

POLICY BRIEF

HEALTH IN THE AMAZON: ENVIRONMENTAL, SOCIAL AND ECONOMIC CHALLENGES

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KEY MESSAGES

(i) Environmental Degradation Increases Health

Risks: Environmental degradation in the Amazon (deforestation, mining, illegal logging, forest fires, unsustainable infrastructure development, crop monoculture, among others) directly increases health risks that exacerbate the susceptibility of local populations to a suite of conditions including, but not limited to, food insecurity, respiratory, cardiovascular, and infectious diseases.

(ii) Climate Change Intensifies Health Impacts:

The Amazon faces a four-fold burden of climate change, biodiversity loss, ecosystem pollution, and deforestation, threatening health of Amazonian people through extreme temperatures, forest fires, land and water pollution, siltation of rivers (especially due to the use of intensive and extensive agrochemicals), droughts, floods, increased mercury loads in aquatic ecosystems, among others.

(iii) Specific Populations are the Most

Vulnerable: Indigenous Peoples and Local Communities (IPLC) are especially vulnerable to droughts, floods, forest fires, food insecurity, and water pollution, facing high rates of malnutrition. Water scarcity and poor quality pose significant challenges in vulnerable regions, including Black, Quilombola, and other Indigenous communities. Furthermore,

individuals with pre-existing noncommunicable diseases (NCDs), particularly children and the elderly, are at increased risk due to exposure to air and water pollution, as well as heatwaves.

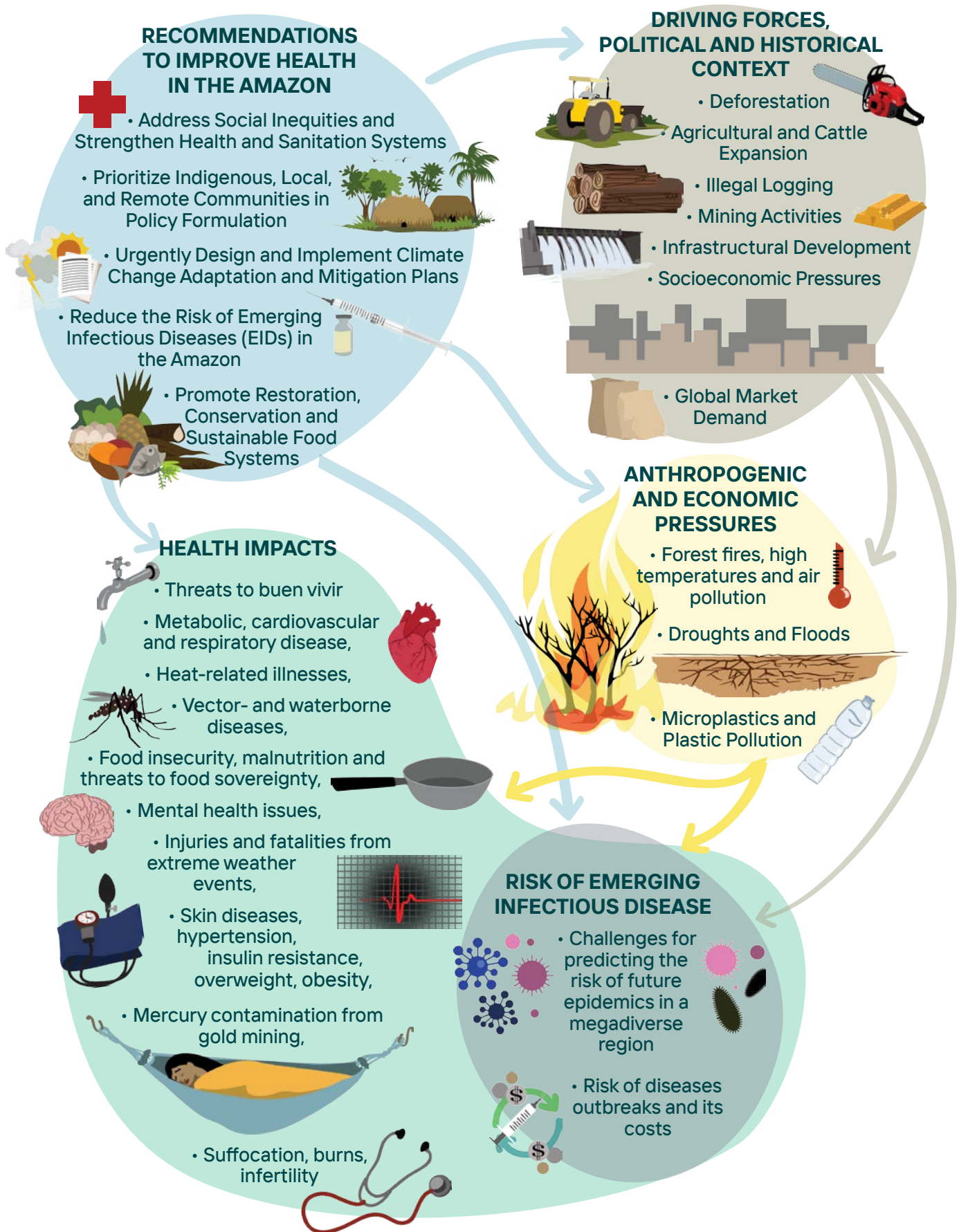
(iv) Healthcare Systems Suffers from Systemic Challenges and Breakdowns:

The Amazon region suffers from inadequate health infrastructure, poor access to basic amenities (e.g., clean water, adequate solid waste management, and wastewater treatment), and weak governance, making it difficult to address the health impacts of environmental degradation and climate change effectively.

(v) Concerns Growing about Emerging Infectious Diseases (EIDs):

The Amazon is increasingly vulnerable to Emerging and Re-Emerging Infectious Diseases due to environmental degradation, deforestation, biodiversity loss, and illegal wildlife trade. These factors bring humans closer to wildlife disease vectors, increasing the risk of zoonotic disease transmission. The disruption of ecosystems not only threatens species and their ecological niches, but also accelerates the spread of pathogens, posing significant health risks locally and globally. Conservation and sustainable practices, as well as innovative technologies are urgently needed to address this growing public health concern.

GRAPHICAL ABSTRACT



RECOMMENDATIONS

(i) Address Social Inequities and Strengthen Health and Sanitation Systems: Promoting poverty alleviation, gender equity, and community engagement, with a focus on women's, children's and elderly's health and participation in environmental protection, is crucial for improving public health outcomes. Investments in health infrastructure, sanitation, and capacity-building for health professionals are essential to ensure effective healthcare delivery and disease prevention in vulnerable communities.

(ii) Prioritize Indigenous, Local, and Remote Communities in Policy Formulation: Health service delivery in remote communities must ensure improved distribution of supplies like medicines and rapid tests. During extreme weather events, it is essential to include equipped mobile health units. Strengthening primary care through experienced teams in remote areas and improving access to specialized care, including telehealth, while addressing mental health needs of IPLC, are essential for comprehensive healthcare support.

(iii) Urgently Design and Implement Climate Change Adaptation and Mitigation Plans: Integrating epidemiological data, Surveillance and Early Warning Systems (EWS), and localized heat stress indices is essential for improving preparedness and responses to climate impacts, while ensuring access to Water,

Sanitation and Hygiene (WASH), and health services to promote thermal comfort. Additionally, adaptation measures like promoting greener spaces, improving air quality monitoring, and implementing policies to reduce deforestation and improve energy consumption efficiency are crucial for mitigating climate-related health risks, especially for vulnerable populations.

