Revista Virtual de Química

Article

http://dx.doi.org/10.21577/1984-6835.20240024

What are the Advantages of Conserving Forests?

Quais são as Vantagens de Conservar as Florestas?

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Recebido: 10 de Agosto de 2023

Aceito: 28 de Abril de 2024

Publicado online: 6 de Maio de 2024

Forests have long been crucial for humanity's survival and economic development. Conservation is essential for sustainability, offering benefits like job creation and renewable resources. However, forests are under threat due to exploitation. Yet, they play a vital role in mitigating natural disasters and supporting biodiversity. Conservation efforts can attract corporations, generating various products sustainably. Achieving sustainable development requires a shift in global economic thinking towards responsible resource use. Rich countries must adopt lifestyles aligned with planetary sustainability. Implementing sustainable development is challenging but crucial for addressing poverty, inequality, and environmental degradation. This article reflects on the advantages of conserving forests and the potential profits from their preservation.

Keywords: Sustainable development; biomass; chemicals; medicines; conservation of fauna and flora.

1. Introduction

"*I'm here to sound the alarm: the world must wake up. We are on the edge of an abyss - and moving in the wrong direction*"
António Guterres Secretário-geral da ONU, 2021

This article intends to address the global climate effects caused by the deforestation of forests in different biomes and the scientific and economic opportunities that will be wasted with the non-conservation of these biomes. It is imperative to stop the loss of life and damage to ecosystems, as well as the impacts on food supply and health. One of the most important actions is to make the forest sector carbon neutral by halting deforestation and recovering degraded areas and, consequently, stabilizing atmospheric greenhouse gas levels. Although deforestation is not explicitly written in the UN Sustainable Development Goals (SDGs), it fits into SDGs 6 (Good health and well-being), 11 (Sustainable cities and communities), 12 (Responsible consumption and production), and 13 (Climate action). Actions that aim to expand the multiple dimensions of sustainability that are fundamental for the continuity of species and ecosystems that sustain them, that is, an expansion of our perceptions of time.

The effects of human activities on the planet are visibly present in the oceans, rivers, air, forests, polar ice caps, terrestrial and marine fauna and flora and with this, the Earth's climate is changing, largely due to greenhouse gas emissions. The decade 2010-2019 had the highest level of emissions compared to any other decade.[1] The extreme alterations of the environment are reaching situations that are apparently on the threshold of irreversibility, as the resilience of these environments will hardly recover spontaneously. On the other hand, global temperatures continue to increase with extremely serious impacts and affecting developing countries and in these the poorest people who are exposed to a greater incidence of droughts and floods, food shortages with agricultural losses, drinking water, diseases, and loss of homes and their livelihoods. The wildfires that are raging all over the world increase pollution and, consequently, asthma and other serious lung diseases.[2,3]

Extreme weather events across the planet are the result of several factors that are normally associated and are cumulative costs. Some are highlighted in Figure 1, such as population growth, intensive exploitation of natural capital, devastation of forests and biomes, exploitation and aggression to rivers, lakes, and oceans, use of fossil fuels, lack of environmental governance, waste management, and education formal of the population. It is important to highlight and reflect that natural disasters disproportionately affect the most unequal. Historically, we have repeatedly seen that the devastating effects of natural events such as hurricanes, earthquakes,

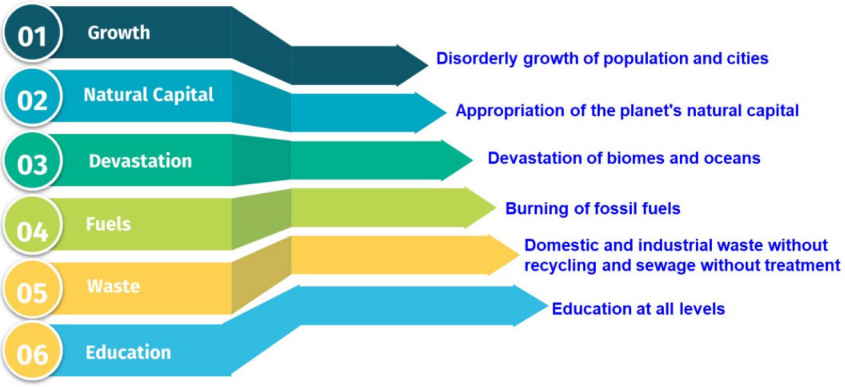

Figure 1. Some factors that contribute to extreme weather events

floods, and droughts tend to be more severe for the most vulnerable and marginalized communities.[4]

One of the activities that most impacts the entire environment is predatory deforestation in mangroves and forests, which eliminates important biomes, affecting the lives of everyone on the planet to the benefit of large corporations that exploit the natural capital of all to the detriment of some. This same natural capital of forests, apart from logging, can be a way out of poverty, which is the number one goal of the UN Sustainable Development Goals. However, if the devastation of forests, rivers, lakes, and oceans continues, the planet will not last another century because of the speed at which the world is advancing nowadays, reaching a point of irreversibility. Unfortunately, the world continues to advance in recent years in the devastation of several biomes.[5] The future of this planet depends on the sensible attitudes of policymakers in each country and on the proactive behavior of society. Jared Diamond, in 2005, reported the cases of 8 civilizations going to ruin and disappearing when their forests were decimated. Therefore, humanity on this planet will fundamentally depend on conserving and restoring forests, or what remains of them.

Natural resource sources are in jeopardy due to rising levels of consumerism in large cities that promote GDP growth. If on the one hand GDP is the most common metric of a thriving economy, on the other hand, it blinds us to the devastating impact this economic activity has on our environment and natural capital. However, development should be centered on people and not exclusively based on production, as consumption and economic growth are the main causes of the destruction of natural environments. For many years, scientists have warned about the compromise of natural resources and the environmental impact, since human well-being is always associated with the conscious consumption of renewable natural resources. In this sense, Boyden and Dovers warned in 1992 that in 4000 million years of life on Earth, no species has caused as many ecological disturbances as Homo sapiens,[6] and that urgent containment actions must be taken to solve the environmental problems with the implanted scale of a sustainable economy, to improve people's living conditions in a world that is estimated to have 9 billion people on Earth by 2050.

In order to guarantee food and water supply, it will be necessary to recompose the forests and their water sources and recover the rivers, lakes, and polluted oceans.[7] These challenges represent just a few important examples that humanity will have to face and that we can call challenges for sustainable development.

The transition to a low carbon economy has become the icon of the 21st century where sustainability and sustainable development should be focused on research and evidence-based thinking.[8] Although the terms sustainability and sustainable development are worn out by being used as a deception, without precision and commitment by governments, companies and institutions. In some products and processes, sustainability is a type of greenwash to increase consumption and production practices without compromising the environment. About this issue wrote Leonardo Boff – "*The current mode of production aiming at the highest possible level of accumulation (how can I earn more?) involves the domination of nature and the exploitation of all its goods and resources*".[9]

2. Actions of the United Nations (UN) for the Environment

The UN has been for the last 40 years very concerned with issues related to the degradation of the environment at a global level. Since then, it has organized periodic conferences with countries on the principles of global cooperation, setting goals to achieve sustainable environmental and social development. These conferences have attracted a lot of attention from educational and academic circles, as they are focused on the multiple aspects of sustainability.

The concept of sustainability entered the scientific literature through the work of Wes Jackson on sustainable agriculture in 1985,[10] who noted that there are still problems today in agriculture that are totally dependent on pesticides, herbicides, and chemical fertilizers that are poisoning ecosystems around the world.[11,12] From the

publication Wes Jackson, the term sustainability began to gain importance in political and academic circles, and was reinforced with the publication of the Report – "*Our Common Future. A global agenda for change*" or also known as "*Brundtland Report*", which was presented on 27 April 1987 to the World Commission on Environment and Development chaired by Gro Harlem Brundtland.[13] The report has valuable documentation on global growth issues and socio-environmental issues. Despite the various criticisms for not pointing out solutions that are at the origin of the problems, its objective was achieved and it challenged the ignorance and global inadequacy of the dominant policy on the environment, poor and vulnerable people, alternative energies (biofuels),[14] natural resources, predatory industrial activities and the degradation of the developing world.[15] From this report came the best-known definition of sustainable development that could serve the world of the next century: "*Sustainable development is, in essence, development that meets the needs and aspirations of the present generation without destroying the resources needed for future generations to meet their needs*". This report triggered all other UN conferences ("Only One Earth", 1972, Stockholm;[16] "Our Common Future", 1992, Rio de Janeiro;[17] "The Future We Want", 2012, Rio de Janeiro; "Millennium Development Goals", 2000, UN General Assembly"[18]) and several climate panels and, even after 40 years, only some progress was achieved in raising awareness and understanding the obstacles to sustainable development, which continued and worsened both in terms of the urgency of needs and their indicators of socio-environmental conditions.

