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Review Article

# Can We Still Save Our Goldilocks Zone From Climate Change Catastrophes?

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## Abstract

Trees are the lungs of our planet. Among all the planets in our solar system, only Earth is habitable. Heterotrophic life forms survived better after the evolution of photosynthetic cyanobacteria and the earliest marine and freshwater algal mats about 2.460-2.426 Ga [1,2]. With photosynthesis, atmospheric oxygen levels rose, the ozone layer formed, and life flourished on Earth. During photosynthesis, chloroplasts convert carbon dioxide and water into glucose and oxygen in the sunlight. There are about 100 chloroplasts in each mesophyll layer of leaves [3]. Photosynthesis converts ~200 billion tons of $CO_2$ into complex organic compounds annually and produces ~140 billion tons of oxygen in the atmosphere [4]. By harnessing solar energy through photosynthesis green plants and trees are the sole source of food on Earth. In addition to the source of oxygen, and food, trees release negative ions, beneficial vapors and aerosols of many biogenic volatile compounds like terpenes that prevent lifestyle-related diseases like cardiovascular, cerebrovascular, metabolic, and cancer. The only way to save our future is by stopping trees cutting and preserving our old forests. It is beneficial to grow trees around hospitals and workplaces so that people can enjoy forest therapy during lunchtime or leisure time. Students should have classes and study time in these forest areas. Can we still restore our forests and stop climate change?

**Keywords:** Agarikon; Forests,; Forest Bathing; Climate Change; Photosynthesis; Respiration

## Abbreviations

ADD/ADHD: Attention-deficit Disorder/Attention Deficit Hyperactivity Disorder; ATP: Adenosine; NADPH: Nicotinamide Adenine Dinucleotide Phosphate; OHC: Ocean Heat Content; W $m^{-2}$: Watts Per Square Meter; WGI: Working Group I; GHGs: Greenhouse Gases; $CO_2$: Carbon Dioxide; $N_2$: Nitrogen; $O_3$: Ozone; $CH_4$: Methane; $N_2O$: Nitrous Oxide, Laughing Gas; $NaHCO_3$: Sodium Bicarbonate; $C_6H_8O_7$ or $HOC(CH_2CO_2H)_2$: Citric Acid; $Na_3C_6H_5O_7$: Sodium Citrate; $SF_6$: Sulfur Hexafluoride; CFCs: Chlorofluorocarbons; HCFCs: Hydrochlorofluorocarbons; Ppm: Parts Per Million; Dbar: Decibar (1dbar: 10,000 Pascals); AR: Assessment Report; F: Fahrenheit; C: Celsius; ANS: Autonomous Nervous System; SNS: Sympathetic Nervous System; PNS: Parasympathetic Nervous System; NE: Norepinephrine; PgC: Petagrams of Carbon

## Introduction

Trees play a vital role in our physical, mental, emotional, and social well-being. Trees "eat" greenhouse gases that cause climate change for breakfast, lunch, and dinner. Trees are not only a source of clean air, trees filter groundwater and surface water, prevent erosion, and also regulate rain, temperature, and our seasons. This is not only for humans but also for other plants, animals, birds, and microorganisms that live on or not on trees. They provide a natural refuge for most of Earth's inhabitants and also protect life below or on water and land [5]. Trees promote social and community ties and reduce crime [5].

Love of nature reduces stress and revitalizes children's minds [5]. Trees improve cognitive development, and increase self-discipline, attention, and concentration which leads to improved test scores [5,6]. They also reduce the symptoms of ADD/ADHD (attention-deficit disorder/attention deficit hyperactivity disorder) [5]. We cannot survive without nature. Green trees, green shrubs, green plants, and green spaces are indispensable for human survival. Photosynthesis is the biggest miracle on Earth. "No Photosynthesis Means No Respiration". No photosynthesis means no life on Earth. Green plants around us are constantly busy removing carbon dioxide, methane, and nitrous oxide [7,8] from the air to utilize in a process known as photosynthesis. Via this process, trees remove pollutants and provide a constant supply of oxygen. Living organisms that depend on oxygen came only after the first massive oxygenation event or oxygen catastrophe [9] when photosynthetic bacteria developed the capability to oxidize water and learned how to use water as an electron donor about 2.460-2.426 Ga (billion years) ago. Early photosynthetic systems were developed in green and purple sulfur bacteria and green and purple nonsulfur [10] bacteria, but through anoxygenic mode (photosynthesis without oxygen production). Green and purple sulfur bacteria used hydrogen and hydrogen sulfide as electron and hydrogen donors, green nonsulfur bacteria used various amino acids and other organic acids, and purple nonsulfur bacteria used a variety of nonspecific organic and inorganic molecules. Oxygenic photosynthesis evolved from a common ancestor of extant cyanobacteria that used water as an electron donor. It is oxidized to molecular oxygen ($O_2$) in the photosynthetic reaction center [11]. The primary photoautotrophs during the Proterozoic period (2.50 Gs-0.5 Ga) were cyanobacteria, followed by green algae, dinoflagellates, coccolithophorids, and diatoms, followed by land plants such as mosses and liverworts, which gradually evolved into vascular plants [11,12].

A healthy lifestyle involves a balanced nutritional program and moderate physical activity. However, spending time outdoors under a tree canopy is often neglected. This is highly undervalued in modern society. Living among trees includes many benefits along with pleasure and comfort. We do not have full forests, whatever we have are just fragmented forests on Earth and they still have many therapeutic benefits. They protect us against most chronic disorders, like cardiovascular, diabetes, cancer, and respiratory diseases and infections [5,13]. Physical activity builds a strong immune system against bacterial and viral diseases by activating the autonomous nervous system that secretes immunoregulatory hormones [14]. Trees release negative ions (anions) that inhibit bacteria and viruses' growth. The negative air ions (NAI) help in treating respiratory, cardiovascular, and digestive diseases [15,16] (Figure 7). Trees release biogenic volatile organic compounds (VOCs) which include phytoncides (wood essential oils), like alpha-pinene and limonene [17] (Figure 7). The practice of spending time amongst trees is known as forest bathing and started as forest therapy or forest medicine in Japan in 2006 [18,19]. Recently in a forest bathing study [17] on Taiwanese Sugi trees (*Cryptomeria japonica*) phytoncides, a substantial amount of limonene – a key terpenoid constituent – was found. Limonene influences the central nervous system by improving sleep quality, reducing anxiety and easing pain [17]. Along with conifers like Sugi, balsam poplar releases oleoresins and beneficial vapors which spread around and protect humans and other mammals' respiratory health [20]. A lot of plants like cedar, garlic, locust, oak, onion, pine, tea tree, many spices and many other plants give off phytoncides. These are widely used as traditional medicine in Russia, Ukraine, Korea, China, Japan, and India as well as in alternative medicine, and veterinary medicine [21-23].

