-stressed summer forest is no longer a source of oxygen. Once the drought is over, something astonishing happens: the leaves take in more carbon dioxide than normal and produce considerably more sugar. You could say the trees are stuffing themselves to make up for lost time. Their voracious appetites allow to at least partially make up for the shutdown in sugar production during the drought. {Woh17}[19]

3c. Drought Survival - Forest Canopy. Dr. Tsun Fung Au, Indiana University & U. of Michigan, "Conservation of older trees in the upper canopy should be the top priority from a climate mitigation perspective."

An analysis of "20,000 trees on five continents shows that old-growth trees are more drought tolerant than younger trees in the forest canopy"
An older tree and younger ones, Earltown Lakes Trail, Nova Scotia

University of Michigan Ed.: [HOW] A new analysis of more than 20,000 trees on five continents shows that old-growth trees are more drought tolerant than younger trees in the forest canopy and may be better able to withstand future climate extremes.

"The number of old-growth forests on the planet is declining, while drought is predicted to be more frequent and more intense in the future," said Au, [Dr. Tsun Fung Au, Indiana University & U. of Michigan] lead author of the study published online Dec. 1 in the journal *Nature Climate Change*. "Given their high resistance to drought and their exceptional carbon storage capacity, conservation of older trees in the upper canopy should be the top priority from a climate mitigation perspective."

While deforestation, selective logging and other threats have led to the global decline of old-growth forests, subsequent reforestation—either through natural succession or through tree planting—has led to forests dominated by increasingly younger trees.

[HOW] The researchers used long-term tree-ring data from the International Tree-Ring Data Bank to analyze the growth response of 21,964 trees from 119 drought-sensitive species, during and after droughts of the past century. The upper canopy trees were separated into three age groups—young, intermediate and old—and the researchers examined how age influenced drought response for different species of hardwoods and conifers.

They found that young hardwoods in the upper canopy experienced a 28% growth reduction during drought, compared to a 21% growth reduction for old hardwoods. The 7% difference between young and old hardwoods grew to 17% during extreme drought.

[19] Woh = Peter Wohlleben 2021 German. 2023 English. "Is Wood as Eco-Friendly as We Think?" The Power of Trees – How Ancient Forests Can Save Us If We Let Them. Vancouver: David Suzuki Institute, *Greystone Books*: pp. 272. Peter Wohlleben Author of The Hidden Life of Trees and The Power of Trees. (forest ranger, and lecturer at Forest Academy & Eberswalde University) Biography and contact; contact; Wikipedia; Intelligent Trees Trailer; Video. From Frank Hagedorn (Zürcherstrasse 111, Birmensdorf, Switzerland), Jobin Joseph, Martina Peter, et al (+16 others) July 18 2016 "Recovery of Trees from Drought Depends on Belowground Sink Control." Nature Plants 2, no. 16111. Frank Hagedorn, Zürcherstrasse 111, Birmensdorf, Switzerland. Biography and contact; Researchgate; Google Scholar.

While those age-related differences may appear fairly minor, when applied at the global scale they could have "huge impacts" on regional carbon storage and the global carbon budget, according to the study authors. That's especially true in temperate forests that are among the largest carbon sinks worldwide. In the study, age-related drought-response differences in conifers were smaller than in hardwoods, likely because needle-bearing trees tend to inhabit more arid environments, the researchers say.

The new study is a synthesis that represents the net effects of thousands of trees in diverse forests across five continents, rather than focusing on single forest types. In addition, the new study is unique in its focus on trees in the upper forest canopy, which reduces the confounding effects of tree height and size, according to the authors. [20]

3d. Drought Survival. Special qualities of ponderosa pine, Douglas fir, aspen, and dying grasses. Dr. Suzanne Simard, UBC, "I'd read that dying grasses shuttled phosphorus and nitrogen to their off-spring through arbuscular mycorrhizal networks."

Dr. Suzanne Simard: I scrambled onto a knoll where a single ponderosa pine grew, its long needles in scanty bundles to save precious water. This afforded ponderosa the distinction as the most drought-tolerant of all the tree species in these parts. {Si46}

The Douglas fir and ponderosa pine were better than the spruce and subalpine fir at minimizing water loss, helping them cope with the drought – they did this by opening their stomata [tiny holes in their leaves] for only a few hours in the morning when the dew was heavy. In these early hours, trees sucked carbon dioxide in through the open pores to make sugar, and in the process, transpired water brought up from the roots. By noon, they slammed their stomata closed, shutting down photosynthesis and transpiration for the day. [Bark, particularly of the Douglas fir, also absorbed the heat and was thick to prevent water loss.] {Si46-47}

Trembling aspen are unique in that many stems of the same individual spring from subterranean buds along a shared network of roots, and I wondered if the aspen copses [small groups of trees] were accessing water from the ravines and passing it upslope through their shared root systems. {Si48}

I thought of new research on hydraulic redistribution by Douglas firs, where the deep-rooted trees lifted water to the soil surface at night and replenished shallow-rooted seedlings so they were vibrant during the day. Had anyone examined whether firs spread water through mycorrhizal networks? {Si179}

[HOW. Using a new safer soil-moisture sensor, Simard found water loss around dead trees and lost soil structure.] I'd read that dying grasses shuttled phosphorus and nitrogen to their off-spring through arbuscular mycorrhizal networks and wondered if this Mother tree did the same as she died. Sending them her last drops of water, along with some nutrients and food. {Si244-245.} [21]

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[20] University of Michigan Dec. 1, 2022 "Old-growth trees more drought tolerant than younger ones, providing a buffer against climate change." *Phys.Org News*. From: Dr. Tsun Fung Au (Indiana U), Justin T. Maxwell (Indiana U), Scott M. Robeson (Indiana U) *et al.* (+8 others) Dec. 1, 2022 "Younger trees in the upper canopy are more sensitive but also more resilient to drought." *Nat. Clim. Chang*. 12, 1168–1174 (2022). Dr. Tsun Fung Au Indiana University & U. of Michigan. Biography and Contact; Google Scholar; Researchgate. Dr. Justin T. Maxwell, Indiana U. Biography and Contact; Google Scholar; Researchgate. Dr. Scott M. Robeson, Indiana U. Biography and Contact; Google Scholar; Researchgate.

[21] Si = page number within Dr. Suzanne Simard, *Finding the Mother Tree*. Canada: Allen Lane 2021. pp. 350. Dr. Suzanne Simard (U. of British Columbia) *Website*, *Biography and contact*, Wikipedia; *Researchgate*; *Google Scholar*. See also Si45-63. 179, 244-245.

 3e. Fire, Plant Succession, Fire Breaks of Aspen and Birch. Dr. Suzanne Simard, "As fire fingered through the landscape, it petered out in these aspen-clad glades." We should be planning for "corridors of birch and aspen to serve as firebreaks, because their leaves were moister and less resinous than those of conifers."

Aspen trees, left standing "surrounding conifers that were incinerated." Credit James Steidle and *CBC News*.

Dr. Simard: The scattered alders help replenish the nitrogen gassed out by the wildfire. {Si68} [After fires burn the overstory, alders and nitrogen-fixing *Frankia* bacteria in its modified root branches, are among the first shrubs to appear.]

Flames released pine seeds from resinous cones and stimulated aspens to sprout from thousand-year old root systems, their moist leaves reducing the flammability of the young forest. As fire fingered through the landscape, it petered out in these aspen-clad glades, leaving a mosaic of different-aged forest that was itself resistant to future fires." {Si181-182} [Drought's ecosystem changes, and taproots were a key to those seedlings that lived.]

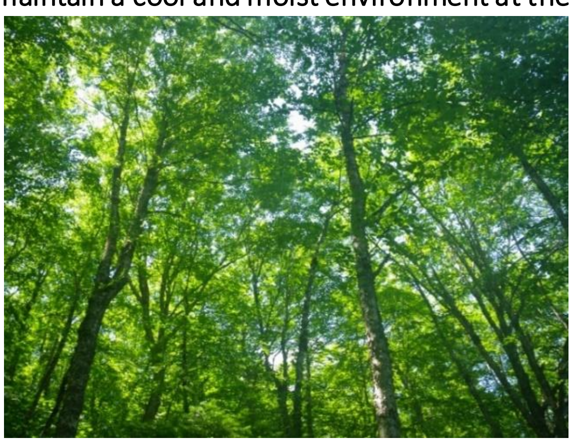
Overestimating the threat of a few birch neighbors could bring unexpected consequences, potentially setting the forest for a vulnerable future, where lowered biodiversity might reduce productivity, increase the risk of poor health, and augment the spread of fire. {Si198}

We should be trying to reduce the risk [of fire] by planning for landscapes of mixed forest instead of coniferous forests, and for corridors of birch and aspen to serve as firebreaks, because their leaves were moister and less resinous than those of conifers. {Si202}

The dead trees have been considered at fire risk, but more likely a convenient commodity. This salvage clear-cutting has been amplifying emissions, changing the seasonal hydrology in watersheds and in some cases causing streams to flood their banks. {Si288} [22]

4. COVERING SOIL'S CARBON, MOISTURE, AND NUTRIENTS AND PREVENTING EROSION.

 4a. Covering Soil Carbon Release and Moisture, Overhead by Trees. Dale Prest, Community Forests International, "We should aim to maintain a cool and moist environment at the forest floor."



Dale Prest, "If you keep canopy openings below 10m in diameter, soil nutrient cycling doesn't much change."
Taylor Lake forest, Earltown

[22] See Si68, 181-182,185,197-198, 202, 207,220,240,243-246, 288. See also Bethany Lindsay, Investigative Journalism Foundation. Nov. 17, 2018 "'It blows my mind': How B.C. destroys a key natural wildfire defence every year." *CBC News*

Dale Prest: Perhaps most importantly, we should aim to maintain a cool and moist environment at the forest floor. Studies of other soil nutrient dynamics suggest that if you keep canopy openings below 10m in diameter, soil nutrient cycling doesn't much change. Likewise, maintaining at least 70% canopy closure in thinnings or multi-stage shelterwoods ought to do the same, and make sure established regeneration covers the forest floor before you do that final removal. In other words, by avoiding exposing the ground to too much sunlight at any one time we can at least maintain the amount of carbon in our soils. Rebuilding depleted soil carbon stocks will require allowing low value wood to remain following harvests. In addition, maintaining abundant dead wood and soil organic matter levels will contribute to the health of the forest soil, increasing productivity and tree growth. [23]

 4b. Covering Soil Carbon Release and Moisture by Moss. Dr. Robin Wall Kimmerer, State U. of New York, Carbon dioxide above the decaying log "is readily absorbed into the moist leaves of the mosses."

Dr. Robin Wall Kimmerer, "But, the boundary layer above a log may be enriched in carbon dioxide to ten times that amount. Carbon dioxide is the raw material of photosynthesis, and is readily absorbed into the moist leaves of the mosses."
Brocade Moss, *Hypnum Imponens* on log, Portage Trail, Earltown

Dr. Robin Wall Kimmerer: The boundary layer traps not only heat, but water vapor, as well. For example, moisture evaporating from the surface of a damp log is captured in the boundary layer, creating a humid zone in which the mosses flourish. Mosses can grow only when they are moist. As soon as they dry out, photosynthesis must cease, and growth is halted.

Living within the confines of the boundary layer prolongs the window of opportunity for growth, by keeping the wind from stealing the moisture. Being small enough to live within the boundary layer allows the mosses to experience a warm, moist habitat unknown by the larger plants. {Ki18}

The boundary layer can also hold gases other than water vapor. The chemical composition of the atmosphere in the slim boundary layer of a log differs considerably from that of the surrounding forest. The decaying log is inhabited by a myriad of microorganisms. Fungi and bacteria are constantly at work degrading the log, with an outcome as sure as that of a wrecking ball. The continual work of the decomposers slowly turns the solid log to crumbling humus and releases vapors rich in carbon dioxide, which is also trapped in the boundary layer.

The ambient atmosphere has a carbon dioxide concentration of approximately 380 parts per million. But, the boundary layer above a log may contain up to ten times that amount. Carbon dioxide is the raw material of photosynthesis, and is readily absorbed into the moist leaves of the mosses. Thus, the boundary layer can provide not only

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[23] Dale Prest. Fall 2013. "Forests – and Their Soils – Are Twice As Important As Carbon Sinks." ***Silviculture Magazine***. Based upon his own research and partially based upon Thomas Buchholz; Andrew J. Friedland; Clairee Hornig; William S. Keeton; Giuliana Zanchi; and Jared Nunery. 29 January 2013. "Mineral soil carbon fluxes in forests and implications for carbon balance assessments." ***Global Change Biology Bioenergy***. (GCB) GCB Bioenergy (2013). Dale Prest is Ecosystem Service Specialist. Community Forests International. Biography and Contact; Researchgate. CBC Documentary 2025-01-26 Its Literally Life-Protecting Private Woodlots.

a favorable microclimate for moss growth, but also an enhanced supply of carbon dioxide, the raw material for photosynthesis. Why live anywhere else? [24] {Ki18}

 4c. Covering Soil Carbon and Gathering Atmospheric CO_2, by Moss. Dr. David J. Eldridge, U. of New South Wales + 50 others, "We found that soil mosses are associated with greater carbon sequestration, pool sizes for key nutrients and organic matter decomposition rates."

Dr. David J. Eldridge and 50 other authors, "Globally, soil mosses potentially support 6.43 Gt more carbon in the soil layer than do bare soils."
Haircap moss, *Polytrichum*, amid fungi and conifer seedlings, off Kemptown Road, NS

Dr. David J. Eldridge (U. of New South Wales) et al. (50 authors): [HOW] Here we conducted the most comprehensive global standardized field study to quantify how soil mosses influence 8 ecosystem services associated with 24 soil biodiversity and functional attributes across wide environmental gradients from all continents. We found that soil mosses are associated with greater carbon sequestration, pool sizes for key nutrients and organic matter decomposition rates but a lower proportion of soil-borne plant pathogens than unvegetated soils. Mosses are especially important for supporting multiple ecosystem services where vascular-plant cover is low.

Globally, soil mosses potentially support 6.43 Gt more carbon in the soil layer than do bare soils. The amount of soil carbon associated with mosses is up to six times the annual global carbon emissions from any altered land use globally. The largest positive contribution of mosses to soils occurs under perennial, mat and turf mosses, in less-productive ecosystems and on sandy soils. [25]

[24] Ki = Dr. Robin Wall Kimmerer. Gathering Moss – A Natural and Cultural History of Mosses. Oregon State University Press 2003 pp. 169. Dr. Robin Wall Kimmerer, College of Environmental Science and Forestry, State University of New York, Syracuse, NY, and lives in Fabius, NY Biography, videos, and contact, Wikipedia and Researchgate

[25] Dr. David J. Eldridge (U. of New South Wales) et al. (50 authors) 1 May 2023 "The Global Contribution on Soil Mosses to Ecosystem Services." *Nature Geoscience* 16, 430-438 (2023). Dr. David J. Eldridge (U. of New South Wales) Biography and Contact; Google Scholar; Researchgate

 4d. Covering Soil and much more, by Lichens. Joe Walewski, Wolf Ridge Environmental Learning Center: [Due to the pale color of the lichen] "light and heat are reflected allowing the soil to remain both cool and moist."

