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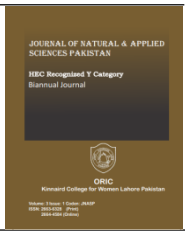

THE DETRIMENTAL IMPACTS OF DEFORESTATION: CAUSES, EFFECTS, AND POTENTIAL SOLUTIONS

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Abstract

Deforestation is defined as the removal of tree cover doe long-time, is a global issue growing with significant environmental, public health related, and economic consequences. This work reviews the major causes of deforestation, including natural calamities, human activities like commercial and agricultural factors and infrastructure development, and underlying socioeconomic drivers. It highlights the wide-ranging effects of deforestation on Earth's atmosphere, water systems, biodiversity, and health of soil. In addition, the research discusses how deforestation can increase the spread of communicable diseases, reduce access to medicinal plants, and cause long-term financial losses that outweigh short-term gains. Potential solutions like forest transition theory, increasing off-farm employment, and stronger political actions to curb deforestation are also outlined. Overall, this research underscores the need for more sustainable land management practices and forest conservation policies to mitigate the impacts of rampant worldwide deforestation.

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Keywords

deforestation, tropical rainforests, biodiversity loss, infectious diseases, climate change, forest policy.

1.Introduction

It is indisputable that trees hold a significant part of the answer to the global quest to address the challenges of climate change and support life for wildlife and humans. However, the rate of mass destruction of trees, deforestation, is alarming as people continue to embrace the short-term gains at the expense of the long-term benefits of trees. This practice continues to widen the rift between the effort and target, putting the survival of many species under a significant threat and negatively impacting the livelihoods of more than 1.6 billion people, one billion of which consist of the world's poorest, who depend on forests in various ways (IUCN, 2020). Deforestation entails the "conversion of forested areas to non-forest land use such as arable land, urban use, logged area or wasteland [or] the conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10% threshold" (Tejaswi, 2007). Deforestation is a major global land use issue (Pimm, 2020*).* Deforestation happens as humans increasingly cut down trees to meet the increasing demand for resources to meet human needs, among them agricultural land, land for human-made developments, and wood products. Some agricultural and developmental land use requires the complete removal of trees from the land, meaning the absolute destruction of forests. Partial logging, diseases, livestock, insects, and accidental forest fires, which are capable of dramatically damaging the structure of forests, are other contributors to the growing rate of deforestation (IUCN, 2020), (Pimm, 2020). Deforestation to create land for human use did not start recently. From the 1960s to date, the world has lost at least half of its tropical forests, and at least a hectare of tropical forests is destroyed or degraded every second (IUCN, 2020). A significant part of the Earth's agricultural land, currently standing at about 49 million square kilometers, is a result of deforestation (Pimm, 2020). This claim, as this source notes, owes to the fact that the rainfall and temperature of the majority of present-day croplands are high enough for the survival of forests. About one million sq. km of these croplands occupy areas whose climatic conditions could support cool boreal forests, which is the case for Scandinavia and northern Canada. The majority of the remainder shows evidence of having once been occupied by subtropical or tropical forests or temperate forests in the case of Eastern North America, Eastern China, and Western Europe *(*Pimm, 2020). While forests still cover approximately 30% of the Earth's land surface (Nunez, 2019), recent trends show that deforestation is reducing that coverage alarmingly (Nunez, 2019). As the World Bank shows, the world lost 1.3 million sq. km of forests between 1990 and 2016, while a 2015 study found that 46% of forests have been cut down since humans started felling trees (Nunez, 2019). As this source further shows, the Amazonian rainforest has been reduced by over 17% over the last 50 years, which is mainly a result of converting land to cattle ranches (World Wildlife Fund, 2020). Other estimates show that the world is losing forests at an annual rate of 18.7%, which roughly equals 27 soccer pitches every minute (World Wildlife Fund, 2020). As of 2016, the Amazonian Rainforest, the largest in the world, recorded a sharp increase in the rate of deforestation, a call for stringent steps toward protection

(Fearnside, 2017).

