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AMAZON RAINFOREST WILDFIRES: CAUSES AND IMPACT ON MAMMALIAN AND AVIAN DIVERSITY

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ABSTRACT

Amazon rainforest is having huge role in the regulation of the environment as it provides massive amount of oxygen to the Earth and is one of the most important carbon sinks. World's most important plants and animal species are present in the Amazon rainforests. The Amazon rainforest wildfires especially wildfires of 2019 are one of the major global issues. There can be natural and human activities which can cause wildfires in Amazon Forest. The impacts due to wildfires in Amazon rainforest includes conversion of Amazon Forest into white savannas, threats to human security, negative effects on health, decrease in rainfall, effects on biodiversity, biomass burning aerosols, effects on ecosystem, increase in carbon emission, greenhouse effect, global warming and impact on environment and climatic feedbacks. In the end, some suggestions and strategies are given for the control of wildfires in Amazon rainforest.

1. INTRODUCTION

The Amazon rainforest comprises of 670 million hectares of area. The Amazon rainforest is a major source of producing oxygen for the globe and also constitutes 10 percent of plants and animal species in it. It is also a very important carbon sink of the world. The Amazon rainforest wildfires will cause the decrease of oxygen which is produced by the forests. It will also cause an increase in the carbon dioxide level. The Amazon rainforest is considered to be one of the biggest tropical rainforests. It also plays an important role to regulate the temperature of the Earth (D'Amore, 2019; Mufson & Freedman, 2019). The Amazon rainforest is present in different countries of South America. This includes Brazil, Peru, Venezuela, and Colombia, etc. Amazon rainforest includes 20% of birds' species which are present in world. Thousands of species of insects are also present in them. They also include terrifying species for example Anaconda, Jaguar etc. So due to these reasons the protection of Amazon rainforest is an important issue. As the temperature is increasing abruptly it will cause huge destruction of Amazon rainforest (Isola & Yusuf, 2020). Approximately, 60% of the Amazon rainforest is present in Brazil. As we know that Amazon rainforest is an important carbon sink. So, it is also having relation with the climate change and global warming (de Oliveira, 2019). According to Brazil's National Institute for Space Research (INPE) there had been approximately 76,000 wildfire spots in Brazil in 2019. Different institutes for example Global Wildfire Emission Database Project had also obtained the same results of the fire (Escobar, 2019). These fires had also caused negative ecological impacts on the biodiversity of birds, vertebrates and different arthropods (González *et al.*, 2022; Silveira *et al.*, 2010). These wildfires are converting rainforests into agricultural areas. The wildfire in United States in 2000 is considered one of the worst Amazon fires. It burned the area of 3.4 million hectare. Amazon rainforests are sensitive to fires causing change in the structure and composition of the forest (Pivello, 2011). In the

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present times wildfires return after 5 to 10 years but in the past this time span was more. These fires convert the forests into savannah. Most often fire occurs in states of Mato Grosso where the temperature is seasonal and is affected by human activities. In Brazilian Amazon rainforest, destruction is occurring and is destroying 2 million hectares of forest per year (Laurance *et al.*, 2001).

The wildfires of Amazon rainforest in 2019 had been the most important issue globally. This news was one of the most important headlines all over the world. The smoke which was emitted due to forest fires was also visible from the space (Smith, 2019). This smoke had covered lots of cities some of them were even very far away from the forests. Sao Paulo which is the city of South America was completely covered in dark smoke on 19 August 2019. So, we can say that the environmental changes due to these wildfires would cause severe effects on all species on this planet. It will also cause huge release of carbon dioxide into the atmosphere. These will cause negative impact on biodiversity of animals. The human health will be disturbed and the economic damage will also be huge (Aragão *et al.*, 2018). According to estimates, 92,000 km^2 areas of the forests were affected by the fire in 2019. The Moderate Resolution Imaging Spectroradiometer calculated burned area in the Amazon rainforest. According to them 69,000 Km^2 area was burned in Amazonian basin (Giglio *et al.*, 2016). Amazon rainforest is having a huge variety of flora. These fires cause increase in carbon dioxide which will cause increase in global temperature. So, this is one of the most important issues in the world (Mohla *et al.*, 2020). These forests are considered one of the richest regions on the Earth. Almost 25% of the biodiversity is present in these forests. These are also having a huge rule in biogeochemical cycles (Malhi *et al.*, 2009).