(iv) Reduce the Risk of Emerging Infectious Diseases (EIDs) in the Amazon: A coordinated transnational response that integrates research agendas, traditional knowledge, surveillance systems, and predictive models is essential for early identification and monitoring of viruses, fungi and bacteria in sentinel populations. Collaborating with international initiatives, promoting the support funding for identification and dissemination of zoonotic risks, and investing in ecological restoration and land-use interventions are critical for mitigating zoonotic disease risks in the Amazon.

(v) Promote Restoration, Conservation and Sustainable Food Systems: Halting deforestation is critical for maintaining water bodies, soil productivity, regulating disease vectors, and reducing zoonotic disease risks. Promoting a just energy transition, supporting community-based ecotourism, restoring degraded areas, conserving aquatic ecosystems, and fostering agroecology and food sovereignty are essential for sustainable livelihoods and environmental resilience.

1. INTRODUCTION

The Amazon, vital for global climate regulation and biodiversity, encompasses an area of about seven million square kilometers across eight countries and one overseas territory, and is home to 47 million people, including more than two million Indigenous inhabitants^{1,2}. The region faces a four-fold burden of accelerating climate change, biodiversity loss, ecosystem pollution and deforestation, and intensive and extensive use of

pesticides which have a large negative impact on the health of Amazonian people. These negative effects are exacerbated by the fact that the region is characterized by socioeconomic inequalities, lack of access to basic amenities, violence, and difficulties in implementing public policies³.

The effects of climate change are increasingly impacting the entire region⁴. For example, the extreme droughts of 2023 and 2024 have led to an increase in wildfires, releasing pollutants causing respiratory and

cardiovascular diseases. In addition, the changing precipitation patterns affect water availability and quality in a large area of the basin. This has resulted in an increase in outbreaks of waterborne and vector-borne diseases, such as yellow fever, dengue, malaria, Saint Louis encephalitis, Mayaro fever, and Oropouche. The impacts of climate change are strongly influenced by social vulnerabilities, such as high poverty levels, informal employment, education and health systems gaps. These inequalities together with weak governance, limited disaster risk management policies, and inadequate climate adaptation efforts contribute to the devastating health impacts of climate change. These impacts disrupt daily life, affecting health, well-being, social development, and human capital^{5,6}. Indigenous communities are particularly vulnerable due to their reliance on forest resources and high exposure to the extreme weather events, immunity issues, multidimensional poverty, and low education levels^{7,8}

Land and water pollution are also serious threats for human health. In the Brazilian Amazon, it is estimated that soybean cultivation and intensive use of pesticides left residents of the state of Mato Grosso exposed to an average of 65.8 liters/inhabitant/year of pesticides in 2018, and an average of 300 liters/inhabitant/year in cities where this use is even more intensive⁹. In addition, health and environmental implications of coca cultivation and drug trafficking have extended its tentacles to the political scene of the countries of the Amazon basin, such as Colombia, among others¹⁰. Similarly, both legal and illegal mining for minerals, like gold, cassiterite, and iron, cause deforestation, water pollution, the life of aquatic ecosystems, and soil erosion. Illegal mercury use in gold extraction contaminates water bodies and especially fish, a crucial dietary resource for urban and rural communities¹¹.

Economic expansion and deforestation interact with socio-environmental factors, creating conditions for increases in homicide rates, sexual exploitation

and child abuse, the exacerbation of sexually-transmitted infections, and increased psychological stress resulting from violence and the erosion of social cohesion^{12,13}. In addition, weak enforcement of environmental laws and high market demand drive illegal activities (e.g., illegal logging, mining), degrading ecosystems, reducing biodiversity, and impacting resources critical to Indigenous populations. In addition, drug cartels are also diversifying into other illegal activities that contribute to deforestation, and consequently, deteriorate the health of the Amazonian population.

Infrastructure projects, such as road construction and hydroelectric dams, provide access to remote forests, accelerating deforestation, fragmenting habitats, and displacing Indigenous communities. These projects are often associated with the agroindustrial development rather than focusing on the needs of IPLC, also bringing an influx of people, spreading pathogens and disrupting local ecosystems. Governance issues, including corruption and insufficient resources, allow illegal logging and mining to occur with little resistance, undermining legal frameworks and Indigenous rights. Political lobbying often favors resource exploitation over forest conservation, reducing regulatory enforcement in the Amazon. Socioeconomic pressures, including high poverty levels and limited sustainable economic opportunities, push some local community members toward illegal mining, logging, or unregulated agriculture, leading to environmental degradation. Additionally, the global market demand for commodities, such as beef, soybean, and minerals, further incentivizes the illegal and unsustainable exploitation of forest resources, contributing significantly to deforestation and degradation^{5,6}. In addition to government interventions, immediate action from civil society and non-governmental organizations is crucial to protect Indigenous Peoples and Local Communities' (IPLC) health and well-being, improve their quality of life, and conserving the Amazon.

BOX 1: THE FLYING RIVERS OF THE AMAZON AND IMPLICATIONS FOR HUMAN HEALTH⁷

The Amazon rainforest generates “flying rivers,” vast atmospheric waterways transporting ~20 billion tons of water vapor daily. Usually, the hydrological cycle begins with evapotranspiration, with the forest acting as a water pump that releases moisture to the atmosphere. This water vapor is carried across the continent through atmospheric air currents (the “flying rivers”), which are redirected by the Andes mountains causing precipitation south of the Amazon basin. Finally, this cyclical process repeats itself, with the forests recirculating water back to the atmosphere. This process maintains the hydrological cycle and rainfall patterns across South America, significantly impacting human health and well-being. Flying rivers ensure fresh water for drinking, sanitation, and agriculture; maintain cooler temperatures, reduce heat-related illnesses; and promote emotional well-being. However, deforestation and climate change disrupt this hydrological cycle, leading to water shortages, crop failures, food insecurity, increased disease transmission, among others. Recent droughts and wildfires demonstrate the disruption of the hydrological cycle and the functionality of the Amazon’s flying rivers^{7,8}. As a matter of fact, due to land use change, increase in temperatures and extreme events, these flying rivers turn into “smoke rivers” in the dry season, transporting smoke from forest fires not only in the Amazon but also to many highly dense populated urban areas in South America increasing the risk of respiratory and cardiovascular diseases¹⁴

2. HEALTH IMPACTS FROM CLIMATE CHANGE, ANTHROPOGENIC AND ECONOMIC PRESSURES

Climate change, biodiversity loss, pollution and deforestation contribute to major health issues. Here we highlight some of them, namely: threats to buen vivir; metabolic, cardiovascular and respiratory diseases; heat-related illnesses; vector- and waterborne diseases; food insecurity, malnutrition and threats to food sovereignty; mental health issues; and health risks due to pollution. These health issues highlight the deep connection between ecological degradation and public health, and underscore the need for urgent, coordinated action.