Joe Walewski, Wolf Ridge Environmental Learning Center, "Because this species is an important colonizer of bare soil, forest managers in Quebec have spread it over recently burned forestland to prevent soil erosion."
Lichen ground cover binding soil particles and contributing to soil fertility for vegetation, MacKenzie Settlement, Nova Scotia.

Joe Walewski, Wolf Ridge Environmental Learning Center, Finland, Minnesota: Mottled Disk Lichen *Trapeliopsis granulosa*. Nature Notes – Because this species is an important colonizer of bare soil, forest managers in Quebec have spread it over recently burned forestland to prevent soil erosion. These lichens produce hyphae that bind soil particles and also make contributions to soil fertility. {Wal27}

Additionally, by changing the dominant color of the surrounding area from the soil's dark brown to a pale gray of the lichen, light and heat are reflected allowing the soil to remain both cool and moist. [26] {Wal27}

[Lots of other lichen have this pale gray or white enhancing reflectivity. Some reflecting lichen, covering bare ground, include Brown Beret Lichen *Baeomyces rufus*; and Candy Lichen *Icmadophila ericetorum*. {Wal24-25}]

4e. Covering CO_2 Emissions with Coastal Wetland's Mud. Prof. Kerrylee Rogers, U. Wollongong, "This sediment not only buries and traps root material and other organic matter, but also increases the elevation of wetlands."

Victoria Gill, BBC Science correspondent: Many habitats that are rich in plant life are important stores of carbon. But coastal wetlands are particularly efficient at locking it away. When the marshland plants die, rather than decomposing and releasing their carbon into the atmosphere, they become buried in the mud. As sea levels rise, more sediment layers wash over tidal marshes and bury the carbon-rich material, locking it beneath the muddy layers.

Lead researcher Prof. Kerrylee Rogers, from the University of Wollongong, explained: "This sediment not only buries and traps root material and other organic matter, but also increases the elevation of wetlands." "With sea-level rise, this acts as an adaptation measure by enabling wetlands to build elevation as the sea rises." [27]

SECTION C. CARBON EMISSIONS FROM CLEARCUTS, FRAGMENTED FORESTS, WOOD PRODUCTS, BIOMASS BURNING AND THE CONSEQUENT CARBON DEPLETION FROM THE SOIL.

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[26] Joe Walewski, Wolf Ridge Environmental Learning Center, Finland, Minnesota. Lichens of the North Woods Duluth, Minnesota: Kollath+Stensaas Publishing 2007 pp. 152. [Simple, light to carry book, but very inspirational book for me. NMW.] Joe Walewski Wolf Ridge Environmental Learning Center, Finland, Minnesota. Biography and Contact; Publishing; Field Notes – A Naturalist's Life Blog.

[27] Victoria Gill, BBC Science correspondent, 6 March 2019. "Wetland mud is 'secret weapon' against climate change." *BBC News*. From Kerrylee Rogers (U. of Wollongong, Australia), et al. (+10 others) March 7, 2019 Wetland carbon storage controlled by millennial-scale variation in relative sea-level rise *Nature*. Vol. 567 Issue 7746 pp. 91-95. Dr. Kerrylee Rogers, U. of Wollongong, Australia. Biography and Contact; Google Scholar; Researchgate.

5. CARBON EMISSIONS FROM CLEARCUTS.

5a. Carbon Chemical Bonds within Soils of Various Forests. Dartmouth College Ed., "Carbon is stored in soil by binding only to certain soil structures." Clear-cutting makes carbon "more likely to leave the soil."

Prof. Andrew Friedland, Dartmouth College, "Clear-cutting forests has an effect of mobilizing the carbon, making it more likely to leave the soil and end up in the atmosphere." Area along the Cobequid Trail, Old Barns, Nova Scotia

Dartmouth College Ed.: The Dartmouth researchers explored whether clear-cutting changes the strength of the chemical bonds of carbon stored in mineral soils in hardwood forests in the northeastern United States. Clear-cutting involves harvesting all timber from a site at once rather than selectively culling mature trees. Carbon is stored in soil by binding only to certain soil structures. [HOW] The researchers collected soils from recently clear-cut forests and from older forests, and pulled carbon from the soil in a sequence of gentle to stronger extractions. The results showed that mature forest stands stored significantly more soil organic carbon in strongly mineral-bound and stable carbon pools than did soils from cut stands.

[Prof. Andrew Friedland, environmental studies, Dartmouth College] "Clear-cutting forests has an effect of mobilizing the carbon, making it more likely to leave the soil and end up in the atmosphere." [28]

5b. CO_2 Emissions from Exposed Soil and from Decaying Deadwood. David Broadland, "removal of the trees allows the sun to warm the forest soil."

David Broadland, "First, the removal of the trees allows the sun to warm the forest soil to a higher temperature than was possible when it was shaded by trees. That additional warmth speeds up decay processes and the release of greenhouse gases." Highway 104, Cumberland County, NS

[28] Dartmouth College. 15 April 2016. "Clear-Cutting Destabilizes Carbon in Forest Soils, Study Finds." LINKS *Phys.Org. News*. Based upon Emily M. Lacroix; Chelsea L. Petrenko; & Andrew J. Friedland. 2016. "Evidence for Losses from Strongly Bound SOM Pools after Clear Cutting in a Northern Hardwood Forest" *Soil Science*. May 2016 Volume 181 Issue 5 pp. 202-207. Dr. Emily M. Lacroix, Dartmouth College, Stanford U., & U. of Lausanne, Biography and Contact; Google Scholar; Researchgate. Dr. Chelsea L. Petrenko, Dartmouth College, Energy & Environmental Economics. Biography and Contact; Researchgate. Dr. Andrew J. Friedland, Dartmouth C. Biography and Contact; Google Scholar; Researchgate.

David Broadland, Focus on Victoria: First, the removal of the trees allows the sun to warm the forest soil to a higher temperature than was possible when it was shaded by trees. That additional warmth speeds up decay processes and the release of greenhouse gases, a process somewhat akin to the melting of permafrost in the Arctic. Soil scientists tell us that forest soil contains even more carbon than all the trees and other biomass that grow in it. Recent studies have reported that as much as 20 percent of the carbon in the layer of soil at the forest floor is released to the atmosphere after an area of forest has been clearcut. This release is a wild card in our emerging understanding of the impact of clearcut logging on carbon emissions. For now it remains unquantified, but it's definitely not zero.

The second decay process begins after an area of forest is clearcut and the unused parts of trees left on the forest floor begin to decay. In his 2019 report *Forestry and Carbon in BC* (document at end of story) [Broadland's story. See footnote.], BC forest ecologist Jim Pojar estimated that 40 to 60 percent of the biomass of a forest is left in a clearcut. That includes the branches, stumps, roots, pieces of the stems that shattered when felled, the unutilizable tops of the trees, and unmerchantable trees that are killed in the mayhem of clearcut logging. For our purpose, we will use the mid-point of Pojar's 40 to 60 percent estimate: half of the biomass is removed, and half remains on the forest floor. The Ministry of Forests' log scaling system tells us what volume of wood is removed from the forest as merchantable logs. We then assume that an equal volume of wood is left in the clearcut. [29] [This analysis is about the consequences of uncovering the soil by the forest canopy. NMW]

5c. CO_2 Emissions from Soils, the Effects of Rising Temperatures. Dr. Kristiina Karhu, University of Helsinki, "It means that more carbon can be released from the northern soils than is projected by the models at the moment."

Matt McGrath, BBC Science Journalist: The huge stores of carbon locked in the world's soils [four times as much as plant biomass] are more vulnerable to rising temperatures than previously thought. Researchers found that microbes [soil microorganisms] in the soil were more likely to enhance the release of CO_2 in a warming world. Soils from colder regions and those with greater amounts of carbon were seen to emit more as temperatures went up. The world's soils hold about twice the amount of carbon as the atmosphere. Every year the activities of microbes in the soil on organic matter release around 60bn tonnes of carbon dioxide into the air.

[HOW] This new work set out to test 22 different soil samples from the Arctic to the Amazon. In their experiments the researchers cooked and cooled the material to ascertain how it responded to increased temperatures, over the mid to long term, in this case defined as 90 days."

According to Dr. Karhu [University of Helsinki], this level of increase in colder regions raises concerns as more than half of the carbon that's stored in soils in the world is found in these locations. "It means that more carbon can be released from the northern soils than is projected by the models at the moment. This is worrying because these soils have a lot of carbon." [30]

5d. CO_2 Emissions from Clearcuts. "Dartmouth [College] findings show deep soil can play an important role in carbon emissions in clear-cutting and other intensive forest management practices."

Dartmouth College: Global atmospheric studies often don't consider carbon in deep (or mineral) soil because it is thought to be stable and unaffected by timber harvesting. But the Dartmouth findings show deep soil can play an important role in carbon emissions in clear-cutting and other intensive forest management practices.

[Prof. Andrew Friedland, Dartmouth College] "Our paper suggests that increased reliance on wood may have the unintended effect of increasing the transfer of carbon from the mineral soil to the atmosphere. So the intended goal of reducing carbon in the atmosphere may not be met." [31]

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[29] David Broadland Jan. 6, 2020 "Defusing BC's big, bad carbon bomb." ***Focus on Victoria***. These quotes are within an article about British Columbia deforestation and its carbon footprint. Mr. Broadband's analysis on tree cover seems well suited to fit here. David Broadland Focus on Victoria Reporting, The Evergreen Alliance articles; Contact. Dr. Jim Pojar U. British Columbia, British Columbia Forest Service. Biography; Wikipedia; British Columbia Publications; Researchgate.

[30] Matt McGrath. 3 Sept. 2014. "Warning over vulnerability of soil carbon to warming." ***BBC News***. Based upon Karhu, Dr. Kristiina (University of Helsinki) et al. (+15 others). Marc D. Auffret, Jennifer A. J. Dungait, David W. Hopkins, James I. Prosser, Brahesh K. Singh, Jens-Arne Subke, Philip A. Wookey, Göran I. Afren, Maria-Teresa Sebastià, Fabrice Gouriveau, Göran Bergkvist, Patrick Meir, Andrew T. Nottingham, Norma Salinas, and Dr. Iain Hartley (University of Exeter). Sept. 4, 2014. "Temperature sensitivity of soil respiration rates enhanced by microbial community response." ***Nature*** 513: 81-84 (4 Sept. 2014). Dr. Kristiina Karhu, University of Helsinki. Biography and Contact; Google Scholar; Researchgate.

[31] Dartmouth College. 11 June 2013. Wood Not So Green a Biofuel (WITH LINKS) *Phys.Org News*. Based upon Buchholz, Thomas, Andrew J. Friedland, Claire E. Hornig, William S. Keeton, Giulianna Zanchi, & Jared Nunery. 29 January 2013. "Mineral soil carbon fluxes in forests and implications for carbon balance assessments" *Global Change Biology-Bioenergy*. Vol. 6 Issue 4 July 2014 P 305-311. Dr. Thomas Buchholz Dartmouth College & U. of Vermont. Biography and Contact; Google Scholar; Researchgate. Dr. Andrew J. Friedland, Dartmouth C. Biography

5e. CO_2 Emissions Microbes Releasing Extra Carbon as Atmospheric CO_2 Grows.

Princeton University Ed.: The carbon in soil—which contains twice the amount of carbon in all plants and Earth's atmosphere combined—could become increasingly volatile as people add more carbon dioxide to the atmosphere, largely because of increased plant growth. The researchers developed the first computer model to show at a global scale the complex interaction between carbon, plants and soil, which includes numerous bacteria, fungi, minerals and carbon compounds that respond in complex ways to temperature, moisture and the carbon that plants contribute to soil.

Although a greenhouse gas and pollutant, carbon dioxide also supports plant growth. As trees and other vegetation flourish in a carbon dioxide-rich future, their roots could stimulate microbial activity in soil that in turn accelerates the decomposition of soil carbon and its release into the atmosphere as carbon dioxide, the researchers found.

On the other hand, microbial activity initiated by root growth could lock carbon onto mineral particles and protect it from decomposition, which would increase long-term storage of carbon in soils, the researchers report. [32]

5f. CO_2 Soil Emissions Immediately. Dr. Suzanne Simard, UBC, "[Dr. Dan Durall was] soon to discover that clear-cutting was causing carbon dioxide to pulse into the atmosphere at unprecedented rates."

Dr. Suzanne Simard, UBC: Dan [Dr. Dan Durall, Oregon State University] was working on his own dissertation, examining clear-cutting effects on forest composition and carbon storage patterns across a portion of British Columbia the size of Oregon, soon to discover that clear-cutting was causing carbon dioxide to pulse into the atmosphere at unprecedented rates. {Si158}

Without the pull of the Mother Trees though, the new forest network might never be the same. The carbon in the trees, and the other half in the soil and mycelium and roots, might vaporize into thin air. Compounding climate change. Then what? Wasn't this the most important question of our lives? {Si232-233} {Si251}[33]

5g. CO_2 Emissions the First 3 Years, from Clearcuts and Their Soils. Dr. Elyn R. Humphreys, UBC and Carlton U., "In all 3 years, the stand was a large source of CO_2 (620, 520, and 600 g C m−2 yr−1 in the first, second, and third years, respectively)."

and Contact; Google Scholar; Researchgate. Claire E. Hornig, Dartmouth C. Biography and Contact; Dr. William S. Keeton, U. or Vermont. Biography and Contact; Google Scholar; Researchgate. Dr. Giuliana Zanchi, Lunds Universitet. Biography; Publications; Researchgate. Jared Nunery, Vermont Dept. of Forest, Parks and Recreation. Biography and Contact; Researchgate.

[32] Princeton University 23 Dec. 2014. "Dirty Pool: Soil's Large Carbon Stores Could Be Freed by Increased CO_2, Plant Growth." *Phys.org News*. Based upon Sulman, Benjamin N.; Richard P. Phillips, A. Christopher Oishi, Elena Shevliakova, and Stephen W. Pacala 2014. "Microbe-driven turnover offsets mineral-mediated storage of soil carbon under elevated CO_2." *Nature Climate Change*. 4 1099-1102. Dec. 2014 (pub. online 10 Nov. 2014). Dr. Benjamin Sulman, Princeton U. & Indiana U. Biography and Contact; Google Scholar; Researchgate. Dr. Richard P. Philips, Indiana U. Bloomington. Biography and Contact; Google Scholar; Researchgate. Dr. Andrew Christopher Oishi, US Forest Service. Biography and Contact; Google Scholar; Researchgate. Elena Shevliakova NOAA Princeton NJ. Biography and Contact; Google Scholar; Researchgate. Prof. Stephen W. Pacala Princeton U. Biography and Contact; Google Scholar; Researchgate.

