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Deforestation and Emerging Zoonotic Diseases: A Global Pandemic Signal

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Abstract

This review examines deforestation as a major anthropogenic-induced factor for emerging zoonotic diseases causing considerable pandemic signals with serious health, social and economic constraints. Forest destruction leads to increased contact between wildlife, domestic animals and humans, thereby increasing the risk of zoonosis transmission and global pandemics. Many of the emerging zoonotic diseases, such as Middle East Respiratory Syndrome and Severe Acute Respiratory Syndrome (Coronavirus), Ebola virus disease, Monkey pox virus, Nipah virus, Yellow fever, Zika virus, Lyme disease, Dengue fever, Cysticercosis, Avian influenza, Changas virus, Lassa fever, and Chikungunya, among others, have been discovered, and these diseases are emerging at a rate that has not been seen before, especially in the last 10 years. The potential for emerging zoonoses to spread rapidly and cause global pandemics is a major source of concern, hence the need for combating measures to deal with the challenges of deforestation and emerging zoonotic disease pandemics, including the implementation of laws and regulations, interdisciplinary collaboration, establishment of disease testing and reporting centers, awareness and surveillance, alternative sources of income, and establishment of essential projects and interventions for forest conservation and zoonosis emergence. These measures will reduce further pandemic signals and their consequences.

Keywords: *Deforestation, Zoonosis emergence, Pandemic, Anthropogenic, Coronavirus.*

Introduction

Forests cover 31% of the world's land surface and the ecosystem they create play important roles in supporting the environment and its inhabitants (Symington, 2023; Prasad Bhatt, 2023; Food and Agriculture Organization, FAO, 2024). Unfortunately, human activities like agriculture, logging, improper forest management, urbanization, forest fires, and deforestation have caused an unprecedented loss of about 13 million hectares of these forests, particularly between 2000 and 2010 (Prasad Bhatt, 2023). This ultimately contributed to environmental problems like the emergence of zoonosis. Deforestation is a major anthropogenic risk factor for zoonosis emergence. It increases human exposure to emerging zoonotic diseases by displacing wildlife species, bringing them into closer proximity to livestock and humans (Rainforest Alliance, 2020). Deforestation forces wildlife to leave their habitat, increasing interactions among humans, wildlife, and livestock, and thus the potential for the transmission of pathogens directly or indirectly to human beings (Fu and Ma, 2008). The spread of zoonotic diseases is impacted by the loss of biodiversity brought on by deforestation (Vora, 2008).

Emerging zoonotic diseases are increasing, causing severe economic impacts and animal and human health risks. Asokan *et al.* (2013) estimate that zoonotic disease pandemics, especially emerging zoonosis, have caused global losses exceeding $US200 billion, including reduced trade, tourism, and tax revenues in the past 10 years. Asokan *et al.* (2013) documented 175 species from 96 genera among the emerging infectious agents, of which 132 (75%) species from 78 genera are zoonotic. Some zoonotic diseases, including mountain and desert subtypes of leishmaniasis in western China, Lyme

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disease in northern China, and Severe Fever with Thrombocytopenia Syndrome (SFTS) in central and northeast China caused by a novel bunyavirus, are related to deforestation, and humans are infected by the bites of wild vectors, *Phlebotomus chinensis* for leishmaniasis, *Ixodes persulcatus* for Lyme disease, and *Haemaphysalis longicornis* for SFTS during agricultural activities on the land changed from forests (Hao *et al*., 2011; Yu *et al*., 2011). In Mato Grosso do Sul state, Brazil, vector-borne Mayaro and Oroupouche viruses have been detected in non-human primates (Batista *et al*., 2012). Similarly, in the states of Tocantins and Maranhão, mimivirus has been discovered to have spilled over from non-human primates to domestic cattle (Dornas *et al*., 2014).

Emerging zoonotic diseases are increasingly recognized as a global pandemic signal, with major concerns about their rapid global spread (Johnson *et al*., 2015). To effectively design emerging zoonotic disease prevention and control programmes, the anthropogenic risk factors and emerging zoonotic disease relationship must be thoroughly understood. This review identifies deforestation as a major anthropogenic risk factor that brings about emerging zoonotic diseases, its mechanisms, effects, and combating measures that can prevent deforestation and zoonosis emergence.