2.1 Noncommunicable Diseases (NCD)

NCDs (e.g., cardiovascular diseases, diabetes, chronic respiratory diseases, cancers, mental health disorders) are a leading cause of death in Brazil, accounting for 74% of all deaths in the country. Between 2010 and 2021, cardiovascular disorders were the leading cause of death in the Amazon, accounting for 23% of all deaths. Respiratory conditions and external causes accounted for 9% and 16% of deaths, respectively^{15,16}. However, NCDs in the Amazon are likely underestimated due to geographical isolation and limited access to health facilities. Important risk factors remain undetermined for the Indigenous, Quilombolas, riverine (characterized by precarious mobility options), and remote communities.

BOX 2: IMPORTANCE OF TERRITORY FOR HEALTH AND BUEN VIVIR IN THE AMAZON

For the Pamiwa people of the Colombian Amazon, the territory is a vital space where visible and invisible beings coexist. Cultural and ancestral norms guide sustainable resource use, promoting *buen vivir* (“good living”), which is understood as physical, spiritual, and emotional well-being in balance with nature. Disruption of this balance leads to diseases imposed by the “seres dueños de la naturaleza” (“masters of nature”). To understand changes in the territory and the actions of the “seres dueños de la naturaleza”, the Pamiwa create ecological calendars. These collectively developed graphic tools illustrate how the environment interacts across the three realms (upper, middle, and lower) to produce health and disease as seen in **Figure 1**.

The ecological calendar of the Pamiwa people of the Colombian Amazon tracks seasonal changes in the environment, marked by the positions of constellations and water levels. The year is divided into five periods: yellow marks the dry season and four different shades of blue highlight the intensity of rains. These periods correspond to natural droughts and floods, with traditional activities like agriculture, fishing, and hunting related to the timing of these phenomena. Potential diseases related to the environmental seasonality are recorded in the calendar’s inner circle. The

Spiritual beings, known to the Pamiwa as the “seres dueños de la naturaleza”, regulate human-nature interactions through animals (e.g., spiders, snakes) and weather (e.g., lightning and high winds). Traditional healers perform protective rituals to maintain harmony and recalibrate balance in the territory or individual community members.

Disturbances to this harmony include diseases introduced by foreigners, such as measles and COVID-19, viewed as evils. Climate change is disrupting the calendars, as altered rain patterns, rising river levels, extreme temperatures, and drought create unprecedented conditions, including increased mosquito populations and greater spread of diseases like malaria and dengue. Indigenous Peoples are also observing environmental changes via shifts in animal behaviors, including the timing of the emergence of ants, birds, and frogs. Ecological calendars have guided Indigenous Peoples for millennia and allowed them to live as part of a complex web of relationships in the Amazon’s forests. These calendars hold important Indigenous knowledge and wisdom that can provide guidance in the face of urgent global challenges and damaging environmental impacts from climate change and capitalism’s economic model. It is necessary to safeguard these Indigenous knowledge, which is crucial to the health of Indigenous communities and mitigation of climate crisis.

2.2 Health Risks due to High Temperatures and Air Pollution

Heatwaves in the Amazon increase morbidity and mortality due to metabolic conditions, particularly cardiovascular and respiratory diseases, such as ischemic heart disease, stroke, heart failure, Chronic Obstructive Pulmonary Disease (COPD), and Chronic Kidney Diseases (CKD)^{17,18}. The risk of mortality from cardiovascular disease rises

with more intense heat waves, with the greatest impact on elderly populations and women^{19,20}. High temperatures increase heart and respiratory rates, dehydration, blood viscosity, and blood pressure, stressing the heart and lungs, especially of the elderly^{20,21}. Prolonged heat waves exacerbate cardiovascular stress, amplify air pollutants, and worsen existing respiratory and cardiovascular conditions¹⁷. Future projections for Amazonian

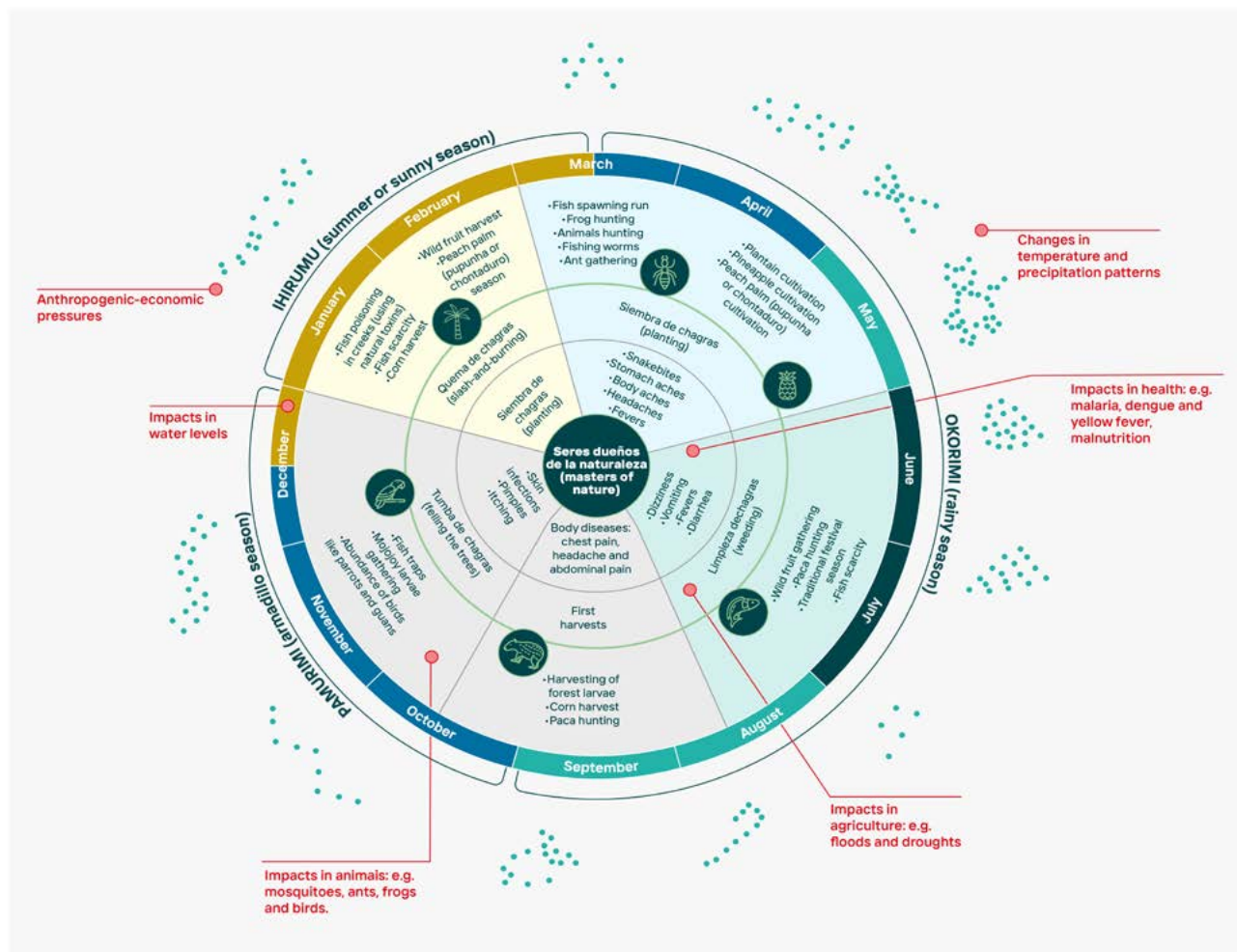


Figure 1: Ecological Calendar of illnesses from the Pamiwa Cosmivision and External Disturbances. Developed by Glória Rivera and Enrique Llanos.

capital cities indicate a significant decrease in life spans due to heat-related cardiovascular diseases between 2040-2069 compared to 1970-2005, assuming rising emissions¹⁹. By 2100, the extreme degradation of the Amazon could expose over 11 million people to heat stress²². Skin cancer and cataracts related to Ultraviolet (UV) radiation are reported in riverine communities, with significant research gaps on UV exposure and health effects in the Amazon. Monitoring ultraviolet (UV) radiation is also crucial due to its impact on health and ecosystems. While skin cancer and cataracts related to UV radiation are reported in riverine communities, there are significant research gaps on UV exposure and health effects in the Amazon. UV-related diseases are largely preventable with proper sun protection, but Indigenous, riverine,

and rural communities may be at higher risk^{23,24}.

