Earth 2020

An Insider's Guide to a Rapidly Changing Planet

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Forests

Sally N. Aitken

In this era of cheap global travel, it is tempting to visit a new place every year to experience diverse landscapes and cultures. But there is also something to be said for observing the same place year after year, slowly and carefully. To understand the dynamic nature of forests, and their response to climate change and other human-induced pressures, it helps to witness the changes firsthand in one place over many years.

That place for me is a small cabin on a remote lake in the Chilcotin region of British Columbia, Canada. Ten hours from Vancouver by car, and two hours from the nearest grocery store, it is set in a landscape of forests and mountains, with just a few hardy souls scratching a living off the land through forestry, ranching, or tourism. Grizzly bears, black bears and moose are common residents, and seasonal visitors include sandhill cranes, pelicans and Arctic terns. Trees in these forests live long, slow lives, growing only a little each summer in preparation for the deep cold of winter.

Since the first Earth Day in 1970, mean annual temperatures in the Chilcotin have risen by about 1.5°C. That may not sound like a lot, but it is more than the global average of 1°C warming over the last fifty years and equal to the average temperature difference between Vancouver, British Columbia and Portland, Oregon, 500 km to the south. One might predict that a little warming would make life easier for trees in such a cold place; instead, the forest is unravelling.

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Freezing winter temperatures historically kept insects such as the mountain pine beetle at bay by periodically killing off a large segment of the population. With milder temperatures and fewer cold spells, beetle populations have exploded over the past twenty years, killing pine trees across eighteen million hectares of forests in British Columbia, an area the size of Washington State. The ravaged Chilcotin forests are now filled with dead, grey trees — some still standing and many covering the forest floor. After the mountain pine beetles came spruce beetles, Douglas-fir beetles and western spruce budworms. Tree defenses were weakened by drought and unable to mount sufficient chemical and physical defenses against attack. The beautiful, white-stemmed aspen are also in decline due to increasing impacts of insects and diseases. To keep a hiking trail clear of fallen trees in these parts is to develop a physical awareness of the extent of tree mortality.

And then came the wildfires. Both 2017 and 2018 were record-shattering years for wildfires in British Columbia, with 2.5 million hectares burned. In early July 2017, my partner and I were forced out of the Chilcotin by a thunderstorm that started over a hundred fires in a single day. The only road out led right through the heart of a wildfire. Although it was still daytime, we drove through dense smoke as dark as night. The only light came from trees alongside us bursting into flames, or stems glowing bright red from bottom to top. This massive fire eventually merged with others to cover 467,000 hectares, the largest ever recorded in the province.

Thankfully, the summer of 2019 was wet and cool in my part of the world. There was fresh snow on the mountains one July morning, perhaps fueling doubts in those who question the reality of climate change. But heat waves in Europe and over much of North America made 2019 the hottest June and July on record globally. People have short memories of weather, and current conditions can distort our perceptions of climate trends. We also have ways of modifying our environments and clothing to suit conditions, insulating us from an external reality. But trees, long-lived and sedentary, must tolerate what comes. Weather events impact tree growth, as recorded in their wood rings over decades, centuries, or even millennia. From these annual growth records, we know that trees can tolerate considerable climate fluctuations. But what happens when those tolerances are exceeded?

Like the trees of the Chilcotin, forests in many parts of the world are suffering due to climate change and other ecological and environmental pressures. Drought-related tree mortality, alone or in combination with insect outbreaks, has been documented on every continent in the past two decades.[1] In California alone, a recent multi-year drought and associated insect outbreaks have caused the death of nearly 150 million trees.[2] While this is just a small percentage of the total number of trees in that state, it is an unsustainable mortality rate for tree species that can live well over a century. In Germany, an estimated one million trees have died in the past two years, generating fears that some parts of the country are becoming unforestable.[3] Drought-related megafires have burned across western North America, Europe and Australia. High northern latitudes, in particular, are experiencing greater warming than elsewhere on Earth. Boreal forests in North America and Siberia are showing those effects. Trees in so-called drunken forests are tilting and tipping as permafrost melts, dying from drought and insects and burning in vast wildfires.

While climate change is impacting the health of the world's forests, humans are also accelerating climate change through deforestation. Since 1970, the total area deforested on Earth has increased by 3 million km^2, an area comparable to the size of India. Prior to 1900, most deforestation was in temperate regions, but recent clearing has been almost exclusively in the tropics, with just 50% of tropical forests remaining globally,[4] and nearly 20% of Amazonian forests lost over the past half-century. Many tropical forests have been razed to make way for industrial agriculture (e.g., cattle grazing, soy production for animal feed and oil palm plantations). In recent years, there had been hopeful signs that deforestation had slowed. Between 2004 and 2012, for example, Brazil's annual deforestation rate dropped considerably. Sadly, this progress has been reversed as the country's pro-development government turns a blind eye to massive, largely illegal forest clearing and burning. These activities resulted in the Amazonian fires of 2019, when more than 80,000 fires burned across Brazil, capturing global attention (at least for a short while). There is a real fear that further deforestation and burning in the Amazon will alter local climate — increasing temperatures and decreasing rainfall — driving that ecosystem past a tipping point where rainforests will be replaced by arid savannahs. Global attention and pledges of support internationally cannot repair the damage that has already been done.