3. The Sustainable Development Goals (ODSs)

The most recent action by the UN was in 2015 when the assembly reaffirmed all its commitments from previous conferences with a broader vision called "Agenda 2030". The vision was that many other problems should be integrated with sustainable development across the planet. Seventeen Sustainable Development Goals (SDGs) were elaborated, for which it will take collective commitment from the entire world population to overcome the problems and the continuity of life on the planet (Figure 2).

The SDGs are integrated in such a way that action in one area of the planet will affect outcomes in others, and therefore economic development must balance environmental and social sustainability. Figure 2 highlights goals such as ending poverty and hunger,[19] promoting peace and justice, and discrimination against women and girls. The SDGs have goals and indicators to be achieved by 2030 to make the planet more sustainable and supportive of the future and for all people to enjoy peace and prosperity. In fact, some of these SDGs are based on solutions that can come from the Basic Sciences, but others clearly reveal that the problems for sustainable development are associated

Sustainable Development Goals (SDGs)	**1** No poverty	**2** Zero hunger	**3** Good health and well-being	**4** Quality education	**5** Gender equality
6 Clean water and sanitation	**7** Affordable and clean energy	**8** Decent work and economic growth	**9** Industry, innovation and infrastructure	**10** Reduced inequalities	**11** Sustainable cities and communities
12 Responsible consumption and production	**13** Climate action	**14** Life below water	**15** Life on land	**16** Peace, justice and strong institutions	**17** Partnerships for the goals

Figure 2. SDGs proposed by the UN in 2015

with different forms of inequalities: financial, gender, race, ethnicity, education, health, and jobs.

Reality shows that our vision of a solidary and sustainable future has not yet been achieved. Peace remains elusive, and we continue to face challenges like terrorism, hunger, poverty, drought, rising global temperatures, rampant consumerism, ocean pollution, and deforestation.[20,21] The environment experienced greater degradation than in previous years, while inequality soared. It is quite clear that this is the most dangerous security issue that humanity has ever faced and how it has been properly dealt with threatens the support and sustainability of life on Earth. It doesn't look like our planet is doing well, given that extreme weather events have progressed in many parts of the world where in the past they were just atypical. Many will say that it was the SARS-CoV-2 (coronavirus) pandemic that increased the use of natural resources and the gap of inequality, unemployment, lack of upward mobility, and, worst of all, hunger and misery, but this does not correspond to reality. Scheidel reports that "the richest 1% of the world's families now own just over half of the global private net worth".[22] The author himself considers this number to be an underestimate, as many billionaires hide their resources in secret accounts abroad. Harari states that there are countries with degrading inequality: "Russia is one of the most unequal countries in the world, with 87% of the wealth concentrated in the hands of the richest 10% of the population".[23]

4. The Importance of Forests

Forests are areas with a high density and variety of trees, shrubs, creeping plants, animals, birds, insects, and microorganisms attached to the plants and soil that occupy the entire planet. Its diverse natural resources have played important roles in ensuring conservation and sustaining the

livelihoods of millions of people around the world, including indigenous and rural communities. Preserved and conserved forests can also be socially useful generating jobs (*e.g.*, guides, guards, agronomists, gardeners, etc.) and income when allocated for recreational use, ecological tourism, scientific and educational research, and for the conservation of cultural sites.

Recently, the Food and Agriculture Organization of the United Nations (FAO) released the report "FAO Global Assessment of Forest Resources"[24] which provides essential information for understanding the extent of forest resources, their condition, management, and uses in 187 countries and territories. According to data from this report, the world has a total forest area of 4.06 billion hectares (ha), which represents 31% of the total land area. As forests are not evenly distributed between countries, more than half (54%) of the world's forests are in just five countries in descending order: Russian Federation (20%), Brazil (12%), Canada (9%), United States of America (8%) and China (5%). Between 1990-2000 forest area loss was 7.8 million ha/year, but decreased to 4.7 million ha/year in 2010-2020. It should be noted that this rate is still considered to be of great danger to the most degraded forests. About 1.15 billion ha (25%) of forests are managed and geared towards the production of non-wood and non-wood forest products (NWFPs – Non-Wood Forest Products).[25] The report also highlights that in the last 10 years forests have increased in watershed areas to protect soil and fresh water.

Brazil has a great diversity of botanical species, and their uses by the population, ranging from medicinal purposes[26] even as the supply of raw materials to generate commercial products relevant to the economy. The forests, such as the Amazon, Cerrado, Atlantic Forest, Caatinga, Pampa, and Pantanal which hold a rich diversity of species (9.5%) of fauna and flora, about 50 thousand species of higher plants representing approximately 19% of the world total.[27,28] All these forests are heavily degraded, deforested and reduced to fragments. FAO defines deforestation as the conversion of forest to other land uses (regardless of whether it is human-induced). A large number of species are already extinct in a serious situation of vulnerability. The most degraded set of forests in Brazil is the Atlantic Forest, which represents several forests and ecosystems and which corresponds to 15% of the Brazilian territory. It covers practically the east coast going from the northeast to the south of Brazil, Paraguay, and Argentina. Currently, the vegetation of these ecosystems has only 7% of the original forest.[29] The Atlantic Forest plays a vital role in water supply, climate regulation, agriculture, fishing, electricity generation, and tourism. However, today, only 12.4% of the original forest remains.[30]

Products classified as NWFPs can play a very important role in supporting rural livelihoods and the economy, as forests have a high intrinsic value.[31] This aspect must be taken into account for their conservation, as they are essential for the survival of humans, animals, insects, microorganisms and plants. When something has intrinsic value, it deserves to be treated with respect for human well-being, for example, sustainable harvesting and the use of NWFPs can encourage forest conservation. Therefore, conserved forests are responsible for providing jobs with poverty reduction, food, and medicine, decreasing water evaporation from ecosystems, making textile materials available, conserving ecological processes; maintaining river sources, fixing carbon, stopping solar heating, feeding fish, insects and animals, maintaining species diversity (fauna and flora), and maintaining climate order in micro- and macro-regions. They are capable of transforming large amounts of solar energy and carbon dioxide primarily into cellulose in leaves, roots, fruits, trunks, and branches.

Brazil has a large forest ecosystem and multifaceted amenities, with many botanical species that could be valued for medicinal and food purposes and, in this way, achieve sustainable development goals in the forestry sector. One of the side effects of deforestation is the extinction of species that can be forever because to bring an animal or plant back (de-extinction or re-creation of the species)[32] it is still scientifically incipient, expensive, and impossible to apply to all species. Advocates of re-creation tend to emphasize the technological and scientific value of such an undertaking, as man has an obligation to the species. Without forests, extinction occurs even with species not yet cataloged and will affect the viability of man on the planet, as there will be no support for life. Ancient forests are made of trees that are usually several thousand years old and take at least 100 years to grow back to maturity if they are cut down. Without forests, the heat and lack of water will be unbearable. Many of these effects can already be seen with extreme weather events.

Forests are very important for maintaining and enhancing biodiversity and they also provide a wide variety of natural products, economic valuation, and ecosystem services.[33] Tropical forests represent the most abundant biome in the world and have the greatest diversity of species representing more than half of the number of species on Earth. Its importance can be evaluated by its ability to generate abundant and relevant natural products for medicinal areas (Figure 3). On this subject, the editorial by Professor Paes de Carvalho is quite enlightening: "Biodiversity is rightly seen in Brazil as one of the important sources of national enrichment. In other words, we must focus attention on how to develop sustainable and conservative solutions to open access to this source for the Brazilian productive sector, understood as the set of companies that have legal existence in Brazil".[34]

Keeping forests intact is fundamental to our survival, and in this sense, the World Commission on Environment and Development argued that "sustainable development must not endanger the natural systems that sustain life on Earth: the atmosphere, waters, soils, and living beings".[35,36] The area most affected by the devastation of forests is the Chemistry of Natural Products, which has always been at the service of men's health. The forests are differentiated by the different

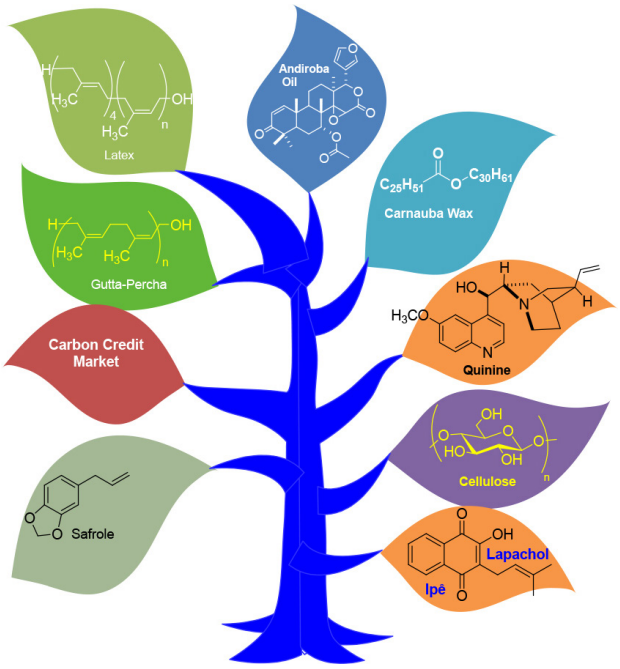

Figure 3. Example of valuable natural products that can be obtained from forests

regions of the planet and each one has its species and dynamics, but all have a vast biodiversity. By destroying an entire forest, we destroy the opportunity to obtain food and discover new bioactive substances that could become drugs and save many lives. There is abundant documentation in the literature that reports several examples of natural products extracted from plants that have become very successful as a drug[37] or products of industrial interest (*e.g.* dyes, flavors, emulsifiers, latex, fragrances and flavors,[38] alkaloids,[39] etc.). The best-known forest is the Amazon rainforest in South America, which is larger than many countries, has the highest carbon density, and covers more land area than the forests of any other biome.