Concept of deforestation and emerging zoonotic diseases

Deforestation is defined by the European Commission (2019) as the destruction and conversion of forest land to other land uses. On the other hand, the World Health Organization (2020a) defines an emerging zoonotic disease as a disease that is "newly recognized or newly evolved, or that has occurred previously but shows an increase in incidence or expansion in geographical, host, or vector range. Emerging zoonosis comprise a large percentage of all newly identified infectious diseases as well as existing infectious diseases (WHO, 2020a).

Deforestation occurs annually at about 13 million hectares per year (EU, 2019). From 1990 to 2005, three percent (3%) of the world's total forest area was lost (Environmental Literacy Council, 2015); this magnitude of destruction has significant social, economic, and environmental impacts, not only at the local level but also globally (EU, 2019). Environmental threats to human health at global and regional levels include: "climate change, stratospheric ozone depletion, changes in ecosystems due to loss of biodiversity, changes in hydrological systems and supplies of freshwater, land degradation, urbanization, and stresses on food-producing systems" (WHO, 2017). Rapid social and environmental changes are occurring globally, affecting both low-income countries and the largest advanced economies. Travel and transportation are the greatest increase to the risks of rapid spread of emerging zoonotic diseases (Jaffry *et al*., 2009). Particularly in the tropics, where there is high biodiversity, ecological change is greatest, making these regions potential hotspots for the emergence of new pathogens affecting wildlife, domestic animals, and human health (Nava *et al*., 2017).

From an ecological perspective, emerging zoonotic diseases might be seen as a continuation of host-parasite interactions. They are just as significant to any ecosystem as predator-prey or plant-herbivore relationships. In fact, disease-causing viruses, bacteria, and protozoa are commonly and collectively referred to as "microparasites" in zoonotic disease epidemiology (Wilcox and Ellis, 2006). Moreover, infection by a microparasite is not inevitably a disease-causing agent. Most often, host and microparasite coexist peacefully, because highly pathogenic genotypes that eliminate the host are selected against, as they are susceptible hosts lacking acquired or native immunity (inherited resistance). Thus, disease emergence is a transient phenomenon in a human population and, in its most severe form, is typically a consequence of rapid social and environmental change or instability (Wilcox and Ellis, 2006). Overcrowding, domestic animals, and wildlife, along with a warm humid climate, were as ideal for pathogen evolution, survival, and transmission several millennia ago as they are now (Wilcox and Ellis, 2006).

The concepts of emerging zoonotic diseases were prompted by the appearance of novel pathogens such as human immune deficiency virus (HIV) (Wilcox and Ellis, 2006). The evolution of more virulent or drug-resistant pathogenic variants of known microbes and the geographic expansion and increasing pandemic signals of the diseases caused by these pathogens, as well as older diseases such as malaria and dengue (Wilcox and Ellis, 2006). More recently, the concept was reinforced by the dramatic outbreak of severe acute respiratory syndrome (SARS) virus (coronavirus) and monkeypox virus. The recent upsurge of coronavirus (code-named Covid-19), which attracts the attention of the World Health Organization and other health agencies, is often attributed to deforestation. This development has caused major upsurges across the globe, leading to a serious pandemic and total lockdown of over 200 countries of the world (WHO, 2020b). According to WHO (2023), the outbreak of monkeypox was linked to wild animals with various small mammals, such as squirrels and monkeys, being susceptible. An increasing number of studies on emerging zoonotic diseases point to changes in land cover and land use, including forest cover change (particularly deforestation) (Wilcox and Ellis, 2006). People receive immediate benefits from activities that result in deforestation; those short-term gains cannot offset the negative long-term losses.