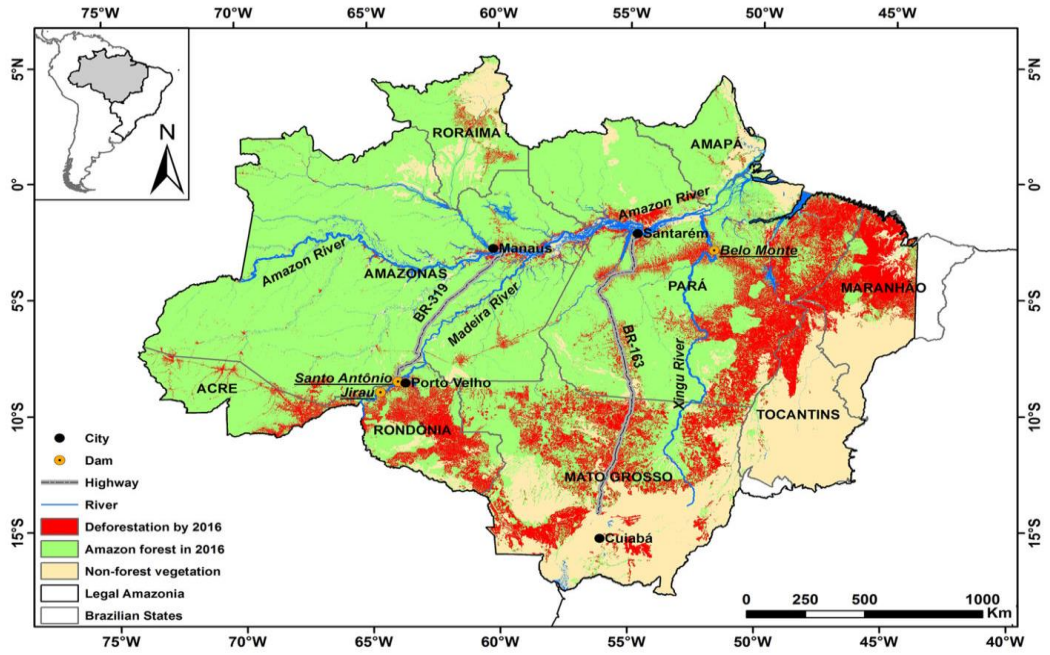
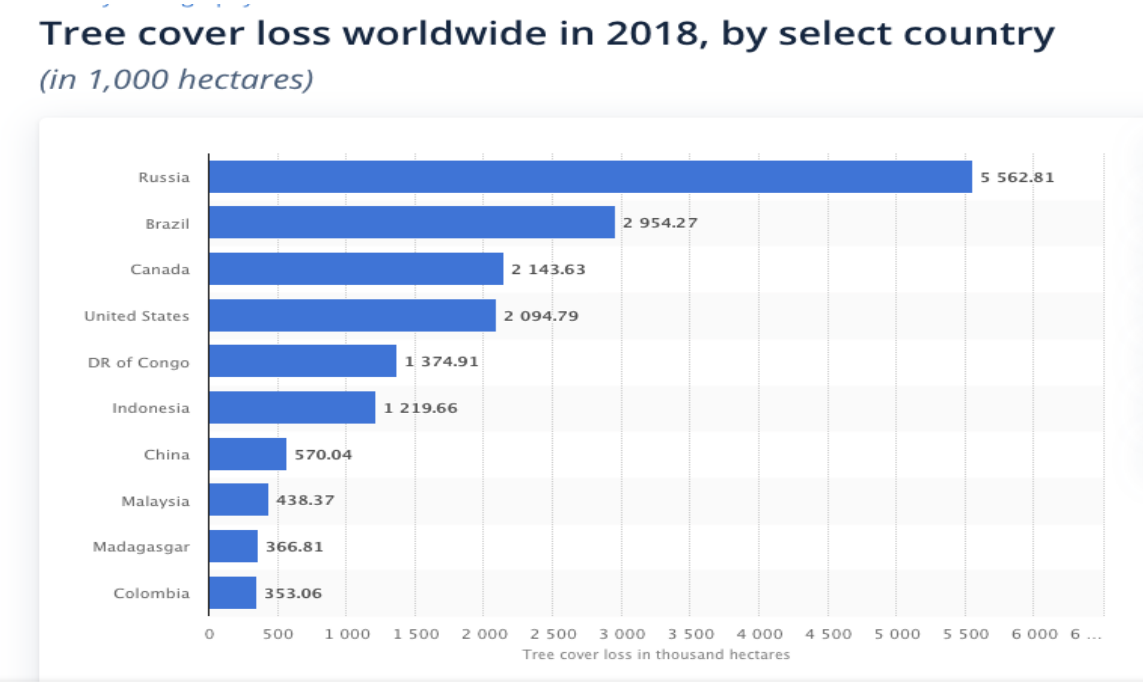


Figure 1: Deforestation of the Amazonian Rainforest as of 2016 (Fearnside, 2017).



Source: ***https://www.statista.com/statistics/1025472/tree-cover-loss-global-by-country/***

2. Causes of Deforestation

To help clarify deforestation, Tejaswi identifies causes and agents. Agents refer to those reasons, given the prevailing socio-economic and political circumstances, necessitate clearing of forests, and even then, such clearing happens in an economically rational manner (Tejaswi, 2007). Such agents include slash-and-burn farmers, cattle rangers,

commercial tree planters, and firewood collectors, among others. Causes, on the other hand, entail socio-demographic factors, an example of which are population growth, the political economy of class structure, and exploitative activities such as commercial logging and pasture clearance for cattle rearing (Tejaswi, 2007). Causes of deforestation can be classified as natural, human-made, or indirect causes, each of which is discussed below.