Forests are threatened by human activities such as deforestation for economic exploitation and fragmentation due to urban encroachment, mining, and conversion into agricultural production areas. Collectively or individually, these activities result in habitat loss and biodiversity loss, consequently leading to increased carbon emissions. Simultaneously, the reduction in forest size and its fragmentation contributes to higher global temperatures, ozone layer depletion (exposure to UV rays affecting both people and ecosystems), and prolonged droughts, creating favorable conditions for forest fires that further devastate biomes and diminish forest resilience to fire.[40] These fires are sometimes part of the dynamics of forests, but human beings are the ones who promote forest fires to "clear the land".[41,42] Disturbance in forest ecosystems increases as the size of the primary patch decreases by pressures for land use.[43]

5. Cellulose: the Most Abundant Natural Polysaccharide

Cellulose is the most abundant natural polysaccharide on the planet that is present in algae and throughout the plant kingdom (Figure 4). It is the main substance formed in forests and represents the storage of CO_2 and energy in the form of cellulose. Its D-glucose units are formed directly by photosynthesis and transformed into polymers and other carbohydrates by biochemical transformations. This biodegradable polymer is inedible due to the β-glycosidic configuration on the anomeric carbons between the D-glucose units. This polysaccharide serves as food for a chain of various animals, insects, and microorganisms capable of digesting the polysaccharide and obtaining energy. It is the most abundant substance in the various terrestrial ecosystems spread across the planet. This biopolymer has been incredibly useful to humanity for millennia, despite being non-edible. It

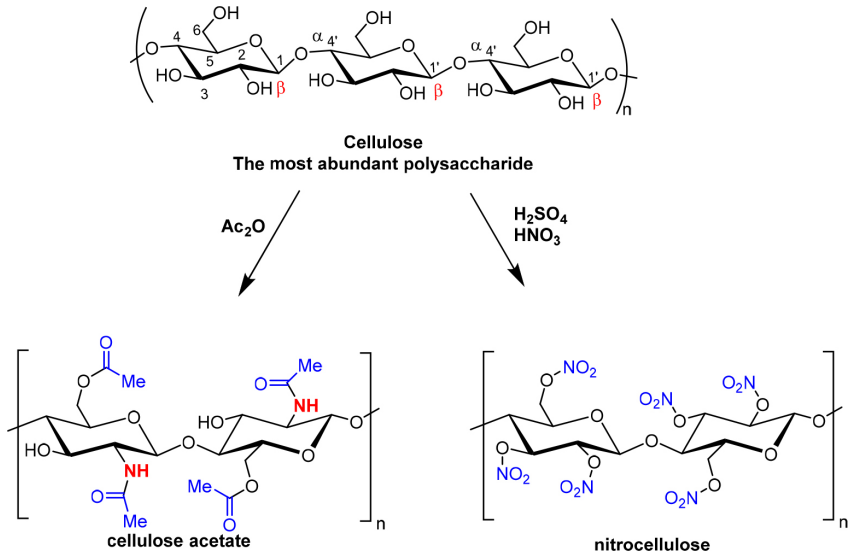

Figure 4. Cellulose and some derivatives

is utilized in clothing production, energy generation, hydrogen production (currently), construction, furniture, and paper manufacturing. In the 20th century, cellulose has also been used in other applications, such as industrial formulations (paints, lubricants, etc.), manufacturing of fine chemical intermediates and other modified main structure derivatives,[44-46] which in turn are used in the industrial production of various materials, including pharmaceuticals. Cellulose is the polysaccharide with the most industrial processes of chemical modification of hydroxyls and with products on the market for various applications, such as cellulose acetate and nitrocellulose (Figure 4). Starch is another abundant polysaccharide biosynthesized by plants and also composed of D-glucose units, with α configuration on the anomeric carbon, being edible by humans and other animals, insects, and microorganisms. It is present in fruits and roots and is found in different proportions in all foods as a combination of linear and branched chains.

6. The Carbon Credits Market is Directly Linked to Trees

Forests play a vital role as a natural buffer against climate change, capturing between 2.2-2.7 gigatons of carbon per year. Unfortunately, forests in several biomes have been devastated by loggers, miners, and ranchers interested in land for monoculture plantations and cattle ranching. These activities account for almost all net carbon dioxide emissions. However, maintaining or reforesting degraded areas can be a very profitable business in terms of a clean economy, utilizing Carbon Credits sold to other companies intending to offset their greenhouse gas emissions. This market has been discussed and refined since the Kyoto Protocol. The fines for companies that continue to emit greenhouse gases will be quite high. The economy's decarbonization will be with disruptive technologies and companies that do not adapt will be obsolete.

The deployment of carbon credit markets is a political success story and today they are an integral part of the core policy of global climate change and the transition to a low-carbon economy. In quantitative terms, a carbon credit represents a ton of carbon that is no longer emitted into the atmosphere, contributing to the reduction of the greenhouse effect. The carbon credit or equivalent carbon obtained by reducing greenhouse gases can be traded on the international market, that is, it is a certificate for a company to emit greenhouse gases, but the price of this permit must be the fine to be paid issuer. These markets have already been implemented in several countries. In Europe, the value of a carbon credit costs around 60 euros and depends on the type of project. However, it is important to highlight that carbon credits alone will not solve the issue of sustainability on the planet, as the issue requires a set of interconnected actions.

There are two types of carbon credit markets: voluntary and regulated. In the volunteer, you find a partner that has a certified carbon credit activity and makes a contract between the parties. The regulated market is derived from international agreements with very clear rules and they are not for all areas. Companies that have a high level of emission of gases causing the effect can buy carbon credits to offset their emissions from other companies that have credits anywhere on the planet. Carbon credits can come from the implementation of sustainable agroforestry, reforestation, regenerative agriculture, restoration of natural soil fertility (carbon fixation), generation of renewable energy, replacement of fossil fuels in factories with biomass or biomass residues (*e.g.* seed of açaí, sawdust, glycerol, etc.) renewable resources that contribute to the reduction of deforestation, use of carbon dioxide as a reagent for the production of fine chemicals, ecotourism (world tourism is responsible for 8% of carbon emissions in the atmosphere),[47] etc. There are dozens of small and large carbon sink projects that could be cited, which have managed to reduce their environmental impact with a strong sustainability component. For example, Cerâmica Bom Jesus (in the Zona da Mata region of Pernambuco) is one such project.[48] produces millions of bricks for civil construction. This company replaced non-renewable fuel with renewable biomass, such as glycerin, sugarcane bagasse, among other waste from local agribusiness. The income from the credits is being turned into socio-economic and environmental benefits.

Brazil recently published Decree No. 11,003 on March 21, 2022, which was later modified on May 19, 2022, which established the procedures for the preparation of Sectoral Plans for Mitigating Climate Change, establishing the National Emission Reduction System of Greenhouse Gases. In addition to providing legal certainty, this decree regulated the carbon market with the creation of a single registration system called the National System for the Reduction of Greenhouse Gas Emissions (SINARE). The Decree defines carbon credit, methane credit, certified emission reduction credit, and offsetting greenhouse gas emissions.

This policy of recovering devastated areas and implementing agroforestry with (regenerative cultivation) remuneration, in its final form, positively affects the most vulnerable, generating employment and, therefore, reducing the profound inequalities in the world, recovering springs, and improving air quality and ground. Additionally, it generates food that fights food insecurity and sequesters CO_2 from the atmosphere. The implementation of carbon markets was only possible when companies and environmentalists were brought to the table for discussion, as well as between developed and developing countries. By this mechanism of tradable pollution permits, both sides win. The innovative solution was to create a tradable system of pollution permits and put limits on pollution to satisfy environmentalists and give the industry flexibility in determining how to achieve the targets.