The Amazon population's exposure to the toxic effects of biomass burning resulting from forest fires in the region is an important risk factor for cardiovascular and respiratory diseases^{25,26}. During the dry season, when most of the wildfires occur, the pollutant levels, like Particulate Matter 2.5 (PM2.5) often exceed World Health Organisation (WHO) limits^{27,28}. In recent years, heatwaves have occurred more frequently in the Amazon, resulting in an intense burning period extending from March to December^{29,30}, depending on variations in rainfall³¹. Most wildfires are anthropogenic, often set to clear land for agriculture and cattle ranching.

Between 2012–2019, deforestation increased by 39%, leading to more dry season fires. In 2019, wildfires caused an estimated 3,400 additional deaths due to increased air pollution³²; with total costs associated with hospitalizations due to deforestation-related fires being estimated at R\$ 5.64 million (USD 1.4 million)^{32,33}. In 2020 and 2021, several forest fires devastated more than 3.8 million hectares with unpredictable impacts on biodiversity, ecological services and human health in the Pantanal biome, part of the Brazilian legal Amazon (with the death of 17 million animals)³⁴. Estimated costs are even larger now because of the historic criminal Amazon wildfires in 2024. Early 2024 saw 7,861 fire outbreaks, the highest amount in the first three months of the year since 2016³³. Wildfire-related air pollution is linked to higher hospital admissions for respiratory conditions, especially among children and the elderly, due to lack of physiological resilience^{35,36}. PM2.5 from wildfires affects water quality and taste of rivers and lakes in the Amazon. It is also associated with a 38% increase in respiratory admissions and a 27% increase in cardiovascular admissions³⁷. Air pollutants and wildfires are also linked to asthma³⁸, COPD³⁹, lung cancer, brain tumors⁴⁰, suffocation, burns, and cerebrovascular events^{41,42}.

2.3 Health Risks related to Droughts and Floods

The Amazon rainforest has experienced severe drought and flood events in recent decades, disproportionately affecting Indigenous and riverine communities. Amazonian urban populations experience relatively higher levels of social vulnerability, making them more vulnerable to floods and droughts⁴³. These extreme events increase the risk of water-, food-, and vector-borne diseases; malnutrition; traumatic injuries; chemical exposures;

cardiovascular and respiratory illnesses; mental health disorders; and mortality^{44,45}. During droughts, water levels in rivers and streams can drop significantly, reducing the availability of clean water. This often forces people to rely on contaminated water sources, leading to an increase in waterborne diseases, such as diarrhea. The scarcity of potable water during these dry periods exacerbates the spread of gastrointestinal infections. Droughts also inhibit aquatic transportation, limiting access to supplies and urban centers where medical care and essential services are located. This situation can exacerbate existing health conditions and make it difficult to manage outbreaks of diseases, increasing the overall vulnerability of these populations. The lack of access to healthcare during these periods underscores the need for improved infrastructure and contingency planning in the region⁴⁶.

Floods, which are exacerbated by deforestation, can lead to dermatological illnesses due to physical trauma, stagnant water, exposure to pollutants and wastewater toxins, crowded shelters, and inadequate sanitation. The highest risk of wound infection and disease transmission occurs during the post-impact phase⁴⁷. Prolonged flooding destroys crops, contaminates water, and affects lives and health in both rural and urban areas^{48,49}. Long-term precipitation also increases the risk of pesticide exposure from agriculture, which is particularly relevant due to soybean monoculture expansion and rising concerns about drinking water contamination in the Amazon^{50,51}. While children and the elderly are the most vulnerable to the health impacts of flooding⁵², maternal exposure to extreme rainfall shocks is also associated with lower mean birth weight, preterm birth, and restricted intrauterine growth⁵³.

2.4 Health Risks of Microplastics and Plastic Pollution

New evidence shows the Amazon basin is highly polluted, with birds incorporating plastic into nests and aquatic plants retaining microplastics, with potential for biomagnification. Due to inadequate water and sewage treatment, tons of plastic enter Amazon waterways annually^{54,55}. The plastic industry contributes significantly to GHG emissions and environmental pollution. The

food and beverage sector is a major source of single-use plastic packaging, linked to ultra-processed food (UPF), posing a significant threat to biodiversity, freshwater resources, and traditional fishing activities. Research gaps on plastic pollution in the Amazon need to be addressed^{56,57}. Plastic polymers have been found in human organs, and plastic additives, known as endocrine-disrupting chemicals, contribute to infertility and NCDs, including obesity, diabetes, cardiovascular disease, and some types of cancer⁵⁸⁻⁶¹.

BOX 3. MENTAL HEALTH IN THE INDIGENOUS TERRITORIES

Mental health is a new concept for many Indigenous communities. Over the past 30 years in the Colombian Amazon, emotional and spiritual imbalances have increased, yet these issues are not properly addressed. Factors such as forced acculturation, family disruption, land displacement due to violence, climate change, food insecurity, inadequate education, healthcare, and job opportunities have weakened the emotional health of young people, leading to substance abuse, depression, and high suicide rates⁶².

The WHO defines mental health as a state of well-being where individuals can manage life's challenges and contribute to their community. However, for Indigenous communities, mental health expands beyond this, as it is deeply connected to *buen vivir* and the territory that integrates physical, spiritual, environmental, and cultural dimensions. Indigenous life is

linked to the moment of origin, the ultimate source of knowledge that is the Amazonian territory, which like a grain of corn, grows little by little, linked first to the mother, and then to the world and culture that surrounds it. This is where strength, vitality, good thought, emotional well-being, and the desire to live in harmony with everything that surrounds Indigenous communities stems from⁶³.

To address these mental health challenges, ancestral knowledge of connection to territory must be integrated into public health systems in the Amazon, supported by policies and resources. These systems should adopt a differential focus to address the region's unique challenges and promote *buen vivir* amidst growing anthropogenic impacts. Health systems in the Amazon should integrate ancestral practices in a new approach that recognizes the deep connection between people, their territory, and the environment. As the territory suffers, so does humanity⁶².