Right now, it is time to revolutionize the whole world, to stop unnecessarily cutting down trees. Trees are the soul of Earth, and the only way to save our future is by stopping trees cutting. Love for nature, wildlife, and humanity will prevent future catastrophes and pandemics. We begin this article by discussing photosynthesis and the reciprocal exchange of its materials with cellular respiration. Following that, we will discuss how climate change occurs when the balance of these processes is disturbed. Can afforestation, reforestation, and preservation of old forests protect us against climate change?

## The global carbon cycle

Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays, described as the electromagnetic spectrum or EMS [24]. The human eye can only detect a small portion of this EMS, known as visible light. Plants are green in color because chloroplasts contain a pigment known as chlorophyll which exists in two forms

chlorophyll a and chlorophyll b. Chlorophylls absorb light most strongly in the blue and red portions of the visible spectrum while reflecting the green color. There are three broad classes of plant pigments: porphyrins, carotenoids, and flavonoids. Chlorophylls are porphyrins. Carotenoids include carotenes (yellow or orange), lycopenes (orange or red), and xanthophylls (yellow). Flavonoids include flavones and flavanols (both yellow) and anthocyanins (red, purple, or even blue) [25].

The global carbon cycle is driven by two main life processes: photosynthesis and respiration (Figure 1). Via photosynthesis, plant chlorophylls convert carbon dioxide and water into glucose and oxygen in sunlight. There are about 100 chloroplasts in each mesophyll layer of leaves [3]. Photosynthesis converts ~200 billion tons of $CO_2$ into complex organic compounds annually and produces ~140 billion tons of oxygen in the atmosphere [4]. Photosynthesis happens in two main reactions at two main chlorophyll centers of photosystem I and II, also known as the antenna complexes, where accessory chlorophylls and other carotenoids like pigments transfer photonic energy by successive fluorescence events to neighboring molecules until they reach the reaction center containing chlorophylla [26]. Light reactions take place in thylakoids and dark reactions take place inside chloroplast stroma [26]. During light reactions, photonic energy oxidizes two water molecules and releases one oxygen molecule. The electrons freed from water are transferred to ATP (Adenosine triphosphate) and NADPH (Nicotinamide adenine dinucleotide phosphate). In dark reactions (Calvin cycle), energy from ATP and NADPH is used to fix carbon dioxide, which forms sugar molecules.

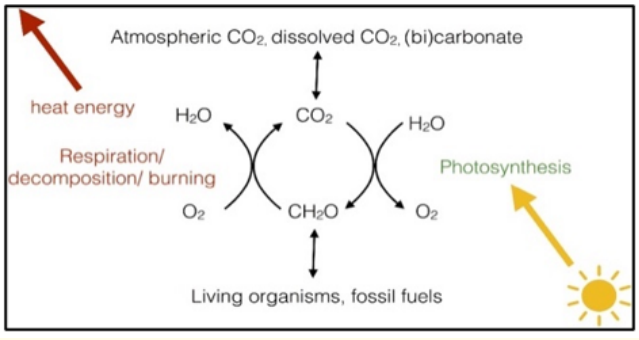


**Figure 1:** The Global Carbon Cycle [4].

Respiration and photosynthesis are the two major driving forces of Earth's carbon cycle (Figure 1). The end products of photosynthesis are used by all consumers on Earth. And the end products of respiration are transformed into usable food and essential gas oxygen ($O_2$) by plants. Life on Earth is based on these two miraculous processes. A series of respiratory reactions take place in cells' cytoplasm and mitochondria. Photosynthetic reactions take place in the chloroplasts of plant cells only. Both organelles evolved from endosymbiotic bacteria [27,28]. At the end of their life cycle when living organisms die, carbon in these decaying organisms becomes fossil fuels and is released back into our atmosphere by humans.

We had an oxygen explosion. As a species, we had more than enough resources to survive on Earth. What did we do with our natural resources? Why do we have natural catastrophes and pandemics? Where have we gone wrong?

## What are climate science and climate change?

What we see and feel in the atmosphere around us every day is the weather. However, the average temperature, humidity, rain amount, and wind from light to stormy gale of a region, for a particular time is known as the climate. The combined climate of our planet Earth is known as Earth's climate.

A change in this usual weather pattern in a certain place for a long period, for example, a drastic change in the amount of rain, snow, or sleet; a rise or fall in the temperature; or a sudden change in the storm frequency, pattern, or category; drought, lack of rain, or desertification of a region, all are part of climate change.

## Evidence that human causing climate change

Based upon the updated and improved uncertainty analysis by Goddard Institute for Space Studies Surface Temperature product, the annual temperature has risen by 1.1°C in the last century (Figure 2) [29,30]. This analysis has been revised from Hames Hansen's late 1970s studies. It includes all spatial variations while collecting weather station data and ocean data from ships, buoys, and other sensors [29]. In the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), which was built upon previous reports, the same global surface temperature rise of 1.09 [0.95 to 1.20]°C in 2011–2020 above 1850–1900 [31] was reported. This estimated increase in global

surface temperature is due to further warming from 2003-2012. According to WGI (Working Group I), there is at least a greater than 50% likelihood that global warming will reach or exceed 1.5°C in the near term (2021-2040), even if we reduce greenhouse gas emissions [31]. If there were no technological or policy changes to reduce emission trends from their current trajectory, then further globally-averaged warming of 2.6 to 4.8 °C (4.7 to 8.6 °F) in addition to what has already occurred would be expected during the 21st century (Figure 6) [32]. Taking drastic measures is vital to prevent the extinction of *Homo sapiens* and our wildlife.

Climate change could happen for many reasons. Climate change has many opinions, such as the distance between Earth and the sun, the amount of energy sent out by the sun, the changing ocean levels, volcanic eruptions, and perhaps human activities. Most peer-reviewed journal studies and IPCC assessment reports have concluded that there is more than a 95% probability that human activities over the past 50 years have warmed up our planet [31]. Fossil fuel combustion for transportation, heating, cooling, and cooking releases greenhouse gases into the atmosphere, which changes Earth's climate.

## Evidence from firn air samples

There is a lot of evidence to support the notion that human activities are the sole cause of climate change. This is based on evidence derived from studies of the rise in Earth's temperature, an increase in $CO_2$ concentration (Figure 3, 4) and other greenhouse gas concentrations, such as methane, nitrous oxide ($N_2O$), and water vapor. This data was mainly derived from firn air samples of ice core studies [33,34]. Other evidence of climate change came from an increase in ocean salinity (Figure 5), ocean sediments, loss of coral reefs, and their catastrophic effects on biodiversity, which we have discussed after firn air samples studies. All of this evidence points to human-based unregulated fossil fuel burning and deforestation [29-31,35].