Drivers of Deforestation and Emerging Zoonotic Diseases

Deforestation is driven by a sophisticated combination of direct and indirect drivers of different natures (social, ecological, economic, environmental, biophysical), which interact with each other, often synergistically; the specific combinations of drivers vary within a region of the globe, by countries, and across localities within countries (Shvidenko, 2018). Direct drivers are basically human activities aggravated by natural factors (like hurricanes, fires, parasites, and floods) at the local level. The human activities are broadly categorized into those related to agricultural expansion, wood

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extraction, technology innovation, mining, and infrastructure extension. Agricultural expansion is the most important direct driver of deforestation in practically all tropical regions and includes shifting cultivation, permanent agriculture, pasture creation, overgrazing, and resettlement programs, following the conversion of the forest to other land uses. Wood extraction includes commercial logging, fuelwood harvesting, and charcoal production (Rahman, 2020). Over 70 countries have problems with illegal logging that leads to dramatic ecological and economic losses (Shvidenko, 2018), giving room for zoonotic disease prevalence. Commercial logging is an important direct driver in Asia and Latin America, while fuelwood gathering is one of the most important drivers in Africa. Infrastructure extension includes construction of transport ways; development of new industrial enterprises; settlement expansion; and a variety of other activities (oil exploration and extraction, mining, construction of hydropower stations, pipelines, and electric grids) (Shvidenko, 2018).

In recent decades, wildfires have been increasing and recognized as a new actor of deforestation in the Tropics. According to the International Sustainability Unit (2015), it poses a threat to the 48.84% of tropical forests that are still in existence worldwide, or approximately 3.6 billion hectares of its original covered area. Forest fires extensively affect vegetation cover, density, structure, composition, diversity, and productivity that result to deforestation and subsequent migration of exotic species (Laurance *et al*., 2012). Shvidenko (2018) pointed out that the construction or paving of roads in forested areas is among the principal causes of deforestation.

Indirect drivers of deforestation are caused by fundamental social processes that are usually revealed as a sophisticated interplay of factors of different natures. Economic factors (e.g., rapid market growth and incorporation into the global economy, commercialization, urbanization and industrialization, growth of demand for forest- or wildlife-related consumer goods, poverty, etc.) are crucial across many tropical regions (Nava *et al*., 2017; Shvidenko, 2018). Institutional factors (taxation, subsidies, corruption, property rights, etc.) are frequently tied to economic drivers (Shvidenko, 2018). Cultural and sociopolitical factors such as lack of public support for forest protection and sustainable use, low educational level, and low perception of public responsibilities also play a substantial role. Population growth, density, and spatial distribution are usually not primary drivers of deforestation; these are always combined with other factors (Shvidenko, 2018). Nevertheless, in a number of studies (Shvidenko, 2018; Rahman, 2020), population density has been shown to be highly correlated with the determination of certain land-use patterns often connected to deforestation. Impacts of some of the above factors are often difficult to separate.

Emerging zoonotic diseases are increasingly recognized as a global threat, with major concerns about their rapid global spread (Johnson *et al*., 2015; Nava *et al*., 2017). Recently, most emerging zoonotic disease events have been linked to anthropogenic drivers without proper biosecurity measures (Nava *et al*., 2017). For instance, Ali *et al*. (2017) and Pinto-Junior *et al*. (2014) confirmed the transmission and outbreak of Zika and Hanta viruses from rodents to humans (vector-borne or direct physical contact), respectively, due to deforestation and urbanization. Wildlife consumption by humans was found to transmit minimal Chagas disease (Fahr *et al*., 2006). Gay *et al*. (2014) and Nava *et al*. (2017) have recorded a greater number and risk of pandemic signals due to anthropogenic-driven land use changes.

Association of Emerging Zoonotic Diseases with Forests

Throughout human history, pathogens have emerged from forests (Robbins, 2016). Forests are believed to be inhospitable areas of mysterious diseases (Guégan *et al*., 2020), and the risk of emerging zoonotic disease pandemics can be greatly magnified after forests are cleared. The Zika virus, for example, emerged from the Zika forest of Uganda in the 1940s. Dengue, chikungunya, yellow fever, and some other pathogens also came out of the forests of Africa (WHO, 2013; Robbins, 2016) after unprecedented removal of forest cover. The first plague-causing pathogens, such as smallpox, are believed to have originated in tropical Asia early in the history of animal husbandry and large-scale forest clearing (Wilcox and Ellis, 2006). Forests contain numerous pathogens that have been passed back and forth among wildlife for ages. Because they evolved together, these pathogens often cause few or no symptoms in their hosts, providing a protective effect from a homegrown infection, but humans often have no such protection (Robbins, 2016).