2.5 Food Insecurity and Threats to Food Sovereignty

In the Amazon, food security and food sovereignty (referring to the IPLC right to use and manage their lands, territories, waters, seeds, livestock and biodiversity to produce locally and sustainably food through agroecological methods according to each region's climate, cultural and geographical context⁶⁴), are threatened by monocrop farming, concentrated land ownership, intense pesticide use, deforestation, biodiversity loss, extreme weather events that restrict access to healthy food and water, unhealthy diets, and loss of traditional practices, as presented in **Figure 2**^{65,66}. Climate change, the contamination of aquatic ecosystems with pesticides and mercury, illegal (over)fishing, and the construction of dams reduce fish diversity, harming fishing communities and their cultures, and posing significant health risks, including malnutrition and metabolic disorders⁶⁷⁻⁷⁰. Chronic malnutrition is a significant health issue in the Amazon region, particularly affecting

Indigenous populations and children under the age of five years old. Multiple factors contribute to this problem, including social inequalities, such as the lack of access to resources, employment, and income; political power; education level; poor sanitation; parasitic infections; geographic isolation; and social exclusion, with intersecting relationships of class, gender, and ethnicity/race⁷¹⁻⁷³. Increased consumption of industrialized products (i.e., the "nutritional transition") in IPLC has further exacerbated the situation⁷⁴.

Vulnerable groups, such as IPLC, pregnant women, low-income families, children, and adolescents face disproportionate effects⁷⁵, with critical nutritional challenges, like high rates of malnutrition, anemia, and stunting among children and maternal IPLC⁷⁹. Research shows that 44.6% of children under five years old in urban areas and 58.7% in rural areas present anemia in Amazonian municipalities⁷⁹. Undernourishment weakens the immune system, increasing susceptibility to infectious diseases⁸⁰.



Figure 2: Key Food Systems Threats to the Amazonian Biome. (Adapted from^{66,88})

High consumption of ultra-processed food (UPF) also contributes to increased energy use, biodiversity loss, GHG emissions, land use, food waste, and water use⁸¹⁻⁸³. Limiting UPF and encouraging the consumption of local, seasonal, organic food improves health and sustainability^{84,85}. Food policies are crucial in this

field, as exemplified by the Brazilian National School Feeding Programme (PNAE)⁸⁶. School feeding programs have proven to be among the most important tools for improving nutrition in vulnerable regions of the world, and providing children with adequate foods at an early age can have lifelong impacts⁸⁷.

BOX 4: CONNECTING CLIMATE, SANITATION AND HEALTH

One of the most critical areas at the nexus of climate and health is access to safe drinking water, but as of 2022, 2.2 billion people lack access to it. The solutions are known, but there is a need for committed funding for their implementation⁸⁹. National, state, and municipal efforts are needed to increase awareness of the critical role of water in maintaining climate stability, health, and economic development, and particularly, in reducing mortality and morbidity rates among children and the elderly in the Amazon basin.

Basic sanitation services are vital for human development, promoting health, preventing the spread of waterborne diseases, and supporting climate adaptation. However, as of 2022, 3.5 billion lacked safely managed sanitation, and 2 billion lacked basic hand washing facilities around the world⁹⁰. The situation in the Brazilian Amazon is especially concerning, with almost half of the country's 20 cities with the worst basic sanitation indicators located in this region⁹¹.

The Amazon region presents high risk for waterborne disease due to inadequate water, sanitation, and hygiene infrastructure. According to the 2010 Census, 68.2% of the population in the Brazilian Amazon lacked access to adequate sanitation⁹². This lack of access, combined with

the significant presence and use of rivers in the local context, contributes to higher mortality rates in the region. The COVID-19 pandemic has further exposed the dire impacts of poor access to clean water and sanitation in vulnerable Amazonian communities⁹³. The climate emergency further exacerbates water quality and scarcity, requiring urgent action and adaptation to droughts and floods, especially in vulnerable territories⁹⁴. Considering this scenario, children live in a state of "multiple deprivation," facing severe health risks due to poor sanitation and poor drinking water quality, especially during flood seasons⁹⁵. The infant mortality rate in the Amazon region is persistently higher than in the rest of its countries, with waterborne diseases being a significant cause. Simple solutions, like decentralized water supply systems, could greatly improve health outcomes in Amazonian communities⁹⁵.

Other key strategies include raising awareness of the importance of water in climate and health action and achieving universal sanitation coverage by 2030. Ensuring that water access is recognized as a human right and investing in infrastructure and management to prevent water-related diseases and improve quality of life in the Amazon are also critical. Civil society organizations should hold governments accountable, invest in water technology research, and promote inclusive governance of water resources⁹⁶.

3. RISK OF EMERGING INFECTIOUS DISEASES (EIDS)

The Amazon is a significant arbovirus reserve⁹⁷, with potential global health impacts⁹⁸. The EIDs risks have increased over time due to climate change, land use change, environmental degradation, global trade, habitat destruction, and pollution⁹⁹⁻¹⁰⁴, suggesting that spillover events may become more frequent. Examples of DIDs include Nipah viral encephalitis; severe acute respiratory syndrome (SARS); hantavirus pulmonary syndrome; highly pathogenic avian influenza, H5N1; influenza virus, H1N1; and human immunodeficiency virus (HIV). While more spillover events have historically occurred in Asia and Africa, the Amazon’s high biodiversity increases the likelihood of pathogen presence and mutations, especially with the growing presence of livestock in the region¹⁰⁵⁻¹⁰⁹. Historically, over 60% of new human pathogens have had animal origins, with 75% stemming from wildlife through zoonotic spillovers^{110,111}. The COVID-19 pandemic and the rise of EIDs have demonstrated the importance of the “One

Health” approach, integrating human, animal, and environmental health seen in **Figure 3**¹¹²⁻¹¹⁴.

Forest clearing and degradation increase human and domestic animal contact with wildlife, facilitating pathogen transmission^{106,115}, and altering pathogen transmission cycles. Even though there is strong evidence that deforestation is associated with enhanced risk of disease transmission, some level of uncertainty about these risks arise due to the complex interactions between environmental, biological, and socioeconomic factors, as well as variations across different regions and diseases^{105,116,117}. **Figure 4** presents the projected mean number of spillover events per capita and changes in vegetation cover between 2020 and 2050 (deforestation). Areas that currently have high tree coverage (> 60%) and low deforestation rates will likely experience low levels of spillovers (< 0.12, lower left corner cell in the inset color code panel), and should be protected from deforestation. Areas with high levels of spillovers and deforestation are clustered around population centers and should be prioritized for land-use planning and community

