Impact of Deforestation on Coastal Communities in the Philippines, Madagascar, Somalia, and Indonesia: Causes and Policy Recommendations

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Abstract:
The proposed research paper explores the crucial issue of deforestation among coastal communities of 4 LMICs. These LMICs include the Philippines, Madagascar, Somalia, and Indonesia. The countries were chosen based on the following criteria: the prominence of mangroves in their ecosystems, the expansion of agriculture and housing in their forests, and their prominence in creating CO2 emissions. Deforestation has a major impact on climate change and biodiversity among these communities, leading to biodiversity loss, destruction of ecosystems, and zoonotic spillover; the interconnected relationship between climate change and deforestation is highlighted and explored. Furthermore, this study provides policy recommendations, potential solutions and adaptive measures to be implemented, including sustainable living and increased government involvement.

Deforestation

Deforestation is the purposeful removal or clearing of trees from forests, which has been traditionally used to convert land (Nunez, 2022). It occurs worldwide and impacts neighboring populations; 31% of Earth is covered in trees (Round Square), but this percentage is dwindling,

as 420 million hectares of forest have been destroyed since 1990 due to conversion efforts (Wcmc, n.d.). This trend has continued in recent years, as 10 million hectares are cut down each year due to human interaction (UNEP).

Although expanding forested lands could be seen as beneficial to commercial, agricultural, and housing value, forests are crucial to maintaining Earth's carbon cycle, which is a natural process where carbon rotates between the atmosphere and Earth (*What Is the Carbon Cycle?*, n.d.).

Forests are hosts of millions of species of plants and animals, influence weather patterns, and are essential in preventing extreme weather disasters. Even more pressing, deforestation causes 10% of global warming on Earth. This is due to carbon sequestration, as trees absorb carbon dioxide from the environment, mitigating climate change; however, when the trees are cut down, the greenhouse gasses are released, causing climate change. So, the key to fighting climate change is curbing forest loss (Mramstead, 2019). For this reason, it is essential to prevent the destruction of Earth's trees.

The Low or Middle-Income Countries (LMICs) of the Philippines, Somalia, Madagascar, and Indonesia stand out as coastal hubs of deforestation. The prominence of agricultural and housing expansion in destroying their forests, the growth of mangrove trees in their ecosystems, and the countries' influence in creating CO2 emissions in these coastal LMICs make them uniquely pertinent to explore deforestation in their forests.

Agriculture and housing production have accelerated deforestation in these LMIC countries because of the need for farmland in a primarily agricultural-based economy. In these four countries, there is a large focus on producing agricultural or wood-based products, such as palm oil in Indonesia, wood in the Philippines, and charcoal in Somalia and Madagascar. The growth of their populations has driven deforestation to create more farmland and land for housing.

Mangroves

Present in the Philippines, Somalia, Madagascar, and Indonesia, mangrove forests are ecosystems that provide benefits to communities in and around them. Unique to the coastal intertidal zone, these ecosystems are groups of trees and shrubs that are made up of 80 different species. Mangrove tree forests tend to grow near the equator in tropical environments and are characterized by their dense, overlapping roots, which are typically flooded by tidal waters (*What is the carbon cycle?*, n.d.). They provide immense benefits to ecosystems, including fostering safe habitats for a variety of organisms, many of which are endangered species. These trees provide for 1,500 plant and animal species, which vary from small birds to large mammals. In addition to providing an animal sanctuary, mangroves have a large impact on carbon sequestration. They store an average of 1,000 tonnes of carbon per hectare, which is crucial to curb emissions. Mangrove soil can also store carbon for centuries, helping mitigate climate change. They also have a large impact on human populations around them. With extreme weather occurring more frequently and severely, as the effects of climate change raise temperatures, mangroves act as a natural barrier to ecological disasters, such as hurricanes, tsunamis, and cyclones. Their trunks can absorb the impact of waves, offering defense to coastal communities and generating four times more value than the cost of investing in mangroves. They can also reduce tsunami wave heights between 5-35%, demonstrating their effectiveness against natural disasters (United Nations Environment Programme, n.d.).

Despite their benefits to humans and the surrounding ecosystems, mangrove forests are declining at a rate of 1%-2% per year due to human activities and climate change (Carugati et al., 2018).

The deforestation of mangroves has several consequences on their surrounding ecosystems. First, due to the carbon sequestration effect, mangrove soils are crucial in curbing carbon dioxide levels in the atmosphere. Thus, the destruction of these trees would both reduce any climate change prevention that they provide and, resultantly, worsen the environmental disasters that they protect against. This ultimately would worsen storms and cause more flooding in the ecosystems. Additionally, the removal of these mangroves increases vulnerability to disasters, which directly disrupts coastal communities. Since there is less defense against environmental disasters without the tree's natural protection blocking waves and sea-level increases, coastal communities become more vulnerable to flooding and destruction. Finally, without the trees, millions of people will be left with a destitute quality of life. Losing mangroves is associated with lower economic growth, poverty, and decreased human security, as many locals depend on the trees for essentials such as food, firewood, and income through goods and services gleaned from them, like tourism, fishing, and wood (*United Nations Environment Program*, n.d.).

