DRAWDOWN

THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING

EDITED BY PAUL HAWKEN

PENGUIN BOOKS

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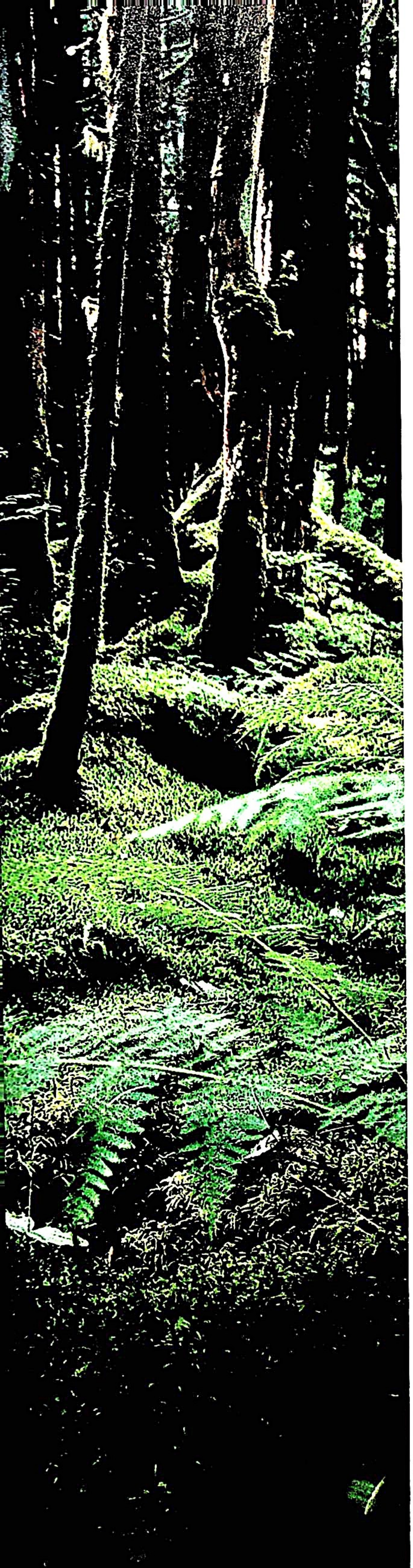
We accumulated more than 5,000 references, citations, and sources in the process of researching and writing Drawdown. *Although they are too numerous to be published in the book, they may be found at www.drawdown.org/references.*


LAND USE
FOREST PROTECTION



RANKING AND RESULTS BY 2050

#38

6.2 GIGATONS
REDUCED CO2

896.29 GIGATONS
CO2 PROTECTED

GLOBAL COST AND SAVINGS DATA
TOO VARIABLE TO BE DETERMINED

The most critical of all forest types is primary forest, known as old-growth or virgin forest. Examples include the Great Bear Rainforest of British Columbia and those of the Amazon and the Congo. These are forests that have achieved great age with mature canopy trees and complex understories, making them the greatest repositories of biodiversity on the planet. Primary forests contain 300 billion tons of carbon yet they are still being logged, sometimes under the guise of harvest being "sustainable." Research shows that once an intact primary forest begins to be cut, even under sustainable forest-management systems, it leads to biological degradation.

At one time, the planet's forests covered vast tracts of land and human incursions were relatively negligible. Stone axes were felling trees ten thousand years ago, but hunter-gatherers did not need significant amounts of wood. That began to shift as agriculture took root and communities remained in place. By 5500 BC, civilization and nation states began to bloom in what was known as the Fertile Crescent, nurtured by agricultural bounty. The first iron tools, writing systems, and crops were developed by the ancient Iraqis and other peoples of the Middle East. Populations swelled, fed by wild wheat, peas, fruits, sheep, pigs, goats, and cows. Abundant food surpluses supported art, politics, governance, laws, mathematics, science, and education.