The major reasons of ignition in forests are forest fragmentation and logging. It also increases due to human settlements near these forests. Due to these reasons 28% of Brazilian rainforest is under the pressure of fire ignition (Barreto *et al.*, 2006). The years 1997, 1998, 2005 and 2007 were the times of drought in Amazon regions. These times resulted in extensive wildfires in the Amazon rainforest (Alencar *et al.*, 2004). According to past 10 year studies it is noted that there is change in rainforest structure and there is also increase in fire events. The trees are having less tolerance towards fire. Even small ignition can result into huge number of trees death (Brando *et al.*, 2014). There is also a huge loss of small and large trees. There is also a decrease in biomass canopy structure. The large vertebrate species had also been decreased due to these wildfires. There is an overall drop in vertebrate and plant species (Cochrane & Schulze, 1999).

Amazon rainforest is an important carbon pool. It also plays an important role in climate stability. The environmental changes are having huge impact on tropical forests of South America (Velastegui *et al.*, 2022). It results in land cover change. The main causes which are affecting Amazon rainforests are deforestation, forest degradation and climate changes. Forest fires and increase in CO_2 has also affected the Amazon rainforest (Nobre & Borma, 2009). There are 9 Amazonian countries in total. However, 80% deforestation occurs in Brazil. Amazon region lost approximately 47.8% of tropical rainforest (Hansen *et al.*, 2008). Amazon rainforest wildfires can be classified into three categories. First one is deforestation fires which cause intensive fire. Second is the maintenance fire. The third category is accidental fires which cause low intensive fire (Cochrane & Laurance, 2008).

In the past, Roraima fires were also very intensive. These fires occurred in 1997. At that time the governor of Roraima declared it a state of emergency. The help was requested from United Nations to control the fire (Cochrane & Schulze, 1998). As stated earlier severe drought were present in years 1997-1998. It causes wildfires and stress to the trees in huge amount. Approximately 39,000 Km^2 of Amazon Forest was burned and massive area of Brazilian Amazon caught fire (Nepstad *et al.*, 2004).

CAUSES

Sometimes fire is also used for the purpose of land management in forests. Although it is one of the reason of wildfires in Amazon rainforests but there are also some other factors. These include forest fragmentation, logging and increase in agricultural activities. Extreme drought also causes wildfires. The burnt forests are having higher chances to catch fire again because it is having higher temperature and are extremely dry so they could catch fire easily. These fires are changing the composition and structure of soil and other plant species (Aragão & Shimabukuro, 2010). All these reasons of wildfires are due to human involvements or we can say that they are not natural causes of wildfires. Human activities can cause wildfires in Amazon rainforest very easily. These can cause fire in the core areas of the forest.

Natural causes of wildfires in Amazon rainforest

Wildfires can be started naturally. This can occur due to strike of lighting and extreme hot weather conditions. These wildfires can be very extreme and can become uncontrollable. The examples include wildfire in Cerrado due to lightning (Ramos & Pivello, 2000). The recurrent fires can happen due to following reasons. It can occur due to dry season or due to flammable materials present in grassy herbs and shrubs (Pivello *et al.*, 2021). Volcanic activities might also be the cause of natural wildfires. Most of lighting incidents occur in Brazil. The number of lightning strikes is increasing day by day and it is leading to cause wildfires in Amazon rainforests. These may be due to climate change and global warming.

Human activities causing wildfire in Amazon rainforest

Human activities are the most important cause of wildfires in Amazon and Cerrado regions (Oliveira *et al.*, 2022). Use of fire by humans to remove natural vegetation is a common practice. It is done to install crop culture and to burn the residues which are present in the soil. It can cause small accidental fires which convert into large wildfires very abruptly. In these regions production of beef cattle is increasing. It is also one of the major reasons of wildfires. The cattle were introduced in this region by Portuguese in 17th century. The production at the large scale started in 1900. The increase in the trend of wildfires was observed. This increase in the wildfires might be due to cattle grazing (Pivello, 2011). Logging activities might be one of the reasons of wildfires in the Amazon region. The decrease in the number of large trees decreases the moisture content in the forest making the forest highly sensitive to the wildfires. These fires can also come from the nearby burned areas (Cochrane *et al.*, 2009). The high temperature in the forest can create water stress in that region which can lead towards wildfires. But the most important reasons of wildfires are deforestation, logging and fragmentation (Malhi *et al.*, 2009). From the early 1970s, the fire situation in Amazon rainforest had changed. Brazil had made roads that connect Amazon to other parts of the country. These factors are causing fragmentation of the Amazon rainforest. To maintain pastures and agricultural lands fire is most commonly used. In the last few years almost 15% of Amazon had been cleared and huge area of Amazon is treated with fire for the management of land which is the reason of wildfires in Amazon (Cochrane & Barber, 2009).