Criteria

Somalia, the Philippines, Madagascar, and Indonesia are all coastal countries in Africa and Asia, which allows for the growth of mangrove trees in their ecosystems due to their tropical environments. Mangroves are uniquely helpful by providing stable, diverse ecosystems for organisms, absorbing carbon dioxide, and protecting from extreme weather. Thus, the deforestation of these ecosystems causes detrimental effects on surrounding communities.

The countries' tropical and dense forests make them uniquely large contributors to CO2 emissions. When deforestation occurs, a large amount of stored CO2 is released into the atmosphere. Prolonged deforestation of the forests in these countries will reverse the carbon sink effect these forests provide, essentially worsening the climate change crisis and warming the Earth to irreversible temperatures.

Finally, these countries are the most at risk for zoonotic spillover, which is the transmission of diseases between different species; for example, a pathogen from wildlife infecting humans (Ellwanger & Chies, 2021). Zoonotic transmission in the developing world harms the health and livelihood of its people. Being an LMIC makes these countries uniquely vulnerable to zoonoses, as zoonotic diseases that emerge there are neglected and under-reported since they are native to the country and less known. These diseases are dubbed "neglected zoonoses," and they have a lower priority compared to more widespread strains of zoonotic pathogens, causing deaths among affected individuals since they are not treated. In LMICs alone, zoonoses have caused 2.7 million deaths per year and 2.4 billion cases of the disease, showing their profound impact on humans in these countries (Rahman et al., 2020).

Philippines

Rate of deforestation

The trend of deforestation is rampant in the Philippines. From 2002 to 2022, 185 kha of humid primary forest was deforested from the country, causing a 4.0% decrease in the total area of humid primary forest (Vizzuality, n.d.). 92% of the Philippines was forest in the 1500s, making

up 27.5 million hectares, but this number has been reduced to about 7 million hectares today (Ilagan & Ilagan, 2021).

Land expansion driving deforestation

One of the primary drivers of deforestation in the Philippines is population increases causing the conversion of forests for farmland. Population growth has increased the demand for agricultural land, as farmers have to produce more food to feed the population and therefore destroy forests to cultivate the land. These individuals often convert the land without government involvement, and usually, the government ignores the behavior of illegal loggers, causing increases in deforestation (UBC Wiki, n.d.-c). Indeed, population growth in the Philippines was a 1.3% increase from 2021 (*Demographics on World Economics*, n.d.-c), and three babies are born in the Philippines per minute, showing that the population is expanding (*Population Dynamics*, 2021). This increase influences the conversion of land, as more locals increase the demand for food and cause them to trade forest loss for farmland. The result is severe and permanent, as forests used for agriculture usually never recover and will not regrow (*World Wildlife Fund*, 2023).

Mangroves

Mangroves are an important aspect of the ecosystems in the Philippines. Local populations use these mangroves for “firewood, charcoal, alcohol, medicine, and thatching used for constructions” ((Long & Giri, 2011). In addition to material goods, mangroves are shielded from extreme weather, mitigate coastal erosion, and foster marine life, providing immense benefits to the Philippines. However, deforestation from human activities has halved the total mangrove area from 500,000 ha, a trend that is predicted to persist (Long & Giri, 2011). The continued destruction of mangroves will inhibit the benefits they provide to the Philippines, negatively impacting human and animal life.

Madagascar

Rate of deforestation

In Madagascar, 27% of it was forested in 1950, but this has declined to only 16% in the 21st century (Clark, 2012). Indeed, from 2010 to 2022, Madagascar lost 256 kha of tree cover (Vizzuality, n.d.-a). Deforestation trends in Madagascar are detrimental to local populations, as forests provide “shelter, food, energy, shade, medicine, and soil protection” among other things Clark, 2012. Depleting such resources will have a devastating impact, as Madagascar will soon be left without any forest.

Land expansion driving deforestation

Due to a recent increase in population, Madagascar has prioritized agricultural production instead of environmental protection. Increased population growth is one of the primary causes of deforestation in Madagascar, causing agricultural land conversion, logging, and conflict that comes from the growth. However, this has led to possibly irreversible damage to the forest and the ecosystems that once existed. Madagascar utilizes slash-and-burn agriculture, a method in which farmers purposely cut down trees and burn away remaining plants, as the ash left behind initially fertilizes the soil for farmers to yield a large crop. However, prolonged use of this tactic in Madagascar has degraded the land and increased deforestation because new trees can no longer grow on that land. Also, once an area is no longer fit for agricultural use, more trees are

cut down to repeat the slash-and-burn tactic, ultimately ending with the degradation of more soil and deforestation of more trees. The effects of deforestation are severe, as Africa has the largest rate of deforestation in the world compared to other countries (Clark, 2012).