The ancestry of the pathogens causing most of the emerging zoonotic diseases can be traced to wildlife (Wilcox and Ellis, 2006). Pathogens whose current emergence patterns show a direct association with forests represent about 15 percent of the approximately 250 emerging zoonotic diseases (Despommier *et al*., 2006). For those emerging zoonotic diseases currently associated with forests, the proximate causal factors in their emergence include a combination of deforestation (Fahr *et al*., 2006) and increased human contact with forest pathogens among populations lacking previous exposure and pathogen adaptation (Wilcox and Ellis, 2006). Many may be transmitted among non-human primate hosts or insect vectors and involve a variety of potential intermediate hosts, including domestic animals (Wilcox and Ellis, 2006). Of most concern, following initial local emergence, a number of these diseases have demonstrated the potential to spread regionally or globally and become a significant threat to humans, domestic animals, and wildlife populations. Although relatively few plant parasites or pathogens are known to infect animals, including humans, the impact of emerging plant diseases on plant populations is also an increasing concern (Wilcox and Ellis, 2006). The problem of emerging zoonotic diseases includes not only the impacts of diseases from forests but also the impacts of disease on forests, including forest wildlife as well as vegetation (Ostfeld *et al*., 2008).

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The majority of zoonotic diseases that originate in forests are caused by viruses, such diseases include simian immunodeficiency, rabies, chikungunya, dengue, yellow fever, chikungunya, oropouche, Nipah virus, Ebola virus disease, severe acute respiratory syndrome, monkey pox, and rocky mountain spotted fever. Although others are caused by bacteria (Lyme disease, Leptospirosis, and Babesiosis), protozoa (malaria, Toxoplasmosis, Leishmaniasis, and Trypanosomiasis), helminthes/worms (Cysticercosis, Eccinococcusis, Gnathostomiasis, Trichinellosis, and Schistosomiasis), and fungi (Aspergillosis, Blastomycosis, Coccidioidomycosis (Wilcox and Ellis, 2006). These diseases are frequently not research priorities until they have become a threat to affluent populations, so knowledge about their distribution and biology is very limited in most cases (Wilcox and Ellis, 2006).

The historical orientation of tropical medicine towards understanding disease natural history and ecology was, unfortunately, abandoned with the advent of modern biomedicine and the mistaken belief that infectious diseases had been conquered by science (Chaves, 2017). Today's biggest research challenge is posed by the disciplinary gaps between zoonotic disease researchers, wildlife experts, foresters, ecologists, and social scientists. The problems are, of course, compounded by the increasing numbers and densities of poor people living without potable water, sanitation, and adequate public health infrastructure in developing countries (Wilcox and Ellis, 2006).

Relationship between deforestation and emerging zoonotic diseases

The link between deforestation and emerging zoonotic diseases has been most thoroughly investigated. Many researchers (Environmental Resources Management, 2015; Faust *et al*., 2018; Bloomfield *et al*., 2020) have found positive relationships between the rates of deforestation and emerging zoonotic diseases prevalence. They pointed out that the continued destruction of forest habitats forces humans and non-human primates into closer proximity. This mechanism likely results from more frequent contact between the infected wildlife and humans, thereby increasing the chances of emerging zoonotic disease transmission. Scientists are growing more worried that human-caused forest loss could lead to more pandemics in the future as a result of the alarming rate at which forests are being cut down around the world.

Pandemic Signals of Emerging Zoonotic Diseases

There are basically two types of emerging zoonotic diseases: endemic, which means they are prevalent in a small area or population, and epidemic, which means they spread widely. Therefore, a pandemic is a worldwide epidemic. Pandemic signals have shown the vulnerability of human beings to new zoonotic health threats. The pandemics have afflicted the human population over the years, and the cumulative mortality exceeds 40 million globally (Fong, 2017). Mortality rates incurred by emerging zoonotic disease pandemics recorded during the past ten (10) years have ranged from a very few to thousands of deaths for a single event (WHO 2020c). These diseases have had a limited direct impact, measured in terms of human mortality and morbidity on human health, the economy, and social life (Meslin *et al.*, 2006).