Deforestation

Deforestation is increasing rapidly due to following reasons. The population of Brazilian Amazon is increasing due to immigration of people from other countries into this region. Mining and the construction of roads are increasing. The formation of highways, industrial logging and colonization near the forests are resulting into deforestation. One of the major reasons of forest loss is wildfires (Fearnside *et al.*, 2012). These are affecting canopy of forests. The fuel moisture of soil decreases. This results in the increase of the temperature. The wind speed increases and humidity level in Amazon rainforest had been decreased. This all is resulting in the wildfires (Barkhordarian *et al.*, 2019). It produces dried conditions in the tropical moist rainforest as well and leads to increase in temperature. It increases the chances of more extreme wildfires and may also burn the interior forests (Lawrence & Vandecar, 2015).

From the above information we can conclude that human activities are the major reason of wildfires in Amazon rainforest. Land cover change is causing wildfires. Climate change and human activities would be the reason of increase in wildfires in the near future (Cochrane, 2002). The temperature is increasing very rapidly. Due to it precipitation is reduced. The conditions in the Amazon rainforest are getting dry and making the forest more susceptible to catch fire. The intensity of drought will estimate the intensity of the wildfires in Amazon rainforest. As the prime example of the fires which occurred in southwest Amazon in year 2005 (Solomon *et al.*, 2007). The infrastructure projects and urban development near the Amazon basin had caused the migration of the people in these areas (Fearnside, 2002). Due to these reasons the population of Amazon had increased a lot. From the year 1960-2000 the population had increased up to 20 million from just 2 million (Soares *et al.*, 2006).

IMPACTS

The wildfires are having huge impacts on the environment and on human beings. It causes losses to human beings. It affects the air quality, soil and biodiversity. So, it is important to learn and understand about impacts of these wildfires on our ecosystem (Finlay *et al.*, 2012). The wildfires had been increased in the recent years due to intense droughts. The wildfires had also been increased due to forest degradation and fragmentation (Bullock *et al.*, 2020). The wild fires lead to soil degradation. It also causes biological invasions. The number of wildfires caused by humans is increasing in number and intensity now as compared to past. This is because people are performing burning processes in dry season as well. These wildfires then become uncontrollable. The dry season wildfire causes huge impacts on biodiversity and causes extinction of plants and animal species. It also causes pollution, destruction of natural biomes and soil erosion. It is affecting the carbon cycle. All these are affecting agricultural production (Mohla *et al.*, 2020). The destruction of these forests will cause world climate change. Each and every person will be affected due to this climate change. Most of the Amazon forest is present in Brazil. However, the climate change and global warming will not only affect Brazil but it will affect the whole planet. The wildfires of 2019 were so intense that the smoke of the fires travelled to the cities which were present 3,000 km away from the Amazon forest. It caused foggy atmosphere in Sao Paulo which is the city of Brazil. NASA also stated that fires were clearly visible from the space even without satellite imagery (Rosen, 2019). In the following headings some of the impacts which are caused due to wildfires in Amazon rainforest had been discussed.

Impacts of wildfires in the bamboo dominated Amazon rainforest

When the intensity of fire is high it will cause more damage in the forest. It is also related to the drought sensitivity. The wildfires had also affected the bamboo dominated tropical forests. It had caused the extinction of the species which are sensitive to wildfires. The types of trees present in eastern and western Amazonian forests show different kinds of responses towards the wildfires. It also depends on the type of soil present in the forest. According to the past researches and studies wildfires had caused less damage in south-western Amazon Forest. Wildfires had affected biodiversity more in Central and Eastern Amazon forests. Bamboo-dominated forests are present in South America. It houses many important, rare and endemic species of animal. The wildfires and droughts are affecting these forests a lot. The fires are increasing the density of bamboo culms (Smith & Nelson, 2011). In 2015 and 2016 when there were drought forest fires burned approximately 9246 km^2 of Brazilian Amazon Forest. These fires were greater than the fires which occurred in the previous drought of 2010. The 2015-2016 droughts were very extreme. They even affected the moist regions of Central Amazon forest. It caused increase in temperature and decrease in rainfall (Silva *et al.*, 2019).

Conversion of Amazon Forest into white savannas

The vegetation shift had been observed in Amazon Forest. Temporal shift had occurred in tree species. The loss of important tree species due to repeated wildfires indicates the conversion of Amazon Forest into white sand savannas. According to one research paper they estimated change from lush green Amazon Forest into savannas within 40 years. This destruction which is occurring due to wildfires can push the forest to tipping point. This is going to cause huge impacts on environment (Flores & Holmgren, 2021).

