TECHNICAL NOTE

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WHAT FORESTS AND DEFORESTATION HAVE TO DO WITH OUR HEALTH

Contact with nature contributes to people's happiness and health[1]. Human populations have been disconnecting from nature since they started moving to urban centers, which has affected their physical and mental health, emotional well-being, personal and social skills[2 3]. Impacts to health arising from this process also include traditional communities losing their sense of social identity associated with the landscape[4] and the wealth of health resulting from experiencing nature and biodiversity[5].

In all biomes, the diversity of natural resources available is crucial to promote the nutritional quality of foods rich in micronutrients, especially fruits and vegetables, for traditional communities. The Amazon is a center of genetic diversity of several crops such as cassava, peanut, corn, sweet potato, yam, pepper, açaí, cupuassu, graviola and Brazil nut[6 7]. In the Cerrado, there are over 100 native species that provide human populations with tasty and nutritious fruits [8], especially pequi and baru. Thus, such regions are important for the conservation of agrobiodiversity[9].

This is just one example of how forests, and other natural ecosystems, are responsible for many aspects directly or indirectly linked to human health and well-being, whether we live within them, such as indigenous and traditional populations, or in its surroundings, or even far away, in cities or rural areas.

This is why deforestation and fires in the Amazon and other biomes, such as the Cerrado, increase the problems related to the food security of populations, and are also connected to health problems caused by air pollution, and by vectors and animals that host pathogens that can spread globally, as explained below.

Deforestation accelerates in the country

The loss of forests in tropical countries accelerated in the first half of the last century and reached a peak in the 1980s. Despite the reduction in deforestation in the following decades, average rates remain at high levels in tropical countries – over 50 million hectares lost in the last decade – with specific dynamics in each region. A recent study[10] based on data from FAO (United Nations) points out that Brazil was the country with the largest deforested area between 1990 and 2020 (355,000 km^2), more than three times larger than the second place.

The Amazon and the Cerrado are the two largest Brazilian biomes and offer valuable ecosystem services for the country and the world, such as climate change mitigation, water security, carbon storage, biodiversity protection, natural pest control and pollinators maintenance.

According to data from Prodes[11], Brazil's official deforestation monitoring system, despite the significant reduction in deforestation in the Brazilian Legal Amazon from almost 28,000 to less than 5,000 km^2 between 2004 and 2012, rates rose again and reached 13,235 km^2 in 2021, a record in the last 15 years. The rates of native vegetation suppression in the Cerrado were progressively reduced between 2001 and 2019, from almost 27,000 km^2 to just over 6,000 km^2. In the last two years, however, such rates have risen again (35% between 2019 and 2021) in a Cerrado that has already lost more than half of its original area.

The use of fire is part of the process of degradation and deforestation of areas that will be destined for agricultural activities. Therefore, the exposure of both biomes to anthropogenic fires has increased with the recent acceleration of deforestation. Agricultural expansion to produce *commodities*, mainly meat and soybean, is the main cause of destruction of natural ecosystems in those biomes. Such a production in Brazil is responsible for one third of carbon emissions in the tropics[12].

During recent years, the federal government has weakened the framework of environmental protection in Brazil. Environmental agencies and institutions responsible for actions aimed at protection have suffered budget cuts, as well as interventions in their management and operations. In addition, the federal government's discourse and position have encouraged and accelerated deforestation in those biomes, in violation of Brazilian environmental legislation, violating the rights of indigenous populations and consuming the Brazilian natural heritage.

AIR POLLUTION

The air over the Amazon rainforest is very clean, especially in the rainy season, when the concentration of suspended solid particles, called aerosols, is very low, because they are eliminated by precipitation. Thus, in the Amazon, the atmospheric composition of essential gases is regulated by the presence of the forest. Among those gases are the volatile organic compounds emitted by plants (known as biogenic VOCs). Such particles of natural biogenic aerosols, or bio aerosols, emitted by the forest, are the ones that provide most of the Cloud Concentration Nuclei (CCN) that assist in the formation of clouds and rains and, therefore, in the maintenance of a clean atmosphere[13].