In addition to carbon credits, it is important to point out that forests are also important in valuing ecosystem services,

in which they contribute to environmental water services, which are fundamental to our society, as they guarantee water security, being important in the selection of areas for receive payment for water environmental services, as the role of ecosystems present in hydrographic basins (forests and wetlands) has been recognized as maintaining water security.[49,50]

7. Latex and Natural Rubber: *Cis*-1,4-polyisoprene Configuration

The milky white, yellowish, orange, or scarlet substance exuded from certain trees and shrubs after tissue injury has long piqued mankind's curiosity for centuries. It has been utilized for various practical purposes, as the water content in these liquids can be evaporated. Upon exposure to air, the milky particles coalesce to form a continuous polymeric film.

The term "latex" (from the Latin word for "fluid" or "liquid") was coined in 1662 for these complex emulsions, which are also used to refer to unvulcanized natural rubber.[51] Latex is a milky aqueous suspension or emulsion that is present in more than 20,000 species distributed in about 40 families. Trees produce this milky liquid as a form of plant defense against natural enemies in tropical and temperate forests.[52] Latex encompasses microscopic particles of emulsion polymers, polymer dispersions, and polymeric colloids. They are extracted from plants as monomer emulsions, that is, monomer droplets of varying molecular weights that are dispersed in water and polymerize to give rise to different types of latex. The monomers are mixtures of linear-chain polymers of isoprene units (*cis*-1,4-poly-isoprenoids) whose composition depends on the plant. The elasticity of natural rubber depends on the *cis* configuration predominant in the polymer. Isoprenes are the basic units of the terpene family that are made up of cyclic or acyclic hydrocarbons, most of which are odoriferous components of plants. Some polyisoprenes have great potential with high commercial values in many products, but the main use is as natural rubber. It is one of the products that can be obtained by extractivism in forests without the need to cut them down. As it is a polymeric mixture, its molecular composition distribution varies a lot and it may contain, in addition to hydrocarbons (94%), proteins, alkaloids, starches, sugars, essential oils, tannins, resins, and gums, among others.

Natural rubber can be chemically modified by copolymerization with other synthetic monomers. In view of this possibility, the ability to produce materials with innovative properties is very large. The most commonly used process to chemically modify natural rubber is through vulcanization. The cis-isoprene units are cross-linked by intermolecular bonds with sulfur and the resulting material is hard and resistant to abrasion, heat, light, and oils, while retaining its unique elasticity, which makes vulcanized rubber useful in the manufacture of a variety of products.

The vast majority of species produce latex, but with low yield and quality to be used in the production of commercial rubbers. Latex is made into a natural polymer used to make many products such as natural rubber, paints, floor polishes, paper, carpets, non-woven fabrics, adhesives, gloves, condoms, clothing, belts, casual and formal protective shoes on soles, swimming caps, seals, tubes, gaskets, cement, preservative adhesives, surgical catheters, tires, and balloons. Natural rubber is a preferred elastic material over synthetic rubber because of its high tensile strength, vibration dampening, adhesion to metals, abrasion resistance along tear resistance. Several tire companies use natural rubber, such as Michelin, Goodyear, and Continental. This makes it important for the construction and automobile industries. The term eraser was coined by British scientist Joseph Priestly because of its ability to erase writing with graphite pencils. These natural emulsions are added or applied to products with the intention of improving chemical resistance, stability, and durability. The chemical structures of exudates, in addition to differing in molecular weights, may also present cis and trans stereochemistry in polyisoprene chains. The trans isomer is much harder than the cis isomer (Figure 5).

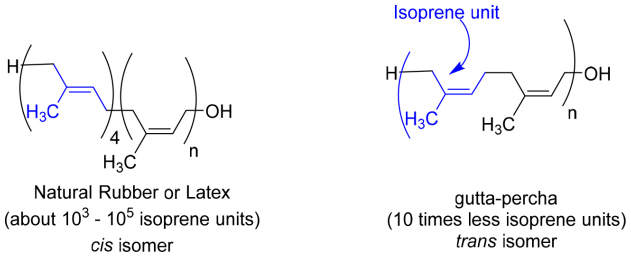

Figura 5. Chemical structure of natural rubber and gutta-percha

The rubber tree (*Hevea brasiliensis*) is the tree from which 99% of the latex is extracted to prepare natural rubber. This species of the genus *Hevea* is the most prevalent in the southern region of the Amazon, extending to the states of Acre, Mato Grosso, and Paraná in Brazil, parts of Bolivia, Peru, northern Amazonia west of Manaus, to southern Colombia.

The rubber tree is a species adapted to the tropical climate and is currently planted in many countries in Asia, Africa, and South America. The biggest producers are Thailand and Indonesia. It is important to note that rubber tree seeds were taken from the Amazon Forest by biopiracy, around 1873, to other countries, which, with the same specific epithet, follow the genus name to form the scientific name *brasiliensis* and the term biopiracy was not even mentioned and Brazil has already been a victim of this.[53]

Even though *H. brasiliensis* originated from the Amazon Basin, 93% of production is concentrated in Southeast Asia, 4.5% comes from Africa, and only 2.5% from Latin America. This somewhat paradoxical situation is due to South American Leaf Blight (SALB) caused by *Microcyclus ulei* P. Henn. Von Arx., an ascomycete fungus

which infects young leaves causing successive leaf fall and, possibly, killing the trees. This disease is confined to Latin America and, although it has never been observed in other parts of the world, its occurrence in one of the rubber-producing countries in Asia or Africa would be a disaster, as the high-yielding clones cultivated there are highly susceptible to the disease. In Latin America, rubber production is still fairly limited although there are now a few resistant cultivars that can be used to develop production in areas where the parasitic fungus is present.[54]

Global natural rubber production is projected to have a compound annual growth rate (CAGR) of 5.0% during the period 2022-2027[55] and is estimated to reach US$ 21.4 billion by 2027.[56] The market is expected to record steady growth and demand for natural rubber production is expected to grow with the growth of the automobile market. Another industry that demands natural rubber is footwear manufacturing due to its properties such as durability, slip resistance, tensile strength, etc. Thus, the increase in natural rubber applications is increasing the demand for natural rubber and hence the preservation of natural rubber trees in forests.

8. Gutta-percha: Cis-1,4-polyisoprene Configuration

From various plants, mixtures of biopolymers of molecular weights can be obtained that, when in contact with air, form cross-links, leading to materials with special properties. Gutta-percha is one of those coagulated and dried materials that can be obtained from several trees that were originally present in the forests of Southeast Asia, in particular the archipelago of Malaysia and Indonesia. When the exudate is dried, it forms a solid material of variable hardness that is called dry coagulated extract. Many species produce exudates that give rise to various types of Gutta-Percha, sourced from the stems and leaves of specific trees and shrubs. Examples include Palaguum gutta, Parthenium argentatum, Isonandra gutta, Palaquium gutta, Dichopsis gutta, Palaquium ellipticum, Palaquium obavatum, Palaquium polyanthum, Palaquium oblongifolium, and Mimusops globsa (bullet tree), among others.

Gutta-percha is yet another product provided by forests for hundreds of years to humanity (Figure 5). Since its discovery in forests, dozens of commercial material applications have been developed for this biopolymer, such as electrical insulation, golf balls, endodontic filling of root canals, jewelry, home ornaments, splints to hold fractured joints, treatment of skin diseases, etc. Long before it was introduced to the West, gutta-percha was used by native Malaysians to make knife handles, canes, etc. In medicine, they were used as splints to hold fractured joints and manufacture forceps handles, catheters, etc. They were also used to treat bleeding after tooth extraction and for skin conditions such as smallpox, erysipelas, psoriasis, and eczema.[57]

The chemical structure of gutta-percha is trans-1,4-polyisoprene. It is similar to the cis-1,4-polyisoprene structure of natural rubber (Figure 5). The change in stereochemistry confers mechanical properties quite different from natural rubber and less elastic. Gutta-percha is rigid at room temperature, becomes flexible at 25-30°C, softens at 60°C, and melts at 100°C with partial decomposition. Gutta-percha behaves more like crystalline polymers with some elasticity. It is composed of two distinct crystalline forms α and β, which can be interconverted. To this day, gutta-percha continues to be explored in nature[58] and used, alone in combination with other materials and nanoparticles or chemically modified, in dentistry for filling of canals[59] and other applications.[60] Gutta-percha is the most common endodontic filling material and is certainly irreplaceable in dentistry.[61]

The global gutta-percha market was valued at US$ 182.0 million in 2020 (US$268.82 million in 2027), i.e., expanding at a compound annual growth rate (CAGR) of 5.77% from 2021 to 2027.[62] The companies that analyze the global market predict that the increase in the prevalence of dental caries should drive the market due to the greater concern about oral hygiene health and the advances made in the root canal filling procedures.