Mangroves

In Madagascar, the estimated total area of mangroves is 270,955 hectares in 2020, representing around 1% of the total forest cover. Mangroves in this area are essential for wildlife, including critically endangered species such as the Madagascar fish eagle. Additionally, much of the wildlife that lives in the Madagascar mangroves is important for human life, as they fuel the fishing industry, a primary sector in the country. However, the mangroves have been declining from 3000 to 7000 hectares per year from 1995-2018. A major cause of this loss is agriculture, as agricultural land is at capacity and needs to expand; but, terrestrial forests are decreasing, leading to less space to expand. So, Madagascar is cutting down its mangroves to make space for agricultural land, causing immense deforestation in local areas. The effects of this initiative is severe, as it causes flooding in the country due to rising sea levels, which were previously managed by the presence of mangroves (*Inicio*, n.d.).

Somalia:

Rate of deforestation

Somalia also faces the issue of deforestation, as between 2001 and 2021, it lost 4.9% of tree cover, or around 429,000 hectares. In fact, Somalia's annual loss made up at least 6% of tree loss in all of Africa, which is equivalent to 205 million trees deforested, indicating rampant deforestation in the country (Dubow, 2024).

Charcoal Production and War

One of the major reasons for the increase in deforestation is due to land conversion for livelihoods, fueled especially by charcoal production (Dubow, 2024). Charcoal is made from burning wood; however, it has a substantial environmental impact on the trees (United Nations Environment Programme, n.d.-d). Due to the government collapse, most Somalians were faced with poverty and unemployment, as the conflict took away traditional livelihoods like agriculture or fishing *(National Geographic*, n.d.). In its place was charcoal production and export, which has devastated the environment by destroying forests. It has caused "deforestation, soil erosion, loss of biodiversity, and a rise in CO2 levels" (United Nations Development Program, n.d.). The effect on trees is prominent, as the annual rate of decline of the Acacia Bussei, a threatened species, was around 5%. Furthermore, the Somali Civil War and government instability have worsened the situation. Though laws ban charcoal exports, government collapse has made it nearly impossible to enforce them, leading to a drastic increase in "illegal, unrestricted charcoal production" (United Nations Environment Programme, n.d.).

Mangroves

Mangrove ecosystems in Somalia make up at least 48 km2 and are scattered across the country in coastal areas and along the border (UNESCO, 2022). These mangroves are essential in protecting communities against natural disasters, as they are able to buffer tsunamis, storms surges, and coastal erosion. In addition to their protective purpose, mangroves are home to diverse plant and animal life, creating biodiversity in their ecosystems. However, mangroves in

Somalia are decreasing, as from 1996 and 2020 they have lost 1.65 km2 of mangroves. This decline is credited to human involvement through urban development and agricultural expansion in the country. The effect of deforesting the mangroves is severe, as they will no longer provide benefits to coastal communities they once protected, leading to land degradation and biodiversity loss (*The State of Mangroves in Somalia: Insights From Satellite Data*, 2023).

Indonesia

Rate of deforestation

The rate of deforestation in Indonesia is increasing each year, as 208,250 hectares were lost in 2022 compared to the 174,620 hectares lost in 2021. So, from 2021 to 2022, there was a 16% increase in forest loss (Teresia, 2023), indicating that deforestation is still rampant in the country and is increasing each passing year. Indeed, the forest cover in Indonesia is shrinking, as in the mid-1980s, 75% of forest cover remained, while in present day only 50% is left (United Nations Environment Programme, n.d.-c).

Agriculture expansion driving deforestation

Oil palm is a huge industry in Indonesia that is connected to deforestation, and the expansion of plantations is a major contributor to forest loss (United Nations Environment Programme, n.d.-c). In 2020, 502 mi2 of forest, an area the size of Los Angeles, was lost because of palm oil plantations (United Nations Environment Programme, n.d.-c). Indeed, oil palm is an important part of Indonesian life, as it is used in food and household items. Additionally, oil palm in general makes up 60% of international trade in vegetable oils, but it is primarily grown in the tropics, such as Indonesia. So, since Indonesia has the environment to grow oil palm, there is an incentive to expand the industry into the country, especially due to the global demand. The demand for the industry coupled with Indonesia's tropical environment causes expansion of oil palm plantations into the environment. To build these plantations, forests are cleared out for space to cultivate the industry. In fact, between 1990 and 2005, 55-60% of tropical forests were destroyed to expand the industry, essentially causing overall forest loss in Indonesia (UNEP Global Environmental Alert Service, 2011).