2.1 Natural Causes

2.1.1 Natural Disasters

Natural disasters causing deforestation include hurricanes, fires, parasites, droughts, and floods. While fires can be beneficial for many forest landscapes, they can have devastating effects when they are excessive. Besides altering the structure and composition of forests, fires also pave the way for invasive species, kill biological diversity, and tamper with water cycles and soil fertility (World Wildlife Fund, 2020). In 2007, fires destroyed Southeast Amazon by more than ten times what any average weather event had done by then (Sivaramanan, 2014). Hurricane Katrina of 2005 alone caused an estimated 5 million acres of forests across Louisiana, Mississippi, and Alabama (Sivaramanan, 2014). Such destruction, as Sivaramanan (Sivaramanan, 2014) explains, results from high wind speeds (up to 140 mph), which are capable of toppling over trees (320 million trees in Louisiana and Mississippi) and removing soil debris. The 1980 hurricane that attacked Mount St. Helens destroyed about 150,000 acres of trees (Sivaramanan, 2014). Bushfires also cause massive destruction of forests; for instance, it took a few months for the recent bushfires to destroy over 26 million acres of forests in Eastern Australia (Pickrell, 2020). Even though some bushfires allow forests to recover, a frequent occurrence of the same can cause permanent damage; some Australian forests have not had a chance to recover after being attacked four times by bushfires in the past 25 years (Pickrell, 2020). The presence of easily burning flora, i.e., species that burn with high intensity and catch on fire easily, as is the case in Australia, exacerbates the extent of the damage caused by bushfires (Nolan & Thornton, 2016). Some forest fires are common with El Nino events, which has been the case in Australia, Brazil, Canada, Indonesia, Russia, and the Southern United States (Sivaramanan, 2014). Other natural causes that contribute significantly to deforestation are earthquakes and volcanic activity. A 2005 Pakistan earthquake of magnitude 7.6 Richter led to about 3% deforestation of the Himalayan region, while the Wenchuan earthquake in China in 2008 destroyed almost 330,000 acres of forest area (Sivaramanan, 2014). Ash falls (more than 500 mm thick) after volcanic eruptions can affect trees, are capable of breaking branches, and cause difficulty in replantation. As Sivaramanan (Sivaramanan, 2014) further notes, the eruption of Ruapehu of New Zealand destroyed 20 sq. km of beach forest, while the 2010 volcanic eruption of Mt. Merapi destroyed 2,800 hectares of forest area. Volcanic emissions can also cause acid rainfall, which can affect forests. Even though not necessarily from volcanic emissions, acid rain and acid deposition cause severe loss of natural forest, where acid precipitation was found to destroy 15,000 hectares of the China Sichuan basin, 34% of countries forests in West

Germany, and 14% in Switzerland (Sivaramanan, 2014). Destruction of forests by acid rain is also a common problem in South Africa, South Asia, Sri Lanka, and Southern India, as Sivaramanan (Sivaramanan, 2014) notes. Severe droughts also significantly contribute to deforestation. The effect of droughts has been experienced in Spain, Greece, Australia, Russia, and North America; for instance, during the 2010 drought that saw 57% of the Amazonian forest experience low rainfall (Sivaramanan, 2014). A 2005 drought destroyed canopy the size of California, 30% of the Amazon, while a drought in 2003 destroyed over 500,000 acres of forest in southern Europe (Sivaramanan, 2014).

2.1.2 Climate change

Global warming and, thus, climate change is increasingly manifesting themselves in extreme weather events, among them hurricanes, floods, and droughts. As seen earlier on, extreme weather events such as these are contributing significantly to deforestation. Scientists have noted that these events are affecting the Amazon (Moutinho, 2005). Tropical forests causing is experiencing droughts resulting from El Nino, and this, for instance, is inducing forest fires in Indonesia (Moutinho, 2005). Besides damages through forest fires, these climate change-related weather events destroy homes and habitats, which can spur population migration that can end up invading forest frontiers as they seek alternative livelihoods.

2.1.3 Invasive species

The introduction and presence of invasive species are almost universal in all forests. These species cause significant stress on the environment and many species. For instance, the spotted lanternfly is increasingly becoming a threat, being an invasive pest that can feed on more than 70 species of trees as well as vines and shrubs (Johnson *et al.,* 2019). Japanese Knotweed, scientifically known as Fallopia japonica, causes significant changes to the communities and ecosystems it inhabits, including visual, structural, and chemical transformations of ecosystems, which are a result of its massive and clonal monocultural growth (Fuchs *et al.,* 2018).

2.1.4 Fragility of forest ecosystems

Forests are among the most fragile ecosystems, which means high vulnerability to edge effects and effects of isolation (Murcia, 1995). Edge effects, as the name suggests, refer to the edges of forests that happen to be the weakest points of a forest (Murcia, 1995). Edges are often hard to penetrate, with smaller, thicker, and bushy vegetation around the forest. These characteristics give the edges the ability to play a critical role in safeguarding the forest against invasive species whose presence in the forest can cause devastating impacts (Murcia, 1995). Cutting and fragmentation of the forests by humans open up the forests, thereby reducing the natural protection they have against invasion by foreign and harmful species (Murcia, 1995).

2.1.5 Connectivity between forests

In isolation, a rainforest or rainforest remnant will be limited to the gene pool it currently has for most species, lowering its threshold for adaptability. Isolation sets in as people, for instance, search for land for agricultural and infrastructural development, fragmenting forests and cutting the existing connectivity. Such “drastic environmental modifications threaten the integrity and long-term

sustainability of ecosystems, as well as the survival of single species" (Rossetto & *et al.,* 2004). Fragmentation and isolation reduce population size, leading to low genetic diversity and gene flow (Rossetto & *et al.,* 2004). Reduced genetic processes, such as inbreeding and drift, can cause the entire metapopulation to lose its potential for fitness and adaptation (Rossetto & *et al.,* 2004). This phenomenon, and thus isolation, has reduced the population and distribution of Elaeocarpus grandis in Australia (Rossetto & *et al.,* 2004).

2.2 Direct Causes Due to Human Activities

2.2.1 Subsistence farming

Forests are currently the last option that the majority of the most vulnerable people worldwide have regarding the search for subsistence land (Chakravarty *et al.,* 2012). As this source further notes, millions of impoverished people who live in tropical forests are forced by degrading lands to migrate and explore new forest frontiers, which results in increased deforestation. The increasing shifting agriculture and smallholder production are estimated to reduce global tropical forests by about one-half and two-thirds: in Asia, shifting agriculture is estimated to cause 30% deforestation and about 15% globally (Chakravarty *et al.,* 2012).