9. Quinine: the Forest Drug that Saved Millions of Lives

Forests are the reservoirs of substances that one day may become drugs, or inspirations for new drugs, to treat the most diverse diseases. The story of the quinine alkaloid is a huge success and one of the oldest and most fascinating stories of a substance extracted from the Amazon rainforest of Bolivia, Colombia, Ecuador, Peru, and northern Venezuela. The peoples of the Inca Empire already knew the healing properties of the "quina-quina" bark, against fevers long before the arrival of the Spanish colonists in South America.[63] There is still controversy over whether malaria existed before the arrival of Europeans in America.[64] Its expansion in the Amazon began with the Spanish Empire, which took over the region called Peru, which was inhabited by the Inca civilization and which was elevated in the 16th century to the Vice-royalty of Peru (Peruvian America).[65]

Its tea contains several alkaloids, but the most important is quinine, which has become a world-renowned drug and saved hundreds of thousands of lives of people who contracted malaria caused by the bite of an infected female Anopheles mosquito, carrying one of the Plasmodium protozoa species (*P. falciparum*, *P. Vivax*, *P. malariae*, *P. ovale* and *P. knowlesi*) described in 1880 by French physician Charles Louis Alphonse Laveran.[66] In addition, quinine became the natural product that most inspired the discovery of new synthetic drugs in the 20th century to treat malaria and other diseases. It is important to emphasize that the Amazonian biomolecular diversity has enormous

potential as a source of molecules with biological activity against *Plasmodium sp*.[67]

Malaria has accompanied humanity for millennia and has spread across most of the planet with major epidemics that have killed millions of people.[68] There are records of its occurrence in China since 2700 BC. In the Roman Empire it was known as Roman Fever and is also considered one of the factors that contributed to its decline.[69] The first decline in the disease occurred in the mid-17th century when cinchona bark (Jesuit powder) was brought from South America to Europe.[70,71] The resistance acquired by the protozoan over the years has diminished its effectiveness. During and after the First World War. The war focused on malaria cases which became a major public health problem in Europe.

Cinchona bark contains 6-10% quinoline alkaloids. The main constituents of alkaloids are quinine, quinidine, cinchonine, and cinchonidine, in addition to 30 other minor bases related to quinine (Figure 6). These alkaloids contain quinoline and quinuclidine rings with a vinyl group attached to it. In addition to alkaloids, the bark has coloring matter (up to 10%), flavonoids, an essential oil, and polyphenols. Quinine purified and crystallized as sulfate is a white, odorless, bitter-tasting powder. Until the 19th century, it was the most used treatment in the world against malaria and other diseases. It was the first drug to effectively fight malaria on a large scale. Later, scientists observed its effects on the heart and quinine began to be applied against cardiac arrhythmias because it directly affects the muscle membrane and sodium channels and as an antipyretic, analgesic, and muscle disorders, especially night cramps in the legs.[72] Quinine is also used as a flavoring in tonic water soft drinks. Quinine sulfate is also mild and has been used in common cold preparations for this purpose.

Quinine is an alkaloid present in several species of quina or quineira or chincona, a tree of the Rubiaceae family. Quina is native to the Andes Mountains and the Amazon Basin and its scientific name of the genus was called Cinchona in honor of the Countess of Chinchón, wife of the Spanish viceroy in Peru. In 1638 the countess was cured of the fever caused by malaria by the Indians with a tea of "quina-quina".[73] The Jesuits who preached in Peru were responsible for introducing Cinchona bark powder to Europe to prevent and treat malaria. As reported by Pinto *et al.*,[74] in 1645 the bark was taken to Rome and widely used among the clergy. The cultivation of Cinchona was of capital importance to the economy of the Viceroyalty of Peru. Extracting and exporting to Europe was such a lucrative process that the Peruvian government banned the export of seeds and the plant's seeds were prohibited from being taken. However, the Dutch managed to send seeds from the tree to Justus Hasskarl, superintendent of the Botanical Garden of Java.[75] Apparently, a Dutch tourist collected cinchona seeds in 1852 as souvenirs while touring the territory of Peru. In 1659 it was taken to India and from there to other Asian and African countries, such as the Philippines, Indonesia (ancient Java), Sri Lanka, China, Taiwan, Burundi, Zaire, etc.

Nowadays, biopiracy has been much discussed in relation to aspects of Biodiversity and Sharing of Biological Resources. Biopiracy is not restricted only to genetic resources of the fauna and flora, but also the traditional knowledge of the forest. In most cases, biopirates infiltrate indigenous communities calling themselves volunteers, however, with the hidden purpose of obtaining ancient herbal knowledge of the culture of these peoples.[76]

The Dutch were the first to make Cinchona a commercial success in the Java colony. Growing Cinchona in India was difficult, as the plant needs special conditions, for example, a cold climate with little temperature variation, and it cannot be grown on plains. Few species of Cinchona had high amounts of quinine. It is now grown in many tropical regions and annually produces somewhere around 8,000 to 10,000 tons of bark, yielding 400 to 500 tons of quinine.

Cinchona is a genus that has about 38 to 50 species of trees and 150 varieties of evergreen shrubs, found on warm and humid slopes of the Andes, mainly at altitudes between 1,500 and 3,000 m. The species with the highest levels of quinine are *Cinchona ledgeriana* Moons and *Cinchona officinalis* Linn. There are other species that have lower levels of quinine, such as *Cinchona pubescens*

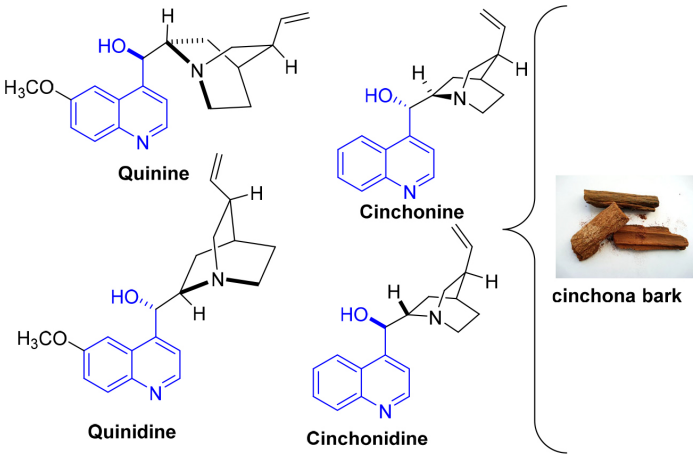

Figure 6. Main isoquinoline alkaloids in cinchona bark

Vahl, *Cinchona calisaya, Cinchona pahudiana,* and *Cinchona lancifolia*. The tree present in the Andean Amazon is not the same found in Brazil (*C. amazonica* Standl.).[77]

Cultivation of species of the genus Cinchona was of great importance to the economy of the Viceroyalty of Peru since the 17th century. It is currently cultivated in many tropical regions, annually producing somewhere around 8,000 to 10,000 tons of bark, producing 400 to 500 tons of alkaloids (mainly quinine). In 1811, Bernardo Antonio Gomes isolated a compound of the gray variety from the bark of the cinchona and called it cinchonina. A few years later, in 1820, Joseph Pelletier and Joseph Caventou, two scientists specializing in the isolation of alkaloids, discovered that Gomes' compound was actually a mixture of two molecules: quinine and cinchonine (Figure 1) and that quinine was the substance more active with the protozoan.[78,79] After this discovery, the powder made with the bark of the tree that was commercialized started to have an isolated active compound, but it was not until 1887 that quinine was produced in the form of a sulfate salt of quinine. The extraction of this substance is not a quick process but continues to the present day. Cinchonas remain the only cost-effective source of quinine, and several pharmaceutical companies manufacture the drug, including GlaxoSmithKline Pharmaceuticals, Novartis AG, and Sanofi-Aventis. The global Quinine Sulfate market will grow at a CAGR of 5.68% between 2019 and 2025. Global demand was valued at approximately US$ 804.98 million in 2018 and is expected to generate revenue of approximately US$ 1,184.15 million by the end of 2025. The growth of the pharmaceutical market for quinine sulfate can be attributed to factors such as the increase in the prevalence of malaria, the use in tonic water that imparts its bitter taste, the treatment of babesiosis, varicose veins, internal hemorrhoids, leg cramps, and growing awareness of its benefits.[80]

