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Impacts of Land-use Change on Biodiversity of Tropical Forests

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Abstract: The tropics possess a higher level of biodiversity compared to other climatic regions on the Earth. The tropics have diverse ecosystems such as forests, savannas, mountains, wetlands, and coral reefs, which provide habitat for thousands of species of fauna and flora. Tropical forests are one of the important tropical ecosystems with high biodiversity. Humans modify tropical forest landscapes on a large scale and use them for different purposes, including logging, mining, agriculture, pastures, urbanization, and road construction. Humans attain resources and profits through transforming tropical landscapes while making negative impacts to biodiversity and the environment of tropical forest ecosystems. Land-use change further causes habitat loss, habitat fragmentation, climate change, pollution, and species invasion of the tropical rainforests. These drivers lead to ecosystem destruction and the biodiversity crisis in the whole tropical region.

Keywords: Tropical forest, land-use change, biodiversity crisis, environmental impacts

1. Introduction

Tropical forests are crucial for maintaining global biodiversity and are integral to the regulation of the Earth's climate system. Tropical forests are situated within a latitude range of 28 degrees north and south of the equator. These areas cover approximately 1.84 billion hectares of the Earth's surface. This area constitutes 12 percent of the Earth's terrestrial surface and 3.6 percent of the total surface of the Earth. The biodiversity observed is notably high. Estimates suggest that tropical rainforests may contain from 3 to 50 million species (Butler, 2019). The Amazon Basin, located on the South American continent, encompasses the largest area of tropical forest globally. The Congo Basin in Africa represents the second largest area, while Southeast Asia ranks as the third largest area. Forests with smaller sizes are located in the Central America, the West Africa, Madagascar and islands on the Pacific Ocean. Brazil possesses the most extensive coverage of tropical forests among all countries. In 2020, Brazil had a total of 318.7 hectares of tropical primary forest cover (Butler, 2020). Approximately 140,000 square kilometers of forests are lost annually on a global scale, a phenomenon that can be attributed to changes in land use.

Land-use changes occur in parts of the Earth with the presence of humans. There are fewer pristine areas on Earth as a result of human modification of natural landscapes. Conversion of natural lands happens in different regions of the world, including the tropics. Drivers of land conversion include industrialization, urbanization, and human populations. Anthropogenic activities have a significant

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impact on the tropical forests. Humans convert tropical forests to various uses, including agriculture, industry, road construction, urbanization, and pastures. The process of conversion is usually irreversible. The demand for natural resources of timbers, minerals, medicines, and wildlife leads to deforestation in tropical forests. The expansion of agricultural lands and pastures also threatens the forests. Anthropogenic activities have caused them in the world to lose and degrade 25 to 50 percent. Anthropogenic activities cause a range of ecological problems like habitat loss, habitat fragmentation, climate change, pollution, and the introduction of species. The destruction and degradation of tropical forests will not only have negative impacts it abundant biodiversity. In recent years, the rate of tropical forest loss has become more rapidly. At the same time, more species in the tropical forest become endangered. It is urgent and crucial to understand the recent status and impacts of land-use change on the tropical forest. The study examines studies regarding the impacts of land-use changes on the tropical forests in several parts of the world and offers insights for future research on regulation and conservation.

2. Habitat loss

Habitat loss occurs in many tropical forests because of land-use change. Purposes of land use can be diverse in different regions. Deforestation is the direct consequence of activities, including logging, mining, and agriculture. It has a direct impact on forest species, causing them to lose the shelter and resources they depend on for survival. Habitat loss leads to significant and widespread biodiversity loss and alteration in the tropical forests.