Mangroves

Indonesia has 22% of global mangrove area, the largest area of them in the world. These forests have massive benefits for the environment, as they can store massive amounts of carbon dioxide and provide habitats for marine organisms. However, mangroves in the Philippines are declining, as between 2001-2020, there was a loss of 193,367 hectares of mangroves in Indonesia. Additionally, over the last 30 years, 800,000 hectares of mangroves have been deforested. This is largely due to human destruction of mangroves to use the land for other purposes, but has caused climate change and sea levels to rise. Finally, cutting down the mangrove forests would harm the environment and people, as preventing further damage could avoid 424 metric tons of carbon dioxide by 2030, which would mitigate climate change; and, conserving the mangroves could benefit 74 million people who live on the coast (Sasmito et al., 2023).

Environmental Effects from Deforestation:

Deforestation among these communities has led to biodiversity loss and ecosystem destruction through land degradation and unsustainable practices. Additionally, the

environmental impacts of the countries' deforestation trends have impacted CO2 emissions through the carbon sink effect.

1. **Biodiversity loss**

A large impact of deforestation is biodiversity loss, as deforestation directly leads to the loss of animal and plant species in an environment.

Biodiversity is the variety of organisms that exist in a specific area, the majority of which live in forests. Forests are hubs for biodiversity, as a UN report confirms that forests contain most of the world's biodiversity (Wcmc, 2020). They house 60,000 tree species, 75% of bird species, and 68% of the mammal species on Earth, an overwhelming margin compared to other environments.

However, humans are increasingly losing their biodiversity, as mammals, birds, fish, reptiles, and amphibian populations have decreased by around two-thirds (Davis, 2022). For this reason, it is more important than ever to curb deforestation. Biodiversity is also a method to defend against climate change and is regarded as "our strongest natural defense against climate change" by the UN; but, decreases in biodiversity weaken its defense against it.

Deforestation directly causes biodiversity loss because tree-dwelling animals lose their habitats and are unable to exist in the remnants of the destruction. They are often unable to relocate to a new ecosystem after deforestation, leading to the overall extinction of the species (Round Square). Deforested areas destroy biodiversity because the habitat can no longer support the needs of the animal populations.

In addition to animal species, deforestation also leads to a decrease in the biodiversity of plants. If there is a large destruction of a specific tree species, they can become completely extinct, impacting the biodiversity of the environment.

Additionally, the extinction of a specific species can impact the entire biodiversity of the ecosystem. A "keystone species" is a defining organism that ensures the ecosystem exists and functions efficiently. If such a species is not present in an ecosystem, the biodiversity decreases (National Geographic). Due to commercial deforestation, keystone species like tigers and Asian elephants are increasingly losing their habitats (WRI). If these species go extinct, the entire ecosystem would collapse and biodiversity would decrease.

Finally, a loss of biodiversity completely disrupts ecosystem stability. Biodiversity and ecosystem functioning have a clear and established relationship, as ecosystems with higher diversity often have more stability (Zúñiga-Sarango et al., 2020). This is because the high genetic diversity of populations allows for the survival of the species against deadly diseases, severe weather, and shifting conditions (*The Elements of Biodiversity*, n.d.). Additionally, if a species is wiped out due to environmental changes, another organism can fulfill its role in a biodiverse ecosystem. However, in a less biodiverse ecosystem, there would not be another species to take its place, destabilizing the ecosystem (Population Matters, 2024).

2. **Land Degradation**

Another pressing impact of deforestation is land degradation, an undesirable disturbance to land or soil in the environment due to human expansion onto land (*Land Degradation*, 2022). Deforestation has a direct impact on decreases in soil fertility and erosion in the environment, as the expansion of deforestation for agricultural purposes ruins the land (*United Nations Convention to Combat Desertification,* 2022). The relationship between deforestation and soil fertility is mainly manifested through slash-and-burn agriculture. Slash-and-burn agriculture is a

method of deforestation in which forested land is cleared and the remaining vegetation is burned to grow food in ecosystems. The ash left over from the fire helps enrich the soil to grow crops. However, the fertility only lasts for a few years, so farmers leave the land to continue the process elsewhere and leave the land degraded permanently (*EcoLogic Development Fund*, n.d.). Though this method has been traditionally used in other countries, there has been a large increase in the amount of land being cleared for this type of farming, worsening the problem of deforestation and leading to land degradation. Although deforestation does not immediately impact the fertility of the soil, this method of clearing the forest degrades the fertility over time.