2.2.2 Commercial agriculture

Motivated by the increasing demand for food, commercial agriculture is significantly adding to the alarming rate of deforestation (Global Forest Atlas. Industrial Agriculture, 2020). According to this source, palm oil, soy, and beef, given the high global demand, are the three foods that have been named as the main drivers of the intensifying investments in commercial agriculture. Developing countries that sell their agricultural produce in the global market are identified as the leaders in industrial agriculture and thus account for the largest part of related deforestation (Global Forest Atlas. Industrial Agriculture, 2020). In Africa and Asia, commercial agriculture accounts for 30% of deforestation and about 70% in Latin America (Global Forest Atlas. Industrial Agriculture, 2020). Illegal clearing of forests for commercial agriculture is estimated to cause about 49% of deforestation in tropical regions (Sivaramanan, 2014). Combined, subsistence and commercial agriculture are responsible for 80% of deforestation that has occurred in tropical and subtropical countries between 2000 and 2010 (Global Forest Atlas. Industrial Agriculture, 2020), or 60% deforestation of global deforestation regarding tropical forests (Chakravarty *et al.,* 2012). Between 2000 and 2012, over 20 million hectares of forests are feared to have been converted to agricultural land, where Brazil and Indonesia combined accounted for 75% of that conversion (Global Forest Atlas. Illegal Logging, 2020).

2.2.3 Logging

2.2.3.1 Legal logging

This type of logging occurs in the form of timber extraction for human consumption, including paper and furniture. In countries like Canada and Malaysia, logging has been associated with an extensive reduction in primary forests (Tejaswi, 2007). The same, as this source notes, is the case for countries like Ireland and Scotland, where the British rule encouraged logging to provide timber for shipbuilding.

2.2.3.2 Illegal logging

Illegal logging, which entails felling protected

species, harvesting timber, and exceeding logging limits, is a common threat to the deforestation of tropical rainforests and boreal forests of Russia's Far East, where the majority of the countries are characterized by poor governance and low capacity to enforce the law (Global Forest Atlas. Illegal Logging, 2020). Also, two-thirds of the 22.2 million cubic meter equivalents of Roundwood, the international timber export volume, is illegally harvested (Global Forest Atlas. Illegal Logging, 2020). While legislation in consumer markets such as the United States, Australia, Japan, and the EU is helping reduce the volume of smuggled illegal timber, emerging markets that are relatively insensitive to sustainability, for instance, China, India, and Vietnam, reduce the effectiveness of such legislation; China alone accounted for half of the timber imported globally (Global Forest Atlas. Illegal Logging, 2020). China's massive consumption of raw materials continues the source, is significantly decreasing the impact of the efforts of industrialized countries regarding reductions in the illegal trade of timbers. Illegal logging in developed countries results from organized crime networks, most of which collaborate with dishonest government officials (Chakravarty *et al.*, 2012).

2.2.4 Wood fuel

Gathering trees for firewood is a common problem facing tropical dry forests (Chakravarty *et al.*, 2012). The same, as the source elaborates, is the problem facing highly populated humid tropics, for instance, the Philippines, Thailand, and some parts of Central America. About half of the illegal logging is associated with fuelwood harvesting (World Wildlife Fund, 2020), which is so because fuel is the primary source of energy for cooking and heating across the world.

2.2.5 Mining and oil extraction

Mining and oil extraction leads to deforestation, both directly and indirectly. As direct causes, mining and oil extraction necessitate the clearing of forests to allow extraction, the impact of which can be intensive and destructive (Chakravarty *et al.*, 2012). According to this source, mining and oil extraction indirectly cause deforestation by promoting development booms, which in turn, create an avenue for deforestation as people flood the vicinity of the extraction sites. For instance, mining activities have been a significant contributor to reduced forest cover in Guiana and the Philippines, among other countries (Chakravarty *et al.*, 2012). The roads that are put up to support mining and oil extraction activities also open up the forested area to uses such as shifting agriculture, permanent settlement, ranching, and infrastructural development; infrastructural development projects set the core of Brazil's Amazon development strategy (Chakravarty *et al.*, 2012). Similarly, some mining operations may depend on wood as fuel, which can also lead to severe deforestation.

2.2.6 Dam construction

The construction of dams is one of the significant anthropogenic features on our planet, but it comes with a myriad of effects, among them the loss of biodiversity (Chakravarty *et al.*, 2012). Directly, the construction of dams leads to deforestation in that large tracts of forested land are cleared to create the dam space. Indirectly, dam construction causes deforestation by opening the dam area to other developments, among them the construction of

infrastructural facilities such as roads and power transmission lines. In the Amazon, the construction of dams for use with hydropower plants led to the destruction of over one million hectares of forests in a radius of 100 kilometers, around 10 plants (Input. Policy Brief, 2020). The ten power plants occupied 222,000 hectares of the forest (Input. Policy Brief, 2020). Dam construction may also attract or displace people from the dam location, some of whom end up encroaching on forests to create new homes (Fearnside, 2017). Dams rank among the major causes of deforestation in Brazil's Amazon forest (Fearnside, 2017).

2.2.7 Housing and Infrastructure development needs

Expansion of cities and other infrastructural facilities hardly occur without encroaching land meant for other purposes, among them forests. Tropical forests are often the primary source of land for infrastructural developments, for instance, oil exploitation, hydropower dam construction, and logging concessions, which also welcome the construction and expansion of road networks in pristine areas (Chakravarty *et al.*, 2012). Additionally, as the source notes, when airports, bridges, railways, roads, irrigation waterways, reservoirs, and dams are constructed, the surrounding land welcomes development and people are inevitably and increasingly attracted to the forest frontier. Infrastructural development is a global concern, bearing in mind that the world has lost about 21% of its tropical forests since 1980 (Chakravarty *et al.*, 2012).