During the dry season, which normally lasts from June to October, however, thousands of square kilometers of fires with smoke clouds occur in the Amazon and central regions of Brazil, causing negative impacts on human health, mainly related to respiratory diseases.

The atmosphere becomes smoky and dusty then, with high concentrations of anthropogenic aerosols caused by fires[14], including several classic pollutants with varying levels of toxicity, such as carbon monoxide and particulate matter (aerosols). The smoke clouds can cover millions of square kilometers during the dry season. On the afternoon of August 19, 2019, the city of São Paulo had the sky covered by clouds and the “day turned into night” due to the arrival of a cold front and smoke particles produced in the forest fires in the Amazon[15]. In September 2020, the smoke from the fires in the Amazon and the Pantanal reached the city of São Paulo and the countryside, also reaching Minas Gerais and Rio de Janeiro[16]. This high load of aerosols still affects the mechanisms of rain production and, therefore, its function of cleaning the atmosphere.

The smoke resulting from the fires in the Amazon is highly toxic, causing shortness of breath, cough and lung damage to the population, and accounts for 80% of the regional increase in fine particle pollution, affecting 24 million people living in the region[17].

Respiratory diseases undoubtedly represent the most significant health impacts related to air pollution, especially in vulnerable groups, such as children and the elderly[18]. Concentrations of particulate matter in the atmosphere are directly related to the increase in hospitalizations of children and the elderly due to respiratory problems, with a delay of three to six days between the occurrence of the former and the latter in several

cities in the south of the Amazon[19][20][21]

Approximately 120,000 people are hospitalized annually during the dry season in the Brazilian Amazon due to asthma, bronchitis and pneumonia problems[22]. During periods of intense fires, especially in extreme drought events, pollutants from biomass burning can increase cardiorespiratory mortality rates, as well as induce genetic damage that contributes to the development of lung cancer. A study analyzed the impact of droughts, in 2005 and 2010, on the total number of hospitalizations for respiratory diseases in children, based on the average of the previous ten years and covering a set of municipalities in the Amazon[23]. The authors showed that in drought years there were increased hospitalizations in all municipalities, and in some of them hospitalizations tripled in years of extreme drought, such as 2005 and 2010.

Poisoning by carbon monoxide (CO), a pollutant produced during burning, can occur if the gas is inhaled in large amounts[24]. Initial symptoms may include headache and arrhythmias, and may lead to death[25]. Long-term complications may include chronic fatigue, memory and movement problems. Firemen and firefighters make up the group with the highest risk of poisoning[26].

Fire recorded in the Cerrado

Burns and Covid-19

In 2020, the Covid-19 crisis took on serious dimensions, with most of the states of the Legal Amazon in precarious situations regarding hospital medical care for Covid-19 cases. A study carried out by WWF-Brazil and Fiocruz in 2021[27] points out that the association of the pandemic with the forest fires in the Amazon may have aggravated the health situation of the legal Amazon population.

The report showed that the pollutants generated by the fires can cause a persistent inflammatory response, and thus increase the risk of infection by viruses that affect the respiratory tract, such as Covid-19. The micro particles constituting the smoke build up in the terminal bronchi and in the alveoli, aggravating respiratory problems. Therefore, chronic exposure to smoke makes individuals who are more vulnerable to covid more likely to present more severe forms of the infection.

ZOONOTIC DISEASES

Forests are natural habitats for disease vectors and animals that host pathogens. Diseases or infections transmitted between humans and wild and domestic animals are called zoonotic diseases[28]. Several of them, such as dengue, Ebola, yellow fever, MERS, SARS and Zika, have been considered threats to global health and economies. The frequency with which new viruses have spread from animal hosts to human populations over the past century is frightening: on average two new viruses per year[29].

Zoonotic diseases emerge when the conditions for expansion and adaptation of pathogens to new niches are met. The main factor of zoonosis today is the change in land use[30], which leads to habitat fragmentation and proximity to the expansion of livestock production[31], increasing people's contact with animals and their potential pathogens. This was pointed out in several studies, such as in the cases of the Ebola[32], Hendra[33] and Nipah[34] viruses. This change has been associated with over 30% of the new diseases reported since1960[35].