Deforestation also has a large impact on soil erosion. In the environment, trees' roots anchor soil into the ground, but cutting the trees causes the erosion of fertile soil into rivers and away from the land. Once this land is used for agriculture, the crops typically grown often worsen the problem, as they are unable to hold the soil into place. This causes a cycle of deforestation and erosion, as once the fertile soil in an area is eroded, farmers clear more forest to grow their crops, leaving the land infertile. The effect of this cycle is profound, as since 1960, research estimates that soil erosion and land degradation has lost a third of arable land globally (*World Wildlife Fund*, 2023). Additionally, areas with good soil are already limited, and once their trees are cut down from deforestation, the good soil is no longer anchored and susceptible to being washed away. Tropical rains then carry the eroded soil into local rivers, leading to a large rate of soil loss after forest clearing. A study in Ivory Coast found that forested slope areas lost 0.03 tons of soil per year per hectare; cultivated slopes annually lost 90 tons per hectare, while bare slopes lost 138 tons per hectare. The difference in loss per hectare with versus without trees highlights deforestation's immense impact on soil loss. This loss then leaves farmers with a decreased crop yield, causing them to clear additional forests and continue the cycle (Butler, 2020).

Slash-and-Burn

Slash-and-burn agriculture also has significant implications for the environment and human populations. Countries have discovered that burning agricultural waste is the easiest and least expensive way to clear land for agriculture (Commission for Environmental Cooperation & Ize, 2014). The benefit of the method is the release of nutrients and the elimination of harmful organisms in the fields, which benefits the crops and workers (Commission for Environmental Cooperation & Ize, 2014). The ash initially fertilizes the land and the fire burns away weeds, but only a few harvests maintain this effect, as fertility soon declines and weeds grow back. The UNEP finds that agricultural burning lowers water retention and fertility of the soil by 25-30% (United Nations Environment Programme, n.d.-e).

However, the effect of burning is extreme, as 40% of CO2, 20% of particulate matter, 50% of polycyclic aromatic hydrocarbons (PAHs), and 32% of carbon monoxide are released into the environment from burning biomass. Since much of the released compounds are contributors to climate change, such as pollutants or greenhouse gasses, slash-and-burn agriculture has a significant impact on the environment (Commission for Environmental Cooperation & Ize, 2014). Black carbon released from agricultural burning can alter weather patterns, as it absorbs light as heat and releases it into the atmosphere (U.S. Environmental Protection Agency, 2011).

Although this method was once sustainable, the modern practice has caused permanent deforestation, as once cleared, the land is left bare (The Editors of Encyclopaedia Britannica, 1998). It impacts humans as well, as smoke carries over to nearby humans who are exposed to

the produced pollutants. Due to the nature of the burning, high concentrations of pollutants are released into the atmosphere. This can cause cancer, respiratory disease, coughing, phlegm, and asthma. The effect is so profound on human health that hospital visits in the USA for respiratory problems increased by 50% during their burning season, an effect that would be replicated in other countries (Commission for Environmental Cooperation & Ize, 2014). Continually, the WHO finds that air pollution from this effect contributes to 7 million deaths a year (World Health Organization, 2019).

3. **Carbon Sink**

The last major impact of deforestation is carbon emissions released from cut trees. Deforestation affects carbon emissions by reducing its role of sequestration and releasing stored CO2 into the atmosphere.

First, deforestation leads to a decrease in the carbon sequestration effect. Around 60% of human emissions are absorbed by land and ocean ecosystems, and they are huge stores of CO2 (United Nations, n.d.-b). Trees can reduce the carbon dioxide from the air through carbon sequestration, where they store carbon in their tissue every year they grow. This phenomenon allows for trees to reduce carbon in the atmosphere and help curve climate change (*U.S. National Park Service*, n.d.). A mature tree can absorb over 48 pounds of carbon and release oxygen for humans to breathe (*U.S. National Park Service*, n.d.); however, deforestation stalls this effect because cutting down forests causes these stores of CO2 to be released into the atmosphere. The effect of the release is so severe that between 2015 and 2017, tropical tree cover loss averaged 4.8 gigatons. Essentially, it causes more carbon release than 85 million cars (Gibbs, n.d.). Additionally, some tropical forests have turned from sinks to sources. Rather than capturing CO2, the forests emit more CO2 than they can store, contributing to climate change. The reversal of a carbon sink is a direct effect of deforestation, as cutting down the trees led to the imbalance of net CO2 from the tropical forest (Grantham Research Institute on Climate Change and the Environment, 2023). For example, the Amazon rainforest now emits 1.3 billion tonnes of carbon a year and absorbs 1 billion tonnes a year because deforestation has caused it to release more carbon than it absorbs.