2.2.8 Purposeful forest fires for land use or just unethical wrongdoing/crimes

Some wildfires occur naturally during the dry seasons, but some are started intentionally to create land for human use, for instance, cattle ranching. The number of wildfires experienced in the Amazon recently has been noted to increase, some of which are different from those typically occurring during the dry seasons (Andreoni, & Hauser, 2019), (BBC, 2019).

2.3 Indirect Causes

2.3.1 Socio-economic causes

2.3.1.1 Population growth

Deforestation happens as humans increasingly cut down trees to meet the increasing demand for resources to meet human needs, among them agricultural land, land for human-made developments, and wood products. Forests are currently the last option that the majority of the most vulnerable people worldwide have regarding the search for subsistence land (Chakravarty *et al.*, 2012). As this source further notes, millions of impoverished people who live in tropical forests are forced by degrading lands to migrate and explore new forest frontiers, which results in increased deforestation (Chakravarty *et al.*, 2012). The increasing shifting agriculture and smallholder production are estimated to reduce global tropical forests by about between one-half and two-thirds (Chakravarty *et al.*, 2012).

2.3.1.2 High illiteracy rate

High illiteracy levels contribute to deforestation when the majority of the poor small-scale farmers fail to seek title deeds; hence dispossession and displacement by those who gain tenure over the lands become easy (Chakravarty *et al.*, 2012). After displacement, one of the survival options these

people have is to clear more forests (Chakravarty *et al.,* 2012).

2.3.1.3 Poverty and income per capita

International agencies such as FAO describe poverty combined with overpopulation as the primary cause of deforestation (Chakravarty *et al.,* 2012). Poverty ranks highly as an underlying cause of the loss of forests as small-scale farmers continuously convert forested areas into farmlands (Chakravarty *et al.,* 2012). Besides, poverty makes these farmers unable to afford farming methods that favor yields from existing land; hence the option of achieving their needs remains to expand their existing lands (Chakravarty *et al.,* 2012).

2.3.1.4 Lack of alternative livelihood

Limited off-farm employment opportunities are among the reasons people convert forest areas into agricultural lands as they seek alternative means of livelihood (Angelsen, 2010). People in rural areas are forced into subsistence farming to provide for their basic and other needs that can be achieved by the small farm produce.

2.3.2 Political causes

2.3.2.1 Unequal land distribution

Inequitable land distribution is a common problem in the tropics (Chakravarty *et al.,* 2012). Inequitable land distribution means a small but influential group of people own most of the available land, thereby displacing the less fortunate majority of farmers into rainforests (Chakravarty *et al.,* 2012). Unfortunately, these groups of small by powerful elites create policies that will favor them as long and much as they remain in power, a challenge to achieve long-term land reform (Chakravarty *et al.,* 2012). As a result, deforestation becomes a perceptual phenomenon.

2.3.2.2 Government corruption

Some of the government's social and economic policies for development act as loopholes for irrational and unscrupulous land uses that lead to deforestation (Chakravarty *et al.,* 2012). In the name of development, people use policies to engage in illegal logging, ranching, colonization schemes, agriculture, and dispossessing peasants and indigenous people of their land, among other acts, that facilitate deforestation (Chakravarty *et al.,* 2012). At times, deforestation is increased when private enterprises use illegal means to enter illegal contracts with forestry management bodies, which is the case in the provision of illegal sale of harvesting permits, understatement of harvested volumes, and logging in protected areas, among other ills (Chakravarty *et al.,* 2012).

2.3.2.3 Insufficient political actions

While legislation in consumer markets such as the United States, Australia, Japan, and the EU is helping reduce the volume of smuggled illegal timber, emerging markets that are relatively insensitive to sustainability, for instance, China, India, and Vietnam, reduce the effectiveness of such legislation; China alone accounted for half of the timber imported globally (Global Forest Atlas. Illegal Logging, 2020). As this source further notes, China’s massive consumption of raw materials is significantly decreasing the impact of the efforts of industrialized countries regarding reductions in the illegal trade of timbers.

2.3.2.4 Governance failure

Government failures manifest themselves in the form of inadequate land tenure systems and wrong public administration investments. Some wealthy governments meet deficits in their natural resources by financially supporting poorer but resource-rich countries, which culminates in the unsustainable exploitation of these resources, among which are forests (Chakravarty *et al.,* 2012). Another problem sets in when the more impoverished countries copy the growth syndrome of wealthy countries that press on increased exports, revenues, and exploitation of natural resources but provide only short-term gains at the expense of the long-term benefits of these resources (Chakravarty *et al.,* 2012).

2.3.2.5 Military conflicts

Military operations such as wars contribute directly and indirectly to deforestation. Military encounters such as during the Vietnam War and the Civil War caused massive destruction of forests (Chakravarty *et al.,* 2012). Sometimes, deforestation results from the use of forest products to get the funds to finance military operations, as in the case of Myanmar, which sold timber to Thailand to finance its military operations in the civil war with the Karen hill tribe (Chakravarty *et al.,* 2012). Military operations are also known to cause deforestation in El Salvador, Southeast Asia, and South America, including part of the deforestation of the Amazonian Forest (Chakravarty *et al.,* 2012).