There is a great diversity of rodents, primates and bats in rainforests such as the Amazon[36]. Therefore, in such forests, where deforestation and degradation rates of native vegetation are high, the risk of new zoonoses appearing is the biggest on the planet[37].

Tropical forests can moderate the risk of infectious diseases by regulating populations of pathogenic organisms (viruses, bacteria, and other parasites), their animal hosts, or the intermediate vectors of diseases. For example, the loss of forest cover can affect the abundance and behavior of mosquitoes – a common disease vector in the tropics – through changes in local *habitat* conditions. Individual species of mosquitoes occupy unique ecological niches and may react quickly to changes in habitat.

In the case of malaria, a 10% increase in deforestation leads to a 3.3% increase in the incidence of the disease. Deforestation changes the reproduction, abundance and composition of mosquito species. The removal of parts of the forest creates an ideal habitat at the edges of the forest for proliferation of *Anopheles darlingi*, the most important malaria transmitter in the Amazon[38].

Research in the Peruvian Amazon[39] has shown the existence of larger numbers of larvae in pools of warm water partially sheltered from the sun, such as those formed on the edge of open roads within the forest, and in water accumulated in the midst of debris, which is not consumed by trees. Studies[40] also show that heavily deforested areas may present up to a 300-fold increase regarding malaria infection risk when compared to intact forest areas, even taking into account the differences in human population density. This interaction, however, is complex and depends on the socioeconomic conditions (housing, health system access, behavior and economic activities) and the forest *status* (deforestation rate, forest cover, distance to the forest edge, forest degradation and configuration of the deforested landscape)[41].

Malaria and malnutrition among the Yanomami

An April 2022 report from the Hutukara Yanomami Association[42] showed an explosion of malaria cases among Yanomami Indigenous people living in villages near illegal mines. The deforestation caused by mining and the pools of waste left by the activity modify the ecosystems of the regions, favoring the increase in the number of mosquitoes transmitting the disease.

Between 2014 and 2020, *Falciparum* malaria cases grew 716 times in the Yanomami Indigenous Land, from five cases in 2014 to 3,585 cases in 2020. The document shows the relationship between the illness of families due to malaria and the worsening of child malnutrition, since adults affected by the disease are unable to provide them with food.

The relationship between the forest and the incidence of waterborne diseases is more precise. The loss of forests associated with the formation of flooded areas by the construction of dams and the conversion of forested areas into flooding irrigated areas increase the incidence of schistosomiasis[43]. On the other hand, the damming of watercourses increases the risk of diarrhea in downstream communities[44], while the increase of forest-protected areas decreases the incidence of diarrhea[45].

A study on the effects of deforestation on ecosystems and infectious diseases[46] concluded that deforestation can increase the risk of other diseases, such as those associated with the arboviruses that cause dengue, meningitis, yellow fever and Mayaro fever.

The conservation of natural tropical forests contributes to prevent disease outbreaks[47], increasing the biodiversity of vector and non-vector species, diluting people's exposure to diseases through a more diverse set of hosts[48]. An example is the reduction of the Chagas disease risk in some places in the Amazon due to the greater diversity of small mammals that "replace" man as the host of the disease[49].

Whether such diseases will remain confined to forests or conquer space among humans, triggering a possible pandemic, depends

only on their transmission. Some viruses, such as the Ebola or Nipah, can be transmitted directly between humans, which theoretically allows them to travel the world. The Zika virus, discovered in Uganda's forests in the 20th century, could only cross the world and infect millions of people because it found *Aedes aegypti* as its host, a mosquito abundant in urban areas, mainly in tropical countries, also a transmitter of other diseases such as dengue.