Human Health

Impacts of deforestation on human health in these countries

The transmission of these diseases from human-animal interactions through factors such as population growth, deforestation, and poor infrastructure, are all present in LMIC countries such as the Philippines, Indonesia, Madagascar, and Somalia (Ellwanger & Bogo Chies, 2021).

Philippines & Indonesia

Major environmental, economic, and social shifts in these countries triggered the emergence of zoonotic viral diseases. Southeast Asia, where these communities are located, is a hotspot for zoonotic diseases caused specifically by deforestation. In this region, 1.2% of forests are lost yearly, as Indonesia lost 28.6 million hectares since 2000. Deforestation in this region stresses the environment and organisms and increases human-animal interactions (Villarroel et al., 2023).

Somalia & Madagascar

Deforestation in Somalia and Madagascar can drive zoonotic disease, as increased land degradation from poor agricultural practices and as a result, deforestation increases the risk of epidemics (Zimmer, 2019). Indeed, populations in African countries like Madagascar and Somalia are at increased risk of zoonoses when they live close to forests "disturbed by deforestation." For example, the transmission of Ebola in Africa was at a higher risk in areas with forest disturbances, indicating a link in African countries between pathogen transmission and forest loss (Rulli et al., 2017).

Deforestation's Impact on Zoonotic Spillover

Zoonotic diseases are infectious diseases that originate from animals and spread to humans. These diseases can range from mild to deadly (CDC) and are caused by pathogens such as bacteria, fungi, viruses, and parasites (Tajudeen et al., 2022). Zoonoses have infected around 2.4 billion cases and caused 2.7 million deaths of humans per year. Transmission occurs through both direct and indirect contact with wild animals that act as reservoirs for pathogens and humans who are susceptible (Rahman et al., 2020). The impact of zoonotic diseases on human populations is profound, as around 60% of human diseases can be attributed to animal origin (United Nations Environment Programme, n.d.). Zoonoses affect both human health and well-being, as affected individuals can lose the ability to work, have lasting side effects, or die from the disease.

Deforestation is linked to the spread of zoonotic diseases because of an increase in human-animal interactions due to human activity. The likelihood of the emergence of a zoonotic disease increased by 75% to 90% in areas with a high human population density, indicating the significance of human hosts in spreading the disease (Keesing & Ostfeld, 2021). This trend has been seen since 1940, as ⅛ of emerging infectious disease (EID) episodes and a higher proportion of zoonotic diseases are linked to land use factors such as deforestation, logging, and agricultural conversion. The proportion of zoonotic diseases caused by human interactions with the environment suggests disease emergence is largely caused by increased human-animal interactions (Murray & Daszak, 2013).

This trend is due to changes in land use. When humans destroy or encroach on habitats, the contact rate between humans and reservoir hosts increases, influencing the probability of "infection given contact" (Murray & Daszak, 2013). Indeed, when humans clear forests and change habitats, they expose themselves to vectors that they previously were isolated from. As seen in Western Uganda, "forest fragmentation" expands encounters between humans and animals, as well as increases the transmission of viral or bacterial pathogens (Estrada-Peña et al., 2014).

Furthermore, deforestation has a large impact on zoonotic spillover because of its impact on the biodiversity of the habitat. Deforestation causes a loss of biodiversity because it creates uninhabitable environments in which animals are unable to survive; it stresses the environment and surrounding wildlife, causing ecological disruption that lowers biodiversity (Tajudeen et al., 2022).

When climate or habitat is altered by a factor like deforestation, it impacts the biodiversity of local animals, pathogenic hosts, and non-hosts in an environment. These changes shift ecosystem dynamics and can increase or decrease disease transmission. For example, increased biodiversity often decreases the risk of transmission between hosts due to a "dilution

effect," which occurs because increasing the number of hosts a parasite can inhabit causes a lower probability of interactions (Estrada-Peña et al., 2014). This theory suggests that the rate of transmission is lower in biodiverse areas and warrants that this occurs because the higher availability of incompetent reservoirs dilutes infection rates between competent hosts and humans (Tajudeen et al., 2022). So, biodiversity serves as an effective defense from infectious disease, indicating its importance in preventing zoonotic spillover (Keesing et al., 2010). Indeed, when animal diversity decreases, the risk of a zoonotic spillover increases because hosts tend to increase. Reservoir hosts, which spread the disease, increase with human activity, as their competitors and predators are lost due to human involvement. Without a predator or competitor, reservoir animals can reproduce in larger numbers, which drives zoonotic spillover (Kulkarni, 2022). For this reason, the direct impact deforestation has on biodiversity has a large impact on the emergence of zoonotic diseases.

Interconnected Relationship Between Climate Change and Deforestation

Deforestation and climate change exist in an everlasting and interconnected cycle. Deforestation exacerbates climate change, while the worsening climate change crisis drives growing deforestation trends.