3. Consequences

3.1 Environmental Impact

3.1.1 Effects on the atmosphere

Deforestation tampers with global energy changes both through micro-meteorological processes and increases in the concentration of atmospheric carbon dioxide, which increases the rate of absorption of thermal infrared radiation (Chakravarty *et al.,* 2012). Besides, deforestation leads to alterations in the flow of wind and water vapor, which combine with changes in the absorption of solar energy to alter the local and global climate (Chakravarty *et al.,* 2012). Trees are known as the most significant sink for carbon dioxide; hence deforestation leads to excessive amounts of greenhouse gases in the atmosphere, which is cited in the explanations for the current increasing trend of global warming (World Wildlife Fund, 2020), (Chakravarty *et al.,* 2012). Cutting, burning, and removal of forests (deforestation and forest degradation) injects 15% of all greenhouse gases into the atmosphere (World Wildlife Fund, 2020). Clearing forests for direct land use alone can release 1.38 billion tons of carbon dioxide into the atmosphere (Bennett, 2017).

3.1.2 Effects on the hydrosphere

Deforestation disrupts the water cycle balance between the atmosphere and land (World Wildlife Fund, 2020). Cutting down trees reduces the amount of water vapor released into the atmosphere due to transpiration, a fundamental part in the cycle, the absence of which culminates in altered precipitation and river flow (Bennett, 2017). Deforestation thus threatens water resources such as drinking water, fisheries, and marine habitats (Chakravarty *et al.,* 2012). For this reason, the continued deforestation of the Amazon rainforest exposes millions of people to the risk of water shortages in the future (Food and Agricultural Organization, 2019). Large-scale deforestation in the southern Amazon has been linked with changes in the mechanisms and patterns of regional precipitation (Chambers & Artaxo,

2017).

3.1.3 Effects on the biosphere

The effect of deforestation on the biosphere starts with the destabilization of the water cycle. As discussed under hydrosphere, deforestation leads to low transpiration and then changes in precipitation patterns. For these reasons, the areas upwind of Amazon's logged areas have decreased cloud cover and precipitation, while the opposite is true for downwind areas (Chambers & Artaxo, 2017). Dry season precipitation leads to stress and vegetation mortality, the investigation of which models show a possibility that the southern Amazon could dry with the warming climate (Chambers & Artaxo, 2017). The induced precipitation patterns could also team up with global precipitation and temperature changes to facilitate the occurrence of extreme events, the effect of which would lead to poor plant health and high economic losses (Chambers & Artaxo, 2017).

3.1.4 Effects on the pedosphere

Trees play a critical role in the control of soil erosion. Cutting down trees loosens the surrounding soil, making it easy for the wind to blow away or rainwater to wash away (Bennett, 2017). Unfortunately, planting crops on deforested land does not offset the vulnerability to soil erosion left by cutting down trees; in some cases, the shallow roots of planted crops amplify the risk instead (Bennett, 2017). Soil erosion affects not only the environment but also the health of the inhabitants of the affected area (Bennett, 2017). Increased erosion as a result of deforestation also has effects such as poor flood/drought control, increased dam siltation, destruction to irrigation systems, and less appealing water for recreational use (Chakravarty *et al.*, 2012). Unforested areas are prone to floods and landslides.

3.2 Health Impact

3.2.1 Emerging diseases linked to deforestation

Deforestation destroys habitats for animals and birds, forcing most of them to migrate to other areas. These animals and birds may carry with them deadly diseases to their new destinations, affecting the existing inhabitants and people (Zimmer, 2019). An example is the 1997 case that happened when fruit bats carried a deadly disease -Nipah virus - from Pennsylvania to Malaysia, infecting pigs and later people (Zimmer, 2019). Deforestation triggers a complex cascade of events that, in turn, create a ground for the spread of deadly pathogens and parasites, some of which are responsible for Nipah and Lassa viruses and malaria and Lyme disease, respectively and dengue fever (Zimmer, 2019), (Robins, 2016). Cash crops cultivation in cleared forests, for instance, palm oil, attract rodents such as mice, coming into contact with whose feces and urine can spread the Lassa virus to humans; this has happened in Liberia, where 36 percent of infected people succumbed to hemorrhagic fever (Zimmer, 2019).

3.2.2 Zoonotic diseases linked to deforestation

Zoonotic pathogens are known to cause three-fourths of emerging infectious diseases, among them agents such as HIV-1 and -2, influenza virus, Nipah virus, Ebola virus, Hantavirus, severe acute respiratory syndrome (SARS) that is associated with coronavirus (Wolfe *et al.*, 2005). Many of these diseases are mainly a result of human and domestic animal contact with wildlife that host zoonotic pathogens (Wolfe *et al.*, 2005), (Nava *et al.*, 2017).