Endemic agent visits household in the Novo Horizonte neighborhood, in Itabuna (BA), and infuses foci of the mosquito Aedes aegypti in a water tank

Finally, the current Covid-19 pandemic is likely a result of anthropogenic pressure on natural systems. The most accepted hypothesis for the disease is that a coronavirus (SARS-CoV-2) spread from a mammal directly or indirectly to humans[50,51]. The impact of the pandemic can be measured in lost human lives and economic loss. As of the publication date of this note, over 6 million deaths from Covid-19 had been recorded worldwide. The difference between the cost of prevention and the economic impact resulting from the pandemic is surprising. Spending 22 to 31.2 billion dollars on prevention per year can significantly reduce tropical forest deforestation and illegal wildlife trade, and favor the implementation of preventive measures to detect and avoid the next overflow event[52], while the economic impact caused by the pandemic is well into the trillions of dollars, which defies any argument against the conservation of forests.

TEMPERATURE REGULATION AND THERMAL COMFORT

In addition to disease prevention, forests contribute to climate regulation, providing a hospitable environment. Studies indicate that the Amazon Forest functions as a huge evaporative cooling device[53,54] (commercially called an air climatizer). This characteristic is mainly related to the ability of forests to evapotranspire large amounts of water from the soil to the atmosphere.

Compared to most species grown in the region, the Amazon Forest trees have rough canopies (which cause turbulence), large leaf areas during most of the year and deep roots, which make them able to maintain high rates of evapotranspiration throughout the year. Combined with the high surface liquid radiation and precipitation inherent to the region, such characteristics make the forest trees highly capable of cooling their leaves. The daytime surface temperature in forested areas of the southeast Amazon, for example, tends to be 5ºC lower than in deforested areas during the dry season[55].

Thermal stress has consequences beyond health and well-being, reducing the viability and productivity of outdoor activities. The cooling effect of forests increases the viability of work in external environments and the well-being of workers. Although humans can adapt to various hot weather conditions, there is a temperature at which mammals are not able to dissipate their metabolic heat. In humans, that happens at 36ºC and 100% air humidity, or in conditions of higher temperatures and lower humidity[56].

Under those conditions, the human body is unable to lose heat through perspiration and begins to suffer from hyperthermia, a situation that happens when the body achieves higher than normal temperatures, to a point that can compromise, or even collapse, its metabolism. By the end of this century, some locations in the Amazon may reach such a climate condition (Sherwood & Huber, 2010) and approximately

5 million people may be exposed to extreme thermal stress for many hours, days and months of the year[57].

IMPORTANCE FOR MENTAL HEALTH

But forests are also important mental health allies of the population. A review led by the Convention on Biological Diversity (CBD), in partnership with the United Nations (UN), entitled "Connecting Global Priorities: Biodiversity and Human Health" [58], points to numerous evidences that highlight the importance of nature to promote an improvement in our mood and well-being, as well as emphasizes that experiences in nature are associated with an improvement in various health indices, such as decreased blood pressure, reduction of stress-associated hormones, improvement in heart rate, mood, cognitive functions, among other aspects. The natural environment affects individual and collective well-being. Such a connection refers to the degree to which individuals include nature as part of their identity and create bonds of belonging to the natural world[59].

A study conducted by researchers at the University of Griffith, Australia (2019), estimates the economic value of global protected areas derived from the improvement in the mental health of its visitors at 6 trillion dollars per year. This amount is two or three times the value that environmental agencies invest in protecting such areas.

MODELS OF PRODUCTION, DEFORESTATION AND FOOD SECURITY

The human species co-evolved with the elements and natural beings of the places they've lived in, the food they've eaten and the landscape they've helped to build. Their connections with nature in general, and with what they produce and consume, have therefore always been linked to their sociocultural origins. In all biomes, forests contribute to the food security and nutritional quality of the inhabitants who depend on them. In a partially anthropized environment, much of the sustainable production can come not only from extractivism, but also from agroforestry.

The Amazonian agricultural systems are highly sophisticated and include a multiplicity of cultivated plants, complex landscape management, articulation with other subsistence activities (hunting, fishing, extractivism) and various management strategies and practices that reflect at least 12,000 years of interaction between plants and landscapes and indigenous peoples and, more recently, Afro-descendants, which remain to the present[60 61].