The treatment of malaria has changed over the years due to the development of Plasmodium strains resistant to the usual drugs. In this way, many researches were carried out to meet the demand for new antimalarial drugs that are highlighted in Figure 7.[81] The drugs most used to fight malaria contain molecules with broad biological action, being effective not only as antimalarial, but also with antiviral, antifungal and antibacterial activities (Figure 7).[82-84] Quinine served as an inspiration for all these substances that have the quinoline nucleus in common (in blue), but the resistance of Plasmodium falciparum strains was the propulsion for all this development. Even today, malaria remains a lethal infection to this day. It is estimated that there were 14 million more cases of malaria and 47.000 more deaths in 2020 compared to 2019. Globally, there were about 241 million cases of malaria in 2020 in 85 malaria-endemic countries.[85]

10. Andiroba: Rosewood of Miraculous Cures

Andiroba is a tall tree that can reach 30 meters in height. It is native to the Amazon forests of Brazil and Peru but has spread to other forests in Western India and South Africa. Andiroba (botanical name *Carapa guianensis* Aubl.) is of

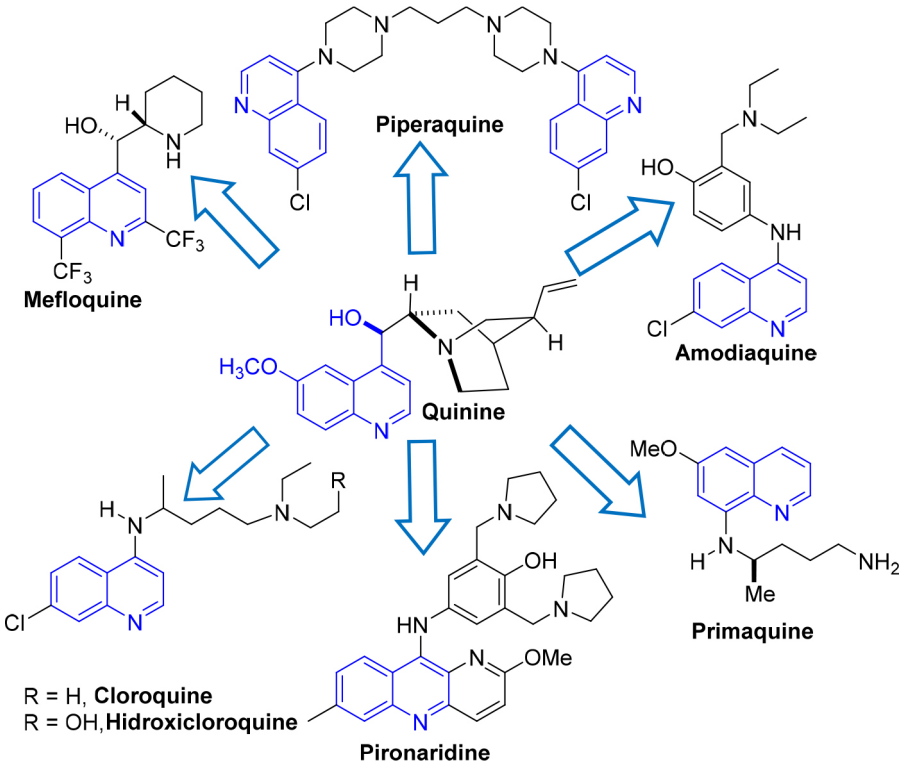

Figure 7. Quinine inspired drugs

the genus Carapa which has approximately 100 species distributed across Central Africa, South America, and Southeast Asia. It receives several names depending on the region (*e.g.* pau-santo and candiroba, etc.). Its name derives from the Tupi language which means bitter oil. Andiroba oil is a complex mixture of substances containing limonoids as bioactive compounds. The oil is a national and international commercial product obtained from chestnuts and has a great tradition in folk medicine as a phytotherapic to act as an analgesic in the relief of pain, bruises, swelling, rheumatism, scarring, astringent, antioxidant, anti-inflammatory, insecticide and insect repellent, antibacterial, antiparasitic, leishmanicidal, and as an anticancer remedy. Andiroba oil is also used as a larvicide and for the preparation of essential oils for pain relief and skin medicines (acne, psoriasis, and eczema).[86] In your hair, in conditioning formulations, they increase the shine, texture, suppleness, and health of the scalp.

In use as a cosmetic, andiroba oil is used for the production of skin moisturizers, soaps, hair shampoos, and detergents. The process of extracting the oil from the walnut is laborious, as it requires extraction in boiling water followed by fermentation for 25 days and then separation of the oil. In the composition of the oil are compounds with medicinal activity and other oils such as palmitic, andirobin, linoleic acid, linolenic acid, stearic acid, and oleic acid. Andiroba oil is also rich in omega 3 fatty acids, vitamins A, C, and E.

Andiroba oil, extracted from *Carapa guianensis*, is rich in limonoids, a type of tetranortriterpenoid responsible for its diverse biological activities. The main limonoids include deoxygedunine, 7-desacetoxy-7-hydroxygedunine, andirobin, and 17-glycolyldeoxygedunin (Figure 8).[87,88]

The global andiroba oil market is estimated to be US$ 95.1 million in 2021 and is projected to reach US$ 145.02 million in 2028, exhibiting a robust 2022-2028 CAGR of 6.21%.[89] A special attraction for this growth is due to its source as natural and organic, easy availability of raw materials and low-cost drive the market growth globally in the manufacture of health products and cosmetics. The global Andiroba Oil market is geographically divided into five major regions which include North America, Latin America, Europe, Asia-Pacific, and the Middle East and Africa.

11. Carnauba: the Tree of Life

The palm trees of the Arecaceae family are the most abundant botanical species in the forests. They have always been of vital importance to the survival of humans and animals since the times of the first hunter-gatherer sapiens. Everything is taken advantage of from these palm trees because they have fruits rich in nutrients and their trunks and leaves are used in the construction of houses. Many of the native palms were domesticated and became of enormous economic and sociocultural importance. Brazil has 38 genera and about 270 species and some of them have commercial interests and are important for the preservation of Brazilian biodiversity.[90] Among the palm trees, some stand out with exceptional commercial interests for different applications: Açaí (*Euterpe Oleracea* Mart.), Buriti (*Mauritia flexuosa* L.f.), coconut tree (*Cocos nucifera* L.), Babassu (*Attalea speciosa* Mart.), Carnauba (*Copernicia prunifera* Mill.), Palm oil (*Elaeis guineenses* Jacq.), Juçara (*Euterpe edulis* Mart.), Jerivá (*Syagrus romanzoffiana* Cham), Pupunha (*Bactris gasipaes* Kunth), Tucumã (*Astrocaryum aculeatum* Meyer).

Among the palm trees of the Arecaceae family, the carnaubeira (*Copernicia prunifera* (Miller) H.E) stands out, native to Brazil and adapted to the dry climate, sandy and swampy soils, floodplains, and banks of the Caatinga rivers. Its name – carnaúba – comes from caraná-iba, which came from caraná, from the Tupi karaná, wood full of scales, rough and scratchy due to the layer of thorns that covers the lower part of the stem. It has been of great use

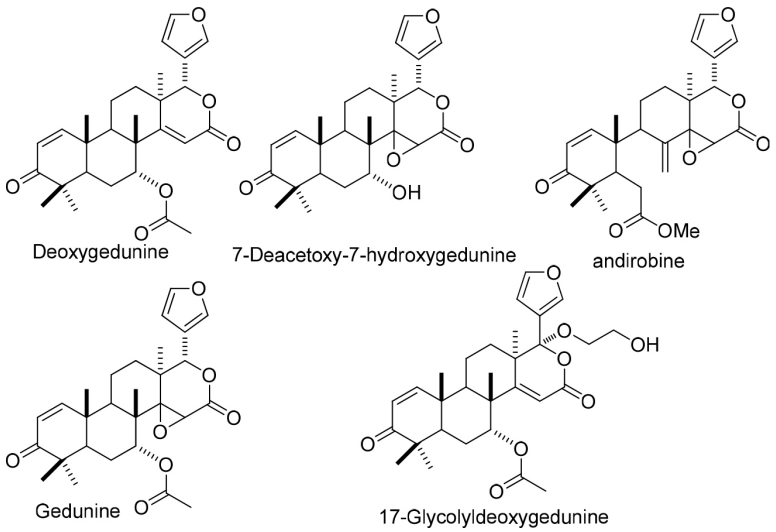

Figure 8. Main limonoids found in andiroba oil

since the arrival of Portuguese navigators and until today its beauty attracts visitors, as well as its multiple economic applications. From a social point of view, it has always supported and sheltered several generations of extractive communities.[91] Therefore, the maintenance of these palm trees is necessary to promote and encourage more and more good practices[92] for the sustainability of this production chain. The production and exploitation of carnauba trees adhere to the Sustainable Development Goals (SDGs), the global agenda (Agenda 2030) established by the United Nations to promote sustainable development globally.