Human activities have increased $CO_2$ levels above 400 ppm which were not so high for the last 400,000 years of Earth's history [36,37]. The answers got clearer after we learned about the changes in atmospheric $CO_2$ concentration by analyzing air enclosed in polar ice sheets [33,38], mainly from air trapped inside the ice bubbles (Figure 3 and Figure 4). Ice is a relatively inert storage medium for $CO_2$ and many other atmospheric trace gases [33]. The ice cores from Law Dome, East Antarctica [33,34] have been under investigation and have provided 2,000 years of data on $CO_2$ levels, minerals, seasonal sea salts, annual trace ions (chloride, nitrate, sulfate, sodium, potassium, calcium, magnesium, methanesulfonic acid, and non-sea-salt sulfate), annual stable hydrogen and oxygen isotopes [34,39]. Firn is the intermediate stage between snow and glacial ice, which constitutes the upper 40 -120 m or the accumulation zone of ice sheets. Within the firn, a vast network of interconnected pores exists, which exchanges air with the overlying atmosphere. We can determine $CO_2$ concentrations in parts per million (ppm) from these firn air samples. These firn air samples point to a direct link of higher $CO_2$ levels with more use of fossil fuels after the industrial revolution (Figure 3).

## Evidence from argo floats

An increase in $CO_2$ levels causes a change in ocean surface water temperature, ocean heat content (Figure 4), and ocean salt composition (Figure 5), affects ocean ecosystems, causes great ice melts, extremes of weather, changes in precipitation patterns, and lack of rain, etc. [37]. Oceanographers deploy Argo floats which collect information from inside the oceans. These are part of an international Argo program for studying the impact of greenhouse gases on oceans and constantly monitoring the basic parameters of oceans [40,41]. In the year 2000, there were about 2,000 Argo floats, by now we have close to 4,000 active floats. An Argo float is a robotic instrument that measures temperature, pressure, and salinity. It is a cylinder of just over 1 meter long and 14 cm wide. At the top, it contains a conductivity, temperature, and depth sensor (CTD) unit [41]. Temperature is measured with an accuracy of 0.001°C, pressure (closely related to depth) is measured within 0.1 dbar (decibar), and it calculates salinity using conductivity, temperature, and pressure within 0.001 psu (practical salinity units) [40,41]. These Argo floats cover about the upper 2,000 m of the oceans. Each one goes through a 10-day cycle, at first, it spends most of its time drifting in deep ocean currents then it takes a series of measurements as it moves back up to the ocean surface, and finally, it communicates and transfers its data through the iridium satellites [41]. These measurements have clearly shown that the rate of ocean warming for the upper 2,000 m has accelerated in the decades after 1991 from 0.55 to 0.67 $Wm^2$ (Watts Per Square Meter) (Figure 4). This warming has contributed to increase in rainfall intensity, rising sea levels, the destruction of coral reefs, declining ocean oxygen levels, and declines in ice sheets, glaciers, and ice caps in the polar regions [40,42,43].

## Evidence from ROCKE-3D models

Evaporation increases as temperature rises, the partial pressure of $CO_2$ changes and the equilibrium between water and air changes (warm water absorbs less $CO_2$ than cold water), and ocean salinity increases. Recently new data on the effects of ocean salinity on climate was reported using the ROCKE-3D ocean-atmosphere general circulation model [44]. These studies clearly showed the relationship between increased salinity and reduction in sea ice covers. They used three complementary model configurations: a full ocean dynamics and freezing point depression; a modified version with full ocean dynamics but no effect of freezing point depression, and lastly a slab ocean lacking ocean dynamics but including freezing point depression (Figure 5). All of these models suggested the increased ocean salinity from 20 to 50 g/kg of seawater resulted in an increase in the density of water, an increase in $pCO_2$, ocean acidification, ocean warming and reduced sea ice levels (Figure 5) [44].