It is easy to cast blame on lower- and middle-income countries where rapid deforestation is currently underway. But we must remember that inhabitants of the industrialized world live in previously forested cities and towns, and farm previously forested fields. Nearly half of global forests were cleared by humans across history, not just in recent decades. We also consume agricultural products that come from deforested tropical areas, fueling economic drivers of deforestation. And in higher-income countries, some natural forests are still being converted to plantations of non-native species such as eucalypts or pines. Such introduced species significantly alter local ecology, and can bring other risks as well. For example, fire-prone eucalyptus plantations in Portugal exploded in flames in 2017, killing sixty-four people in the deadliest wildfire in that country's history.

The degradation of Earth's forests, and tropical rainforests in particular, presents us with both an ecological and climatic catastrophe. Globally, forests and other terrestrial vegetation absorb approximately two billion metric tons of carbon dioxide annually, and have absorbed just over one quarter of the carbon dioxide released to date by human activities in the Anthropocene.[5] This carbon dioxide is taken up during photosynthesis, and the resulting carbohydrates are used to build leaves, stems, branches and roots (carbon makes up about half of the dry weight of wood). Forest soils also store substantial amounts of carbon in fine roots, organic matter, fungi and microorganisms. Together, forest trees and soils currently store more carbon than all of the readily exploitable oil, gas and coal reserves globally, with about half of this stored carbon in tropical regions.

Harvesting of forests, or burning of trees during forest fires or land clearing, converts them from net sinks to sources of greenhouse gases. If cleared sites are rapidly reforested, the net impact on greenhouse gas emissions is lower than if the land is converted to another use, such as agriculture or urban development. Deforestation is responsible for about 18% of global greenhouse gas emissions — more than the total global emissions from transportation. Forest fires are another significant source of carbon dioxide to the atmosphere. In 2017 and 2018, for example, British Columbia wildfires emitted three times as much carbon dioxide as the annual burning of all fossil fuels in that province. After burned and insect-infested trees die, their decay converts them into a further source of atmospheric carbon dioxide, creating a positive feedback cycle. Fires and insect outbreaks have turned British Columbia's vast forests from a net carbon sink to a net carbon source, contributing to rather than mitigating greenhouse gas emissions.

The world's forests are also critical reservoirs of biodiversity, containing 80% of all terrestrial species globally and about three quarters of birds, with most of these found in the tropics. In North America, for example, the total number of birds has dropped by 29% since 1970, a reduction of about three billion individuals.[6] Climate change is only one of the human factors destroying the library of life; others include overharvesting,[7] pollution,[8] and loss of habitat. A recent UN report concluded that up to one million species are at risk of extinction.[9] To slow or avert this biodiversity crisis, forests must be restored or maintained to provide habitat for the many species they house.

So, what is the solution? Perhaps we can simply plant more trees? Indeed, a large global effort to replenish previously existing forests (reforestation) or create new ones (afforestation) has been proposed as the most realistic and cost-effective climate change strategy. Trees are certainly less expensive and easier to scale up than other greenhouse gas reduction technologies. A recent analysis using satellite imagery concluded that there is room globally for an additional 0.9 billion hectares of continuous forest, representing about 500 billion trees.[10] At first glance, this appears to be a win-win solution, restoring native forests, generating forest-based goods and services for local communities, enhancing greenhouse gas sinks and creating habitat for biodiversity. But this view from space misses many details that will determine the feasibility of this solution on the ground.[11]

Afforesting grasslands won't actually increase carbon sequestration, as we now know that grassland soils contain as much carbon as forests, and they regenerate soil carbon faster than forests. We must also consider the individuals and communities that will benefit or be harmed as a result of reforestation. Per-capita greenhouse gas emissions are highest in high-income countries, while deforestation is greatest in those with lower incomes. Some people living in poverty who are already being disproportionately impacted by climate change may also suffer losses in livelihoods from widespread reforestation through loss of grazing or agricultural land. If local communities are not involved in designing and benefiting from reforestation, tree planting programs are destined to fail.

In some places, adapting landscapes to climate change may require planting fewer, not more, trees. While planting more trees per hectare might result in more carbon sequestration, forest managers are shifting to lower-density forests in drought-prone areas to provide trees with sufficient water and mitigate wildfire risks. Some forests will likely shift to grassland ecosystems with further warming. We need to better understand where and when these ecological shifts will occur, and how they will impact carbon storage.

In places where tree planting offers more benefits than risks, we need to consider climate change when selecting trees to plant. Changes in climate over the lifetime of a typical tree will impact forest health and reduce carbon sequestration. Populations of trees of a given species vary genetically, depending on the climates they have evolved in. Scots pine from Finland and Spain, for example, differ considerably in their growth timing, cold hardiness and drought tolerance. Tree species and populations used today for reforestation will need to be carefully chosen to increase the likelihood that they will be healthy and productive throughout their lifetimes as climates change. We are dealing with a moving climate target, and without a crystal ball to pick the best trees for the uncertain climate 50 or 100 years from now, we should hedge our bets by planting a variety of species, each with high genetic diversity. We may also need to assist the migration of genetic populations and even species into new habitats as they become climatically favourable. Fast-growing plantations of non-native species might grow and fix carbon more rapidly than natural forests, and provide some economic and social benefits, but they will not provide critical habitat for rapidly declining biodiversity.