Deforestation is one of the leading ways humans and domestic animals come into contact with wildlife and these zoonotic pathogens. Contact with wildlife/zoonoses increases when people carry out selective extraction, especially when looking for high-value woods. Besides, selective extraction sustains diversity, which leaves zoonotic pathogens with higher survival chances than clear-cutting (Wolfe *et al.,* 2005). Fragmentation, for instance, that resulting from the construction of logging roads, lowers the movement of wildlife between fragments. Coming along with this process are three counteractive effects. One, the smaller size of patches reduces the density of the reservoir population, sometimes to levels below the threshold density that support the survival of some zoonotic microbes; this means a high chance of the pathogens going extinct (Wolfe *et al.,* 2005). The second case is characterized by a loss of the richness of vertebrate reservoir host species, which means a high number of competent reservoirs of the pathogens and, thus, high chances of transmitting diseases to humans (Wolfe *et al.,* 2005). The third case is that fragmentations resulting from roads increase the interface between humans and reservoir hosts (Wolfe *et al.,* 2005), meaning increased chances of contact and spread. Studies are increasingly citing the changing land cover and land use, of which reduced forest cover due to deforestation, intensification of agriculture, and urbanization are examples, as the major contributors to the surge in infectious diseases (Nava *et al.,* 2017), (Wilcox & Ellis, 2006). Specifically, the recent increase in deforestation of tropical forests is closely linked with the emergency of infectious diseases, most of which are getting their way into the rest of the world (Wilcox & Ellis, 2006). However, the causality for emerging infectious diseases is more complex than forests or deforestation per se can account for (Wilcox & Ellis, 2006). The primary driver is, instead, the "exponential growth in population, consumption and waste generation of the past several decades, which has driven the combination of urbanization, agricultural expansion, and intensification, and forest habitat alteration that results in regional environmental change" (Wilcox & Ellis, 2006). Zoonotic diseases associated with deforestation are mainly caused by viruses, for instance, AIDS, dengue haemorrhagic fever, yellow fever, Rocky Mountain spotted fever, Oropouche, Ebola, SARS, and rabies, among others (Wilcox & Ellis, 2006). Others result from bacteria (e.g., Lyme disease, Babesiosis, and Leptospirosis), protozoans (e.g., malaria and sleeping sickness), helminths (e.g., Eccinococcus multiocularis), and fungi (Wilcox & Ellis, 2006). A list of common zoonotic diseases is shown against their causes in the figure below.

Examples of forest-associated emerging infectious diseases

Agent/disease	Distribution	Hosts and/or reservoirs	Exposure	Possible emergence mechanisms
Viruses				
Yellow fever	Africa South America	Non-human primates	Vector	Deforestation and expansion of settlements along forest edges Hunting Water and wood collection Domestication of vectors and pathogen
Dengue	Pantropical	Non-human primates	Vector	Mosquito vector and pathogen adaptation Urbanization and ineffective vector control programmes
Chikungunya	Africa Indian Ocean Southeast Asia	Non-human primates	Vector	Pathogen and vector
Oropouche	South America	Non-human primates Others	Vector	Forest travel Vector composition changes
SIV	Pantropical	Non-human primates	Direct	Deforestation and human expansion into forest Hunting and butchering of forest wildlife Pathogen adaptation
Ebola	Africa	Non-human primates Bats	Direct	Hunting and butchering Logging Outbreaks along forest fringes Agriculture Alteration of natural fauna
Nipah virus	South Asia	Bats Pigs	Direct	Pig and fruit production on forest border
SARS	Southeast Asia	Bats Civets	Direct	Harvesting, marketing and mixing of bats and civet cats Wildlife trade for human consumption
Rabies	Worldwide	Canines Bats Other wildlife	Direct	Human expansion into forest
Rocky Mountain spotted fever	North America	Invertebrate ticks	Vector	Human expansion into forest Forest recreation
Protozoa				
Malaria	Africa Southeast Asia South America	Non-human primates	Vector	Deforestation, habitat alteration beneficial for mosquito breeding Human expansion into forest, non-human primate malaria among humans
Leishmaniasis	South America	Numerous mammals	Vector	Human expansion into forest Domestication of zoophilic vectors Habitat alteration, habitation building near forest edge Deforestation Domestication of zoonotic cycles by non-immune workers
Sleeping sickness	West and Central Africa	Humans	Vector	Human expansion into forest, disease incidence associated with forest edge
Bacteria				
Babesiosis	North America Europe	Humans Wildlife	Vector	Disease often found among ticks in forested areas
Lyme disease	Worldwide	Humans Deer Mice	Vector	Possible association with deforestation and habitat fragmentation Forest workers at increased risk of disease
Leptospirosis	Worldwide	Rodents	Indirect	Watershed alteration and flooding
Helminth				
Eccinococcus multiocularis	Northern Hemisphere	Foxes Rodents Small mammals	Direct	Deforestation Increase in rodent and fox hosts Pathogen spillover to dogs Human expansion into forest, exposure of susceptible population

Figure 3: A list of common zoonotic diseases is shown against their causes in the figure below (Wilcox & Ellis, 2006)

3.2.3 Recent public health concerns linked to anthropogenic changes

One of the recent public health concerns resulting from anthropogenic forest loss is the amplified transmission of malaria (Lehigh University, 2017). Studies show that increasing rates of deforestation facilitate the transmission of malaria in developing nations (Nava *et al.*, 2017), (Lehigh University,

2017). Such an increase arises from multiple mechanisms, among them an increased amount of sunlight and stagnant water as a result of deforestation; these conditions favor the survival of key vectors (Anopheles mosquitoes) in malaria transmission (Lehigh University, 2017). Outbreaks such as of Zika virus and Hantavirus in Brazil are also linked to increased mosquito vector habitats and rodent reservoir-human contacts, respectively, which result from deforestation (Nava *et al.*, 2017).

3.2.3.1 Forest contribution as the world's largest pharmacy

Tropical rainforests have always provided a rich source of raw materials for the pharmaceutical industry. This is so because approximately 80% of the global population in developing significantly relies on plant products for their medical needs, while 25% of the remaining 20% of the world population uses pharmaceuticals directly obtained from plants (Mans, 2013). The Amazon rainforest, for instance, is the source of materials used to develop anti-cancer drugs, sedatives (cocaine), quinine, curare, and HIV and AIDS medications (Huizen, 2016). Unfortunately, the high rate of deforestation is putting about 50,000 known medicinal plants under threat of extinction (The World Bank, 2015). Deforestation destroys biodiversity, which is essential for all industries, including the pharmaceutical industry (The World Bank, 2015).