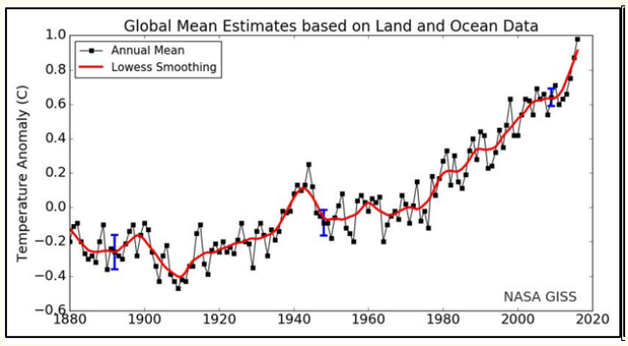


**Figure 2:** Global Mean Estimates based on Land and Ocean Data [29,30] Source: data.giss.nasa.gov.

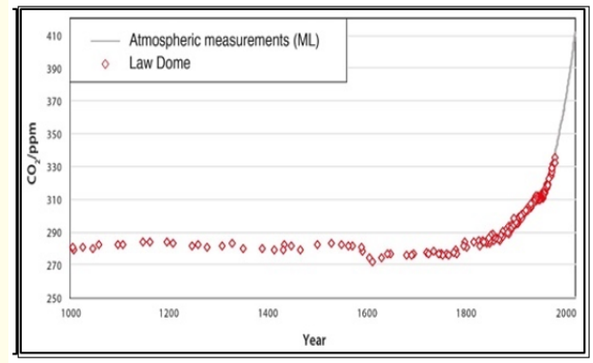


**Figure 3:** Increase in $CO_2$ ppm levels for the last 1,000 years from firn air samples of Law Dome, Antarctica [32].

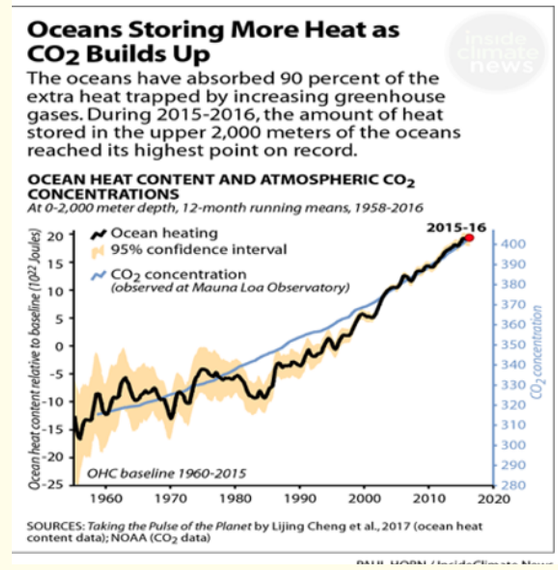


**Figure 4:** Increase in ocean heat content (OHC) with increasing $CO_2$ levels [45].

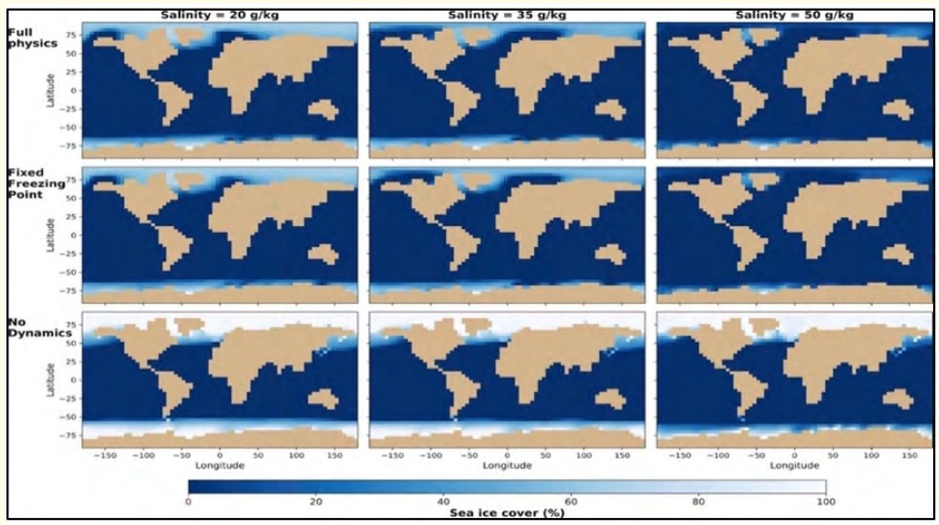


**Figure 5:** Increasing salinity yields lower ice cover in all scenarios, but the effects are most pronounced in model scenarios that include both dynamic and thermodynamic effects [44].

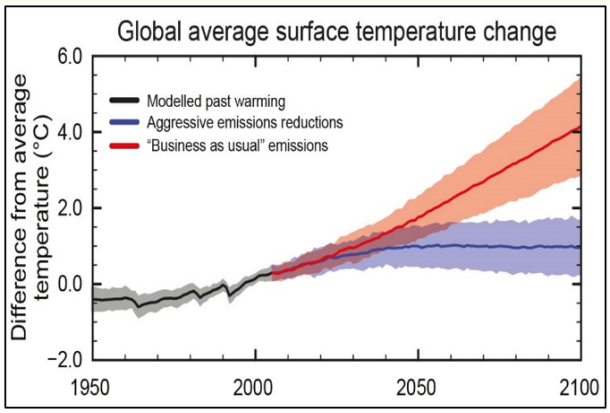


**Figure 6:** The global average surface temperature change expected for the 21st century depends on the total amount of greenhouse gases that we emit or control with aggressive emission reductions [32].

We are on the brink of a major mass extinction and our existence is at risk since we are dependent upon the natural environment for our all-basic needs from clean water, food, and shelter, to medicine. This emphasizes the dire need of educating our communities and neighbors to save our planet from climate change. By educating our students and communities about the benefits of trees and green spaces, we can protect our birds, animals, and biodiversity. The love of trees and knowledge of our remnants of trees are important for building habits of character, social-emotional learning, and life skills, including perseverance, cooperation, equality, equity, solidarity and contributing to the community.

## How do forests protect us?

- **Forests:** Forests are defined as an area of land dominated by trees. There are more than 800 definitions of forests around the world with some countries using several definitions at the same time. According to the Food and Agriculture Organization of the United Nations (FAO), based upon its Global Forest Resources Assessments (FRA), a forest includes a minimum height of trees of 5 m, at least 10 % crown cover or canopy, and a minimum forest area size of 0.5 hectares. Based on this definition, there are 4 billion hectares of forest in the world, covering in all about 30 % of the world's land area [46]. According to a new global map study compiled on 429,775 ground-sourced measurements of tree density from every continent on Earth except Antarctica, we have 3.04 trillion trees, approximately 1.30 trillion in tropical and subtropical forests, 0.74 trillion in boreal regions and 0.66 in temperate regions [47].
- **Forest Bathing:** The World Health Organization has described "Indigenous traditional medicine" as the sum total of knowledge and practices, whether explicable or not, used in diagnosing, preventing or eliminating physical, mental and social diseases [48]. Over 85-90% of the world's inhabitants use indigenous medicines for primary health care. Approximately 50,000–70,000 plant species are used in indigenous medicines [49,50]. India and China use 20% and 19% of the local flora for treating various disorders, respectively [51], and more than 25% of prescription drugs and many more synthetic drugs are derived from plants and phytochemical precursors [50,52]. A study published recently identified 135 species of Queensland (Australia) aboriginal plants as medicinal plants, which treated 62 different diseases, with the highest number of plants used for skin sores and infections [50].

Old forests are the biggest treasure on Earth which human beings have been treating as a wasteyard or menace. Old forests along with purifying air, create a microclimate and irreplicable habitat as compared to young and monoculture forests, especially for endangered species [50]. Old trees also fix nitrogen which allows for its bio-availability, as investigated in forests of British Columbia, Canada [53]. They create below-ground conditions for tree regeneration in their immediate surroundings. Old forests maintain ocean ecosystems, e.g., by providing the necessary iron for the *Cyanobacteria* survival [53,54]. Their unique cellular structure makes them ideal hosts for endogenous fungi, which are a rich source of phytochemicals with high therapeutic applications. One of the recently studied species of arboreal mushroom with a promising treatment for COVID-19 is Agarikon, *Fomitopsis officinalis* [13], also known as an elixir of life. Agarikon has been used for thousands of years for its antiviral, antibacterial, anti-inflammatory, antituberculosis, and antitumor properties [55] (Figure 7).