[33] Si = page number within Dr. Suzanne Simard. *Finding the Mother Tree*. Canada: Allen Lane 2021. pp. 350. Dr. Suzanne Simard (U. of British Columbia) Website, Biography and contact, Wikipedia; Researchgate , Google Scholar. Dr. Dan Durall, Oregon State U. & UBC Okanagan. Biography and contact; and Researchgate

East Preston, Nova Scotia. Credit

Dr. Elyn R. Humphreys (UBC and Carlton U.): [HOW] To investigate the variations in annual and seasonal net ecosystem production (FNEP) during the development of a young forest, 3 years of continuous eddy covariance measurements of carbon dioxide (CO_2) fluxes were collected following clearcut harvesting and replanting of a coastal Douglas-fir stand on the east coast of Vancouver Island, BC, Canada. In all 3 years, the stand was a large source of CO_2 (620, 520, and 600 g C m−2 yr−1 in the first, second, and third years, respectively). [34]

5h. CO_2 Emissions after 3 Years, 15 Years, & 55 Years from Clearcuts and Their Soils. Dr. Andrew Black, Flux researcher, U. British Columbia. "Even 15 years after harvest, the middle-aged stand was still a net carbon source, releasing up to 5 tonnes of CO_2, [per hectare] per year."

Dr. Andrew Black, Flux Researcher, U. British Columbia, "The 3-year old seedling stand released 22 tonnes of CO_2, per hectare annually – the largest carbon source measured for a terrestrial ecosystem."
Mattatall Lake, French Road, Colchester County

Dr. Andrew Black (Flux researcher, U. British Columbia): [55 YEARS] Tree age had a dramatic effect on net CO_2 exchange. The oldest Douglas-fir stand [55 year-old] was a net carbon sink, sequestering on average about 9 tonnes of CO_2, per hectare each year. Not unexpectedly, the two younger stands were net sources rather than net sinks, due to the long-term decomposition of below ground carbon following logging. However, the magnitude of these carbon sources was startling.

[3 YEARS] The 3-year old seedling stand released 22 tonnes of CO_2, per hectare annually – the largest carbon source measured for a terrestrial ecosystem.

[15 YEARS] Even 15 years after harvest, the middle-aged stand was still a net carbon source, releasing up to 5 tonnes of CO_2, [per hectare] per year. Rising levels of CO_2 that have a "fertilizing" effect on tree growth are expected to result in faster tree growth, while warming climate also means increased decomposition of belowground organic matter, more frequent and severe insect outbreaks, and increased risks of forest fire. Large scale carbon losses from pests and fire could quickly negate the benefits of increased CO_2 sequestration in faster-growing, expanding forests. [35]

5i. CO_2 Emissions Recently Clearcut, Pole/Sapling Age, and Rotation Age Stand. Dr. Elyn R. Humphreys, UBC & Carlton U. (& 6 others), "The recently clearcut harvested stand (HDF00) was a large C source, the pole/sapling aged stand (HDF88) was a moderate C source."

Dr. Elyn R. Humphreys et al.: [HOW] The eddy covariance technique was used to measure carbon dioxide fluxes and a portable soil chamber system was used to measure soil respiration in the three stands located within 50 km of each other on the east coast of Vancouver Island, British Columbia, Canada. [RESULTS] In 2002, the recently clearcut

[34] Dr. Elyn R. Humphreys (UBC & Carlton U.), T. Andrew Black, Kai Morgenstern, Zhong Li (UBC), and Zoran Nesic. March 2005. "Net ecosystem production of a Douglas-fir stand for 3 years following clearcut harvesting." Global Change Biology 11(3):450 - 464 · March 2005. Dr. Elyn R. Humphreys, Carlton U. biography and contact and researchgate. See footnotes 22 and 23 for others biography and credentials.

[35] Dr. Andrew Black. January 2006. "Clear-cuts in a Changing Climate. – Implications of forest disturbance on carbon cycling." Issue 12 *BIOCAP*. http://www.biocap.ca/files/Briefs/Issue_12_Black_Brief.pdf]. Prof. Andrew Black, Flux researcher at U. British Columbia. Biography, Contact; and Researchgate.

harvested stand (HDF00) was a large C source, the pole/sapling aged stand (HDF88) was a moderate C source, and the rotation-aged stand (DF49) was a moderate C sink (net ecosystem production of -606, -133, and 254 g C m-2 year-1, respectively)." [36]

5j. CO_2 Emissions from Clearcuts and Their Soils. Jonathan Carter, Forest Ecology Network, "for many years after a clearcut, a re-sprouting forest emits more CO_2 than it absorbs."

Jonathan Carter, Forest Ecology Network: Stephen Wofsy, an atmospheric chemist at Harvard has documented that temperate forests continue to increase carbon uptake with age. Current harvest practices are resulting in a younger forest and reduced stocking levels, both of which reduce the carbon sequestration potential - or simply put, the ability of forests to store and withdraw carbon from the atmosphere.

Research has documented that for many years after a clearcut, a re-sprouting forest emits more CO_2 than it absorbs. This is a result of soil microbes becoming more active due to the greater abundance of dead organic matter in the form of tree roots and slash.

Thomas Peterson, founder of the Center for Climate Strategies at Penn State University using his Forestry Carbon Calculator, has determined that the two most effective ways of maximizing carbon storage in Maine forests are 1) increasing stocking levels and 2) expanding forest protection. Maine forests could easily double or triple their annual carbon uptake with the implementation of longer growing rotations and the setting aside of large wilderness reserves. Enhancing carbon sequestration not only reduces atmospheric CO_2, but it has the added benefits of improving land use practices, enhancing wildlife habitats, increasing water and air filtration, and generally, just improving overall forest health. [37]

5k. CO_2 Emissions from Clearcuts and Their Soils. Imperial College London, "recovering from logging are sources of carbon for years afterward."

"A new study, led by Imperial College London researchers, turns this idea on its head, showing that the carbon released by soil and rotting wood outpaces the carbon absorbed by new growth."
Eddy covariance flux tower over a heavily logged tropical forest landscape. Credit: Maria Mills, University of Leicester, UK.

Imperial College London: A new study finds that tropical forests recovering from logging are sources of carbon for years afterward, contrary to previous assumptions. Tropical forests that are recovering from having trees removed were thought to be carbon absorbers, as the new trees grow quickly.

[36] Dr. Elyn R. Humphreys (UBC & Carlton U.), T. Andrew Black, Kai Morgenstern, Tiebo Cai, Gordon B. Drewitt, Zoran Nesic, J.A. Trofymow. 30 Nov. 2006 "Carbon dioxide fluxes in coastal Douglas-fir stands at different stages of development after clearcut harvesting." *Agricultural and Forest Meteorology* Vol.140, Issues 1–4, pp. 6-22 *Science Direct*. Dr. Elyn R. Humphreys, U. British Columbia & Carlton U. biography and contact; and Researchgate. Prof. Andrew Black, Flux researcher at U. British Columbia. Biography, Contact and Researchgate. Dr. Kai Morgenstern, RKW Kompetenzentrum, Eschborn, Germany. Researchgate. Tiebo Cai, U. British Columbia & U. of Lethbridge. Researchgate. Gordon B. Drewitt U. British Columbia & McMaster U. Biography and Contact; Researchgate. Zoran Nesic U. of British Columbia Biography and contact; Google Scholar. Researchgate. Dr. J.A. (Tony) Trofymow, Canadian Forest Service, Victoria, and U. of Victoria. Biography and Contact; Researchgate.

[37] Carter, Jonathan. "Climate Change and Forest Restoration Campaign." *Forest Ecology Network* [Seen 2017] Based upon research of: Prof. Steven Wofsy, atmospheric chemist, Harvard University; Biography and Contact; Biography and Contact; Google Scholar; Researchgate. Prof. Thomas Peterson, Penn State University & Center for Climate Strategies; and others. Biography and Contact; LinkedIn; Researchgate, and Greenhouse gas inventories for Maryland, Arizona, North Carolina, New Mexico.

A new study, led by Imperial College London researchers, turns this idea on its head, showing that the carbon released by soil and rotting wood outpaces the carbon absorbed by new growth.

[HOW] Many previous studies of recovering forests have focused on measuring tree growth to estimate the amount of carbon taken from the atmosphere. The new study also measured how much carbon was coming from the ground (soil and dead wood) to calculate the carbon budget from the incoming and outgoing carbon flows for logged and unlogged (old-growth) forest.

[HOW] To measure the carbon released from the ground, researchers used a portable carbon dioxide monitor to test patches of ground and pieces of deadwood in several plots monthly for several years. The team had also set up a 52-meter-tall tower above the forest canopy to continuously measure the "flux" of carbon into and out of the forest to see whether it was a net source or sink of carbon. [38]

5l. Carbon, Nitrous Oxide, and Methane Emissions from a Blueberry Field and Its Soil.

Dr. Andrew Black, U. of British Columbia, "The blueberry fields was a very weak carbon sink in summer and has carbon losses in winter months." "Nitrous oxide emissions continued throughout the year"
Using an eddy covariance system to measure greenhouse gas emissions. Faculty of Land and Food Systems, U. of British Columbia.

Dr. Andrew Black, flux researcher, U. of British Columbia: So far, early results are in from a Westham Island blueberry farm. Black and his graduate student Patrick Pow (pictured) used an eddy covariance system to capture GHG [Greenhouse gases] fluxes every 30 minutes.

The blueberry fields was a very weak carbon sink in summer and has carbon losses in winter months. Methane [CH_4] emissions were inconsequential, which, with its global warming potential of 28 times higher than CO_2, was equivalent to one fifth of the magnitude of the CO_2 uptake. The field was a moderate source of N_2O emissions, which is 298 times higher than CO_2. Nitrous oxide emissions continued throughout the year, increasing sharply after application of nitrogen fertilizer and following rain events.

Globally, the agricultural sector is the second largest emitter of GHGs [Greenhouse gases]. In 2017, the sector emitted approximately 11% of global GHG emissions, equal to about 6 billion t of CO_2 equivalent, according to the World Resources Institute. This is second only to the energy sector. [39]

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[38] Imperial College London January 9, 2023 "Forests recovering from logging act as a source of carbon." TOOL PICTURED *Phys.Org News*. From: Mills, Maria B., University of Leicester, UK et al (+14 others), Tropical forests post-logging are a persistent net carbon source to the atmosphere, *Proceedings of the National Academy of Sciences* January 9, 2023 120 (3) e2214462120 (2023). Maria B. Mills, University of Leicester, UK. Biography and Contact; Google Scholar; Researchgate. Prof. Yadvinder Malhi, U. of Oxford, UK. Biography and Contact; Google Scholar; Researchgate. Youtube video

[39] Andrew Black. Faculty of Land and Food Systems, UBC. 2018. "Investigating GHG emissions from B.C. farms." *Land and Food Systems* Faculty of Land and Food Systems, Vancouver Campus. Dr. Andrew Black, Flux researcher at U. British Columbia. Author; Biography and Contact; and Researchgate. Dr. Maja Krzic U. British Columbia. Biography and Contact; Wikipedia; Google Scholar. Dr. Sean Smukler, U. British Columbia. Biography and Contact; Google Scholar; Researchgate. Dr. Rachhpal Jassal, U. British Columbia. Biography and Contact; Google Scholar; Researchgate.

6. CARBON EMISSIONS FROM FRAGMENTED FORESTS AND FIRE.

 6a. CO_2 Emissions from Fragmented Forests. Emily Chung, CBC News, "Canada accounts for 21% of global [forest] degradation." Dr. Nigel Sizer, World Resources Institute, "It's No. 1 on the [world's degradation] list."

Dr. Christoph Thies, "In general, new roads and logging appear to drive the fragmentation of intact forests around the world"
Conifer plantation in Colchester County, Nova Scotia

Emily Chung, CBC News: The world's precious few remaining large forests are fragmenting at an alarming rate, and the degradation in Canada leads the world. The degradation of such pristine "intact" forests threatens species such as Canada's woodland caribou and Asia's tigers that rely on huge unbroken expanses of natural ecosystems in order to survive, said Nigel Sizer [World Resources Institute, Washington, D.C.].

Such forests are considered degraded when they are broken up or fragmented into smaller pieces that are no longer the same kind of ecosystem.

"What is lost is the intactness… This is a process which results in biodiversity loss — particularly, far-ranging species will no longer be able to survive," said Christoph Thies, senior forest campaigner for Greenpeace International.

In addition to playing a critical role in maintaining biodiversity, such forests also regulate air and water cycles and store carbon to slow and prevent climate change, Sizer said. That means their degradation could disrupt those functions, intensifying problems such as climate change.

The researchers also said that it is very difficult to restore intact forests that have been degraded. Potapov estimated it would take 30 years for such forests to be restored in the tropics and more than 100 in boreal regions, such as Canada's north.

Canada accounts for 21% of global [forest] degradation. "Canada is the country with the largest share of intact forest degradation in the world. It's No. 1 on the list," Sizer said.

In fact, the fragmentation of intact forests in Canada represents about 21 per cent of the global total, the analysis shows.

In general, new roads and logging appear to drive the fragmentation of intact forests around the world, Thies said.

He [Christoph Thies] recommended that in order to protect large forests from further degradation, governments should: 1. Establish more protected areas. 2. Take measures to prevent new roads from being pushed into pristine forests. 3. Strengthen the rights of traditional forest users such as indigenous communities. [40]

[40] Emily Chung, 5 Sept. 2014. "Canada's degradation of pristine, intact forests leads world." *CBC News* From interviews of Dr. Peter Potapov, University of Maryland. Biography and Contact; Google Scholar; Researchgate. Dr. Christoph Thies, Greenpeace International; Biography; Contact; Researchgate; Re-Green the Earth. Dr. Nigel Sizer, World Resources Institute. Biography; Trellis author; Researchgate.

6b. CO_2 Emissions from Fragmented Forests. Prof. Jos Barlow, Lancaster U., "with 80% forest cover" "those landscapes only really have 50% of their potential value, because of disturbance in the remaining forest."

Victoria Gill, BBC News, "This activity includes selective logging and forest fragmentation, which increase the likelihood of wildfires."
Clydesdale Road, Colchester County, Nova Scotia

Victoria Gill, BBC News: This is one of the conclusions of a two-year study of the Brazilian Amazon, which revealed that even protected forest is degraded by human activity. This activity includes selective logging and forest fragmentation, which increase the likelihood of wildfires.

"If you can imagine a landscape with 80% forest cover, I think most environmentalists would say that's a very good scenario and you've maintained most of your core habitat there," Prof Barlow [Lancaster University, UK] told the BBC. "But what we found was those landscapes only really have 50% of their potential value, because of disturbance in the remaining forest."

Selective logging, for example, can leave the forest fragmented or punch holes in the canopy, drying out the vegetation below. This, combined with the effects of climate change, is leaving the Amazon [and elsewhere] much more likely to catch fire.[41]

 6c. CO2 Emissions from Fragmented Forests. Chris Mooney, Pulitzer Prize winner, "Sunlight penetrates much farther, not only from above but from every side. It's warmer as a result, and also drier."