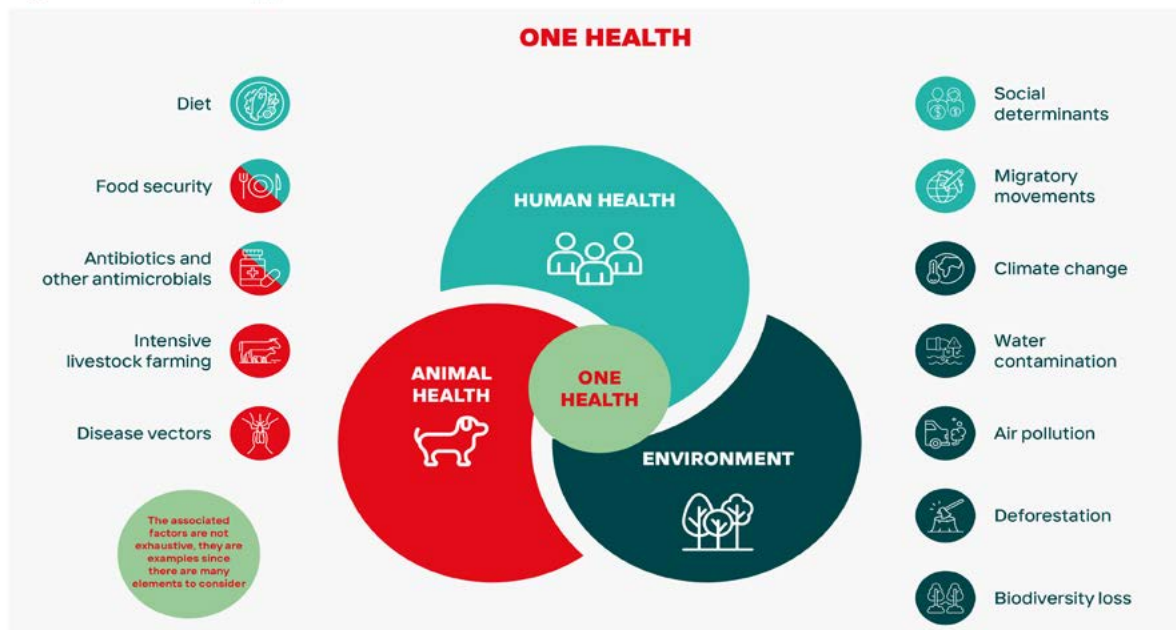


Figure 3: The One Health Approach. (Adapted from Barcelona Institute for Global Health and based on¹¹⁴⁻¹¹⁶)

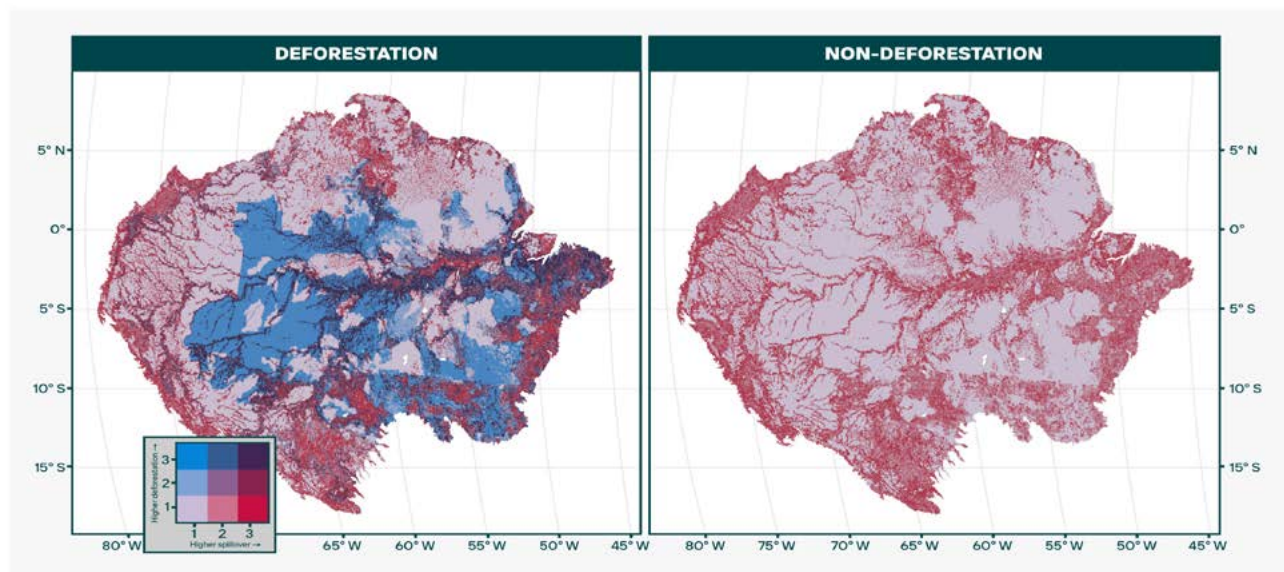


Figure 4: Projected Mean Number of Spillover Events Per Capita and Change in Cover between 2020 and 2050 (Adapted from¹⁰²).

health support efforts. Many areas in the Amazon are already deforested and will have a high level of spillover events (> 0.3), even if they suffer little additional deforestation ($< 40\%$) until 2050 (lower right corner cell in the inset color code panel). These areas should be considered in restoration programs, such as the Brazilian Native Vegetation Recovery Plan (PLANAVEG) and Brazil's Arc of Restoration project launched at COP28 to restore 24 million hectares of the Brazilian Amazon deforested and degraded areas.

EIDs linked to illegal wildlife trade have significantly increased over the past decade due to the rise in human-environment interactions and better diagnostic testing. There is an urgent need to monitor and enforce illegal wildlife trade regulations to protect public health, especially as globalization increases disease risks¹¹⁸. However, data on illegal wildlife trade in South America is limited¹¹⁹. Research shows that in Brazil, more than half (55.8%) of wild animals rescued from illegal trafficking were infected with at least one zoonotic parasite. Non-human primates had a higher infection rate (58.3%) compared to carnivores (41.7%). The zoonotic parasites

detected included helminths (33.5%) and protozoa (66.5%), with 20.8% of infected animals having coinfections¹²⁰. Despite the significant health risks from pathogens in bushmeat, public awareness of these risks remains low¹¹⁸. Increasing extreme weather events due to the climate crisis are expected to heighten the risk of outbreaks of existing vector-borne diseases and the emergence of new ones. These climate effects will interact with ongoing urbanization in areas like Manaus, necessitating a precautionary approach focused on surveillance, preparedness, and alert systems. These measures should be integrated into broader efforts to address environmental changes, including deforestation and climate change, to ensure regional sustainability¹²¹.

3.1 Challenges for Predicting the Risk of Future Epidemics in a Megadiverse Region

Predicting future epidemics in the Amazon is challenging due to the complex interplay of ecological and socioeconomic factors in the region. Human activities have created fragmented landscapes where high-density animal populations in degraded habitats

are prone to epidemics. Anthropogenic agroecosystems attract wildlife, increasing disease spillover risks as interactions between wildlife, humans, and domestic animals rise. Common activities like logging, hunting, agriculture, and cattle breeding also generate conditions for zoonotic disease outbreaks.

New frameworks predict zoonotic disease risks in the region, considering land-use changes, mammalian species richness, social welfare, and geographic connectivity⁹⁹. Data gathered based on the INFORM protocol assessed exposure, vulnerability, and coping capacity. The model showed significant associations between zoonotic epidemic risks and vegetation loss, mammalian richness, and remoteness. The Amazon region is a major concern due to low levels of urban arborization, high levels of mammal richness, and significant vegetation loss. High-risk states, primarily in the Northern region, exhibit these characteristics, while low-risk states have better healthcare access and urban connectivity.

Bushmeat hunting and trading also increase zoonotic disease risks by promoting direct human-wildlife contact. Therefore, it also has clear benefits for food and nutritional security by offsetting the reduced protein consumption in times of fish scarcity¹²² and reducing anemia levels⁷⁸. Bushmeat is part of the food culture of many IPLC in the Amazon, who have specific practices to reduce risks. This issue must be addressed locally and respectfully together with these communities as it is a sensitive topic. A database of frequently poached mammal species in Brazil and their zoonotic parasites highlighted key species for monitoring⁹⁹. The analysis revealed that bacteria, protozoans, and viruses are the main parasite groups, with species like the crab-eating fox, opossums,

and armadillos serving as central hosts. While introduced pathogens have historically caused major outbreaks in Brazil, the risk of zoonotic diseases emerging from native biota is significant, particularly in the Amazon.