What happened? Forests were cut. Soil erosion accelerated. Rain no longer fed the forest soil but removed it. Subsequent irrigation produced salinization; deadened salt pans emerged where crops once flourished. Overgrazing on drying soils caused them to blow away. The story of ancient Iraq and its environs is playing out across the world. Many of the conflict zones in today's world have been deforested: Syria, South Sudan, Libya, Yemen, Nigeria, Somalia, Rwanda, Pakistan, Nepal, the Philippines, Haiti, and Afghanistan. All suffer from deforestation, uncontrolled cutting of fuelwood, overgrazing, soil erosion, and desertification. The following areas have lost 90 percent or more of their original forest habitat: Burma, Thailand, India, Borneo, Sumatra, the Philippines, the Mata Atlântica forest of Brazil, Somalia, Kenya, Madagascar, and Saudi Arabia.

A 2015 estimate of the world's tree population: three trillion. That count is substantially higher than previously thought, but more than 15 billion trees are cut down each year. Since humans began farming, the number of trees on earth has fallen by 46 percent. (Today, forests cover 15.4 million square miles of the earth's surface—or roughly 30 percent of its land area.) The color of China's Yellow River is caused by soil eroding off the Loess Plateau, the result of centuries of deforestation and overgrazing. European forests were cleared from the seventeenth to twentieth centuries. America did the same in the nineteenth and twentieth centuries. Logging, slash-and-burn removal for pasture, and clearing of forests for palm oil wreaked havoc in Central and South America, Southeast Asia, and Africa in the twentieth century. According to the World Wildlife Fund, the world continues to lose forty-eight football fields' worth of forest every minute.

The Kermode bear is known as the spirit bear by the Tsimshian people of the Great Bear Rainforest—a 250-mile coastal temperate rainforest in British Columbia (BC). The Kermode bear is rarely seen but more easily spotted during salmon season when they feast near streams and falls as you see in this photograph. The forest is largely intact today due to the Great Bear Rainforest Campaign, one of the most successful campaigns ever undertaken to stop clear-cutting and logging. Beginning in 1984 in Clayoquot Sound, First Nations peoples and environmental NGOs set up blockades to protest logging rights that had been granted to Macmillan Bloedel. After 22 years of unrelenting work by campaigners, BC premier Christy Clark announced in February 2016 that an agreement between First Nations, timber companies, and environmental organizations would protect 85 percent of the 15.8 million acres.

The Hidden Life of Trees

PETER WOHLLEBEN

Years ago, I stumbled across a patch of strange-looking mossy stones in one of the preserves of old beech trees that grows in the forest I manage. Casting my mind back, I realized I had passed by them many times before without paying them any heed. But that day, I stopped and bent down to take a good look. The stones were an unusual shape: they were gently curved with hollowed-out areas. Carefully, I lifted the moss on one of the stones. What I found underneath was tree bark. So, these were not stones, after all, but old wood. I was surprised at how hard the "stone" was, because it usually takes only a few years for beechwood lying on damp ground to decompose. But what surprised me most was that I couldn't lift the wood. It was obviously attached to the ground in some way.

I took out my pocketknife and carefully scraped away some of the bark until I got down to a greenish layer. Green? This color is found only in chlorophyll, which makes new leaves green; reserves of chlorophyll are also stored in the trunks of living trees. That could mean only one thing: this piece of wood was still alive! I suddenly noticed that the remaining "stones" formed a distinct pattern: they were arranged in a circle with a diameter of about five feet. What I had stumbled upon were the gnarled remains of an enormous ancient tree stump. All that was left were vestiges of the outermost edge. The interior had completely rotted into humus long ago—a clear indication that the tree must have been felled at least four or five hundred years earlier. But how could the remains have clung onto life for so long?

Living cells must have food in the form of sugar, they must breathe, and they must grow, at least a little. But without leaves—and therefore without photosynthesis—that's impossible. No being on our planet can maintain a centuries-long fast, not even the remains of a tree, and certainly not a stump that has had to survive on its own. It was clear that something else was happening with this stump. It must be getting assistance from neighboring trees, specifically from their roots. Scientists investigating similar situations have discovered that assistance may either be delivered remotely by fungal networks around the root tips—which facilitate nutrient exchange between trees—or the roots themselves may be interconnected. In the case of the stump I had stumbled upon, I couldn't find out what was going on, because I didn't want to injure the old stump by digging around it, but one thing was clear: the surrounding beeches were pumping sugar to the stump to keep it alive.