One thing is for certain: we need to dramatically reduce deforestation globally. Higher-income countries with high carbon footprints should continue to encourage and financially support efforts to slow and reverse tropical deforestation. All nations should support their community-driven efforts to restore degraded forest ecosystems and marginal agriculture lands with a diversity of tree species that provide a variety of resources. If deforestation is to be slowed and reforestation is to succeed, trees must be worth more alive than logged to local people.

Sustainable forest management must also be routinely practiced everywhere. Harvesting crop trees after longer rotations will increase rates of carbon sequestration per year. Thinning stands and using the harvested wood in long-lived products will reduce mortality and improve carbon balance. For example, the use of wood to construct buildings with long lifespans helps store carbon, and provides a substitute for building materials like cement with larger carbon footprints. Partial harvesting and rapid reforestation after harvest will accelerate carbon sequestration, and some stands should be left untouched in the hopes they will become the old growth trees of the future. And we should conserve ancient forests that provide habitat for biodiversity and may be irreplaceable in new climates.

We also need to increase tree cover in urban areas, adapting urban infrastructure and environments to climate change and mitigating some greenhouse gas emissions. Urban forests help cool cities, improve air quality and quality of life, and have positive effects on both mental and physical health. Many cities have lost large numbers of urban trees due to introduced invasive insects and diseases, including the emerald ash borer and Dutch elm disease in North America, and, in Europe, ash dieback due to a fungal pathogen. Adapting urban forests to climate change is best done by planting a diversity of species and cultivars.

Trees have long been a symbol of environmental movements, and tree planting is an important tool in the fight against climate change. But planting trees is not enough. Tree planting will not replace the systematic societal changes to energy, transportation and food production systems needed to slow the pace of climate change and other human impacts on forests.[12] We have many opportunities to help the survival of forests and the species they house, while also mitigating climate change. If we reduce greenhouse gas emissions, reverse deforestation and manage forests sustainably, trees will continue storing carbon cheaply and efficiently, providing habitat for biodiversity and a multitude of products that support human well-being across the globe.

Endnotes

1. C. D. Allen, D. D. Breshears and N. G. McDowell, 'On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene', *Ecosphere*, 2015, 6, 129, https://doi.org/10.1890/ES15-00203.1
2. M. L. Goulden and R. C. Bale, 'California forest die-off linked to multi-year deep soil drying in 2012–2015 drought', *Nature Geoscience*, 2019, 12, 632–37, https://doi.org/10.7280/D1DH3B; US Forest Service, *USDA Forest Service Tree Mortality Aerial Detection Survey Results*, Pacific Southwest Region, 2018, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd609295.pdf
3. K. Connolly, 'Part of "German soul" under threat as forests die', *The Guardian*, 20 October 2019, https://www.theguardian.com/environment/2019/aug/07/part-of-german-soul-under-threat-as-forests-die
4. Food and Agriculture Organization of the United Nations, *FAO 2012 State of the World's Forests*, Rome: Food and Agriculture Organization, 2012, http://www.fao.org/3/i3010e/i3010e00.htm
5. C. Le Quéré et al., 'Global Carbon Budget 2017', *Earth Syst. Sci. Data*, 2018, 10, 405–48, https://doi.org/10.5194/essd-10-405-2018
6. K. V. Rosenberg, A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr and P. P. Marra, 'Decline of the North American avifauna', *Science*, 2019, 366, 120–24, https://doi.org/10.1126/science.aaw1313
7. See 'Everyday Biodiversity' by Jeffrey R. Smith and Gretchen C. Daily in this volume.
8. On air pollution, see 'Air' by Jon Abbatt in this volume. On pollution viewed through an economic lens, see 'Environmental Economics' by Don Fullerton in this volume.
9. IPBES, *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, Bonn, Germany: IPEBS Secretariat, 2019, https://ipbes.net/global-assessment-report-biodiversity-ecosystem-services
10. J. F. Bastin, Y. Finegold, C. Garcia, D. Mollicone, M. Rezende, D. Routh, C. M. Zohner and T. W. Crowther, 'The global tree restoration potential', *Science*, 2019, 365, 76–79, https://doi.org/10.1126/science.aax0848
11. S. L. Lewis, E. T. A. Mitchard, C. Prentice, M. Maslin and B. Poulter, 'Comment on "The global tree restoration potential"', *Science*, 2019, 366, 1–3, https://doi.org/10.1126/science.aaz0388; R. Chasdon and P. Brancalion, 'Restoring forests as a means to many ends', *Science*, 2019, 365, 6448–49, https://doi.org/10.1126/science.aax9539

12. IPCC, 'Summary for policymakers', in *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, ed. V. Masson-Delmotte et al., Geneva: World Meteorological Organization, 2018, https://www.ipcc.ch/sr15/chapter/spm/