"Sunlight penetrates much farther, not only from above but from every side. It's warmer as a result, and also drier – the layer of fallen leaves on the forest floor isn't wet and spongy, but crunches and crackles as you walk. This environment sustains less life – animals and plants alike."
Colchester County, NS

[41] Victoria Gill. 29 June 2016. "Amazon Fires: Humans Make Rainforest More Flammable." LINKS, VIDEO 1:35 *BBC News*. From: Jos Barlow, Lancaster University, et al. (+ 29 others), July 2016. "Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation" *Nature* 7; 535(7610):144-7 18326 aop, (2016). Prof. Jos Barlow, Lancaster University. Biography and Contact; Google Scholar; Researchgate.

Chris Mooney, Pulitzer Prize winner, environment reporter: Why a fragmented forest stores less carbon? What science is revealing, meanwhile, is that it's not just deforestation itself that's the problem – it's also the damage to what's left behind.

The study of these fragments, which has been ongoing since 1980, shows that the forest left behind in the wake of deforestation also suffers greatly.

In the intact forest, it's dark and even relatively cool at the forest floor, a simple function of the fact that trees and vines, crowding upward, have managed to claim nearly all of the sunlight. But in the fragment, direct tropical sunlight penetrates much farther, not only from above but from every side. It's warmer as a result, and also drier – the layer of fallen leaves on the forest floor isn't wet and spongy, but crunches and crackles as you walk. This environment sustains less life – animals and plants alike.

"We know that tree mortality went up in this fragment compared to continuous forest." Lovejoy said [Dr. Thomas Lovejoy, ecologist, George Mason University]. The forest, when fragmented, "becomes simpler." Winds also blow down more trees in fragments, Lovejoy's research suggests, another reason that they store less carbon.

And these problems certainly aren't confined to the Amazon. "Seventy percent of the world's remaining forests are within 1 kilometer of a road," Lovejoy said. "Which is a measure of how advanced fragmentation is." [42]

6d. CO_2 Emissions from Fragmented Forests. Phys.Org, "The climate conditions change significantly: The sun's rays are stronger, the temperatures rise and there are areas where the wind is provided with a more effective target."

[Beside clearcuts are edges] "There are areas where the wind is provided with a more effective target."
Wind falls below a clearcut on Earltown Mountain, Nova Scotia

Phys.Org: As scientists of the Hemholtz Centre for Environmental Research (UFZ) write in the scientific journal *Nature Communications*, The effect of the degradation has been underestimated in fragmented forest areas, since it was hitherto not possible to calculate the loss of the biomass at the forest edges and the higher emission of carbon dioxide. The UFZ [Hemholtz Centre for Environmental Research] scientists have now closed this knowledge gap. According to their calculations, the forest fragmentation results in up to a fifth more carbon dioxide being emitted by the vegetation.

[HOW] The scientists defined a strip of 100 meters that runs from the edge of the forest into the inner forest as the peripheral area. The consequences for the trees at the newly created edges of the forest are known. The climate conditions change significantly: The sun's rays are stronger, the temperatures rise and there are areas where the wind is provided with a more effective target. This means that stress increases for trees in peripheral areas. Especially the larger specimens die off.

"Tree mortality increases, so that they can't store as much carbon as healthy trees in the centre of the forest, the core area" says Dr. Sandro Pütz, [Helmholtz Centre for Environmental Research, Leipzig, Germany] the main author of the study.

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[42] Mooney, Chris. 11 Feb. 2016 "The Solution to Climate Change That Has Nothing to Do With Cars or Coal." (VIDEO 1:48) *Washington Post*. Chris Mooney, 2020 Pulitzer Prize winner, science and environment reporter and author. Biography and recent articles. Dr. Thomas Lovejoy, ecologist, George Mason University. Wikipedia; Google Scholar; Researchgate.

"It is a forgotten process in the global carbon circulation of the vegetation," Huth [Dr. Andreas Huth, Leipzig, Germany] states. This aspect has been not directly included in the calculations of the IPCC (Intergovernmental Panel on Climate Change). "However, this effect should urgently be taken into account." [43]

6e. CO_2 Emissions from Fragmented Forests. Dr. Thomas Lovejoy & John Reid, "When forests become fragmented, edge effects (forest damage at created edges), drying and fire cause over 150 million tons of annual emissions"

Dr. Thomas Lovejoy & John Reid 19 April 2018 *NY Times*: When forests become fragmented, edge effects (forest damage at created edges), drying and fire cause over 150 million tons of annual emissions — more than result from outright deforestation. The United States Environmental Protection Agency estimates suggest that those emissions cost us $6.3 billion in lost crops, flood damage, fires and other impacts. In the boreal region, forests protect permafrost, which, if it thaws, will be a huge source of heat-trapping methane emissions. Aside from maintaining the global climate, intact forests stabilize weather locally and regionally, which sustains livelihoods for millions of people.

Forest conservation solutions are practical and affordable. First, roads need to give big forests a wide berth. The principal underlying driver of fragmentation is road-building, which carves forests into progressively smaller patches and has accounted for 81 percent of losses since 2000. [44]

6f. CO_2 Emissions from Fragmented Forests. Bob Yirka, Phys.org, "The researchers found fuel aridity (dryness of the trees) to be the most influential driver of burn severity."

Bob Yirka, Phys.org News, "As the planet grows warmer, wildfires have become more numerous and more severe."
Western Alberta 2009 forest fire. Credit: Cameron Strandberg, Wikimedia Commons.

Bob Yirka, Phys.org News: As the planet grows warmer, wildfires have become more numerous and more severe. They rage harder, grow bigger, and cause more damage. Such wildfires, called forest fires when they burn large swaths of forests, have become more commonplace in parts of Russia, North America, and Australia over the past several decades. Studies into these fires have found that in addition to tree and human structure loss, they are causing more CO2 emissions to be released into the atmosphere as the carbon trapped in trees is set free.

In looking at what their model showed, the researchers found fuel aridity (dryness of the trees) to be the most influential driver of burn severity. They also found that summer wildfires tended to be more severe and conditions for such fires have grown worse over the past two decades. The researchers conclude by noting that variations in drivers led to different outcomes in different parts of the country. [45]

[43] Phys.org. 7 Oct. 2014. "Brazil's Rainforests Are Releasing More Carbon Dioxide than Previously Thought." *Phys.org News*. Based upon Sandro Pütz, Helmholtz Centre for Environmental Research, Leipzig, Germany; Jürgen Groeneveld, Klaus Henle, Christoph Knogge, Alexandre Camargo Martensen, Markus Metz, Jean Paul Metzger, Milton Cezar Ribeiro, Dantas de Paula, M. and Andreas Huth. 2014. "Long-term carbon loss in fragmented Neotropical forests." *Nature Communications* 5: 5037 (7 Oct. 2014). Dr. Sandro Pütz, Helmholtz Centre for Environmental Research, Leipzig, Germany. Biography and Contact; Researchgate. Dr. Andreas Huth, scientist, Helmholtz Centre for Environmental Research, Leipzig, Germany. Biography and Contact; Researchgate.

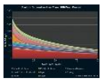
[44] Thomas E. Lovejoy and John Reid 19 April 2018. "How Big Forests Solve Global Problems." LINKS *NY Times*. Dr. Thomas Lovejoy, ecologist, George Mason University. Wikipedia; Google Scholar; Researchgate. John Reid is the founder and former president of Conservation Strategy Fund. Wikipedia; Biography; Website; Researchgate.

[45] Bob Yirka, Phys.org January 4, 2025 "Fuel aridity emerges as dominant driver of severity in recent Canadian wildfires." LINKS MAPS Phys.org News. From: Weiwei Wang, Faculty of Forestry, U of British Columbia, Vancouver & Canadian Forest Service. et al (+7 others), 2 Jan 2025

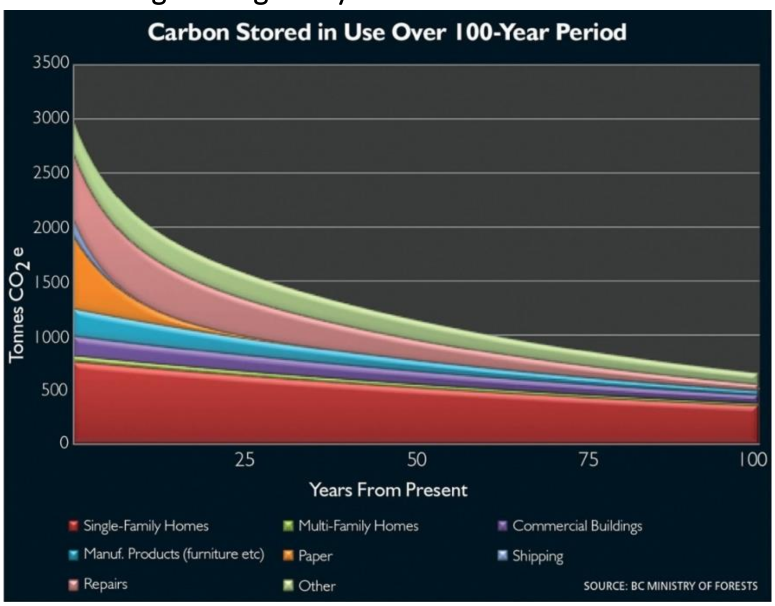
7. CARBON EMISSIONS FROM WOOD PRODUCTS AND BIOMASS BURNING.

7a. CO2 Emissions from Wood Products. Peter Wohlleben, author of Hidden Life of Trees, "the carbon these products contain would be released back into the atmosphere as carbon dioxide within a couple of decades."

Peter Wohlleben, author of Hidden Life of Trees: But back to the argument that long-lived wood products store carbon better than forests. Even if all wood were processed into durable products, the carbon these products contain would be released back into the atmosphere as carbon dioxide within a couple of decades. Professor Arno Frühwald at the University of Hamburg has pieced together how long wood products actually last. Cheap furniture lasts ten years, books do better at twenty-five years, and wood used in home construction (for example, in roof trusses) last for seventy-five years. The average for all wood product is thirty-three years, which is not particularly long for what is touted as long-term carbon storage. In an untouched forest, carbon dioxide would have been captured in the trees for centuries - and cut and processed wood no longer cools any landscapes, nor does it create more rain. {Woh143} [46]



7b. CO2 Emissions from Wood Products. David Broadland, Focus on Victoria, "After 28 years, half of the carbon in the wood products is no longer being safely stored."



Source: BC Ministry of Forests, through *Focus on Victoria*

David Broadland, Focus on Victoria: You might have heard that the carbon in the logs that are harvested and turned into finished wood products will be safely stored in those products indefinitely. But the Ministry of Forests' own research shows that after 28 years, half of the carbon in the wood products is no longer being safely stored; at 100 years, only 33 percent of the wood is still in safe storage. The rest will have returned to the atmosphere or is headed in that direction.

BC's Greenhouse Gas Inventory quantifies the magnitude of the currently acknowledged deterioration of wood products. For 2017 it noted that "Emissions from Decomposition of Harvested Wood Products" contributed 42 megatonnes annually to the provincial greenhouse gas inventory, which is close to our estimate of 44 megatonnes for 2018 (8). For ethical reasons, we ought to attribute all of those future emissions to the year in which the wood was harvested.

"Canadian forests are more conducive to high-severity fires in recent decades," *Science*. Vol 387, Issue 6729 pp. 91-97 (2025). And from: Jianbang Gan, Texas A&M U., Jan. 2, 2025. "Disentangling the drivers of wildfires," *Science*. 2 Jan 2025 Vol 387, Issue 6729 pp. 22-23. (2025). Weiwei Wang (Faculty of Forestry, U of British Columbia. Biography and Contact; Google Scholar; Researchgate. Dr. Gan Jianbang, Texas A&M U. Biography and Contact; Google Scholar; Researchgate.

[46] Peter Wohlleben 2021 German. 2023 English. "Is Wood as Eco-Friendly as We Think?" The Power of Trees – How Ancient Forests Can Save Us If We Let Them. Vancouver: David Suzuki Institute, *Greystone Books*: pp. 272. p. 142-143. Peter Wohlleben Author of The Hidden Life of Trees and The Power of Trees. (forest ranger, and lecturer at Forest Academy & Eberswalde University) Biography and contact; contact; Wikipedia; Intelligent Trees Trailer; Video. Professor Arno Frühwald at the University of Hamburg. Biography and Contact; Google Scholar; Researchgate. Earlier papers and lectures on line.

Note that the period of safe storage of carbon in wood products is much shorter than the expected life of most of the tree species that grow in coastal BC. A Sitka spruce is capable of attaining 700 years of age. Douglas fir commonly reach 600 to 800 years of age, and have been known to survive to 1000 years. Red cedar can reach even greater longevity. The Cheewat Lake Cedar near Clo-oose has been estimated to be as old as 2,500 years. [47]

7c. CO_2 Emissions, Nitrous Oxide, Carbon Monoxide, Particulate Matter, Sulfur Dioxide, and Volatile Organic Compounds Emissions from Biomass Burning. Dr. Mary S. Booth, "Biomass power plants are also a danger to the climate, emitting nearly 50 percent more CO_2 per megawatt generated than the next biggest carbon polluter, coal."