3.2.3.2 Loss of biodiversity and habitat

Seventy percent of plants and animals in the world live in forests (Bennett, 2017). Consequently, deforestation poses a severe threat to the loss of habitat for these plants and animals, which will, in turn, lead to a loss of species and hence biodiversity. Large-scale loss of biodiversity can lead to permanent loss of species (Bennett, 2017). Endemic species that are densely populated in tropical rainforests continue facing the risk of extinction as deforestation of these rainforests, for instance, to create land for urban development, keeps surging. Decreased biodiversity is injurious to the environment as it not only welcomes significant changes in land use and the ecology of the land but also heightens the potential for the survival of invasive species whose presence means a menace in surrounding areas (Bennett, 2017). Additionally, low biodiversity incapacitates forests regarding the provision of such essential services as climate regulation, healthy soils, clean air, and water (IUCN, 2020).

3.3 Impact on Economy

3.3.1 Short-term gains

Short-term gains from deforestation include all the goals humans achieve by converting forest land into other uses. The forested area has provided resources to meet the expanding world population's increasing demand for food, timber, and fuel, among other related products. By clearing trees, people get the land to establish settlements, open up cities, set up industries, and various infrastructural facilities such as roads, airports, dams, and irrigation systems that contribute to the well-being of humans. Governments, especially from Third World Countries, earn good revenue by exporting forest-related products such as timber to meet the increasing consumption rates in industrialized countries (Chakravarty *et al.*, 2012).

3.3.2 Long-term losses

Long-term damages to the environment quickly offset the short-term gains from deforestation. Deforestation disrupts the natural balance of the ecosystem, which paves the way for various effects. By tampering with the natural water cycle, increasing the amount of carbon dioxide in the atmosphere, and killing biodiversity, deforestation paves the way for climatic changes such as droughts and unpredictable precipitation; the impact of these changes is significantly felt in the agricultural sector, which now has to suffer low yields, for instance, due to droughts or floods (Tejaswi, 2007). Cutting down trees in an area for agricultural purposes leads to less naturally occurring water, which, in the long run, calls for a more intensive and costlier effort, e.g., through irrigation, to maintain crop yields (Bennett, 2017). Clearing forests for activities such as mining opens the soil to various problems, among the disturbances, soil erosion, and changes in the soil's physical, biological and chemical properties, all of which lead to degradation (Olofin, 2017). The combined effect of climate change and soil degradation reduces the biological and economic productivity of the soil, an ingredient for food insecurity (Tejaswi, 2007), (Olofin, 2017). Each year, deforestation in tropical forests causes an estimated loss of forest capital equivalent to US$ 45 billion, which threatens the disappearance of potential future revenues and employment related to timber and timber products should sustainable management be practiced (Tejaswi, 2007). The water shortages are projected to affect 2 billion people, most of whom live in developing countries, by the year 2050 as the denudation of watersheds continues due to deforestation; such shortages pose a significant health threat due to poor sanitation (Tejaswi, 2007).

3.3.3 Forest transition theory

3.3.3.1 Theory definition

The Forest Transition (FT) theory refers to a sequential decrease to a minimum point and then expansion of forest cover to stability, which has happened in several developed countries (Angelsen, 2010), (Wolfersberger *et al.*, 2015). FT is a three-phase evolution of forests in a developing country, starting from deforestation stagnation and then reforestation (Wolfersberger *et al.,* 2015). Further, this source notes that deforestation reduces forest cover to the minimum possible level, a point called the turning point; it is at this point that the cumulative deforestation of a can be assessed alongside a country's development path (Wolfersberger *et al.,* 2015). Stagnation, which may last from decades to centuries, occurs when rents for agriculture reduce while those of forests increase, which corresponds to the turning point as the deforestation rate starts to reduce (Wolfersberger *et al.,* 2015). After stagnation sets in the reforestation phase, where forest cover regrows due to the nationwide discovery that forests are ecologically beneficial, hence turning the focus to taking advantage of reducing forest rents to increase forest cover (Wolfersberger *et al.,* 2015).

3.3.3.2 Forest scarcity

Forest scarcity is the comparison among land-use marginal values (Wolfersberger *et al.,* 2015). It relies on an increase in forest rents, where a nation has a relatively intense forest cover at the start of the development phase compared to agricultural lands (Wolfersberger *et al.,* 2015). This means at the start

of a development phase, forests hold a smaller marginal value because they are abundant, compared to limited agricultural lands, hence the latter's higher marginal value. Reducing forest cover (scarcity) increases their marginal value, while increasing agricultural lands reduces their marginal value until an equilibrium point (turning point) is reached (Wolfersberger *et al.,* 2015). The risk of natural events such as floods, which are also induced by forest scarcity, can boost the marginal value of forests, in which case nations will embrace plantations (Wolfersberger *et al.,* 2015).

3.3.3.3 Off-farm employment

The shortage of off-farm employment opportunities is among the reasons people convert forest areas into agricultural lands as they seek survival means (Angelsen, 2010). Off-farm opportunities are a major driver of FT as they pull people out of agriculture, reducing the need for land and thus encroaching forested areas (Angelsen, 2010). Some of the ways to increase off-farm opportunities include targeted stimulation of nonfarm economic activities in rural areas. By reducing the profitability of frontier agriculture, off-farm opportunities slow deforestation.

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