The population of northern Brazil considers carnauba as the "Tree of Life" due not only to the wax produced but also to a multitude of economic uses derived from it. Everything is used from the carnauba palm, such as trunk, fruits, leaves, hearts of palm, roots and seeds, which range from uses to food, handicrafts, cosmetics and pharmaceutical products.[93] Vegetable wax is removed as a powder from the leaves (100 g per tree in a year) is the material of greatest economic importance, being used in the automobile industry, computers, paper coating,[94] cosmetics, essential oils and soil protection and fertilization in agriculture, food (fruit glazing agent),[95] pharmaceutical and food formulations[96] (bulking agent, acidity regulator, carrier and anti-caking agent) and pharmaceutical products (with authorization from health surveillance bodies), component of thermal printing inks, vinyl records, varnishes, seals, polishing waxes, waxes for floor, also acting as a waterproofing agent, in packaging, insulating in electrical materials, microencapsulation of flavors for food (flavoring), in the preparation of edible and super hydrophobic films and in biodegradable packaging and as raw material for the manufacture of candles.[97]

Its main features are hardness, low solubility, and higher melting point than other commercial natural waxes. Its composition has predominantly aliphatic esters and diesters of cinnamic acid that are relatively stable in the air, non-toxic, stabilizer and viscosity modifier, and do not suffer from attack by microorganisms, biological and physicochemical characteristics important for several applications. In hair care products, carnauba wax provides stability and in W/O emulsions it is used as a stabilizer and viscosity modifier.

Carnauba wax is a very complex mixture of compounds of varying proportions (Figure 9). There are two ways of extracting carnauba wax, the artisanal one that classifies it into three types: yellow or eye wax, sandy and fat, and the industrial one. It mainly contains fatty esters with fatty acids ranging from C18-C30 (80-85%), free fatty alcohols with chains of 30-34 carbon atoms (10-15%), free fatty acids (3-6%) and hydrocarbons (1-3%) and minor triterpenes (triterpene esters, steroids, etc.).[98,99] The antioxidant capacity of the wax is due to phenolic acid in the free, hydroxylated or methoxylated form.[100] Cinnamic acid derivatives (*trans*-phenyl-3-propenoic acids) have a broad spectrum of biological activities.

Carnauba provides many other important products. The unripe fruits are boiled in water and become soft and can be mixed with hot milk and served as food. The pulp is used for the production of flour and the extraction of a milky liquid. The seed can also be roasted and ground and used in food as a substitute for ground coffee. The leaves and trunks are used to make roofs for houses and the fibers become bags, baskets, and nets, and the roots have medicinal use as a diuretic.

According to the company Grand View Research which specializes in product market research on a world scale, the global carnauba wax market size was US$ 246.0 million in 2015 and is expected to grow significantly in the next eight years due to the increasing usage. in confectionery products. The increase in this demand is expected to be due to use in confectionery products such as jellies, chewing gums, and glazing agents for food and cosmetics, mainly in Asia Pacific.

According to Future Market Insights' market report for carnauba wax, its market is predicted to have an effective CAGR of 4.2% during the period 2022-2032.[101] The carnauba wax market is expected to grow from US$ 290.0 million in 2022 to US$ 435.8 million in 2032. Previously, the market grew at a faster rate of 3.4% from 2015 to 2021,[102] culminating in a market of US$ 281.3 million in 2021.

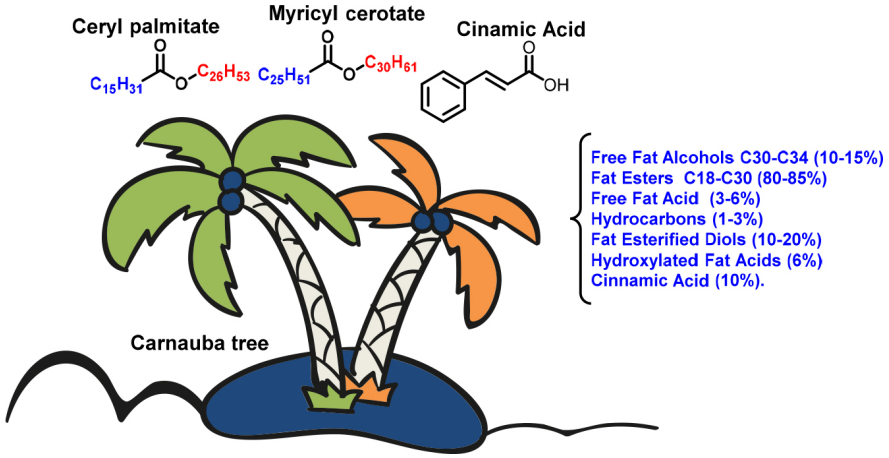

Figure 9. Partial composition of carnauba wax

The increased market demand for this special wax will be driven by the growing interest in the use of natural products from renewable sources. The characteristics of this wax have gained importance among cosmetics manufacturers, driving the growth of the market in personal use products, such as lip balms, hand sanitizers, shampoos, hair products, lipsticks, and mascara.

12. Safrole: a Fine Chemical Intermediary Straight from the Forest

Sassafras oil is the generic name given to essential oils in which the chemical compound safrole (1,3-benzodioxol-5-(2-propenyl)) is the main natural product of the mixture. Sassafras oil has several biological activities and materials for personal and domestic use (fragrances in floor waxes, polishes, soaps, detergents, and cleaning agents). However, the main use today is as a raw material for safrole isolation.[103] Safrole extracted from oil is yet another commercial chemical obtained from forests that go directly to industries for the production of various drugs and bioactive products. Its main use in the chemical industry is in two important derivatives: piperonal or heliotropine, which is widely used as a fragrance and flavoring agent, and piperonal butoxide (PBO), a synergistic ingredient for pyrethroid insecticides. In addition to these applications, it served as a tuning for several organic syntheses in the search for new prototypes.[104-107]

Sassafras oil can be extracted from several plants and is attractive because it is a renewable and biodegradable product. Initially, it was obtained from plants of the Lauraceae family, such as *Ocotea pretiosa* (Nees) Mez., *Ocotea odorifera*, *Cinamomum petrophilum*, *Cinamomum mollissim, Cinnamomum camphora,* and *Sassafras albidum* Nutt. For many years sassafras oil was obtained from the Brazilian plant *Ocotea pretiosa*, a tree native to the Atlantic Forest that grows from Bahia to Santa Catarina. From this oil, the chemical compound safrole is obtained by distillation. Brazil once produced 1,500 t/year of this oil, but it has now become an importer due to predatory exploitation that threatened the extinction of this species since to obtain the oil it was necessary to use wood in distillation. This tree grows very slowly and bears fruit sporadically. Cutting for the extraction of *O. pretiosa* oil was prohibited by Ibama in the 1990s, so as not to definitively eradicate the population of these trees in the Atlantic Forest. Later, it was discovered that the oil from the leaves of the long pepper (*Piper hispidinervium*),[108-109] gnarled and branched shrub endemic to Acre in Brazil and other South American countries had a safrole content in the oil that reached 90%.[111,112] The Brazilian Amazon contains a wide variety of Piper species, but attention ended up focusing on the species *P. hispidinervum* and *P. callosum*, two species with a high safrole content, but *P. hispidinervum* ended up being the shrub of choice for industrial productionof safrole. The advantage of this shrub is its ease of cultivation, the ability to re-sprout, the same plant can be exploited several times over the years, the ease and transport of the leaves harvested for oil extraction, and the simple industrialization process to extract the oil. Other species of the genus *Piper*, including *P. divaricatum*, *P. nigrum*, *P. callosum, P. aduncum,* and *P. auritum* also produce oil from the leaves with varying amounts of safrole and can be economical and sustainable sources for this important substance. Currently, the main source of this oil in Brazil, with about 90% of safrole, is long pepper (*P. hispidinervium*). In China, sassafras oil is obtained from *Cinnamomum camphora* and it contains about 80 percent or more of safrole. In the US *Sassafras albidum* was used to make "root beer", a type of beer in which sassafras oil imparts a special flavor. However, its use in food and beverages was banned a few years ago due to toxicological issues with safrole consumption.