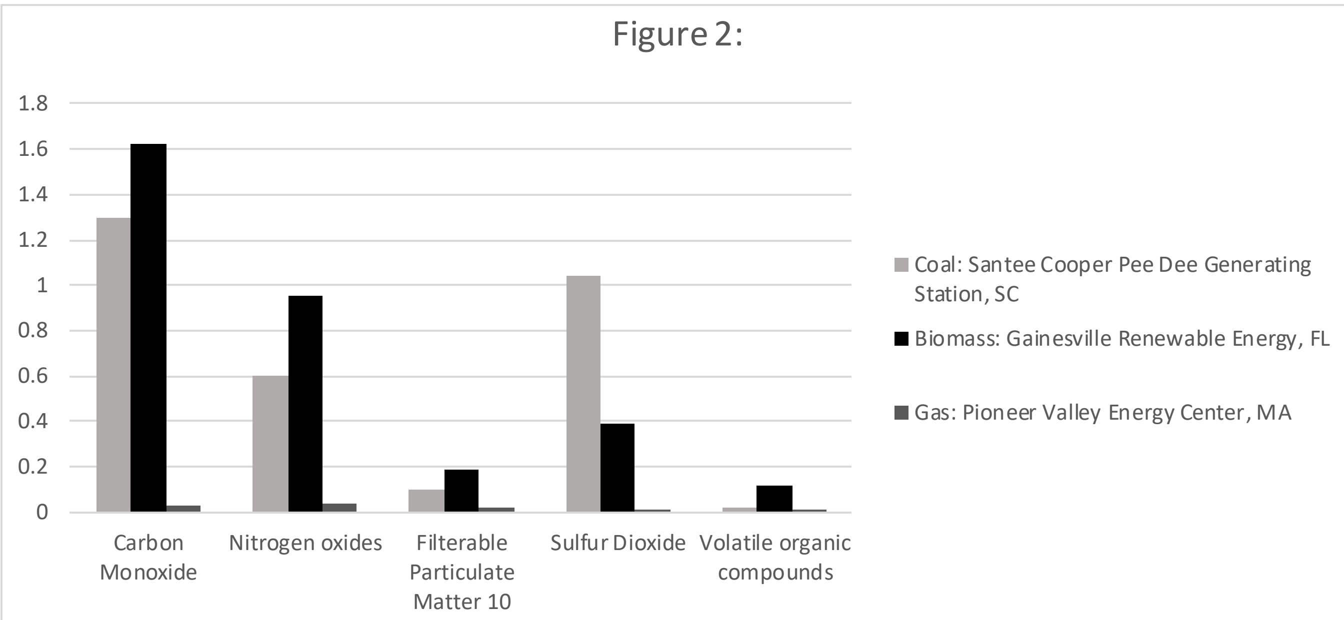


Figure 2:

Dr. Mary S. Booth, Partnership for Policy Integrity: In most states, biomass power is subsidized along with solar and wind as green, renewable energy, and biomass plant developers routinely tell host communities that biomass power is "clean energy." {Booth5}

But this first-ever detailed analysis of the bioenergy industry reveals that the rebooted industry is still a major polluter. [HOW] Comparison of permits from modern coal, biomass, and gas plants shows that even the " cleanest" biomass plants can emit > 150% the nitrogen oxides, > 600% the volatile organic compounds, > 190% the particulate matter [tiny particles which float through the air and cause various lung diseases and birth defects.], and > 125% the carbon monoxide of a coal plant per megawatt-hour, although coal produces more sulfur dioxide (SO_2). Emissions from a biomass plant exceed those from a natural gas plant by more than 800% for every major pollutant. {Booth5}

Biomass power plants are also a danger to the climate, emitting nearly 50 percent more CO_2 per megawatt generated than the next biggest carbon polluter, coal. {Booth5}

Hazardous air pollutants (HAPs) is the collective name for the group of 187+ compounds that EPA considers especially toxic in air. Although biomass energy is routinely presented as "clean," in fact, biomass burning emits large amounts of HAPs, also known as "air toxics" – including hydrochloric acid, dioxins, "organic" compounds such as benzene and formaldehyde, and heavy metals like arsenic, chromium, cadmium, lead, and mercury. Emissions of metals and other HAPs are likely to be highest when contaminated materials like construction and demolition debris are burned as fuel, but burning just unadulterated forest wood also emits toxic air pollutants. Some of these compounds are contained in the fuel itself while others are created during the combustion process. {Booth38}

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[47] David Broadland Jan. 6, 2020 "Defusing BC's big, bad carbon bomb." PICTURES GRAPH MAP *Focus on Victoria*. David Broadland Focus on Victoria Reporting, The Evergreen Alliance articles; Contact.

Burning biomass emits a wide variety of air toxics, but the HAP typically thought to be emitted in the greatest quantities is hydrochloric acid (HCL). Other HAPs emitted at relatively high rates include acrolein, acetaldehyde, styrene, benzene, and formaldehyde, which have various respiratory and carcinogenic effects. {Booth38-39} [48]

[There is lots in this section and throughout the book. Graph is on page 17.]

8. CARBON, NITROGEN, & PHOSPHORUS DEPLETION TO THE SOIL AFTER CLEARCUT.

8a. Carbon Depletion and Nitrogen & Phosphorus Depletion to the Soil after 16 Years. Dr. LeRoy Bandy and Barbara Bandy, after 16 years the "clearcut has 25% less organic matter in the soil than adjacent unharvested plots."

Dr. LeRoy Bandy and Barbara Bandy, U. of Maine - Orono: [16 YEARS] Research in Maine has shown that sixteen years after a whole-tree harvest, an area that was clearcut has 25% less organic matter in the soil than adjacent unharvested plots. The level of organic matter in the soil is important for nutrient cycling, water-holding ability, and other properties important for plant growth.

Data from the same research site has shown that whole-tree clearcutting has caused long-term disruptions in nitrogen cycling, and potential depletion of phosphorus.

In addition to nutrient loss, research at the Hubbard Brook Experimental Forest in New Hampshire showed that aluminum ions in levels toxic to fish and other aquatic organisms were released into stream waters draining clearcut sites.[49]

8b. Carbon Depletion to the Soil, after 30-40 Years, 35 Years, & over 80 Years. Carrie-Ellen Gabriel, St. Frances Xavier U., & Dalhousie U., "with the soil containing the lowest mineral carbon contents after 30-40 years."

Carrie-Ellen Gabriel, St. Frances Xavier U., Antigonish, NS & Dalhousie U., Halifax, NS: Soil micro-organisms, in their work as decomposers, use carbon compounds in the organic matter in soil for energy—the same process as higher life forms like us—and they breathe out carbon dioxide. In fact, soil respiration can tell us a lot about the activity of microbes below ground: When conditions for microbial life improve (abundant nutrition, adequate moisture, warm temperatures), decomposition and therefore soil respiration increases.

One study in a set of sites in the Abraham's Lake area in central Nova Scotia found that there was a 50 percent reduction in carbon storage following the clear-cutting of spruce forests, [30-40 YEARS] with the soil containing the lowest mineral carbon contents after 30-40 years. [35 YEARS] A second study in nearby Mooseland confirms this result, with a more modest 27 percent lower carbon storage at the 35-year-old site. Similar results have been obtained by research teams in New England and across Europe. *** In fact, there is now enough compelling global evidence to warrant a strong statement: intensive forest harvesting threatens soil carbon storage.

And it's not just a carbon story. Soil erodes into streams following intensive forestry practices, and nitrogen and mineral nutrients are leached through the groundwater in disturbed watersheds. [OVER 80 YEARS] Research is also showing that these losses continue for years following clear-cutting and requires a long time (over 80 years) for soil to recover. [50]

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[48] Dr. Mary S. Booth. 2 April 2014. *Trees, Trash, and Toxics: How Biomass Energy Has Become the New Coal* Pelham, Massachusetts: Partnership for Policy Integrity 81 pp. (PFPI driven by data) [See the whole PDF there.] From: Analysis of 88 air emissions permits for biomass plants in 25 states submitted to US Environmental Protection Agency (EPA). Dr. Mary S. Booth, Partnership for Policy Integrity, Pelham, Massachusetts. Biography; Contact; Researchgate. Green Voices Ep. 3 Youtube 28:13; Related - The Global Biomass Scam Youtube 11:11 [For a quick perusal of this report, jump to page 5 the executive summary, page 18 some graphs, and page 38 a summary of the medical consequences of biomass burning.]

[49] Dr. LeRoy Bandy and Barbara Bandy (Orono). 1999. "The Case against Intensive Forest Management in Maine." The Maine Woods. Winter 1999 – Volume 2 Number 2. Paragraphs 4 and 5. Forest Ecology Network. From R. A. Dahlgren & C. T. Driscoll. Jan. 1994. "The effects of whole-tree clearcutting on soil processes at the Hubbard Brook Experimental Forest, New Hampshire, USA." Plant and Soil 158: Issue 3 pp. 239-262. https://link.springer.com/article/10.1007/BF00009499 and from a local Maine study, presumably by the Bandys. Dr. Randy A. Dahlgren UC Davis. Biography and Contact; Google Scholar; Researchgate. Dr. Charles T. Driscoll Syracuse U. Biography and Contact; Google Scholar; Researchgate.

[50] Carrie-Ellen Gabriel 21 April 2016. "The Scoop on Soil: Carbon Storage Is Lost After Clear-Cutting." The Coast. Carrie-Ellen Gabriel (St. Frances Xavier U., Antigonish, Nova Scotia & Dalhousie U., Halifax, NS) PhD Thesis Dalhousie. Losses of Carbon Associated with Clear-Cut Harvesting. See its bibliography for further sources; Researchgate. Slide presentation: Carbon on the Move.

SECTION D. ATMOSPHERIC CO_2 COLLECTORS, FOREST PROTECTION & RESTORATION, AND THE EFFECTS TO THE WORLD's ATMOSPHERIC CARBON FROM FORESTRY.

9. ATMOSPHERIC CO_2 COLLECTORS AND FOREST PROTECTION & RESTORATION.

9a. CO_2 Collectors, Broadleaved Species Instead of Conifers. Matt McGrath, BBC Environment Journalist, "Researchers found that in Europe, trees grown since 1750 have actually increased global warming."

Matt McGrath, BBC Environment Journalist: The assumption that planting new forests helps limit climate change has been challenged by a new study. Researchers found that in Europe, trees grown since 1750 have actually increased global warming. The scientists believe that replacing broadleaved species with conifers is a key reason for the negative climate impact. Conifers like pines and spruce are generally darker and absorb more heat than species such as oak and birch.

In the distant past, these forests ran wild - but in the modern world, some 85% of Europe's trees are managed by humans. And over the past 150 years, foresters have adopted a scientific approach to woodlands - planting faster growing, more commercially valuable trees such as a Scots pine and Norway spruce.

Removing trees in an organized fashion tends to release carbon that would otherwise remain stored in forest litter, dead wood and soil.

Choosing conifers over broadleaved varieties also had significant impacts on the albedo - the amount of solar radiation reflected back into space.

"Even well managed forests today store less carbon than their natural counterparts in 1750," said Dr Kim Naudts who carried out the study while at the Laboratory of Climate Science and Environment in Gif-sur-Yvette, France.[51]

9b. CO_2 Collectors, Forests with Nitrogen-Fixing Capabilities. Cary Institute of Ecosystem Studies, [Such forests] "could double the amount of carbon a forest stores in its first 30 years of regrowth."

Dr. Sarah Batterman, Cary Inst. of Ecosystem Studies, "Our findings suggest that nitrogen-fixing trees are a key ingredient in the reforestation recipe." Speckled alder, *Alnus rugosa*, assisted by nitrogen-fixing *Frankia* bacteria in its roots, contributing nitrates to its ecosystem. NS

Cary Institute of Ecosystem Studies: The study modeled how the mix of tree species growing in a tropical forest following a disturbance, such as clearcutting, can affect the forest's ability to sequester carbon. The team found that the presence of trees that fix nitrogen could double the amount of carbon a forest stores in its first 30 years of regrowth. At maturity, forests with nitrogen fixation took up 10% more carbon than forests without.

[Dr. Sarah Batterman, Cary Inst. of Ecosystem Studies, Millbrook, New York] "Our findings suggest that nitrogen-fixing trees are a key ingredient in the reforestation recipe."

Nitrogen-fixing plants partner with soil microbes to turn atmospheric nitrogen gas into a form of nitrogen that is available to fuel plant growth. Through these interactions, nitrogen fixers are able to self-fertilize. This adaptation gives

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[51] Matt McGrath, BBC Science Journalist. 5 February 2016. "Wrong Type of Trees' In Europe Increased Global Warming." *BBC News*. Dr. Kim Naudts, U. of Amsterdam and Laboratory of Climate Science and Environment in Gif-sur-Yvette, France. Biography and Contact; Researchgate.

them an edge in recently cleared, early succession tropical soils that are nitrogen-poor. Fixers also help fertilize nearby plants when they shed their leaves and return nitrogen to the soil.

In the tropics, nitrogen-fixing trees are common, but they can be relatively rare in newly recovering forests. Their large, nutrient-packed seeds are often dispersed by wildlife. Having animal dispersed seeds is a disadvantage in the early stages of forest regrowth, when animals that once lived in the forest have not yet returned. Planting fixers as part of reforestation efforts could boost forest development and carbon accumulation. [52]

9c. CO_2 Collectors, Biodiversity. Dr. Lalasia Murphy, Swiss Federal Institute of Technology, "We also find that more diverse forests, which include a wider range of fast-growing, short-lived, and slow-growing, long-lived species, tend to sequester more carbon."

Dr. Adriane Esquivel-Muelbert, Brazilian researcher, U. of Birmingham, "Forests with diverse tree species can capture carbon more effectively." Maggie the-famous-hiker-dog, having a swim in Sandy Cope Lake, Earltown, Nova Scotia.

University of Birmingham: Forests with a greater diversity of trees are more productive—potentially leading to greater efficiency in capturing planet-warming carbon dioxide from the atmosphere, a new study reveals. Researchers found that trees that grow quickly, and capture carbon faster, tend to be smaller and have shorter lifespans, leading to lower carbon storage and faster release back into the atmosphere. Slower growing species live longer and grow larger, tending to capture more atmospheric carbon—particularly in the setting of more diverse forests.

[HOW] Analyzing 3.2 million measurements from 1,127 species of trees across the Americas—from southern Brazil to northern Canada—an international team of experts mapped life expectancies for trees ranging from 1.3 to 3,195 years.

[Dr. Adriane Esquivel-Muelbert, U. of Birmingham] "Tree growth and lifespan trade-offs are crucial for the planet's carbon balance. The positive relationship between trait diversity and productivity suggests that maintaining diverse forests is crucial for ecosystem health and climate change mitigation."

"Forests with diverse tree species can capture carbon more effectively, meaning that promoting forest biodiversity in forests can help capture more carbon. Understanding how these factors are linked can guide restoration and conservation projects."

"By selecting the right mix of tree species, we may be able to maximize carbon storage and develop strategies that enhance forest resilience to climate change."

[HOW] Experts used the largest dataset of dynamic tree information to date—calculating the mean life expectancy and maximal lifespan for a wide range of trees from Northern Canada to Southern Brazil.

[Dr. Lalasia Murphy, ETH Zurich,] "We also find that more diverse forests, which include a wider range of fast-growing, short-lived, and slow-growing, long-lived species, tend to sequester more carbon. These findings provide new insights that can be used to inform biodiversity conservation and climate change mitigation." [53]

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[52] Cary Institute of Ecosystem Studies 13 Feb. 2020. "Nitrogen-fixing trees help tropical forests grow faster and store more carbon" *Phys.Org News*. Based upon {Jennifer H. Levy-Varon (Princeton U.), Sarah A. Batterman, S.A. (Princeton U.), David Medvigy (U. of Notre Dame) (+4 others) 10 December 2019 Tropical carbon sink accelerated by symbiotic dinitrogen fixation. *Nature Communications*. **10,** 5637 (2019). Jennifer H. Levy-Varon, Princeton U. Biography and Contact; Google Scholar; Researchgate. Dr. Sarah A. Batterman, Princeton U. Biography and Contact; Google Scholar; Researchgate. Asso. Prof. David Medvigy U. of Notre Dame Biography and Contact; Google Scholar; Researchgate.

[53] University of Birmingham October 7, 2024 "Diverse forests better at capturing planet-warming carbon dioxide, study finds." *Phys.Org News*. From: Dr. Lalasia Bialic-Murphy (Swiss Federal Institute of Technology, in Zurich, Switzerland.) et al, (+117 others). "The pace of life for forest

 9d. CO_2 Collectors, Structurally Complex and Dense Forests. Dr. Chris Gough, Virginia Commonwealth U., "How a forest is put together matters for carbon sequestration."

Brian Mcneill, Virginia Commonwealth U., "Forests in the eastern United States that are structurally complex—meaning the arrangement of vegetation is highly varied— sequester more carbon, according to a new study."
There are five types of chlorophyll. They mix and change in relative quantity. See Chlorophyll biology 2 VIDEOS *Britannica*. Complex forest with evergreen wood fern, *Dryopteris intermedia*, in the shade, and hay scented fern, *Dennstaedtia punctilobula*, in the sun, Earltown Lakes Trail, NS.