The Amazon Forest is currently under serious threat from habitat loss, which is primarily a result of deforestation activities. The primary activities contributing to land-use change encompass the logging industry, agricultural expansion, and cattle ranching. The Amazon experienced a loss exceeding 3,800 square miles of forested area, a figure that corresponds to approximately 1.8 million football fields (Thomson, 2020). A draft of a scientific report from the Science Panel of the Amazon in 2021 indicates that over ten thousand species of plants and animals face a significant risk of extinction as a result of forest destruction (Eisenhammer & Griffin, 2021). Deforestation occurs in various countries, including Brazil and Colombia. The former president of Brazil, Bolsonaro, has advocated for the expansion of mining and agricultural activities within the designated protected regions of the Amazon Forest in his term from 2019 to 2023. The action contributed to the increasing rate of deforestation in the Brazilian Amazon Forest. The Brazilian Amazon Forest is home to a diverse array of New World monkey species. The forest serves as the habitat for the critically endangered monkey species known as Vieira's titi (Plecturocebus vieirai). The habitats of Vieira's titi are located at the eastern and southern edges of the forest, areas that are experiencing significant forest loss in Brazil (Mowbray 2022). Investigations on this species have shown that the availability of suitable habitats has decreased to 65 percent. The main factors causing deforestation comprise soy cultivation and cattle ranching practices. Habitat loss resulting from land-use change is also observed in the rainforests of Colombia. According to the Colombian Environmental Minister, in the year 2020, Colombia witnessed an 8 percent increase in the deforestation rate and a loss of 171,685 hectares of forested land, the extent of which is comparable to twice the size of New York City. (Acosta, 2021). The Colombian Amazon exhibits the highest rates of deforestation among all the forests in Colombia. Similar to the Brazilian Amazon Forests, logging and mining operations—which are frequently associated with illegal organizations—drive significant changes in land use. Certain areas of the forest have been transformed into cocoa plantations for the purpose of cocaine production. Certain areas of the forests were deforested and repurposed for grazing and land investment, resulting in significant financial returns. Species residing in forest ecosystems include avian populations that have experienced habitat loss. A study was conducted on 550 bird species that are dependent on forest ecosystems in Colombia. The findings indicate that 96.5 percent of avian species have experienced

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habitat loss, with 18 percent of these species having lost at least 50 percent of their habitats as of 2015. The research employs the Loss Index (LI) as a metric to quantify forest loss within the forest bird assemblage. The current Conservation Index (CI) has been determined to be 35, suggesting that 35 percent of forest bird species have experienced a loss of at least 35 percent of their habitat. The ongoing trend of forest loss indicates that the LI at the national level is anticipated to increase to 40 by the year 2040. The number of species that have lost their habitats is increasing alongside the sizes of these habitats (Negret et al., 2021).

Habitat loss is also occurring in Southeast Asian tropical forests, resulting in adverse effects on local species. Southeast Asia contains approximately 15 percent of the world's tropical forests. Simultaneously, Southeast Asia possesses a significant expanse of tropical mountain forests, accounting for approximately fifty percent of the global total. However, alterations in land use contribute to the escalation of deforestation and the establishment of plantations within mountainous forest regions. Analysis of forest loss in Southeast Asia from 2001 to 2019 indicates a significant reduction, with an estimated 610,000 square kilometers of forest cover diminished (Cowan, 2021). The majority of forest loss has been observed in mountainous regions, primarily attributed to the conversion of highland forests into croplands and plantations. The environmental and climatic conditions of the mountainous region exhibit distinct characteristics when compared to the adjacent areas, primarily due to variations in elevation. Diverse environmental and climatic conditions foster the development of additional ecological niches, thereby enhancing species survival and contributing to increased biodiversity. Concurrently, numerous species, such as monkeys, exhibit migratory behavior from lowland areas as a reaction to climate change. The establishment of croplands and plantations significantly alters the landscape, leading to the degradation of highland forests and resulting in a loss of vegetation cover. Mountainous species experienced habitat loss due to the unsuitability of their environment, leading them towards the risk of extinction.

3. Habitat fragmentation

Habitat fragmentation results from land-change in the forms of construction, dam construction, and plantations. Deforestation is the driver of habitat loss but also for habitat fragmentation. Deforestation transforms the intact forest into landscape isolated forest fragments and declining biodiversity. Fragmentation can have negative impacts on the tropical forest. Due to edge effects caused by fragmentation, wind and drought stress can affect forests from the forest's edge. Wind and drought stress will affect the microclimate of the forest and increase the mortality of trees in the forests (Fischer et al., 2021). The edge effect can have impacts on the species richness and forest dynamics in the forest fragments. The edge of the forest fragment will undergo a reduction in forest biomass and an escalation in fire frequency.