The Amazonian agroforestry involved the integration of tree cultivation and agricultural practices, which provided economic, ecological and sociocultural benefits to indigenous peoples and local Amazonian communities, and to society in general[62]. Hundreds of species and varieties cultivated in agroforestry systems have an outstanding economic importance in the market chains, such as the peach palm (*Bactris gasipaes*), cassava (*Manihot esculenta Crantz*), cocoa (*Theobroma cacao*), açaí (*Euterpe oleraceae*), babassu (*Attalea speciosa*), cupuassu (*Theobroma gradiflorum*), and Brazil nut (*Bertholletia excelsa*) [63].

Agroecology and the Green Revolution

Rooted in the knowledge and practices of indigenous peoples' agricultural management, the field of agroecology emerged in the 1970s-1980s as a response to the socio-environmental problems caused by the Green Revolution: the modernization of agriculture on a global scale with the objective of increasing food production from technological innovations, such as mechanization, use of pesticides and fertilizers.

Among the consequences of such a process are the loss of crop diversity and land ownership by small owners, contamination of soils, rivers and water sources by the extensive use of pesticides, control of food production systems by large agribusiness companies and multinational conglomerates, with the poorly regulated production and trade of genetically modified seeds and crops, and their corresponding pesticides[64].

The agroecological agriculture combines the principles of ecology with the local knowledge of indigenous groups and small farmers, in a sustainable production system that values and protects agrobiodiversity, sustains human subsistence, food security and sovereignty, and protects important ecosystem services, such as soil, water and forest conservation[65].

In a recent report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on Land Degradation and Restoration, the authors advocate the adoption of agroforestry systems as viable economic options to conserve and, equally important, restore forest ecosystems worldwide[66]. The importance of such systems for sustainable economies based in the Amazon has been acknowledged, to a greater or lesser extent, in the Amazonian countries, including the design and implementation of public policies and specific programs with various levels of success[67].

The Amazon is a genetic diversity center of various crops, such as cassava, peanut, corn, sweet potato, yam, pepper, açaí, cupuassu, graviola, Brazil nut, among others. The region is therefore an important site for the conservation of agrobiodiversity[68].

Among over 100 native species of the Cerrado that provide tasty and nutritious fruits (Pereira et al., 2012), the pequi (*Caryocar brisiliense*) stands out, a species in the initial stage of domestication[69]. Its fruit is used for food and oil, with great economic relevance for traditional peoples (Sousa Júnior et al., 2013). The extraction of the pequi and its almond in Brazil increased 35% between 2014 and 2019[70], largely due to pickling preservation, a technique that extends its validity and has enabled its export[71], with up to 28 times value aggregation when compared to unprocessed pequi[72].

Photo of a WWF-Brazil workshop held in Barra de São Manoel (PA) on good practices in Brazil nut extraction

Urbanization has created markets for perennial crops, such as fruits. The increased preference of urban dwellers for healthy, nutritious and less industrialized foods has created regional, national and international markets for fruits such as açaí, cupuassu, graviola and a diversity of other perennial crops.

Unlike food diversity and ecosystems, in radical anthropization, land will typically be cultivated with monocultures for the production of agricultural commodities, that is, non-specialized mass-produced products whose value is defined by the market. The main *commodities* produced in Brazil are beef and soybean.

CONCLUSION

Natural environments are sources of benefits for humans, but their degradation and suppression may pose serious risks to human health. Unadulterated forest ecosystems prevent new diseases from affecting humans, for example. Maintaining these and other natural ecosystems conserved can also prevent respiratory diseases caused by fires and ensure thermal comfort for local residents and the general population.

As it has been shown, natural ecosystems and agroforestry systems allow for nutritional quality, food diversity and food security, not only for the populations who live and depend on the forest, but also for those who live in urban centers.

Some actions can help maintain ecosystem services and avoid the risks of natural *habitats* destruction. Among them are the conservation of forests, the better management of the landscape in areas of agricultural and livestock raising activities, the restoration of deforested or degraded environments, including those near urban centers.

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