Brian Mcneill, Virginia Commonwealth U.: Forests in the eastern United States that are structurally complex—meaning the arrangement of vegetation is highly varied—sequester more carbon, according to a new study led by researchers at Virginia Commonwealth University.

[Dr. Chris Gough, Dept. Biology, Virginia Commonwealth U.] "Our study shows that more complex forests are better at taking up and sequestering carbon in wood and, in doing so, they leave less carbon dioxide in the air."

Carbon sequestration in forests and wood helps offset sources of carbon dioxide to the atmosphere, such as deforestation, forest fires and fossil-fuel emissions, according to the Forest Service of the U.S. Department of Agriculture.

Why are structurally complex forests better at carbon sequestration? Gough suggests that multiple layers of leaves may optimize how efficiently light is used to power carbon sequestration in wood.

"In other words, forests that are structurally variable and contain multiple layers of leaves outperform structurally simple forests with a single concentrated band of vegetation," he said.

"These results, we hope, push the science forward by showing that how a forest is put together matters for carbon sequestration," Gough said. "And this relationship extends broadly to a number of different forests, from evergreen to deciduous and mid-Atlantic to Midwest."

While the researchers found that structural complexity outperformed species diversity measures as predictors of carbon sequestration, they noted that diversity is also important as one of many components that determine how structurally complex a forest is. [Dr. Gough:] "It takes tree diversity to produce a variety of leaf and plant shapes and, additionally, a critical quantity of leaves to supply the building blocks required to assemble a structurally complex forest capable of sequestering lots of carbon." [54]

trees." *Science*. 3 Oct 2024 Vol 386, Issue 6717 pp. 92-98. Dr. Lalasia Bialic-Murphy Biography and Contact; Google Scholar; Researchgate; The fascinating world of trees' life strategies. Oct 3 2024 Youtube 9:56. Dr. Adriane Esquivel-Muelbert, Brazilian researcher, U. of Birmingham. Biography and Contact; Google Scholar; Researchgate.

[54] Mcneill, Brian Virginia Commonwealth U. 12 August 2019. "Structurally complex forests better at carbon sequestration." LINKS *Phys.org News*. Based upon Christopher M. Gough (Virginia Commonwealth U.); Dr. Jeff Atkins, Dr. Robert T. Fahey, & Dr. Brady S. Hardiman. 9 Aug. 2019. "High Rates of Primary Production in Structurally Complex Forests." *Ecology*. Vol. 100 Issue 10 eo2864 (October 2019). Dr. Chris Gough, Dept. Biology, Virginia Commonwealth U. Biography and Contact; Google Scholar; Researchgate. Dr. Jeff Atkins, Virginia Commonwealth U., Biography and Contact; Google Scholar; Researchgate. Dr. Robert T. Fahey, U. Connecticut. Biography and Contact; Google Scholar; Researchgate. Dr. Brady S. Hardiman, Purdue U. Biography and Contact; Google Scholar; Researchgate.

 9e. CO_2 Collectors, Old Trees. Becky Olsen, Live Science, "Giant Surprise: Old Trees Grow Fastest."

Dr. Nathan Stephenson, U. S. Dept. of the Interior, "They [The older trees] never stop. Every year, they are always putting on more weight than before." The 38 researchers looked at more than 670,000 tropical and temperate trees, from 6 continents.
Older trees on Rogart Mountain Trail, Earltown NS

Becky Oskin, science reporter for *Live Science*, *Scientific American* and other media: The results of the survey of 403 tree species around the world suggest that trees never suffer the ill effects of old age. In animals, cells change and break down over a lifetime, eventually causing death. But trees seem free from this growth limit, called senescence. Instead, only disease, insects, fire or accidents such as lightning will kill a tree,

Stephenson [Dr. Nathan Stephenson, U. S. Dept. of the Interior] said. "They never stop," he said. "Every year, they are always putting on more weight than before."

Gathering forestry experts from six continents, Stephenson and his collaborators [37 others] tested whether trees really grow more slowly with age. They looked at more than 670,000 tropical and temperate trees, and found that for more than 90 percent of species, the trees kept growing throughout their entire lifespan, gaining weight as the years progressed. Each species grows at its own rate, but the biggest, oldest trees can swell their wood, bark and leaf mass by 1,300 lbs. (about 600 kilograms) in one year, the researchers report.

"I think one of the reasons [the idea that older trees grew more slowly] had such staying power is because it's what humans do," Stephenson said. "We [humans] start growing slowly, then reach adolescence and have a growth spurt, then slow down again," he [Dr. Stephenson] told *LiveScience*. But as the new findings show, "trees reach that adolescent growth spurt and never stop."

But on a tree-by-tree basis, ancient giants are much more effective at removing carbon dioxide from the atmosphere than young trees. "We realize now the big, old trees are the ones pulling carbon most rapidly out of the atmosphere," Stephenson said. "This maybe puts an exclamation point on the importance of maintaining big, old trees." [55]

[55] Becky Oskin. 15 Jan. 2014. "Giant Surprise: Old Trees Grow Fastest." *Live Science*. Based upon Stephenson, N. L. et al. (37 others) 15 Jan. 2014. "Rate of tree carbon accumulation increases continuously with tree size." *Nature* 507 90-93 (6 March 2014 web pub. 15 Jan. 2014) Also a pdf at Forest Forever.Org. Dr. Nathan Stephenson, U. S. Dept. of the Interior, U. S. Geological Survey, Three Rivers, California. Biography and Contact; Google Scholar; Researchgate.

 9f. CO_2 Collectors, Old Trees. Peter Wohlleben, author of Hidden Life of Trees, [Dr. Hans Pretzsch] "discovered that beeches and oaks don't slow down until they have surpassed the ripe old age of 450."

Peter Wohlleben, author of Hidden Life of Trees, "A large tree stores a whole lot more carbon in the form of wood along its 165-foot (50 meter) trunk than could be stored by many thin trees taking up a similar amount of space."
American beech, *Fagus grandifolia*, Rogart Mountain, Earltown, Nova Scotia

Peter Wohlleben, author, Forest Academy & Eberswalde University: Older trees take up larger amounts of greenhouse gases than younger ones, as you can see for yourself simply by looking at the growth rings after a tree has been cut down. Every year, as the tree increases in girth, it grows a new ring between its bark and its trunk. The width of these new rings doesn't decrease appreciably with age as the trunk steadily increases in diameter. As the trunk expands, the volume of the tree increases at the same rate. This cumulative growth pattern holds steady until long after the normal age at which a tree is harvested (which is when it is between 80 and 150 years old). Hans Pretzsch from the Technical University of Munich discovered that beeches and oaks don't slow down until they have surpassed the ripe old age of 450, and even then, the rate of growth slows down only gradually and not by much. {Woh139}

A large tree stores a whole lot more carbon in the form of wood along its 165-foot (50 meter) trunk than could be stored by many thin trees taking up a similar amount of space. But there are hardly any big trees left in the world's forests, not in Europe and not even in Canada. With continuous logging and replanting, the average age of a tree in Germany today is only 77 years. Our native trees can live 500 years or more. This means that before we get to the natural cycle of life and death the forest sector keeps talking about, we still have about 400 years in which the forest could continue to store greenhouse gases. Every time trees are felled before they reach old age, the process of carbon sequestration is interrupted – and not only that. Forests ravaged by timber harvests can no longer cool themselves as efficiently and create less rain, as we've seen from Pierre Ibisch's research. {Woh140} [56]

9g. CO_2 Collectors. The Largest Trees. Dr. Beverly Law, Oregon State Univ., "There is no action required from us but to leave these large trees standing so they can continue to store and accumulate carbon for climate mitigation and provide critical habitat."

Conservation Biology Institute: An earlier analysis found that large trees protected by the "21-inch rule" account for just 3% of total stems in the affected forests but hold 42% of the total aboveground carbon. Large-scale cutting of even some of the existing big trees would eliminate these carbon stores while releasing vast amounts of carbon dioxide to the atmosphere when we need to have greater sequestration by natural systems to stabilize Earth's climate.

"These are public lands that are providing a natural climate solution and performing multiple additional services at no cost. We suggest policy to keep existing forest carbon stores out of the atmosphere and accumulate additional amounts while protecting habitat and biodiversity." said David Mildrexler, lead author of the study [Dr. David Mildrexler, Eastern Oregon Legacy Lands]

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[56] Peter Wohlleben 2021 German. 2023 English. The Power of Trees – How Ancient Forests Can Save Us If We Let Them. Vancouver: David Suzuki Institute, *Greystone Books*: pp. 272. p.139, 140. Peter Wohlleben, forest ranger, and lecturer at Forest Academy & Eberswalde University. Biography and contact; contact; Wikipedia; Intelligent Trees Trailer; Video. Dr. Hans Pretzsch, Technical University of Munich. Biography and Contact; Google Scholar; Researchgate. Dr. Pierre Ibisch, Eberswalde University for Sustainable Development. Biography; Google Scholar; Researchgate.

"There is no action required from us but to leave these large trees standing so they can continue to store and accumulate carbon for climate mitigation and provide critical habitat," said co-author Bev Law [Dr. Beverly Law, Oregon State U]. [57]

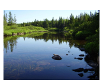
9h. CO_2 Collectors, Large City Trees. TD Economics, "As a general rule of thumb, we can say bigger is better."

Table 3 - Air effects of average tree in Toronto by size			
Diameter of tree	Carbon stored (kg)	Carbon sequestered (kg/yr)	Pollutants removed (kg/yr)
0cm - 15cm	9	1	0.1
15cm - 30cm	89	6	0.3
30cm - 45 cm	283	12	0.5
45cm - 60 cm	655	19	0.7
60cm - 75cm	1176	29	1.0
> 75 cm	2709	52	1.8
Source: United States Department of Agriculture, TD Economics.			

"Large, healthy trees absorb up to 10 times more air pollutants, 90 times more carbon, and contribute up to 100 times more leaf area to our urban forest canopy relative to smaller trees." TD Economics. June 9, 2014 page 3 Special report TD Economics.

Debbie Huron, "The cost savings produced by our urban forests make it clear that keeping the green on our streets, keeps the green in our wallets," are the report's final words. They are fitting, considering the source.

"As a general rule of thumb, we can say bigger is better," the report states. "Large, healthy trees absorb up to 10 times more air pollutants, 90 times more carbon, and contribute up to 100 times more leaf area to our urban forest canopy relative to smaller trees." The numbers in the table show that a tree between 45 and 60 cm in diameter (which is the minimum size to fit the definition of a distinctive tree under Ottawa's Urban Tree Conservation By-law) is storing TWICE as much carbon as trees one rung down on the ladder. Trees larger than 75 cm in diameter are storing NINE times as much carbon as those that measure a measly 44 cm or less." [58]



91. CO_2 Collectors, Protecting and Restoring Forests, the Paris Agreement. Chris Mooney, journalist and 2020 Pulitzer Prize winner, "Moreover, stopping deforestation could buy precious time to ratchet down fossil fuel emissions."

[57] Conservation Biology Institute April 24, 2023 "Protecting big trees for wildlife also benefits climate, says study." *Phys.Org News*. From: David J. Mildrexler (Eastern Oregon Legacy Lands), Logan T. Berner (EcoSpatial Services, Juneau, Alaska), Beverly E. Law (Oregon State U.), Richard A. Birdsey (Woodwell Climate Research Center, Falmouth, Mass.), William R. Moomaw (Woodwell Climate Research Center, Falmouth, Mass.) 22 April 2023 "Protect large trees for climate mitigation, biodiversity, and forest resilience." *Conservation Science and Practice* Vol. 5 Issue 7 July 2023 e12944 https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.12944 DOI: 10.1111/csp2.12944 . Dr. David Mildrexler, Eastern Oregon Legacy Lands, Wallowology. Biography and Contact; Researchgate; The Future of Eastern Oregon Forests Youtube 1:29:35. Dr. Beverly Law, Oregon State University. Biography and contact; Wikipedia; Google Scholar; Researchgate. Forests and Climate Change Mitigation and Adaptation, Youtube Video 8:35

[58] Debra Huron, 10 June 2014. "Toronto's trees worth $7 billion; what about Ottawa's?" NICE CHART *Champlain Oaks*. Based upon Craig Alexander and Connor McDonald, TD Economics. 9 June 2014. "Urban Forests: The Value of Trees in the City of Toronto." *Toronto Dominion report*. See also. [There were many articles on the TD report including CBC, Toronto Environment Alliance; City of Toronto; Globe and Mail; the Toronto Star; and Green Communities.

Dr. Naoko Ishii, Univ. of Tokyo, "Without taking care of the forests, it's going to be just impossible to achieve the Paris agreement."
Forests on the sides of Salmon River, Gully Lake Trail, Kemptown, NS

Chris Mooney, science and environment reporter, author, and 2020 Pulitzer Prize winner: Of all the components of the recent Paris accord on climate change, the one that probably got the least attention but could have the most immediate potential involves the world's forests. In a section some hailed as historic, the document endorsed a United Nations mechanism for wealthier nations to pay developing countries like Brazil for reducing deforestation.

Trees are good at keeping carbon out of the air, and simply preserving the planet's vast forests is a straightforward way to get a huge head start on the business of slowing climate change. But that effort grows tougher every day. After years of progress, deforestation rates have increased recently in Brazil, and deforestation continues apace across much of the global tropics. The economic forces of agriculture and trade remain too strong to resist.

[Dr. Naoko Ishii, U. of Tokyo, CEO of the Global Environment Facility, Washington D.C.,] "Without taking care of the forests, it's going to be just impossible to achieve the Paris agreement."

"In fact, recent estimates suggest as much as a third of climate emissions could be offset by stopping deforestation and restoring forest land — and that this solution could be achieved much faster than cuts to fossil fuels."

Moreover, stopping deforestation could buy precious time to ratchet down fossil fuel emissions. "It's very hard to suddenly convert everyone to electric cars, and power generation is gradually changing, but it's going to take decades." said Paul Salaman, CEO of the Rainforest Trust. "But tropical deforestation can literally be stopped point blank with commitment of countries." [59]

9j. CO_2 Collectors, Protecting and Restoring Forests. Dr. Beverly Law, Oregon State U. and Dr. William Moomaw, Tufts U, "Allowing mature forests to keep growing could enable forests to take up twice as much carbon."

Beverly Law (Oregon State U.) and William Moomaw (Tufts U.), *The Conversation*: "Yet although tree-planting initiatives are popular, protecting and restoring existing forests rarely attracts the same level of support. In our work as forest carbon cycle and climate change scientists, we track carbon emissions from forests to wood products and all the way to landfills—and from forest fires. Our research shows that protecting carbon in forests is essential for meeting global climate goals.

Forests pull about one-third of all human-caused carbon dioxide emissions from the atmosphere each year. Researchers have calculated that ending deforestation and allowing mature forests to keep growing could enable forests to take up twice as much carbon. [60]

9k. CO_2 Collectors, Protecting and Restoring Forests. Joe Rankin, "Well, our changing planet can use the help."