If you look at roadside embankments, you might be able to see how trees connect with each other through their root systems. On these slopes, rain often washes away the soil, leaving the underground networks exposed. Scientists in the Harz Mountains in Germany have discovered that this really is a case of interdependence, and most individual trees of the same species growing in the same stand are connected to each other through their root systems. It appears that nutrient exchange and helping neighbors in times of need is the rule, and this leads to the conclusion that forests are superorganisms with interconnections much like ant colonies.

Of course, it makes sense to ask whether tree roots are simply wandering around aimlessly underground and connecting up when they happen to bump into roots of their own kind. Once connected, they have no choice but to exchange nutrients. They create what looks like a social network, but what they are experiencing is nothing more than a purely accidental give and take. In this scenario, chance encounters replace the more emotionally charged image of active support, though even chance encounters offer benefits for the forest ecosystem. But Nature is more complicated than that. According to Massimo Maffei from the University of Turin, plants—and that includes trees—are perfectly capable of distinguishing their own roots from the roots of other species and even from the roots of related individuals.

But why are trees such social beings? Why do they share food with their own species and sometimes even go so far as to nourish their competitors? The reasons are the same as for human communities: there are advantages to working together. A tree is not a forest. On its own, a tree cannot establish a consistent local climate. It is at the mercy of wind and weather. But together, many trees create an ecosystem that moderates extremes of heat and cold, stores a great deal of water, and generates a great deal of humidity. And in this protected environment, trees can live to be very old. To get to this point, the community must remain intact no matter what. If every tree were looking out only for itself, then quite a few of them would never reach old age. Regular fatalities would result in many large gaps in the tree canopy, which would make it easier for storms to get inside the forest and uproot more trees. The heat of summer would reach the forest floor and dry it out. Every tree would suffer.

Every tree, therefore, is valuable to the community and worth keeping around for as long as possible. And that is why even sick individuals are supported and nourished until they recover. Next time, perhaps it will be the other way round, and the supporting tree might be the one in need of assistance. When thick silver-gray beeches behave like this, they remind me of a herd of elephants. Like the herd, they, too, look after their own, and they help their sick and weak back up onto their feet. They are even reluctant to abandon their dead.

Every tree is a member of this community, but there are different levels of membership. For example, most stumps rot away into humus and disappear within a couple of hundred years (which is not very long for a tree). Only a few individuals are kept alive over the centuries, like the mossy "stones" I've just described. What's the difference? Do tree societies have second-class citizens just like human societies? It seems they do,

though the idea of "class" doesn't quite fit. It is rather the degree of connection — or maybe even affection — that decides how helpful a tree's colleagues will be.

You can check this out for yourself simply by looking up into the forest canopy. The average tree grows its branches out until it encounters the branch tips of a neighboring tree of the same height. It doesn't grow any wider because the air and better light in this space are already taken. However, it heavily reinforces the branches it has extended, so you get the impression that there's quite a shoving match going on up there. But a pair of true friends is careful right from the outset not to grow overly thick branches in each other's direction. The trees don't want to take anything away from each other, and so they develop sturdy branches only at the outer edges of their crowns, that is to say, only in the direction of "non-friends." Such partners are often so tightly connected at the roots that sometimes they even die together.

Tree roots extend a long way, more than twice the spread of the crown. So the root systems of neighboring trees inevitably intersect and grow into one another — though there are always some exceptions. Even in a forest, there are loners, would-be hermits who want little to do with others. Can such antisocial trees block alarm calls simply by not participating? Luckily, they can't. For usually there are fungi present that act as intermediaries to guarantee quick dissemination of news. These fungi operate like fiber-optic Internet cables. Their thin filaments penetrate the ground, weaving through it in almost unbelievable density. One teaspoon of forest soil contains many miles of these "hyphae." Over centuries, a single fungus can cover many square miles and network an entire forest. The fungal connections transmit signals from one tree to the next, helping the trees exchange news about insects, drought, and other dangers. Science has adopted a term first coined by the journal *Nature* for Dr. Simard's discovery of the "wood wide web" pervading our forests. What and how much information is exchanged are subjects we have only just begun to research. For instance, Simard discovered that different tree species are in contact with one another, even when they regard each other as competitors. And the fungi are pursuing their own agendas and appear to be very much in favor of conciliation and equitable distribution of information and resources.