Road construction represents a significant anthropogenic activity that contributes to habitat fragmentation within tropical forest ecosystems. On one hand, roads can enhance transportation efficiency and facilitate connectivity between various locations. Conversely, roads have the potential to fragment entire forests into distinct sections, thereby impacting the species that inhabit these ecosystems. The construction of roads in the Amazon Forest in Brazil leads to habitat fragmentation and significantly affects the species residing within these forests. The construction of roads results in significant disruption to forest ecosystems and induces edge effects that impact wildlife habitats in the Amazon region. According to a study by the Brazilian conservation organization Imazon, both official and unofficial roads have aggravated the condition of nearby forests. The length of unofficial roads spans 853 thousand kilometers within the public domain, representing approximately one-fourth of the total road network in the Amazon region. (Acosta, 2021). The establishment of unofficial roads enhances accessibility to forested areas, thereby facilitating activities such as illegal logging, mining, and land appropriation within these ecosystems. The construction of unofficial roads

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extending into protected areas results in significant destruction to these sites. The edge effect significantly influences the populations and behaviors of small mammals inhabiting forested environments. Prior research indicates that small mammals reliant on rainforests in tropical regions tend to avoid edge environments. One of the research demonstrates that the edges of Brazilian forest fragments' forest roads and forest matrix have an impact on small mammals (da Rosa et al., 2018). The model highlights the preferences of small mammals, indicating that ground-dwelling species tend to favor lower vegetation habitats, while arboreal species are more inclined towards high vegetation environments. The construction of roads and the resulting habitat fragmentation may exert significant effects on arboreal species.

Dam construction is another anthropogenic activity that also causes habitat fragmentation in tropical forests. Human activities, such as the construction of dams and reservoirs for water storage and the utilization of hydropower for electricity generation, are expected to have significant implications for the landscape as the water levels increase, resulting in the inundation of lower-lying areas. This phenomenon establishes obstacles that hinder the movement and dispersal of terrestrial organisms. In tropical forests, numerous organisms engage in mutualistic relationships that facilitate their coexistence and survival. A variety of insect species engage in mutualistic interactions with plants, with ants serving as a notable example. The investigation into the ant-myrmecophyte relationship within Balbina, the largest dam in Central Amazon, highlights the impacts resulting from the construction of the dam (Emer & Fonseca). The dam generated a cascade effect within the ant-myrmecophyte mutualistic networks. The ant-myrmecophyte networks within undisturbed forests exhibit highly compartmentalized structures. The network structures observed at the lake edges and forest islands exhibit a lack of compartmentalization. In disturbed forest sites, plants either lost their mutualistic ant partners or were colonized by opportunistic ant species. The local extinction of plant species, along with their mutualistic ant partners, results in a significant loss of ecological compartments. Habitat fragmentation has resulted in the inability of plants and their mutualistic ant partners to effectively disperse and sustain viable populations. Smaller islands exhibited a higher prevalence of unoccupied plants compared to their larger counterparts, indicating a notable trend in plant occupancy across different island sizes. The phenomenon of habitat fragmentation has resulted in each island evolving into distinct evolutionary zones, characterized by varying mutualist partnerships. The construction of dams leads to habitat fragmentation, which adversely affects species, ecological interactions, and the evolutionary processes within tropical forest regions.

4. Climate change

The transformation of land use in tropical forests, particularly through deforestation for agricultural purposes, leads to a rise in carbon emissions, a reduction in vegetation cover, and an increased susceptibility to climate change-related occurrences, including forest fires. Tropical forests significantly contribute to the mitigation of climate change. Tropical forests maintain high rates of transpiration, decrease surface air temperature, and increase precipitation compared with pastureland (SOM) (Bonan, G. B., 2008). Tropical forests in the world contain 25 percent of carbon in the terrestrial biosphere and play a role in carbon natural and carbon sink. Conversions of tropical forests for timber industries, pastures, farmlands, and plantations lead to vegetation loss. Vegetation loss causes more carbon emissions and less moisture in the atmosphere. Warmer and drier climates make the habitat unsuitable for organisms in the forests. The change in climate also increases the frequency of catastrophes like fire. Climate change makes tropical forests more vulnerable to forest fires. At the same time, forest fires release particles into the atmosphere and cause haze. It causes air pollution and has a negative impact on the health and safety of humans.