Well, even having green colored, nature, or forest pictures around our home or workplace relaxes us, and being around forests may even help us be better. An ancient practice involving

spending time around trees, also known as "Shirin Yoku" or forest bathing [17,19] has many physiological, immune, and mental health benefits (Figure 7) [56]. The new science of forest medicine promises to make us healthier, happier, more active, and more relaxed. Technology stress or techno-stress has increased the risk of lifestyle-related diseases like heart, respiratory, metabolic, and mental illnesses [17]. Since the industrial and technological revolution, suicide rates have increased significantly among children, teenagers, and adults. Also, overwork and overtime-related deaths have been on the rise [19]. As a result of technology, humans are facing a major pandemic, acute stress syndrome or stress-related illnesses. This has led to a new form of medicine known as Shirin Yoku or forest medicine. It was originally started in Japan in 1982 but was proposed in 2006 [19]. This is a research-based promising health practice that cultivates the love and beauty of nature or trees not only to relax but to promote mental and physical health and disease prevention. The study of forest medicine is a new interdisciplinary science covering alternative, preventive, and environmental medicine [57]. From medicinal point of view, trees release biogenic volatile organic compounds (VOCs) including phytoncides [17] and are therapeutic. Recently in a forest bathing study on Taiwanese Sugi trees (*Cryptomeria japonica*) phytoncides, a substantial amount of limonene – a key terpenoid constituent – was found, which influences the central nervous system ... improves sleep quality, reduces anxiety, and eases pain (Figure 7) [17]. Most of the conifer forests release d-limonene, a-cedrene, β -elemene, α -terpinene, sabinene and α -copaene, but α -pinene is the main compound in phytoncides (Figure 7) [17]. The oleoresins vapors from balsam poplar or *Populus balsamifera* found in boreal forests of North America are known for protecting the respiratory health of humans and all other mammals [13,20]. There is a strong link between forest therapy and the reduction of stress hormone levels such as adrenaline, noradrenaline and cortisol (Figure 7) [17] . Forest therapy can reduce the risk of heart disease, and hypertension, and enhance the immune response to cancer, and bacterial and viral infections [19,58-60]. Spending time in the forest increases parasympathetic nerve activity and lowers sympathetic nerve activity, so it has relaxing and psychologically calming effects. Symptoms of anxiety, depression, anger and confusion are reduced in both male and female patients [57] by reducing stress hormones and sympathetic nerves' activity. Forest therapy enhances serum dehydroepiandrosterone sulfate levels (secreted by adrenal glands) that decrease with aging and cause onset of degenerative and chronic diseases related to aging [19,61,62]. In summary, we should be revitalizing our old forests, rehabilitating damaged forests and growing new forests. It is important to grow these trees around the hospitals and workplaces, so employees can enjoy forest therapy during lunchtime. Students should have their classes and important study time in these forest areas.

This figure was developed from *Thangaleela., et al.* 2022 [63], Wang, 2019 [17], and *Antonelli., et al.* 2019 [56]. This Fig was Created with BioRender.com.

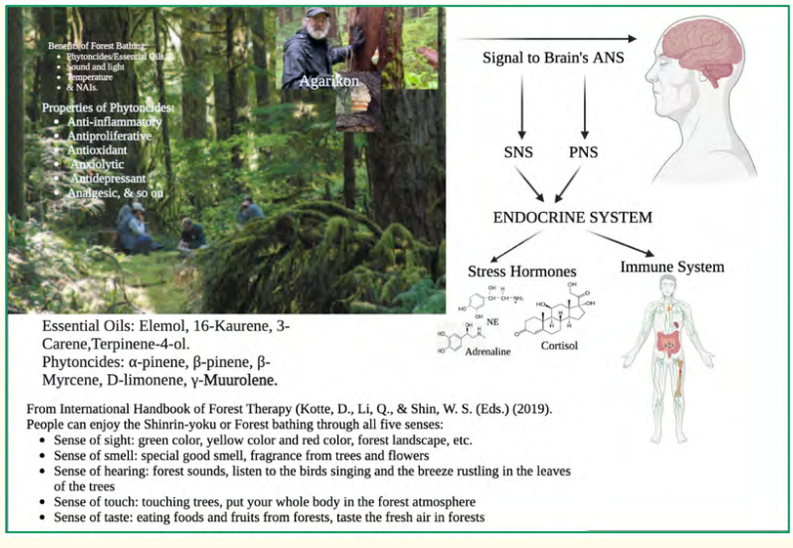


**Figure 7:** Showing the benefits of Forest bathing. Dr. Paul Edward Stamets, the famous mycologist and his favorite mushroom, *Agarikon* (*Fomitopsis officinalis*) [64]. His group has isolated and genomically sequenced 27 strains of Agarikon mushroom [64].

ANS = Autonomous Nervous System; SNS = Sympathetic Nervous System; PNS = Parasympathetic Nervous System; NE = Norepinephrine; Adrenaline or Epinephrine; NAI=Negative Air Ions.

## Deforestation facts [65]

Between 2015-2020, 10 million hectares of forest were destroyed every year, 2,400 trees are cut down each minute. By the time you finish reading this sentence, another three hectares of forest have been cut down. 25.8 million hectares of forest were lost in 2020, double the amount of forested land lost in 2001 [65].

## Greenhouse effect

We are surrounded by a layer of atmosphere, the troposphere, which reaches about 10 km or 6.2 miles above the ground. Most of the Earth's inhabitants live here, nearly all weather, clouds, precipitation, air pollution, and global warming happen in this layer. Our atmosphere's dry air by volume contains 78.09 percent nitrogen, 20.95 percent oxygen, and 0.93 percent argon. A brew of trace gases accounts for the rest of 0.03 percent [66]. These trace gases are also known as greenhouse gases (GHGs), which include carbon dioxide, sulfur dioxide, sulfur hexafluoride ($SF_6$), methane, nitrous oxide, ozone, water vapor, halocarbons (chlorine, bromine, and fluorine) and solid or liquid particulates also known as aerosols [67]. These aerosols could vary from micrometers to millimeters in size. Aerosols arise from natural sources like dust, sea salt, and volcanic emissions but also include pollutants from power plant emissions, traffic emissions, and fossil fuel emissions [67]. The Montreal Protocol gases like chlorofluorocarbons (CFCs, particularly CFC-11 and CFC-12), hydrochlorofluorocarbons (HCFCs), and chlorocarbons have also contributed to GHGs although they have begun to decline [35]. Concentrations of many of the fluorine-containing Kyoto Protocol gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$) have increased by large factors (between 4.3 and 1.3) from 1998 to 2005 [35]. The reactive gas OH, which influences the radiative forcing values of $CH_4$, HFCs, HCFCs, and ozone, also plays an important role in the formation of sulphate, nitrate and organic aerosol species [35]. The increase in these GHGs came mainly from the start of the industrial era (about 1760) and the major contribution is by burning fossil fuels, which release carbon dioxide gas into the atmosphere. Whether we agree or not, the change in climate due to human activities has exceeded the natural or solar change and volcanic emissions [35].