Under the canopy of the trees, daily dramas and moving love stories are played out. Here is the last remaining piece of Nature, right on our doorstep, where adventures are to be experienced and secrets discovered. And who knows, perhaps one day the language of trees will eventually be deciphered, giving us the raw material for further amazing stories. Until then, when you take your next walk in the forest, give free rein to your imagination — in many cases, what you imagine is not so far removed from reality, after all.

Excerpted from *The Hidden Life of Trees: What They Feel, How They Communicate, Discoveries from a Secret World*, by Peter Wohlleben, 2016 (Greystone Books).

LAND USE
AFFORESTATION

The capacity of trees to synthesize and sequester carbon through photosynthesis as they grow has made afforestation an important practice in the age of warming. Creating new forests where there were none before in areas that have been treeless for at least fifty years is the aim of afforestation. Degraded pasture and agricultural lands, or other lands severely corrupted from uses such as mining, are ripe for strategic planting of trees and perennial biomass. So are eroding slopes, industrial properties, abandoned lots, highway medians, and wastelands of all stripes—almost any space that is unattended or forgotten can help draw down atmospheric carbon.

The most successful afforestation projects are those that plant native trees. Replanting, however, can take a variety of forms—from seeding dense plots of diverse indigenous species to introducing a single exotic as a plantation crop, such as the fast-growing Monterey pine, the most widely planted tree in the world. Whatever the structure, they all function as carbon sinks, drawing in and holding on to carbon, and distributing carbon into the soil. How much carbon is sequestered annually depends on the details of species, site, soil conditions, and structure.

A recent paper out of the University of Oxford makes a conservative estimate that afforestation could draw down one to three gigatons of carbon dioxide per year in 2030. Global availability of land is a key variable and one that is difficult to predict, affected by factors ranging from population and diet to crop yields and bioenergy demands. While afforestation projects have significant carbon sequestration potential, forests, new or old, are vulnerable to fire, drought, pests, and the ax or saw.

To date, plantations comprise the majority of afforestation projects and are on the rise globally, planting trees for timber and fiber and, increasingly, selling carbon offsets as well. (While plantation forestry makes up just 7 percent of total forest cover, it generates roughly 60 percent of commercial wood.) Plantations have been and remain controversial because they are often created with purely economic motives and little regard for the long-term well-being of the land, environment, or surrounding

18.06 GIGATONS REDUCED CO2	$29.4 BILLION NET COST	$392.3 BILLION NET SAVINGS

communities. Some displace natural forests or other vital ecosystems and then support much lower levels of fauna, from songbirds to snails. They are susceptible to disease, often requiring chemicals to control infestation, and can sap groundwater, as has been the case with China's Three-North Shelter Program—the "Great Green Wall." In their wake, the rights and interests of local and indigenous communities can be disregarded or deliberately transgressed, particularly in low-income countries where foreign interests acquire land to establish them. It has led to strong push-back against how afforestation is being implemented and to concerns about a profit-fueled land rush following the Paris Agreement, potentially accompanied by forced relocation, cultural deracination, and violation of human rights.

These issues are part of the reason efforts have cropped up to make plantation forestry more sustainable, efforts such as third-party certification schemes that disallow conversion of natural forest. But there is no denying the benefits plantations provide. Beyond their usefulness in wood production and carbon

Far Left: This is a typical single-story tree plantation in Umatilla, Oregon, consisting of cottonwood trees planted with eight-foot spacing in order to force upward, knot-free growth.