Joe Rankin, author on forestry and nature: Now, a new book makes the point that, not only should we value the old-growth forests we have, and make sure we keep them around, but that we ought to protect tracts that aren't protected

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[59] Chris Mooney, Pulitzer Prize winner, science and environment reporter and author. 11 Feb. 2016 "The Solution to Climate Change That Has Nothing to Do With Cars or Coal." (VIDEO 1:48) *Washington Post*. Chris Mooney, 2020 Pulitzer Prize winner, science and environment reporter and author. Biography and recent articles. Dr. Naoko Ishii, Univ. of Tokyo. Biography and contact; Researchgate; Forward to Globe Forest Legislation, within GFLI Study. Dr. Paul Salaman Wikipedia; Biography and contact; Researchgate.

[60] Dr. Beverly Law (Oregon State U.) and Dr. William Moomaw (Tufts U.) The Conversation April 7, 2021 "Curb climate change the easy way: Don't cut down big trees." VIDEO 4:47 *Phys.Org News*. Dr. Beverly Law, Oregon State University Biography and contact Wikipedia Google Scholar Researchgate; Dr. William Moomaw, Tufts University and elsewhere, Boston Wikipedia Researchgate

already and put new knowledge of how old-growth ecosystems work to use re-creating old forests because, well, our changing planet can use the help.

"But there are also ways that, if we do management right, we can have more old-growth in 50 or 100 years," said Barton [Prof. Andrew M. Barton, U. Maine – Farmington]. "It's important because if you look at how much biomass is in old-growth forests, half of that is carbon. That forest is keeping carbon out of the atmosphere."

"Once scientists believed that a forest's carbon-sequestration potential had been pretty much used up by the time it reached the old-growth stage, but that has been disproven," said Barton. "Bill's (William Keeton) chapter shows that forests continue to keep up net carbon intake over time."

When first propounded several years ago, "that was a blockbuster idea," Barton said. "The other thing that is so important about these forests is that they are going to provide refugia for animals that are vulnerable to climate change." But "the challenge now is that there is not an uninterrupted landscape over which they can migrate."

Continuing that discussion, Keeton and three colleagues say that, using forestry techniques to accelerate the re-creation of old-growth forests from previously harvested ones, is possible. And given the characteristics of old-growth forests — prime wildlife habitat, clean water, carbon sequestration — that they provide, worth the effort.

Barton said another lesson that comes across in the book is that we just can't bring back old trees, we have to bring back the other elements of the forests, from the fungi to the invertebrates to the insects and microbes. And that's a lot of ecosystems.

Because when it comes to restoring the old-growth forested landscape science isn't enough, Barton acknowledges — there has to be a political will to do it. [61]

9l. CO_2 Collectors, Restoration versus Biomass Energy or Heat. Prof. Tom Crowther, ETH-Zurich University, Switzerland, "This new quantitative evaluation shows restoration isn't just one of our climate change solutions, it is overwhelmingly the top one." "What blows my mind is the scale."

Paul Schneidereit, PNI Atlantic: A groundbreaking scientific study released earlier this week showed the unparalleled power of the world's trees to quickly and cheaply limit climate change. The new report from scientists at ETH-Zurich University in Switzerland looked at where, and how many, more trees could be grown worldwide. Crucially, the study also highlighted how much of an unexpectedly large effect those trees could have on reducing greenhouse gas emissions.

[Prof. Tom Crowther, ETH-Zurich University, Switzerland,] "This new quantitative evaluation shows restoration isn't just one of our climate change solutions, it is overwhelmingly the top one." "What blows my mind is the scale. I thought restoration would be in the top 10, but it is overwhelmingly more powerful than all of the other climate change solutions proposed." Crowther said stopping current forest destruction is also vital. Even though young, growing trees do capture and lock in carbon, mature forests have a greater capacity to do so.


Paul Schneidereit, PNI Atlantic, "In light of the climate change crisis, and now what's even more definitively known about the vital importance of preserving forest cover, how does it make sense for the province to be allowing, in fact encouraging, biomass energy?"
Northern Fibre Terminal, Sheet Harbour, Nova Scotia. Where biomass is put on ships to be sent overseas for biomass energy.

[61] Joe Rankin. 29 January 2019. "Old-Growth Forests: Back to the Future?" *Maine Tree Foundation* Based upon Prof. Andrew M. Barton (U. Maine) & Prof. William S. Keaton (U. Vermont). *Ecology and Recovery of Eastern Old-Growth Forest* Washington D. C.: Island Press 2018. Pp. 360. $80.00. Joe Rankin writes on forestry, nature and sustainability for websites and magazines. He lives in New Sharon, Maine. Dr. Andrew M. Barton, U. Maine – Farmington. Biography and Contact; Google Scholar; Researchgate. Dr. William S. Keeton, U. Vermont. Biography and Contact; Google Scholar; Researchgate. At The Ilsley: "Carbon Friendly Forest" Youtube 1:23:56 *MCTVermont.*

Which brings us to Nova Scotia's current wrongheaded policy of allowing a growing amount of biomass — meaning the trees in our forests — to be cut down and burned, or exported to be burned, for energy. In light of the climate change crisis, and now what's even more definitively known about the vital importance of preserving forest cover, how does it make sense for the province to be allowing, in fact encouraging, biomass energy?

And that doesn't take into account that Nova Scotia forest biomass is also exported to Europe to burn for energy. Or that this government is now pushing to convert large rural buildings, such as hospitals and schools, to burn wood for heat.[62]

9m. CO_2 Collectors, Protecting and Restoring Forest. Dr. Euan Ritchie, Deakin University, Australia, *** "Ecosystems have developed over millions of years, and to think we humans can replace their vital functions with technofixes etc. is arrogant, foolish, and dangerous."

Tessa Koumoundouros, journalist and editorial assistant at *ScienceAlert*: Restoring forests, marshes, peatlands, seaweed and other ecosystems has a massive potential to take back some of that carbon dioxide we've spewed into our precious atmosphere. In 2017, a PNAS study estimated that natural carbon solutions (essentially ecosystem regeneration) have the potential to provide up to 37 percent of the CO_2 mitigation that we'd need through 2030, for a 66 percent chance of holding warming to below 2°C.

"Much of Earth's ecosystems are now substantially modified or degraded, but with care and increased investment there is huge potential to reap benefits for humans and other species," ecologist Euan Ritchie from Deakin University told *ScienceAlert*.

Of course, how we do this matters as well. Merely plonking trees down, plantation style, is not going to cut it if the goal is to permanently improve our situation.

"Ecosystems are a bit like engines, all the various components relate to each other in some way. Take one part out and things can go awry." explained Ritchie. "Conserving a diversity of species (parts) leads to healthier and better functioning ecosystems."

As Ritchie points out, healthy ecosystems also offer a lot of other value to us and the incredible array of species we share our planet with. These include water filtration, flood buffering, healthy soils, and enhanced resilience to climate change, among other things. Their ability to store so much CO_2 is only one of many reasons it's vital to preserve all our remaining functioning ecosystems. Yet even wealthy countries like Australia are failing dismally at doing this.

[Dr. Euan Ritchie] "Ecosystems have developed over millions of years, and to think we humans can replace their vital functions with technofixes etc. is arrogant, foolish, and dangerous." [63]

10. ATMOSPHERIC METHANE CH_4 & NITROUS OXIDE N_2O COLLECTORS.

10a. Methane Collectors in Tree Bark. Many tree species' bark is also host to *methanotrophs.*

"Yet there seems to be a third important and previously unquantified methane sink at play: trees.
The bark on many tree species is also host to *methanotrophs*, per the new study."
Measuring gas exchange in Amazon upland forest. Credit: Vincent Gauci, U. of Birmingham

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[62] Paul Schneidereit, PNI Atlantic. 5 July 2019. "EDITORIAL: Senseless biomassacre." (*Halifax*) *Saltwire*. Based upon Crowther Lab at ETH Zurich. 4 July 2019. "How trees could save the climate." *ETH Zurich University*. Prof. Tom Crowther Biography and Contact; For the Protection and Restoration of Nature Youtube 16:14; Google Scholar; Researchgate. Paul Schneidereit, Canadian Association of Journalists. Biography and contact; Articles.

[63] Tessa Koumoundouros (Journalist and editorial assistant at ScienceAlert) 19 SEP 2019. "There Is One Safe Geoengineering Option Guaranteed to Reduce CO_2 in Our Atmosphere." MANY LINKS *Science Alert*. Dr. Euan Ritchie, Deakin U., Australia; Biography and Contact; Google Scholar; Researchgate. Trisha Atwood, ecologist, Utah State U. Google Scholar

Lauren Leffer, *Popular Science*: Trees are a key component of a healthy planet. Through photosynthesis, trees take in atmospheric carbon dioxide and release the oxygen we need to breathe. Earth's forests hold an estimated 861 gigatons of carbon, which is about equivalent to 100 years of anthropogenic fossil fuel emissions. Keeping trees intact ensures all that carbon stays stored and supporting careful reforestation efforts ensures additional carbon gets locked away.

Methane, a less-frequently discussed type of carbon emissions, is a major driver of human-caused climate change, released through industries like agriculture and natural gas extraction. Over a century, one ton of atmospheric CH_4 is about 28 to 36 times as warming as carbon dioxide. Though methane is much less abundant in the atmosphere than CO_2, the potent greenhouse gas is responsible for about 20 to 30 percent of global temperature increases since the industrial revolution, according to NASA estimates.

It's long been understood that there are two primary ways methane disappears. Over a decade or so, methane molecules break down into carbon dioxide and water in the atmosphere. This is the biggest methane sink, or source of loss, in Earth's carbon cycle. The planet's soils represent the second largest known sink. Below ground, so-called *methanotrophs* (single-celled organisms that rely on methane for energy) metabolize the gas.

Yet there seems to be a third important and previously unquantified methane sink at play: trees. The bark on many tree species is also host to *methanotrophs*, per the new study. Added altogether, the researchers calculate that microbes inhabiting all the tree surface area worldwide are absorbing and eliminating between 24.6 and 49.9 teragrams (about 29 to 55 million tons) of the greenhouse gas each year. That puts the estimated impact of trees on par with the soil sink. [64]

11. WORLD CARBON DIOXIDE EMISSIONS FROM DEFORESTATION.

11a. CO_2 Emissions from Oregon Deforestation. "The wood products sector generated about one and a half times more emissions than the transportation or energy sector emissions reported by the Oregon Global Warming Commission."

"Oregon State University and University of Idaho researchers found that the wood products industry is the largest sector contributing to carbon pollution in the state." Northern Oregon Coast Range on the border of Washington and Yamhill counties. Credit M. O. Stevens, Wikimedia.

Carl Segerstrom, High Country News: Because of the human health impacts of smoke, the conversation about pollution and forests is typically centered on fires. But the study Law and her colleagues put together earlier this year found that wildfire is not the biggest source of climate-warming carbon dioxide in Oregon forests — logging and wood products are.

The conversation about carbon pollution often centers on emissions from automobile tailpipes and burning coal, but plants that absorb carbon from the atmosphere are also an important part of the equation. According to the study, Oregon's ecosystems were able to soak in more than 70 percent of the carbon emissions in the state between 2011 and 2015.

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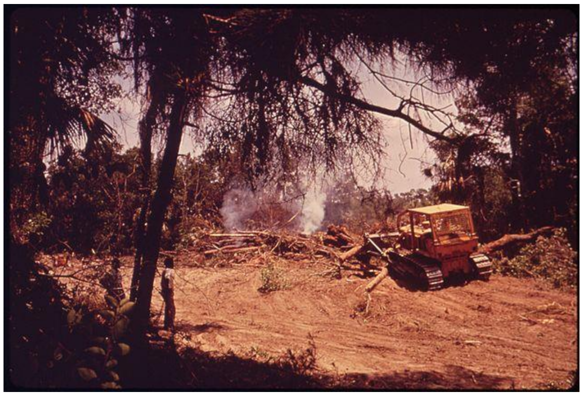
[64] Lauren Leffer Jul 24, 2024 "Tree bark demonstrates an unexpected climate superpower." TOOL SHOWN *Popular Science*. See also University of Birmingham July 24, 2024 "Trees reveal climate surprise: Microbes living in bark remove methane from the atmosphere." *Phys.Org News*. From: Dr. Vincent Gauci (U. of Birmingham) et al. (+14 others) 24 July 2024 "Global atmospheric methane uptake by upland tree woody surface" *Nature*. 631 pp. 796-800. Dr. Vincent Gauci U. of Birmingham Biography and Contact; Google Scholar; Researchgate.

While Oregon forests absorb a lot of carbon, the team of Oregon State University and University of Idaho researchers found that the wood products industry is the largest sector contributing to carbon pollution in the state and "that in a relative sense, fires are small for carbon loss," Law [Dr. Beverly Law, Oregon State U.] says. The wood products sector generated about one and a half times more emissions than the transportation or energy sector emissions reported by the Oregon Global Warming Commission. Wood product emissions are the result of fuel burned by logging equipment, the hauling of timber, milling, wood burned during forestry activities, and the ongoing decomposition of trees after they are cut. Forest fire emissions were less than a quarter of all forest sector emissions in each of the five-year increments studied between 2001 and 2015. [65]

 11b. CO_2 Emissions from North Carolina Deforestation. Dr. John Talberth, "The accounting rules were written by loggers for loggers. That's why you hear of agriculture as a big source of emissions, but not logging and wood products."



Michael Le Page, New Scientist, "The wood industry is a massive source of uncounted carbon emissions, according to a pioneering study in North Carolina. The same is probably true globally." John's Island, North Carolina. Credit Paul Conklin Wikimedia Commons

Michael Le Page, New Scientist Reporter: The wood industry is a massive source of uncounted carbon emissions, according to a pioneering study in North Carolina. The same is probably true globally. In places where trees are replanted after being cut down, the wood industry is often promoted as being sustainable. But no one is counting all the carbon emissions associated with logging because international rules on how this should be done are wildly inadequate, says economist John Talberth at the Center for Sustainable Economy, an environmental think-tank based in Oregon, US

"The accounting rules were written by loggers for loggers," he says. "That's why you hear of agriculture as a big source of emissions, but not logging and wood products."

[HOW] Each year 80,000 hectares of trees in North Carolina are cut down to produce wood pellets that are then burnt in power plants in the UK, as well as for paper and timber. The state does not count the resulting emissions. But Talberth has calculated them based on data from the US Department of Agriculture's Forest Inventory and Analysis Program. His life-cycle analysis takes account of factors such as the carbon released as the roots of cut trees rot in the ground and the fertiliser, herbicides and pesticides applied to tree plantations. The conclusion: logging in North Carolina emits 44 million tonnes of carbon dioxide a year.