The imbalanced levels of these trace gases cause catastrophic effects on our climate. The sun's radiant energy is crucial to keeping our planet warm. Some of this inbound energy is reflected into space as infrared radiation (thermal energy). With the rise of greenhouse gases because of human anthropogenic activities, outgoing energy is trapped, which increases the surface temperature- the root cause of the climate crisis. Among these greenhouse gases, water vapor which most of us tend to overlook plays a critical role. Water vapor concentration varies and affects global warming significantly. As the atmospheric temperature increases, the amount of humidity in the atmosphere also goes up, further heating our planet. This changes the oceans' salinity and the overall water cycle of our planet in a vicious loop [66].

In summary, this imbalance of radiant energy leads to Earth's energy imbalance or EEI, which is what drives global warming. As mentioned above, the EEI is a combination of greenhouse gases: $CO_2$, $N_2O$, $CH_4$, $O_3$, and water vapor. It affects our climate by altering outgoing infrared (thermal) radiation [35,43].

## Forests are the climate change solution

Forests protect us from the greenhouse effect by sequestering (absorbing) and storing $CO_2$, thereby acting as a sponge that prevents climate change on Earth. Forests remove on average 2.4 billion tonnes of carbon per year from the atmosphere [68,69]. The current carbon (C) stock in the world's forests is estimated to be 861 ± 66 PgC (petagrams of carbon), with 383 ± 30 PgC (44%) in soil (to 1m depth), 363 ± 28 PgC (42%) in live biomass (above- and below-ground), 73 ± 6 PgC (8%) in deadwood, and 43 ± 3 PgC (5%) in litter [68]. The preservation of old forests is extremely important because when we lose trees, we lose our carbon sink, and when these trees degrade, they release much of this stored carbon dioxide into the atmosphere. Thus, deforestation and forest degradation contribute significantly to global warming by releasing more carbon dioxide into the atmosphere.

When we compare the carbon sink (C sink means anything that absorbs more carbon from the atmosphere than it releases) values of different forest biomes, we found that tropical rainforests showed a decrease in C sink by 23%, and temperate forests showed an increase in C sink by 17% in 2000-2007 compared to 1990-1999. While boreal forests, on average, showed little difference between these two time periods. These numbers highly suggest how to plan before reforestation and afforestation in order to have better values of C sink. Temperate forests are easy to grow and have a higher photosynthetic potential. It is better to grow temperate forests for human daily use rather than cutting old rainforests [70]. Temperate species also show a higher acclimation potential the way they live in the larger seasonal and day-to-day variation in temperature of the temperate climate compared with the tropical climate. The temperate species showed at least 80% of maximum net photosynthesis over a larger span of acclimation temperature than the tropical species [70].

There are three ways to reverse forest losses: afforestation, reforestation, and the natural regeneration of forest ecosystems. Afforestation means to plant forests where there were no trees before, or a region where forests have been missing for a long time—50 years or more. Reforestation is planting trees in a recently cleared forest. Natural regeneration means letting nature grows trees successively, it does not involve human tree planting. Instead, local communities or forest officers help damaged forests by human activities, forest fires, or other natural calamities, by just letting trees grow naturally or by re-seed, and through techniques like coppicing [71], in which trees are cut down to stumps so new shoots can grow.

Our planet would benefit from the restoration and preservation of forests, while deforestation would exacerbate climate change. Fossil fuels release emissions above 8 billion tonnes per year compared to deforestation, which is responsible for emitting 2.9 billion tonnes of carbon per year [68]. Since 1850, about 30% of all $CO_2$ emissions have come from deforestation. Deforestation also contributes to local climate impacts. Because trees release moisture that cools the air around them, more intense heat waves have been found in North America and Eurasia [72,73]. We are already seeing the effects of deforestation in our backyard (Figure 8). We need to take immediate action now. If properly planned, forestation can provide more than one-third of the total $CO_2$ reductions to keep global warming below 2°C through 2030 [74]. If we even act now, worldwide natural regeneration of forests could capture up to 70 billion tons of carbon in plants and soils between now and 2050 [75].

In the end, time to find a few answers from natural climate solutions of the Climate Change Conference, COP27. According to U.S. Nature4Climate, natural climate solutions are conservation, restoration, and improved land management strategies that help remove carbon from the air while also keeping our air and water clean and our soil healthy and productive. To reduce global emissions by about 37% or more than a third by 2030, and to keep the rise in global average temperature below 2°C, the U.S. will prioritize forest and ecosystem conservation, will also ocean-based measures for reducing emissions, U.S. is among 71 other countries to preserve coastal wetlands to reduce emissions. Also stop methane emissions from the agricultural sectors [74,76].

Our climate catastrophes can still be prevented by correctly planning reforestation, afforestation, and preserving old forests. Our global efforts to reforest and preserve old forests need to be planned, designed, and delegated together.

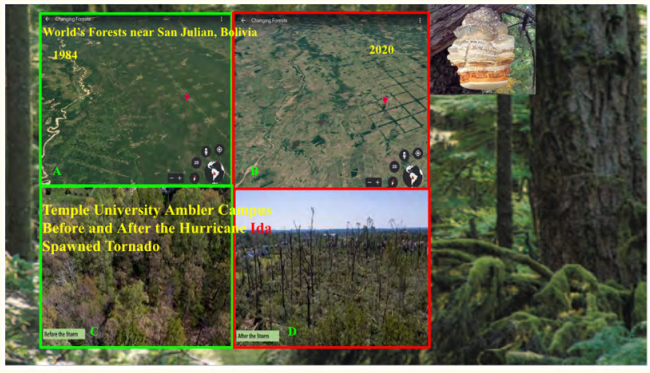


**Figure 8:** Deforestation and Climate Change's catastrophic effects in our backyards. These pictures were taken from a time-lapse of Amazon forests in Google Earth; Temple University's Ambler campus before and after a tornado in October 2021, Philadelphia Inquirer.

ADD/ADHD= Attention-deficit disorder/attention deficit hyperactivity disorder; ATP= Adenosine

NADPH= Nicotinamide adenine dinucleotide phosphate

OHC=Ocean Heat Content; W m-2=Watts Per Square Meter;

WGI= Working Group I; GHGs=greenhouse gases ;

$CO_2$= Carbon Dioxide; $N_2$= Nitrogen; $O_3$= Ozone;

$CH_4$=Methane; $N_2O$= Nitrous Oxide, Laughing Gas

NaHCO3=Sodium Bicarbonate; $C_6H_8O_7$ or $HOC(CH_2CO_2H)_2$ =Citric Acid; $Na_3C_6H_5O_7$ = Sodium Citrate;

$SF_6$ =sulfur hexafluoride; CFCs=chlorofluorocarbons

HCFCs=hydrochlorofluorocarbons; PPM= Parts Per Million;

Dbar=Decibar (1dbar=10,000 Pascals); AR=Assessment Report;

F=Fahrenheit; C=Celsius; ANS=Autonomous Nervous System;

SNS=Sympathetic Nervous System;

PNS=Parasympathetic Nervous System; NE=Norepinephrine;

PgC: petagrams of carbon.