Carbon Dioxide

First, the degradation of land and land ecosystems from deforestation has worsened the effects of climate change. Land and land-based ecosystems act as a carbon sink by storing carbon and aiding in stabilizing the plant's temperature (United Nations, n.d.). Indeed, land-based ecosystems have stored 30% of human-generated emissions in the last decade. The importance of this effect should not be understated, as the UN predicts that this effect could provide 20-30% of warming mitigation to ensure the Earth stays below 1.5 degrees Celsius. Indeed, an IPCC report finds that land-based efforts can dramatically contribute to climate change mitigation by reducing greenhouse gas emissions (*United Nations Convention to Combat Desertification,* 2022).

However, the state of our land poses a challenge to this proposed solution. By 2050, reports project the additional degradation of land to be around the size of South America in addition to the 40% of land that is already degraded (*United Nations Convention to Combat Desertification,* 2022). This degradation limits the sequestration effect that mitigates climate change, worsening the crisis.

Land degradation also has significant implications for the environment, as when forests are cleared, they release their stored carbon into the atmosphere. Trees and soil can store carbon dioxide through carbon sequestration, which is "the process of capturing and storing atmospheric carbon dioxide" (*U.S. Geological Survey*, 2019). Degrading the land and land ecosystems releases the stored carbon dioxide, which alone has caused 10% of human-induced greenhouse gas emissions (United Nations, n.d.) and accounted for 4.4 billion tonnes of CO2 emissions in the 2000s, causing climate change.

Climate Patterns

Second, deforestation alters rainfall patterns, leading to drier conditions and hotter temperatures (Data, n.d.). Through evaporation and transpiration, trees shape the climate, as evapotranspiration, the process in which water moves from land to the atmosphere, causes humidification and surface cooling of the Earth. This effect is profound, as one tree can cool 70

kWh per 100 liters of water. Forests also influence wind currents, as the tree's physical shape reduces the speed of wind currents and increases convection, which is when air moves vertically into the atmosphere. So, without the physical presence of trees, faster winds occur in the ecosystem. These winds dry out the land, so in tropical areas, even partial deforestation causes drier and hotter local conditions. Essentially, the effect of deforestation on climate change extends past the greenhouse effect (Wolosin & Harris, 2018).

Additionally, the changes in temperature and climate have an impact on forest health, leading to the cycle between deforestation and climate change. Due to rising temperatures, which deforestation contributes to, droughts become more common and severe, worsening forest health (Data, n.d.). Without the maintenance of forests, there is no way to reverse climate change or mitigate its effects, as the UN finds that limiting the global temperature increase is not possible without forests; furthermore, there is no way to buffer the extreme weather, which is caused by deforestation, which threatens infrastructure and forest-dependent populations (UN Environment Programme, n.d.).

Recommendations

Madagascar

The World Health Organization suggests that the solution to prevent deforestation is to focus on the people, as major communities contributing to deforestation in Madagascar suffer from extreme poverty, the effects of which lead to slash-and-burn agriculture and illegal logging. This causes a cycle, as deforestation worsens climate change, but climate change exacerbates stresses on the community that lead to deforestation. The WHO finds that the best way to curb the cycle is to provide supportive services, such as healthcare services.

Allowing access to high-quality healthcare provides a long-term solution for the community, as it can be used as an incentive for communities. Selected members of the communities monitor the state of the forests, such as the amount of trees locals are deforesting due to different industries in the country. Then, communities with lower rates are rewarded with discounts and benefits for healthcare for their efforts, providing an incentive for them to curb deforestation (World Health Organization: WHO, 2021).

The recommendation for Madagascar would be to use this working method alongside "shifting cultivation," a sustainable type of farming used in Asia. Essentially, small patches of forest are cleared to plant crops, but after a couple of seasons, trees are regrown before the land degrades completely. This method has worked exceptionally well in the Hin Lad Nai forest, as it "has remained remarkably healthy, despite centuries of shifting cultivation", indicating a potential long-term solution for Madagascar's communities. Additionally, this system is not a trigger of climate change, as Miguel Piendo-Vasquez from Columbia University's Earth Institute Center for Environmental Sustainability writes, "The shift to a Green Economy must include shifting cultivation", indicating this practice's success mitigating climate change (Raygorodetsky, 2016).

Philippines

The UN Food and Agriculture Organization shows a 0.5% increase in forest cover from 2010-2020 in the Philippines, indicating that current efforts in the Philippines are successful (*Global Forest Resources Assessment 2020*, 2020). One such program is the National Greening Program, which aims "to plant 1.5 billion trees in 1.5 million hectares" to reforest the Philippines.