Below: Single-story afforestation consists of monocultures of pines, poplars, and other fast-growing trees, some of which are genetically modified to speed up their growth. Although single-story plantations sequester carbon in significant quantities, they are the equivalent of arboreal deserts due to their lack of biodiversity and the speed with which they exhaust and acidify the soil. Below is the Miyawaki method or what is called analog forestry, an afforestation technique that mimics natural forest formation. It creates a multistory forest consisting of diverse upper, middle, and lower canopy trees, shrubs, and plants—an ecosystem sustainable for a hundred years or more. This method of afforestation has a higher ratio of biodiversity to biomass, is more productive, and sequesters far more carbon. However, it is unsuitable for the harvesting methods employed in even-aged, industrial tree farms where all trees are cut at the same time.

sequestration, tree farms have a "plantation conservation benefit": They can actually reduce logging of natural forest. A 2014 study calculates a 26 percent reduction in natural forest harvest around the world thanks to planted forests. Initiatives such as New Generation Plantations, out of the World Wide Fund for Nature (WWF), are working to ensure that well-designed plantations and inclusive management practices become mainstream, so that the good (and the goods) of plantations can be optimized, while ensuring the integrity of ecosystems and communities. Because plantations are here to stay, groups such as WWF know it is critically important to engage key actors such as companies and governments, and to identify degraded lands ideal for afforestation. Multipurpose plantations can meet a variety of social, economic, and environmental aims (including providing jobs in places where few exist), but they have to be conceived and implemented with those aims in mind.

Plantations are far from the only option. To counter the ecological deserts of monoculture tree farms, which often introduce invasive species with their potential negative impact, an extraordinary Japanese botanist, Akira Miyawaki, devised a completely different method of afforestation. In the 1970s and '80s, Miyawaki studied the temples and shrines of Japan to better understand the country's original forests. Over decades, perhaps enturies, indigenous oaks, chestnuts, and laurels had been re-laced almost completely by pine, cypress, and cedar introduced for timber. These ersatz native forests, he realized, were not resilient or adaptable to climate change. Drawing on a German technique called potential natural vegetation, Miyawaki became a passionate champion of creating indigenous, authentic forests; he now has been part of planting more than 40 million trees around the world.

The Miyawaki method calls for dozens of native tree species and other indigenous flora to be planted close together, often on degraded land devoid of organic matter. As these saplings grow, natural selection plays out and a richly biodiverse, resilient forest results. Miyawaki's forests are completely self-sustaining after the first two years, when weeding and watering are required, and mature in just ten to twenty years—rather than the centuries nature requires to regrow a forest. In the same amount of space, they are one hundred times more biodiverse and thirty times denser than a conventional plantation, while sequestering more carbon. They provide beauty, habitat, food, and tsunami protection.

We think of afforestation as something happening on large tracts of land, but individuals can do this everywhere. Inspired by Miyawaki's approach and drawing on Toyota's assembly line process, entrepreneur Shubhendu Sharma's company Afforestt is developing an open-source methodology to enable anyone to create forest ecosystems on any patch of land. In an area the size of six parking spaces, a three-hundred-tree forest can come to life—for the cost of an iPhone.

Jadav Payeng, the "forest-man of India," single-handedly afforested a 1,300-acre area on Majuli, the world's largest river island. Jadav, without any subsidy or financial support, tilled and sowed native species based on traditional knowledge, on the completely denuded sandbars of the Brahmaputra River, paving the way for natural regeneration. Today, Jadav's forest is home to an astounding array of floral and faunal biodiversity, at the same time serving as a natural erosion control method for the island.

Many of the places prime for afforestation are located in low-income countries, where there is often a multifaceted opportunity for impact. Creating new forest can sink carbon and support biodiversity, address human needs for firewood, food, and medicine, and provide ecosystem services such as flood and drought protection. Engaging local communities in afforestation projects by making them aware of the socioeconomic and environmental benefits of forests is the key to success. Because afforestation is a multidecade endeavor, what properly enables it are provisions for up-front costs, developing markets for forest products, and ensuring clear land rights in order to maintain continuity between planting and eventual harvest. Emerging geospatial and remote sensing technologies along with mobile-based ground validation can serve as powerful monitoring tools to ensure healthy plantations. Applying these approaches can do more than draw down atmospheric carbon; it can create new forests in ways that are ecologically sound, socially just, and economically beneficial.

IMPACT: *As of 2014, 709 million acres of land were used for afforestation. Establishing timber plantations on an additional 204 million acres of marginal lands can sequester 18.1 gigatons of carbon dioxide by 2050. The use of marginal lands for afforestation also indirectly avoids deforestation that otherwise would be done in the conventional system. At a cost of $29 billion to implement, this additional area of timber plantations could produce a net profit for landowners of over $392 billion by 2050.*