The good news is that Talberth's study also showed that if land owners adopted "climate smart" practices, forests in North Carolina could soak up 3 gigatonnes of CO_2 over two or three decades. That would cancel out 20 years of the state's carbon emissions. The main such practice would be to cut trees every 60 or 90 years rather than every 30 years or less. Those cuts should be done in small patches rather than clearcutting vast areas and foresters should grow a mix of

[65] Carl Segerstrom May 16, 2018. "Timber is Oregon's biggest carbon polluter." PIE GRAPH *High Country News*. From: Beverly E. Law, Tara W. Hudiburg (U. of Idaho, Moscow), Logan T. Berner, Jeffery J. Kent (U. of Idaho, Moscow), Polly C. Buotte (Oregon State U., Corvallis), and Mark E. Harmon (Oregon State U, Corvallis) March 19, 2018 "Land use strategies to mitigate climate change in carbon dense temperate forests." PNAS 115 (14) 3663-3668. Dr. Beverly Law, Oregon State U. Biography and contact Wikipedia, Phys.Org, Trellis; Google Scholar, Researchgate. Dr. Tara W. Hudiburg, U. of Idaho. Biography and Contact; Google Scholar; Wikipedia; Researchgate. Dr. Logan T. Berner, Northern Arizona U. Biography and Contact; Google Scholar; Researchgate. Dr. Jeffrey J. Kent, U. of Idaho, Moscow > Indigo. Researchgate. Polly C. Buotte, Oregon State U.; Corvallis > UC Berkeley. Biography and Contact; Researchgate. Dr. Mark E. Harmon, Oregon State U, Corvallis. Biography and Contact; Researchgate.

native species rather than monocultures of alien species. Such forests would store more carbon and support more wildlife.[66]

11c. CO_2 Emissions from Various Studies throughout United States. Dr. Beverly Law (Oregon State U.) and Dr. William Moomaw (Tufts U.), "A 2016 study found that nationwide, between 2006 and 2010, total carbon emissions from logging were comparable to emissions from all U.S. coal plants, or to direct emissions from the entire building sector."

Dr. Beverly Law (Oregon State U.) and Dr. William Moomaw (Tufts U.) in *The Conversation*: Mature and old-growth forests, with larger trees than younger forests, play an outsized role in accumulating carbon and keeping it out of the atmosphere. These forests are especially resistant to wildfires and other natural disturbances as the climate warms.

Remarkably, however, logging is hardly considered in the Forest Service's initial analysis, although studies show that it causes greater carbon losses than wildfires and pest infestations. In one analysis across 11 western U.S. states, researchers calculated total above ground tree carbon loss from logging, beetle infestations and fire between 2003 and 2012 and found that logging accounted for half of it. Across the states of California, Oregon and Washington, harvest-related carbon emissions between 2001 and 2016 averaged five times the emissions from wildfires. A 2016 study found that nationwide, between 2006 and 2010, total carbon emissions from logging were comparable to emissions from all U.S. coal plants, or to direct emissions from the entire building sector. [67]

11d. CO_2 Emissions from Canada Wide Deforestation. Dr. Jennifer Skene, "The government has simply chosen to look away."

The report concluded that logging is Canada's third-highest-emitting sector (147 Mt CO2 in 2022), behind oil and gas (217 Mt CO2) and transportation (156 Mt CO2). Highway 224, Marinetta, Halifax Co. NS

Michael Polanyi, Nature Canada, Jennifer Skene, Natural Resources Defense Council, Alice-Anne Simard, Nature Québec: The report, released by Nature Canada, Nature Québec and NRDC (Natural Resources Defense Council), found that the logging industry in Canada emitted almost 150 million tonnes (Mt) of carbon dioxide (CO2) in 2022, more than 20% of Canada's total reported emissions.

"This study dismantles the industry and government narrative that the current scale of clear-cut logging is sustainable," said Michael Polanyi of Nature Canada. "Federal and provincial governments must take immediate action to reduce the logging sector's significant carbon footprint and ensure genuinely sustainable practices."

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[66] Le Page, Michael, New Scientist Reporter 10 September 2019. "Logging study reveals huge hidden emissions of the forestry industry." LINKS *New Scientist*. See also Emily Green 18 Oct. 2019 Street Roots. Dr. John Talberth, Center for Sustainable Economy, Port Townsend, WA. Biography and Contact; Researchgate.

[67] Dr. Beverly Law (Oregon State U.) and Dr. William Moomaw (Tufts U.), *The Conversation* January 20, 2024 "Old forests critically important for slowing climate change, merit immediate protection from logging." MANY LINKS *Phys.org News*. See also Resilience.Org. Dr. Beverly Law Oregon State University Biography and contact; Wikipedia; Google Scholar; Researchgate. Dr. William Moomaw Tufts University, Boston, Wellwood Climate Research Center, & Fletcher School of Law and Diplomacy. Biography and contact; Wikipedia; Researchgate .

The report concluded that logging is Canada's third-highest-emitting sector (147 Mt CO2 in 2022), behind oil and gas (217 Mt CO2) and transportation (156 Mt CO2). [HOW] Logging emissions were calculated from government data in Canada's 2024 National Inventory Report (NIR) using the methodology from a 2024 peer-reviewed article.

Scientists, policymakers, the Commissioner of the Environment and Sustainable Development, and most recently, a United Nations expert review panel, have raised concerns that the way in which Canada reports logging emissions in its NIR is not transparent.

"The logging industry's climate impact is right there in the numbers; the government has simply chosen to look away," said Jennifer Skene of NRDC. "This disavowal of reality doesn't change the fact that much of the logging in Canada is out of alignment with climate-safe practices and, increasingly, out of alignment with marketplace expectations for sustainability." [68] [69]

 11e. CO_2 Emissions from British Columbia Deforestation. Sean Boynton, Global News, "Those [the clearcut] areas are considered 'sequestration dead zones.'"

"That means until newly-planted trees grow and mature, the areas release more carbon into the atmosphere from decomposing matter and soil than those young trees can capture and absorb."
Gordon River Clearcut. Credit T. J. Watt Wikimedia Commons

Sean Boynton, Global News: While B.C. aims to drastically cut fossil fuel emissions, a new report from an environmental action group says the province should end an even more dangerous contributor to climate change: clearcutting forests. The report released last week by Sierra Club BC found 3.6 million hectares of forest were clearcut across B.C. between 2005 and 2017 — an area larger than the size of Vancouver Island. Those areas are considered "sequestration dead zones" for 13 years after they're clearcut. That means until newly-planted trees grow and mature, the areas release more carbon into the atmosphere from decomposing matter and soil than those young trees can capture and absorb.

[HOW] After reviewing provincial data, the report found logging in B.C. contributes 42 million tonnes of carbon emissions into the atmosphere. Add on the 26 million tonnes of carbon per year that cannot be captured because of clearcutting, and those emissions outpace the 65 million tonnes of emissions recorded annually in B.C., mainly from fossil fuels.

"At a time when we urgently need to be reducing all forms of carbon pollution to defend our communities from the climate crisis, clearcut logging in B.C. is making the problem notably worse," the study's author and Sierra Club BC's senior forest and climate campaigner Jens Wieting said in a statement.

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[68] Michael Polanyi, Nature Canada, Jennifer Skene, Natural Resources Defense Council, Alice-Anne Simard, Nature Québec Sept. 4, 2024 "Logging Emerges as Canada's Third Largest Climate Polluter." LINKS *Nature Canada*. See also Inayat Singh, Benjamin Shingler *CBC News* Sep 04, 2024 "Logging is the 3rd highest emitter in Canada. It should be measured that way, a new report says." *CBC News*. Originally from: Jennifer Skene, Natural Resources Defense Council and Michael Polanyi, Nature Canada. October 2022 "Lost in the Woods: Canada's Hidden Logging Emissions are Equivalent to Those from Oil Sands Operations." *Natural Resources Defense Council* (NRDC) *Nature Canada*. In turn from Matthew Bramley and Graham Saul Oct. 2022 "What are the Net GHG Emissions from Logging Canada?" *Nature Canada*. Dr. Jennifer Skene Natural Resources Defense Council. Biography and Contact. Dr. Michael Polanyi, Nature Canada. Biography and Contact. See also Logging's climate threat: Emissions now rival transportation. National Observer Sept. 25 2024.

[69] The comment, by David Broadland (Author of Defusing BC's big, bad carbon bomb and other such articles) at the end is quite noteworthy. "In BC, biogenic carbon emissions prematurely emitted to the atmosphere by logging don't even count in the government's assessment of provincial GHG emissions." "Worse, only about half of logging-related biogenic emissions are even recorded—those related to decomposition of forest products, as well as an estimate of emissions from slash pile burning. But much of the organic material killed by logging does not make it into the government's calculations." [This report was alluded to on CBC news report on Wed., Sept. 4, 2024.]

"We can only have a stable climate if we protect intact forests, and we can only sustain intact forests if we stabilize the climate. Both are only possible if we reform forestry and give up clearcutting." [70]

11f. CO_2 Emissions from Amazon Deforestation. Gabriel Gatehouse, BBC News, "Up to one fifth of the Amazon rainforest is emitting more CO_2 than it absorbs, new research suggests." "One of the main causes is deforestation."

Gabriel Gatehouse, BBC News: Up to one fifth of the Amazon rainforest is emitting more CO_2 than it absorbs, new research suggests. Results from a decade-long study of greenhouse gases over the Amazon basin appear to show around 20% of the total area has become a net source of carbon dioxide in the atmosphere.

One of the main causes is deforestation. While trees are growing, they absorb carbon dioxide from the atmosphere; dead trees release it again. Millions of trees have been lost to logging and fires in recent years.

The results of the study, which have not yet been published, have implications for the effort to combat climate change. They suggest that the Amazon rainforest - a vital carbon store, or "sink", that slows the pace of global warming - may be turning into a carbon source faster than previously thought.

[HOW In the video at 3:40 Prof. Luciana Gatti, Brazilian National Institute for Space Research is shown here doing her airplane research] Every two weeks for the past 10 years, a team of scientists has been measuring greenhouse gases by flying aircraft fitted with sensors over different parts of the Amazon basin. What the group found was startling: while most of the rainforest still retains its ability to absorb large quantities of carbon dioxide - especially in wetter years - one portion of the forest, which is especially heavily deforested, appears to have lost that capacity. Gatti's research suggests this southeastern part of the forest, about 20% of the total area, has become a carbon source. "Each year is worse," she told Newsnight. [71]

11g. CO_2 Emissions from Australian Deforestation. Dr. Kate Dooley, University of Melburne, "Carbon dioxide emissions are effectively permanent, as the buried carbon we dig up and burn stays in the atmosphere for millennia, while carbon in trees is temporary in comparison."

Logging near Bright, Victoria, Australia. Credit: Stephen Edmonds, Wikimedia Commons

Dr. Kate Dooley, University of Melbourne: What is being overlooked in current international climate policy under the Paris Agreement is the crucial role of biodiversity in maintaining healthy ecosystems and their integrity, which keeps carbon stored in forests, not the atmosphere. Healthy ecosystems are more stable and resilient, with a lower risk of trees dying and lower rates of carbon emissions.

[70] Boynton, Sean 15 December 2019. "Clearcutting B.C. forests contributing more to climate change than fossil fuels: report." VIDEOS 1:56 & 2:06 *Global News*. (LINKS) Based upon *Jens Wieting, Senior Forest and Climate Campaigner, with mapping analysis by David Leversee* Dec. 2019. "Clearcut Carbon - A Sierra Club BC report on the future of forests in British Columbia Sierra Club." *Sierra Club*. Full Report. (20 pages). Executive Summary. (2 pages). Jens Wieting, BC Sierra Club. Biography and Contact; Sierra Club Stories. National Observer.

[71] Gabriel Gatehouse, 11 February 2020. "Deforested parts of Amazon 'emitting more CO_2 than they absorb'" *BBC News*. & VIDEO 6:59 *BBC Newsnight program*. Based upon interviews with Dr. Luciana Vanni Gatti, researcher at Brazil's National Institute for Space Research (INPE), Biography and Contact; Google Scholar; Researchgate. Dr. Carlos Nobre, who co-authored Prof Gatti's study; Wikipedia; Biography and Contact; Google Scholar; Researchgate. Dr. Simon L. Lewis Biography and Contact; Google Scholar; Researchgate

The way we currently count carbon stores risks creating incentives to plant new trees rather than protect existing forests. Yet old-growth forests store vastly more carbon than young saplings, which will take decades or even centuries to reach the same size.

On January 1 this year [2024], both Victoria and Western Australia ended native forest logging in state forests. This is a good start. But the rest of Australia is still logging native forests. The Victorian government has also put in place a Forestry Transition Program to help forest contractors find alternative work in forest and land management. Some of these transition programs are proving controversial. In Western Australia, around 2.5 million hectares of the state's south-west forests will be protected under a new Forest Management Plan. Protection of these landscapes is critical, as they have been hit by another die-back event due to drought and record heat.

Another problem with net accounting is it treats all carbon as equivalent, meaning a ton of carbon sequestered in trees compensates for a ton of carbon from burned fossil fuels. This has no scientific basis. Carbon dioxide emissions are effectively permanent, as the buried carbon we dig up and burn stays in the atmosphere for millennia, while carbon in trees is temporary in comparison. [72]

11h. CO_2 Emissions from East Europe Deforestation. Karlsruhe Institute of Technology Ed., "The Eastern European carbon sink is shrinking."

Karlsruhe Institute of Technology Ed.: The [land use and management] area studied covers 13 countries, from Poland in the West to the Russian Ural Mountains in the East, from Estonia in the North to Rumania in the South. Calculations are based on different data sources, such as models, satellite-based biomass estimates, forest inventories, and national statistics. "From the datasets, we concluded that Eastern Europe stored most of Europe's carbon from 2010 to 2019," Winkler says. Comparison of carbon balances revealed that the land surface in Eastern Europe bound about 410 million tons of carbon in biomass every year. This corresponds to about 78% of the carbon sink of entire [the entirety of] Europe. The biggest carbon sinks can be found in border region of Ukraine, Belarus and Russia, in the southern Ural Mountains, and on the Kola Peninsula. Timber extraction has the biggest influence on the carbon sink in Eastern Europe.

However, data also show that carbon absorption in Eastern Europe with time was anything but constant and has even declined. The Eastern European carbon sink is shrinking. They found that environmental impacts, such as the change in soil humidity, have a big influence on the carbon balance. Still, spatial patterns of the carbon sink in Eastern Europe can be explained mainly by land use changes. From 2010 to 2019, timber extraction had the biggest influence on the land-based carbon sink in the region. Data analysis suggests that an increase in timber extraction in West Russia and reduced forest growth on former agricultural areas caused the carbon sink in Eastern Europe to decline between 2010 and 2019. [73]

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[72] Kate Dooley, The Conversation June 16, 2024 "Ending native forest logging would help Australia's climate goals much more than planting trees." MANY LINKS ***Phys.Org News***. Dr. Kate Dooley University of Melbourne. Biography and Contact; Google Scholar; Researchgate.

[73] Karlsruhe Institute of Technology August 9, 2023 "Climate protection: Land use changes cause the carbon sink to decline." ***Phys.org News***. From: Karina Winkler (Karlsruhe Institute of Technology (KIT), Garmisch-Partenkirchen, Germany) et al, (13 others) 3 July 2023 "Changes in land use and management led to a decline in Eastern Europe's terrestrial carbon sink." ***Communications Earth & Environment*** **4**, Article number: 237. Dr. Karina Winkler, Karlsruhe Institute of Technology. Biography and Contact; Orcid;