Despite advances in understanding drivers of emerging and reemerging infectious disease outbreaks, predicting zoonotic risks and outcomes in the Amazon remains difficult. Factors, such as the effectiveness of healthcare systems and the pathogen's spread potential, lead to varied hospitalization and mortality rates. Surveillance data often focuses on introduced diseases, with limited knowledge of native pathogens. While the Amazon is identified as a hotspot for emerging zoonotic diseases, COVID-19 revealed deficiencies in the region's preparedness for epidemiological emergencies.

Predicting and mitigating the risk of future epidemics in the Amazon involves understanding the complex interplay of ecological degradation and socio-economic activities. There is an urgent need for integrative public health policies combining human and wildlife monitoring, reflecting the One Health paradigm. Preventive strategies should integrate ecosystem and urbanization characteristics, improve public health infrastructure in remote areas, and promote sustainable practices. Effective prevention and response strategies require collaboration across governmental, agricultural, and societal sectors, promoting sustainable practices and informed community engagement to mitigate zoonotic risks.

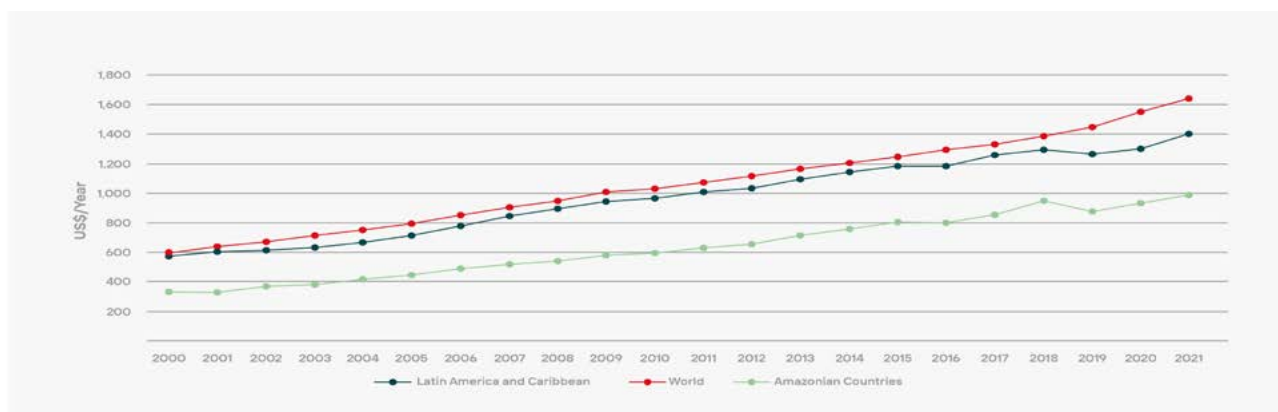


Figure 5: Health Expenditure in Amazonian Counties, Latin America and the Caribbean, and the World (2000-2021). Own elaboration based on World Health Organization Global Health Expenditure database (apps.who.int/nha/database). The data was retrieved on April 15, 2024.

3.2 Risk of Diseases Outbreaks and Its Costs

The current state of health in the Amazon is complex and hampered by incomplete data due to gaps in surveillance and diagnostic capacities in areas with weak or nonexistent health systems. Health systems in Latin America are highly fragmented and segmented, leading to significant challenges in providing quality care and ensuring equity. Market, social, and political pressures drive poorly regulated privatization of public healthcare, undermining public services where management capacities are already limited¹²³. Historical data from The Global Health Observatory of the WHO

indicates that Amazonian countries have very weak health systems compared to the most developed countries. The current health expenditure per capita in Amazonian countries ranges from \$330 to \$984, compared to \$575 to \$1,406 in Latin America and the Caribbean and \$594 to \$1,639 in the world average (from 43 to 67% less). This situation is also observed at sub-national levels (Figure 5).

On the other hand, when doing a sub-national analysis, for example, in Brazil, the expenditure in Amazonian states is much less than in states from other biomes (Figure 6, Amazon states in light green). These numbers highlight the need

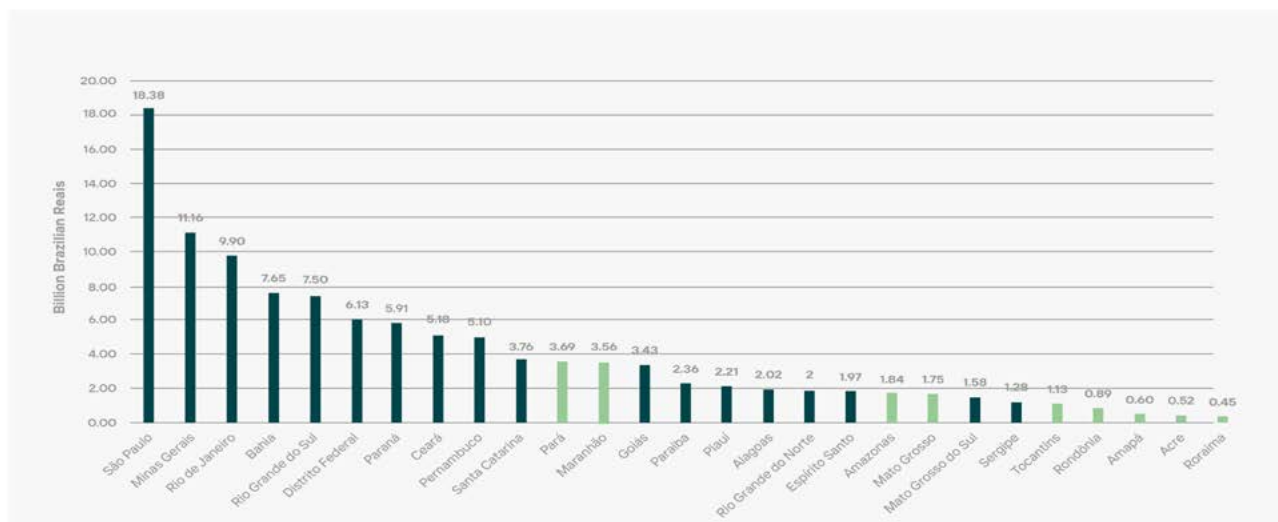


Figure 6: Governmental Health Expenditure in Brazil by State in 2023. Own elaboration based on Controladoria-Geral da União (Brazil) (Portal da Transparência). The data was retrieved in June, 2024.

for more prioritization and investment in health systems in Amazonian countries due to their higher vulnerability and increasing pressures. Certain areas, particularly in the Cerrado tropical savanna, are identified as “disease hot spots” prone to high risks of zoonotic diseases from anthropogenic land use changes¹²⁴. Disease risks and impacts on human health are likely to be significant even before reaching the Paris Agreement’s 2-degree target, necessitating immediate action.