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## Bibliography

1. Strother P K., *et al*. "Earth's earliest non-marine eukaryotes". *Nature* 473.7348 (2011): 505-509.

2. Knauth L P and M J Kennedy. "The late Precambrian greening of the Earth". *Nature* 460 (2009): 728-732.

3. Woodson J D. "Chloroplast quality control - balancing energy production and stress". *New Phytology* 212.1 (2016): 36-41.

4. Johnson M P. "Photosynthesis". *Essays Biochemistry* 60.3 (2016): 255-273.

5. Turner-Skoff J B and N Cavender. "The benefits of trees for liveable and sustainable communities". *Plants, People, Planet* 1.4 (2019): 323-335.

6. Vella-Brodrick D A and K Gilowska. "Effects of Nature (Greenspace) on Cognitive Functioning in School Children and Adolescents: a Systematic Review". *Educational Psychology Review* 34.3 (2022): 1217-1254.

7. Timilsina A., *et al*. "Potential Pathway of Nitrous Oxide Formation in Plants". *Frontiers in Plant Science* 11 (2020): 1177.

8. Sundqvist E., *et al*. "Atmospheric methane removal by boreal plants". *Geophysical Research Letters* 39.21 (2021).

9. Margulis L S and Dorion. Microcosmos: Four Billion Years of Microbial Evolution. Microcosmos: Four Billion Years of Microbial Evolution. California: University of California Press. ed. "Chapter 6, "The Oxygen Holocaust"". (1986).

10. Tang K H., *et al*. "Carbon metabolic pathways in phototrophic bacteria and their broader evolutionary implications". *Frontiers in Microbiology* 2 (2011): 165.

11. Cardona T., *et al*. "Origin and Evolution of Water Oxidation before the Last Common Ancestor of the Cyanobacteria". *Molecular Biology and Evolution* 32.5 (2015): 1310-1328.

12. Dismukes G C., *et al*. "The origin of atmospheric oxygen on Earth: the innovation of oxygenic photosynthesis". *Proceedings of the National Academy of Sciences of the United States of America* 98.5 (2001): 2170-2175.

13. Roviello V., *et al*. "Forest-bathing and physical activity as weapons against COVID-19: a review". *Environmental Chemistry Letters* 20.1 (2022): 131-140.

14. Jesus I., *et al*. "Promising effects of exercise on the cardiovascular, metabolic and immune system during COVID-19 period". *Journal of Human Hypertension* 35.1 (2021): 1-3.

15. Wang H., *et al*. "Study on the change of negative air ion concentration and its influencing factors at different spatio-temporal scales". *Global Ecology and Conservation* 23 (2020): e01008.

16. Jiang S Y., *et al*. "Negative Air Ions and Their Effects on Human Health and Air Quality Improvement". *International Journal of Molecular Sciences* 19.10 (2018).

17. Wang S Y. "The Effect of Phytoncides". International Handbook of Forest Therapy, ed. D. Kotte, Q. Li, and W.S. Shin. 2019, Newcastle-upon-Tyne, UNITED KINGDOM: Cambridge Scholars Publisher (2019).

18. Wolf K. International Handbook of Forest Therapy. International Handbook of Forest Therapy, ed. D. Kotte, Q. Li, and W.S. Shin. 2019, Newcastle-upon-Tyne, UNITED KINGDOM: Cambridge Scholars Publisher (2019).

19. Qi L and Shinrin-yoku. "The Art and Science of Forest Bathing – How Trees Can Help You Find Health and Happiness". London: Penguin Random House (2018).

20. Beresford-Kroeger D and C H Kroeger. "Arboretum borealis. Arboretum borealis". 2010: University of Michigan Press (2010).

21. Borukh I., *et al*. "bactericidal effect of volatile phytoncides of garlic". Voprosy pitaniia, (1974).

22. Phytoncide, in In Wikipedia (2022).

23. Park, Y L., *et al*. "Comparative Study on the Education System of Traditional Medicine in China, Japan, Korea, and Taiwan". Explore (NY), 12.5 (2016): 375-83.

24. Introduction to the Electromagnetic Spectrum. NASA Science (2016).

25. Helmenstine A. Leaf Chromatography Experiment – Easy Paper Chromatography (2022).

26. GM C. "The Cell: A Molecular Approach". 2nd edition. The Cell: A Molecular Approach. 2nd edition. Sunderland (MA): Sinauer Associates ed. Photosynthesis (2000).

27. Archibald J M. "Endosymbiosis and Eukaryotic Cell Evolution". *Current Biology* 25.19 (2015): R911-921.

28. Howe C J. "Cellular evolution: what's in a mitochondrion?" *Current Biology* 18.10 (2008): R429-r431.

29. Lenssen N J L., *et al*. "Improvements in the GISTEMP Uncertainty Model". *Journal of Geophysical Research: Atmospheres* 124.12 (2019): 6307-6326.

30. GISS Surface Temperature Analysis (GISTEMP). NASA Goddard Institute for Space Studies (2023).

31. Hans Pörtner D C R. Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change. [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck,A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)] ed. In: Climate Change. 2022, Impacts, Adaptation and Vulnerability Cambridge University Press, Cambridge,UK and New York, NY, USA (2022): 37-118.

32. The Basics of Climate Change. Climate Change: Evidence and Causes (2020).

33. Etheridge D M., *et al*. "Natural and anthropogenic changes in atmospheric CO2 over the last 1000 years from air in Antarctic ice and firn". *Journal of Geophysical Research-Atmospheres* 101. D2 (1996): 4115-4128.

34. Jong L M., *et al*. "2000 years of annual ice core data from Law Dome, East Antarctica". *Earth System Science Data* 14.7 (2022): 3313-3328.

35. Forster, P., *et al*. "Changes in Atmospheric Constituents and in Radiative Forcing" (2007).

36. Schmidt L J. "Satellite data confirm annual carbon dioxide minimum above 400 ppm" (2017).

37. Wheeler N and N Watts. "Climate Change: From Science to Practice". *Current Environmental Health Reports* 5.1 (2018): 170-178.

38. Keeling, C D. "Atmospheric $CO_2$-modern record, South Pole". Atmospheric $CO_2$-modern record, South Pole. A Compendium of Data on Global Change, edited by T.A. Voden, R.J. Sepanski, and F.W. Stoss ed. in Trends. (1991a).