The molecular characteristics of safrole, including a trisubstituted benzene ring and easy manipulation around this ring, a double bond capable of isomerizing to isosafrole, and the abundance and diversity of renewable sources, make this natural product particularly noteworthy in transformations in Fine Chemistry products. Safrole serves as a precursor to compounds such as piperonal and isosafrole, which are starting materials utilized in various organic syntheses, as summarized in Figure 10. In the pharmaceutical industry, safrole was used as a synthetic precursor of several drugs, such as tadalafil (indicated for erectile dysfunction, benign prostatic hyperplasia, and pulmonary hypertension),[113] cinoxacin (indicated as an antimicrobial for urinary tract infections),[114] and levodopa (a neurotransmitter used in the treatment of Parkinson's disease).[115] Another important commercial product obtained from safrole is piperonyl butoxide which has a synergistic effect with several organophosphate insecticides and pesticides is the pyrethroid deltamethrin.[116]

13. Lapachol: a Natural Product of Multiple Biological Activities Derived from Ipe

The large tree known as Ipe is widely distributed in all regions of Brazil and belongs to a wide variety of genera and species of the Bignoniaceae, Verbenaceae, and Proteaceae families. Its beauty is related to the exuberance of the flower clusters and the varied colors. Interestingly, its name Ipe comes from the Tupi language, which means hard shell. The Yellow Ipe (*Handroanthus ochraceus* or *Tabebuia ochracea*) is distributed in several biomes in South America. They are common in the Amazon region, cerrado, swampland, caatinga, and Atlantic forest as far south as South America. In the Cerrado, it occurs as a tortuous and smaller tree (*Tabebuia aurea* or *Handroanthus caraíba*). It is interesting to note that it blooms outside of spring.

From the heart of these trees, a functionalized naphthoquinone called lapachol is extracted, and, depending

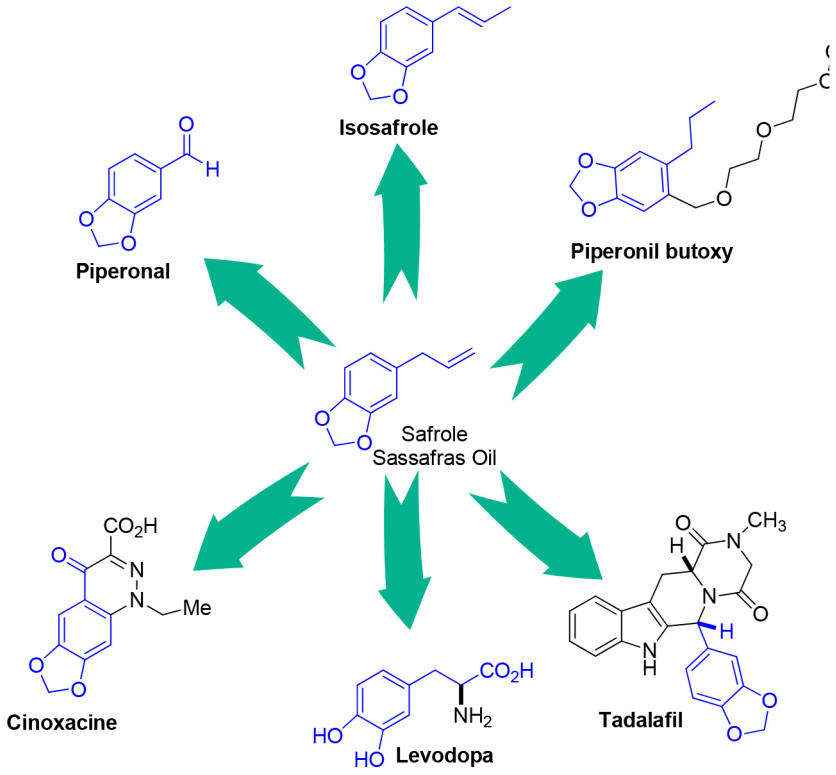

Figure 10. Examples of uses of safrole in organic synthesis

on the species, up to 5% of this substance can be obtained, for example from *Tabebuia impetiginosa* (purple Ipe) found in the north and northeast regions. It was first isolated in 1858 (Figure 11)[117] by acid-base extraction.[118] Since showing significant activity against Walker-256 carcinoma, a study carried out by the CCNSC (Cancer Chemotherapy National Service Center), lapachol has undergone several structural modifications in order to obtain new bioactive compounds against a series of pathogens, which demonstrates its great relevance in the field of medicinal chemistry. Lapachol and its derivatives have been the subject of pharmacological investigations in Brazil since the 1960s, whose results have indicated redox properties of naphthoquinones, which confer activities in various biological oxidative processes, such as antitumor, antimalarial, bactericidal, and fungicidal activity.[119]

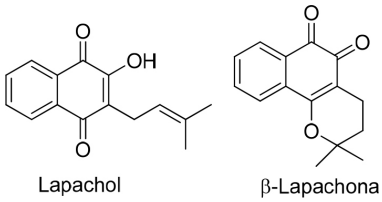

Figure 11. Products obtained from Ipe - Lapachol and β-lapachona

The global lapachol market, which was valued in millions of dollars in 2020, is predicted to experience exponential growth in the industrial sector during the period 2020-2030.[120]

From Lapachol, β-lapachone can be easily obtained by semi-synthesis (Figure 11), which is also a substance of natural origin, as a minor constituent of the heartwood of trees of the Bignoniaceae family.[121,122] Its pharmacological activities against cancer cells and *T. cruzi*, which causes Chagas disease, distinguish it from other naphthoquinones. However, due to its high cytotoxicity, it cannot be used in the treatment of Chagas disease, but its structure has served as an inspiration for medicinal chemists, who seek analogous structures with the quinonoid ring intact, with regard to the development of substances more selective against the parasite.[123]

This cytotoxicity is important for controlling the proliferation of several types of cancer cells, such as human malignant cell lines of the lung, breast, colorectal, prostate, melanoma, and leukemia.[124] β-lapachone is currently in phase 2 of clinical trials for pancreatic cancer and phase 1b for solid tumors. ARQ 761 is a synthetic and soluble prodrug of β-lapachone, with antineoplastic and radiosensitizing activity, which has demonstrated in vitro activity against several solid tumors.[125] Due to the variety of microbicidal effects of β-lapachone and its easy access from natural sources and, more recently, through synthetic routes, it has become a starting point for the application of naphthoquinones in medicinal chemistry.[126]

14. Final Considerations

If the international community does nothing to reduce deforestation, forest fragmentation, mercury poisoning of fauna caused by gold mining, and the indiscriminate use

of natural resources, the global economic damage from global warming is expected to reach US$ 1 trillion a year, until 2100. Deforestation is expected to accelerate global warming causing devastating climate events with immense deaths and financial losses. Without combating forest loss, it is highly unlikely that humanity will continue to exist.

The devastation of forests is compromising the global environment, with the disappearance of the diversity of fauna and flora, global warming, water, soil, and air quality, and, consequently, people's health and the spread of new endemics. The situation of the planet has been constantly declining, as few actions have been effectively implemented to stop deforestation and the recovery of devastated areas. However, if reforestation measures and conscious exploitation of forests are taken, many valuable products for industries, food, jobs, and income can be obtained using forests as a common and essential good for humanity.

NWFPs play a fundamental role in the relationship between forest conservation, sustainability, and economic impact. These products encompass a wide variety of resources provided by forests, beyond timber, such as fruits, nuts, oils, resins, medicinal herbs, fibers, among others. The diversity and abundance of NWFPs underscore the importance of forests as multifunctional ecosystems capable of offering a variety of benefits to local communities and society at large.

The UN meetings for the environment are very important and try to raise awareness among countries, but they do not have the power to impose positive policies on countries. Everything that has already been proposed and signed by the countries in these meetings has not been accepted by the signatories, in the sense of reversing the unsustainability that manifests itself in extreme weather events. The latest Sustainable Development Goals will not be fully met until 2030 and the dire situation of the planet's forests, together with poverty, hunger, inequality, mining, and poor waste management will cause an annihilation of biodiversity. It cannot be denied that there have been advances in the use of commercial products of biological basis with economic, environmental, and social viability, but it is still a very timid advance, given the almost irreversible situation that the planet's environment is in. The 27th UN Climate Change Conference (COP27) in November 2022 presented more real-world climate data that indicate that we will see more compound extreme weather events (like simultaneous heat waves and droughts) in the coming decade. Consequently, the goal of limiting global temperature rise to 1.5 degrees Celsius seems increasingly unlikely.

Author Contributions

Luana da S. M. Forezi: Coordination and contributions to manuscript writing; Patricia G. Ferreira: Contributions to manuscript writing; Cristina Moll Hüther: Contributions to manuscript writing; Wilson da C. Santos: Contributions to manuscript writing; Fernando de C. da Silva: Coordination and contributions to manuscript writing; Vitor F. Ferreira: Coordination and contributions to manuscript writing.

Acknowledgments

Fellowships granted by CNPq (1A 301873/2019-4, 301873/2019-4.), FAPERJ (E-26/203.191/2017-JCNE, E-26/202.800/2017-CNE, E-26/010.101106/2018, E-26/200.870/2021-CNE, E-26/201.369/2021-JCNE (SEI-260003/001178/2020), E-26/010/001687/2015 (FAPERJ Pensa-Rio) and CAPES (Finance Code 001) are gratefully acknowledged.

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