The climate crisis and COVID-19 pandemic highlight the critical need for ongoing investment in Global Health Security (GHS) preparedness, as previously demonstrated by the outbreaks of Ebola, Zika, and H1N1. Enhancing GHS requires greater regional cooperation and improved infectious disease surveillance systems. Frameworks like the International Health Regulations and the GHS Agenda provide a foundation for strengthening health systems in the Amazon. International cooperation is essential to enhance surveillance, build trust among partner countries, and improve health security systems and practices to effectively respond to and mitigate infectious disease outbreaks. Health systems must be a priority for governments in Amazonian countries, and financing must be increased^{124,125}.

4. THE PATH FORWARD: IMPROVING HEALTH IN THE AMAZON

Address Social Inequities and Strengthen Health and Sanitation Systems: It is essential to promote poverty alleviation and reduce social and gender inequities (e.g., ensure women’s participation in forest

protection initiatives, address sexual violence around megaprojects, focus on women’s health, and establish networks among women’s organizations of IPLC)¹²⁶. Health education and prevention programs need to be strengthened as well as community engagement, and community-based surveillance in vulnerable communities^{127,128}. Investments in adequate infrastructure for health (e.g., healthcare facilities in safe locations) and sanitation are required to provide clean water, adequate solid waste management and wastewater treatment. Effective capacity-building for all health professionals need to be implemented beyond physicians and nurses (e.g., updating health curricula, training primary care teams and community health workers, expanding internship opportunities, and promoting exchange programs)¹²⁹.

Prioritize Indigenous, Local, and Remote Communities in Policy

Formulation: Health service delivery in remote communities must ensure improved distribution of supplies like medicines and tests for diseases such as HIV and malaria which can have a substantial impact on children and pregnant women. During extreme weather events, it is essential to include boats or amphibious vehicles equipped with mobile health units^{130,131}. Teams experienced in remote areas (e.g., *Mais Médicos* and community-based agents programs, *Agentes Comunitários de Saúde*, *Agentes Indígenas de Saúde* and *Agentes Indígenas de Saneamento*), as well as multidisciplinary teams in the territory, especially during emergencies reinforce primary care. The access to hospitals and specialized care (e.g., telehealth services) need to be improved^{129,132} and the gaps of

IPLC's mental health need to be addressed (e.g., measuring and monitoring the prevalence of mental health disorders and mental health risks from climate change, providing adequate mental healthcare, diagnosis, and treatment).

Urgently Design and Implement Climate Change Adaptation and Mitigation Plans:

Epidemiological data integration (e.g., web applications that allow identification of spatial-temporal patterns of different diseases) and Early Warning Systems (EWS) are required to improve advanced alerts on mobile devices that provide lead-time appropriate preparedness and responses. Localized heat stress indices, like the region-specific Wet Bulb Globe Temperature (WBGT) and heat index, further contribute to timely response strategies. Additionally, the availability of WASH and health services is crucial for promoting thermal comfort and implementing effective cooling strategies¹³³. Greener spaces, local communitarian architecture and materials are great strategies for adapting to high temperatures¹³⁴. These strategies need to focus on the elderly, children, people with NDCs, and women, and consider heatwave intensity in rural, remote, and urban settings²⁰. Health co-benefits need to be considered in public health policies across all ministry projects and coordinated by the health sector (e.g., reducing deforestation and wildfires, expanding public transportation using cleaner fuels, and changing building construction standards to reduce energy consumption)^{19,135}. Adaptation measures like air quality monitoring, clean air shelters (e.g., high efficiency particulate air filters in key locations), distribution of masks or air purifiers, restriction of outdoor activities during high pollutant events like wildfires⁴¹, and inform

communities about air quality levels (e.g., Air Quality Index)¹³⁶ are essential for protecting public health in the face of air quality challenges.

Reduce the Risk of Emerging Infectious Diseases (EIDs) in the Amazon: A

coordinated transnational response requires the unification of research agendas and the integration of traditional knowledge, surveillance systems, platforms, and predictive models. Such an approach fosters the early identification, monitoring, and surveying of viruses in sentinel populations, thereby addressing the increasing incidence of emerging and reemerging infectious diseases^{137,138}. Addressing zoonotic disease risks in the Amazon region benefits from alignment with international initiatives like Finance for Biodiversity (FfB), Global Canopy's Forest 500, and the Investors Policy Dialogue on Deforestation (IPDD). National and multilateral development banks, including the Inter-American Development Bank, play a key role by supporting the financial disclosure of climate and zoonotic risks related to anthropogenic land-use changes in high-risk regions and sectors. Additionally, companies contribute to zoonotic risk mitigation by protecting or restoring ecological conditions that limit pathogen spillover, implementing land-use interventions to reduce "edge effects," and co-investing with the public sector in zoonotic disease hotspots.

Promote Restoration, Conservation and Sustainable Food Systems: Halting deforestation (e.g., prohibiting unsustainable extractivism and the export of goods causing deforestation) and forest fragmentation are crucial for maintain water bodies, regulating disease vector populations, and reducing

human-animal contact, lowering the risk of zoonotic disease and other diseases. A just and decentralized energy transition, grounded in the recognition of the Amazon's rights and informed by ancestral knowledge, fosters environmental sustainability and respects the region's cultural heritage¹³⁹. Encouraging community-based ecotourism as an alternative to extractivism further promotes local economic resilience and sustainable livelihoods¹⁴⁰. Areas with intense deforestation (e.g., transforming the Arc of Deforestation into Arcs of Restoration)¹⁴¹ need to be restored and aquatic ecosystems need to be conserved inspired by successful conservation strategies (e.g., pirarucu management)¹⁴². Biodiversity, fishing resources, and communities need to be supported to promote agroecology and prevent severe food insecurity¹⁴³. Other necessary measures are traditional and family-scale pesticide-free agriculture; food sovereignty for sustainable resource management¹⁴⁴; and school feeding programs based on sociobiodiversity^{145,146}.

CONCLUSION

The Amazon region confronts pressing health and environmental challenges driven by climate change, deforestation, biodiversity loss, pollution, and socio-economic pressures. The deep connection between ecological degradation and public health highlights the need for urgent, coordinated action. Indigenous and local communities (especially children, women, and the elderly are particularly vulnerable), facing limited health infrastructure, weak governance, and a dependence on forest ecosystems for their

livelihoods. To protect these communities and sustain the Amazon's ecological integrity, comprehensive strategies are essential, including strengthening public health and sanitation, reducing socio-economic disparities, and empowering local communities in policy-making.

Effective climate adaptation and mitigation efforts must target the growing impacts of extreme weather, emerging infectious diseases, and pollution from deforestation and industrial activities. Combining Indigenous knowledge and community-led practices with scientific research and early warning systems can bolster resilience to environmental threats and health risks. Furthermore, sustainable food systems and conservation initiatives (such as halting deforestation and restoring degraded lands), are vital for securing food supplies, protecting biodiversity, and reducing zoonotic disease transmission. However, meeting these ambitious goals requires substantial support from the international community, particularly from developed countries. By increasing financial investments, developed nations can help fund critical infrastructure, healthcare systems, and sustainable economic opportunities in the Amazon region. This support, in alignment with climate finance commitments, is crucial to empower Amazonian communities in climate adaptation efforts and to protect a globally significant ecosystem. By adopting these measures and mobilizing resources, the Amazon region can address its complex challenges, ensuring the health, well-being, and cultural preservation of its people while safeguarding the forest ecosystem essential for global environmental stability.

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