The transformation of tropical forests into agricultural lands is associated with an increase in the frequency of forest fires in Southeast Asia. In Borneo, there has been a notable conversion of tropical

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forests into oil palm plantations and various vegetation mosaics. One study examined the effects of land-use change on forest fire occurrences in Borneo, focusing on two distinct land cover scenarios: the forest scenario and the deforestation scenario (Trancoso et al., 2022). According to the forest scenario, tropical forests covered 86.8% of the land in the 1980s, but the projection shows that they are expected to encompass only 32.7% of the land area by 2050. Between 1980 and 2015, there was a significant reduction of 37.1 percent in primary forest cover in Borneo, and the projections regarding deforestation indicate that the primary forest cover is expected to decrease by 20.6 percent by 2050. The initial transformation of tropical forests into oil palm plantations and vegetation mosaics results in an increase in near-surface atmospheric temperatures and a reduction in humidity levels. The alteration of near-surface atmospheric conditions has the potential to modify the distribution of atmospheric precursors associated with wildfires. Secondly, deforestation has significant effects on water balance and aridity. Deforestation results in the edge effect within forest ecosystems and contributes to alterations in climate patterns. The simulation indicates a reduction in precipitation alongside an increase in potential evaporation within the deforested region. Moreover, the consequences of deforestation may be exacerbated during the dry season and in the context of El Niño events. Deforestation results from land-use change, which alters both the microclimate and regional climate of tropical forests, subsequently leading to an increase in wildfire occurrences.

5. Species invasion

Land-use changes have the potential to significantly impact the structural characteristics and species composition within tropical forest ecosystems. Land-use practices contribute to the increased vulnerability of forests to invasive species. Forests that have been transformed into plantations and agricultural lands exhibit elevated levels of disturbance and distinct abiotic conditions when compared to intact forests. Alterations in abiotic factors, including heightened light intensity, reduced humidity, and modifications in soil nutrient composition and pH levels, facilitate the establishment and expansion of invasive species in transformed landscapes. A survey was conducted on native and exotic plants within a forest remnant situated in an oil palm-dominated landscape in Sabah. Land-use change not only modifies the environment conducive to invasive plant species but also enhances the transport of propagules (Waddell et al., 2020). Isolated forests surrounded by oil palm or other agricultural lands show a higher influx of propagules. The presence of significant disturbance correlates with an increase in species invasion within forest ecosystems. Disturbance enhances the availability of resources, thereby facilitating the colonization of exotic plant species. The responses of native and exotic plant communities to disturbance and fragmentation within forest ecosystems exhibit notable differences. The native plant community exhibited a negative correlation with both disturbance and fragmentation, albeit indirectly. In contrast, a positive correlation was observed between invasive plants and land-change variables. Land-use change introduces exotic plant propagules to forest remnants, while environmental alterations promote colonization and species invasion.

6. Conclusion

The impacts of human activities have fundamentally transformed the original condition of tropical forests, highlighting the urgent necessity for conserving these essential ecosystems. Previous research and data discussed in this study emphasized that anthropogenic activities have a significant impact on the tropical forests. Land-use changes like habitat loss, habitat fragmentation, climate change, and invasive species can affect tropical forests on different levels, from species to the whole forest system. Land-use changes impact on forest species at the species level and ecosystem services at the community level. Environmental factors like microclimate and regional climate are also negatively

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impacted. In the short term, land-use changes lead to loss of biodiversity and destruction of tropical forest habitats. In the long term, land-use changes could lead to destruction on the entire tropical forest system and species in the world. It is a challenge to exam all the cases and impacts at a short time because of the vast regions and diverse drivers of the tropical forest. It will be effective to concentrate on a specific forest plot or nature reserves in future studies. At the same time, it will be effective to conduct a systematic study on the specific impact of land-use changes on a threatened or rare species for conservation. Researchers can gather more detailed data on the effects of land-use changes on the tropical forest. This targeted approach can help inform conservation efforts and policy decisions to protect tropical forests and the species in the face of increasing threats.

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