39. Rubino, M., *et al*. "A revised 1000 year atmospheric δ13C-CO2 record from Law Dome and South Pole, Antarctica". *Journal of Geophysical Research: Atmospheres* 118.15 (2013): 8482-8499.

40. What is Argo. "These data were collected and made freely available by the International Argo Program and the national programs that contribute to it".

41. The Argo Program is part of the Global Ocean Observing System" (2000).

42. How Argo floats work.

43. Cheng, L., *et al*. "How fast are the oceans warming?" *Science* 363 (2019): 128-129.

44. Cheng L., *et al*. "Improved estimates of ocean heat content from 1960 to 2015". *Science Advances* 3.3 (2017): e1601545.

45. Olson S., *et al*. "The Effect of Ocean Salinity on Climate and Its Implications for Earth's Habitability". *Geophysical Research Letters* 49.10 (2022): e2021GL095748.

46. Horn P. Oceans Storing More Heat as $CO_2$ Builds Up, in Inside Climate News (2017).

47. Forest definition and extent, in United Nations Environment Programme. 27 January (2010).

48. Crowther T W., *et al*. "Mapping tree density at a global scale". *Nature* 525.7568 (2015): 201-205.

49. World Health O. WHO global report on traditional and complementary medicine 2019. WHO global report on traditional and complementary medicine 2019. 2019, Geneva: World Health Organization (2019).

50. Wangchuk P. "Therapeutic Applications of Natural Products in Herbal Medicines, Biodiscovery Programs, and Biomedicine". *Journal of Biologically Active Products from Nature* 8.1 (2018): 1-20.

51. Turpin G., *et al*. "Aboriginal medicinal plants of Queensland: ethnopharmacological uses, species diversity, and biodiscovery pathways". *Journal of Ethnobiology and Ethnomedicine* 18.1 (2022): 54.

52. Wangchuk P and T Tobgay. "Contributions of medicinal plants to the Gross National Happiness and Biodiscovery in Bhutan". *Journal of Ethnobiology and Ethnomedicine* 11 (2015): 48.

53. Rates S M. "Plants as source of drugs". *Toxicon* 39.5 (2001): 603-13.

54. Gilhen-Baker M., *et al*. "Old growth forests and large old trees as critical organisms connecting ecosystems and human health. A review". *Environmental Chemistry Letters* 20.2 (2022): 1529-1538.

55. Krachler R., *et al*. "Natural iron fertilization of the coastal ocean by "blackwater rivers". *Science of the Total Environment* 656 (2019): 952-958.

56. Elkhateeb W., *et al*. "Fomitopsis officinalis mushroom: ancient gold mine of functional components and biological activities for modern medicine". *Egyptian Pharmaceutical Journal* 18.4 (2019): 285-289.

57. Antonelli M., *et al*. "Effects of forest bathing (shinrin-yoku) on levels of cortisol as a stress biomarker: a systematic review and meta-analysis". *International Journal of Biometeorology* 63.8 (2019): 1117-1134.

58. Qing L. "Forest Medicine". ln: Li Q (ed): Forest Medicine. New York: Nova Science Publishers Inc (2012).

59. Li Q., *et al*. "Acute effects of walking in forest environments on cardiovascular and metabolic parameters". *European Journal of Applied Physiology* 111.11 (2011): 2845-2853.

60. Li Q., *et al*. "Forest bathing enhances human natural killer activity and expression of anti-cancer proteins". *International Journal of Immunopathology and Pharmacology* 20.2 (2007): 3-8.

61. Li Q., *et al*. "A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects". *Journal of Biological Regulators and Homeostatic Agents* 24.2 (2010): 157-165.

62. Bjørnerem A., *et al*. "Endogenous sex hormones in relation to age, sex, lifestyle factors, and chronic diseases in a general population: the Tromsø Study". *The Journal of Clinical Endocrinology and Metabolism* 89.12 (2004): 6039-6047.

63. Tsai Y-M., *et al*. "Effect of resistance exercise on dehydroepiandrosterone sulfate concentrations during a 72-h recovery: relation to glucose tolerance and insulin response". *Life Sciences* 79.13 (2006): 1281-1286.

64. Thangaleela S., *et al*. "Essential Oils, Phytoncides, Aromachology, and Aromatherapy— A Review". *Applied Sciences* 12.9 (2022): 4495.

65. Stamets P. Fungi Perfecti. November 13, (2009).

66. Deforestation Facts and Statistics Deforestation Facts and Statistics (2022).

67. Buis A. The Atmosphere: Getting a Handle on Carbon Dioxide. October 9 (2019).

68. Wofsy S C., *et al*. "ATom: Merged Atmospheric Chemistry, Trace Gases, and Aerosols (Version 1.5)". 2018 (ORNL Distributed Active Archive Center.).

69. Pan Y., *et al*. "A large and persistent carbon sink in the world's forests". *Science (New York, N.Y.)* 333.6045 (2011): 988-993.

70. Harris, N L., *et al*. "Global maps of twenty-first century forest carbon fluxes". *Nature Climate Change* 11.3 (2021): 234-240.

71. Cunningham S C and J Read. "Do temperate rainforest trees have a greater ability to acclimate to changing temperatures than tropical rainforest trees?" *New Phytologist* 157.1 (2003): 55-64.

72. Stanford G. SHORT-ROTATION FORESTRY AS A SOLAR ENERGY TRANSDUCER AND STORAGE SYSTEM G. Stanford is director, Greenhills Center, Cedar Hill, Texas 75106. Editor's Note: This report is based on a larger study now in progress. Because of space limitations, it was necessary to remove a considerable amount of material from the original manuscript submitted by the author. Anyone wishing to obtain the complete paper can do so by writing to Dr. Stanford at Greenhills Center, Route 1, Box 861, Cedar Hill, Texas 75106, in Agriculture and Energy, W. Lockeretz, Editor. (1977): 535-557.

73. Le Quéré, C., *et al*. "Global Carbon Budget 2016". *Earth System Science Data* 2 (2016): 605-649.

74. Lejeune Q., *et al*. "Historical deforestation locally increased the intensity of hot days in northern mid-latitudes". *Nature Climate Change* 8.5 (2018): 386-390.

75. Griscom B W., *et al*. "Natural climate solutions". *Proceedings of the National Academy of Sciences of the United States of America* 114.44 (2017): 11645-11650.

76. Cook-Patton S C., *et al*. "Mapping carbon accumulation potential from global natural forest regrowth". *Nature* 585.7826 (2020): 545-550.

77. Natural Climate Solutions Briefing Series: What Congress Needs to Know About COP27 (2022).