This program's 3-pronged implementation strategy has planted 156,570 hectares since December 2018, a number which has likely increased in the present day (Commission on Audit, 2019). The recommendation is to continue with this program while executing stricter laws against illegal logging and forest destruction, as the Philippines faces major problems with logging that destroys the efforts made by this program.

Continually, due to rapid population growth, agricultural expansion has fueled immense deforestation in the Philippines. For this reason, the recommendation for the Philippines would be to enforce and implement population management policies to curb their overpopulation. Indeed, overpopulation is a major factor in forest cover, as there is a relationship between tree loss and demographic changes. When compared to settlements with higher populations, settlements with depopulation have had increases in forest cover. Studies found that the significance of human influence in both the deforestation and reforestation processes is generally indicated by all the major trends and changes, demonstrating the impact depopulation efforts in the Philippines would have on the forest cover in the area (Gatarić et al., 2022).

Indonesia

The UNEP suggests that a solution to curb the rampant deforestation is to recognize the importance of local communities in protecting the environment. So, the recommendation for Indonesia is to empower local communities through government programs. This is an effective way to protect the environment, as such communities have both an understanding of the environment and a motivation to conserve them for future generations. Musdalifah Machmud, Deputy Minister for Food and Agriculture at the Coordinating Ministry for Economic Affairs for the Republic of Indonesia, affirms "Local communities are the best guardians of their forests. They have a deep understanding of the ecosystems they call home and a vested interest in managing them sustainably", indicating that transferring land to locals is a sustainable and effective solution.

This method has already begun in Indonesia, as by 2022 the government has granted 4.7 million hectares of forests to local communities to protect their land. Indeed, when oil palm plantations threatened the forests in the village of Gunung Salihan, community-led rallies secured legal rights to their forests and protected the forests, indicating the success of this solution (United Nations Environment Programme, n.d.-c). Additionally, 12 studies focusing on decentralized forest management found that giving local people the power to protect their forests affects reducing deforestation, indicating that the recommendation to empower local communities could have a positive effect on Indonesia (International Initiative for Impact Evaluation, n.d.).

Somalia

Charcoal production is one of the major factors fueling deforestation in Somalia, so finding an alternative energy source is key to curbing it in the country. The UNDP recommends that a sustainable solution to curb charcoal production is to promote both clean lifestyles and reduce the demand for charcoal.

The first step of the recommendation is to build awareness about the harmful nature of charcoal, which will usher local populations into using clean energy. By engaging local, regional, and national populations in education about the harmful environmental effects of charcoal production, people in Somalia could switch to alternate energy sources. Additionally, to spread education about the drawbacks of charcoal usage, journalists in Somalia should be targeted to

learn about the negative impacts and write about them to the local population. Such articles would raise awareness about the problem at the local level. This method has worked in the country, as over 5,000 people in Somalia are educated on charcoal production's negative impacts, as well as have learned sustainable and healthy agricultural methods. The success of this method is why it should continue to be implemented in Somalia and is the recommendation for the country.

Furthermore, working with neighboring countries and the charcoal export markets could help curb the charcoal trade. Common techniques, such as Somalians faking documents about the source of their charcoal, that charcoal traders within Somalia use should be taught to the surrounding countries and markets. This way, when traders attempt to sell charcoal from Somalia, it can be recognized and reported to the government. This method would ensure that the market dies down and reduce the trade of charcoal.

Finally, the last part of the recommendation is to provide other methods of fuel for the people of Somalia. By providing alternative methods of fuel, the demand for charcoal in Somalia should decrease, effectively lowering the rate of deforestation because there is no need for charcoal production. The UN has provided households with fuel-efficient stoves, which lowers the demand for charcoal; this individualized approach has been implemented in over 6,000 households. Continuing this effort in Somalia will continue to lower the need for charcoal and thus lower the deforestation rate (United Nations Development Program, n.d.).

Conclusion

The effects of deforestation are severe, as it causes biodiversity loss, land degradation, and the release of carbon emissions into Earth's atmosphere. All of these factors lead to devastating impacts on local communities, such as destabilizing ecosystems, lowering crop yield, and releasing greenhouse gasses into the environment. Furthermore, deforestation impacts vulnerable populations through the spread of zoonoses, which are infectious diseases that spread from animals to humans; they are especially prevalent in LMICs due to their population growth and poor infrastructure, causing zoonoses to spread in the Philippines, Madagascar, Somalia, and Indonesia, among other countries. Deforestation also exacerbates climate change while climate change worsens deforestation, existing in an everlasting cycle that will continue unless logging is curbed. Following the recommendations are essential to benefit the countries long term in building climate resilience and mitigating the effects of deforestation. For this reason, it is essential that policy makers consider the recommendations proposed and initiate appropriate legislation to foster a cleaner climate and more successful country.

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