For example, EVD, formerly known as Ebola hemorrhagic fever, is a severe, often fatal illness affecting humans and other primates (WHO 2020c). The first EVD outbreaks occurred in remote villages in Central Africa, near tropical rainforests. In previous pandemics, mortality rates have averaged 50% and ranged from 25% to 90%. West Africa saw the largest and most complex Ebola outbreak since the virus was discovered in 1976 from 2014 to 2016. This pandemic had more cases and fatalities than any prior zoonosis (WHO 2020c) until the emergence of coronavirus in Wuhan, China, in 2019.

The ferocity and speed with which the avian influenza pandemic spread was nearly unfathomable, infecting one-third of the world's population. The epidemic began in 1918, during World War I, and spread to countries around the world. The cost in human life eclipsed that of World War I, with tens of millions of people believed to have died (WHO, 2020c). An estimated 15% of cases of Lassa fever are fatal, and the disease is believed to be endemic in West African countries (WHO, 2020c). With a fatality rate of up to 88%, Marburg virus disease was first identified in 1967 as a result of two significant pandemics that struck Germany and Serbia at the same time (WHO, 2020c). The majority of the 2494 laboratory-confirmed cases of Middle East Respiratory Syndrome (MERS) that were reported worldwide at the end of November 2019 came from Saudi Arabia (2102 cases, including 780 related deaths with a case fatality rate of 37.1%). Of these, 858 associated deaths (case-fatality rate: 34.4%) were reported (WHO, 2020c).

Nipah virus has caused only a few known outbreaks in Asia; it infects a wide range of animals and causes severe disease and death in people, making it a public health concern (WHO, 2020c). Furthermore, rabies, which is the leading cause of reported deaths in zoonosis, is responsible for more than 55,000 deaths per year in Asia (31,000) and Africa (24,000). In 2002, 1.38 million people were thought to have died from six parasitic diseases, including leishmaniasis and trypanosomiasis (Meslin, 2006).

Plague disease has been responsible for widespread pandemics throughout history, including the so-called "Black Death" that caused over 50 million deaths in Europe during the fourteenth century. It can be a very severe disease in people, particularly in its septicemia and pneumonic forms, with a case-fatality ratio of 30-100% if left untreated (WHO, 2020c). According to Bhatt *et al*., 2013), about 390 million people are infected each year, and 96 million manifests with clinically apparent disease.

Severe Acute Respiratory Syndrome (SARS), also known as coronavirus disease (COVID-19), is one example of the

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scores of zoonotic diseases responsible for various outbreaks resulting in the deaths of millions of people for centuries (Bardhan *et al*., 2023). According to the World Health Organization (2020b), a total of 8,098 people worldwide became sick with SARS (coronavirus) during the 2003 pandemic; out of these, 774 died (Meslin, 2006; WHO, 2020b). Following the recent pandemic in 2020, coronavirus has spread to over 200 countries of the world. The virus has reportedly infected 7,410,510 people and claimed 418,294 lives as of 12th June, 2020 (WHO, 2020b). Coronavirus (Covid-19) is the only pandemic that has locked down most countries of the world with adverse effects on global human health. In addition to its impacts on human health, coronavirus often has huge economic, social, and political consequences. There is widespread agreement among economists that the global Covid-19 pandemic had severe negative impacts on the global economy (Duffin, 2020). The pandemic has directly affected social interaction.

A global outbreak of monkeypox occurred in 2022–2024. In May 2022, the outbreak appeared suddenly and rapidly spread across Europe, the Americas, and then all the regions of the world (WHO, 2023a). A cumulative total of 87,377 laboratory-confirmed cases of monkeypox, including 140 deaths, have been reported from 111 countries from 1 January 2022 through 8 May 2023 (WHO, 2023b). As of October 2024, there were over 24,000 confirmed monkeypox cases in African Union member states, including over 600 deaths, with the Democratic Republic of the Congo (DRC) being the most affected country (WHO, 2024). Given the existence of the zoonotic pathogens in wildlife and domestic animal reservoirs. new pandemic signals are anticipated.

Combating Deforestation and Emerging Zoonotic Diseases

Efforts to stop or slow down deforestation have been attempted for many centuries because it has long been known that deforestation can cause environmental damage sufficient in some cases to cause societies to collapse (Rahman, 2020) and pandemics. Reforestation is the national and international restocking of the existing forests and woodlands that have been depleted, usually through deforestation. It is the reestablishment of forest cover either naturally or artificially (Rahman, 2020). Afforestation, which is the planting of trees where there was no previous tree coverage (Rahman, 2020), these practices can combat deforestation. Other ways include the spread of awareness and educative campaigns about the effects of deforestation, policy formulation and implementation, law enforcement and legal protection of forest and wildlife resources, substitution of alternative livelihoods, and provision of incentives, among others.

The following actions should be adopted as a means to minimize the emergence of pandemic signals, given the increasing frequency of pandemic events involving emerging zoonotic diseases:

i. Improved communication and relationships are necessary among ecologists, wildlife managers, foresters, veterinarians, and human health professionals in order to strengthen the surveillance of animal populations (such as wildlife and companion animals) and thus control and prevent the outbreak and transmission of zoonosis among animals (Lin, 2015) and humans. It is difficult to predict when or where the next zoonotic disease will emerge. Therefore, close collaboration among ecologists, wildlife managers, foresters, veterinarians, and public health specialists is important. The goal of this inter-sectoral collaboration will enhance interpersonal and inter-organizational communication. An inter-agency task force can lead this process of fostering collaboration through regular exchange of scientific information proactively between the two sectors. Within a coordinated framework of partnerships and agreements supporting the One Health idea, the task force can also pool institutional resources and direct collaborative field research. According to the World Health Organization and Regional Office for the Eastern Mediterranean, WHO. EMRO (2019), this would coordinate successful preventative and control initiatives at the animal–human interface.
ii. There should be adequate planning, such as diagnostic tools, drugs, and vaccinations for the emerging zoonotic diseases. Personal protective equipment (such as eye protection, gowns, gloves, and masks) would facilitate reducing the likelihood of infection through either direct contact or respiratory droplets (Lin, 2015). Laboratory services would be more effective in early detection of any zoonoses when there is a common and agreed communication protocol for sharing laboratory surveillance data between animal and human health sectors in real time. In addition, a mechanism needs to be put in place for sharing of laboratory investigation data within the health sector, principally between the disease surveillance and the clinical services departments (WHO. EMRO, 2019).
iii. The success or failure of interrupting the transmission chain for most of the emerging zoonoses, especially those involving intermediate vertebrate hosts, will depend on the relevance of the behavioural response of the exposed populations. Socio- or psycho-cognitive factors that characterize the behavior of the exposed population, as well as cultural factors that influence protective factors and the sustainability of adherence to such protective behavior, must all be taken into consideration when designing appropriate social and behavioral interventions for such pandemics (WHO. EMRO, 2019).

Conclusion

The Earth is losing its original forest cover at an alarming rate through the process of deforestation due to anthropogenic reasons, driven by a sophisticated combination of direct and indirect drivers, which interact with each other. Deforestation

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brings humans and wildlife closer; this makes it more likely for zoonotic disease pathogens to cross animal-human species barriers and send out pandemic alerts. Continued deforestation and the widespread of zoonotic diseases such as monkeypox virus, Middle East respiratory syndrome (coronavirus), severe acute respiratory syndrome, Ebola virus illness, hanta viral, avian influenza, chikungunya, oropouche, and Nipah virus have threatened the stability of the Earth system, creating more pandemic signals that have societal effects at local, national, and global levels.

Understanding the effects of emerging zoonotic diseases and human-induced deforestation is crucial for promoting closer cooperation between ecologists, wildlife managers, foresters, veterinarians, and human health professionals. This will help to improve animal population surveillance, control, prevention, and transmission, particularly in rural areas. Effectively designed prevention and control programs, the complex and fluid relationships among multi-host (wildlife), multi-pathogen systems, and human impacts, and environmental change due to deforestation, zoonosis, and human populations must be thoroughly understood in order to reduce the risk of future pandemics.

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