Threats to human security

Biodiversity loss will have huge impact on environment. The wild animals which would escape wildfires would be transported to other countries. This will also lead to some other problems as well. These fires will upset the ecosystem. It will disturb the food chain causing threat to food security for humans and animals as well. The wild fire will cause loss of insects, birds and animals. It will reduce the richness of species on the Earth. The Amazon River will also be affected due to these wildfires. The heat from the wildfires will increase the temperature of the river and will lead to the death of several fishes, dolphins, armadillos etc. It will affect the water ecosystem very badly. The wildfires will cause habitat loss. This will lead to biodiversity loss and then extinction of species. These all will pose huge challenge to mankind (Upadhyay, 2020).

Impact on health

The wildfire leads to increase in release of carbon dioxide and causes air pollution. This will cause huge impact on human health. The long-term effects on human health would be severe (Epstein, 1999; Wu *et al.,* 2016). Wildfires which are causing landscape changes are disturbing ecological elements and will result in increase of vector-borne and zoonotic diseases. The mosquito production had increase in Amazon forest which resulted in more cases of malaria in this region (Rodriguez *et al.,* 2017). Many zoonotic diseases are endemic in Brazilian Amazon. Wildfires may cause increase in these diseases due to change in soil structure. The Amazon rainforest have many zoonotic bacteria, viruses and parasites. These can become adapt to the changing landscape due to wildfires. It can lead to emergence of new diseases in different areas (Cascio *et al.,* 2011). The example includes yellow fever epidemic which began in Brazil in 2016. The vectors of this disease were *Haemagogus leucocelaenus* and *H. janthinomys*. These are wild mosquitoes (Possas *et al.,* 2018; Brock *et al.,* 2019).

Decrease in rainfall

Studies have shown that forest biomass stocks and processes such as tree growth, recruitment and mortality change remarkably after Amazon wildfires. These average gradient rainfalls lower than 100 mm a month in a dry season causes the occurrence of huge wildfires. Fires occurring in 1998-1999, 2009-2010 and 2015-2016 were limited have shown that in the Central Amazon there are high levels of rainfalls (Berenguer *et al.,* 2021; Berenguer *et al.,* 2018).

Effects on biodiversity

Amazon is the area with high diversity of species having great medicinal and molecular value, most of which is still undiscovered. Studies from few localities of Amazon have shown that wildfires tend to change the faunal composition of that specific area, understanding of which is essential for conservation strategies. It is supposed that a single fire incident can have its effects on land for at least one decade. In Roraima and Mato Grosso Leaf litter ant communities were greatly changed by wildfires and it also results the change in seed removal, predation rates and herbivory activities (Silveira *et al.,* 2013). Small non-volant mammal's abundance and richness is negatively affected by Amazon wildfires (Mendes *et al.,* 2012). *Hylaeamys megacephalus* found in upland Brazilian Amazon basin forest and absence of terrestrial species such as *Necromys lasiurus* and *Oligoryzomys microtis* from wildfire areas is due to the burning pattern of fires and humidity in that area. Moreover, terrestrial, burrowers and ground dwelling species such as *Didelphis marsupialis* and *Metachirus nudicaudatus* are more susceptible to the Amazon fires in brief period of time.

Impact on bird's diversity

It was found that low intensity fires can affect understory bird communities up to 10 years. Especially, birds with specialized behaviors and foraging strategies were more and then less abundant on place of wildfires followed by 1-3 years. Birds from Trochilidae and Pipridae families who used to take advantage of increased understory flowering and fruiting were found abundant in the burned areas (Mestre *et al.,* 2013).

Biomass burning aerosols

Between August and October, the average aerosol optical depth at 550 nm surpasses 1.0 at Amazon and Brazil through dry biomass burning season and during the raining season the value is below 0.2 (Moreira *et al.,* 2017). These biomass particles and aerosol layers decreases the solar radiations cool off the surface air and upsurges the diffuse radiation fraction of the Amazon rainforest, which ultimately affects surface's energy as well as CO_2 changes. According to a study carried out to check the impact of biomass burning in Amazon during 2010, there was an increase of 27% and 10% in gross primary production and plant respiration respectively.

Effects on ecosystem

Reduction in seed availability in the soil's litter and upper layers, decreased fruiting and flowering in and near burned areas decreases the chances of the species recovery (Gerwing, 2002). Especially recovery of wind-borne, light-demanding pioneer species, unburned forest islands, gallery forests, regenerating vegetation, grasses, small vines become more prolonged due to wildfires. There are different, complex, dynamic and ununderstood responses of animals to wildfires, due to which some species get rich and some decline (Fredericksen & Fredericksen, 2002).

Carbon emission

Depending upon previous fires and land usage net annual carbon emissions ranges from 7.5 to 70 Mg ha in Amazon. One hectare of forest fire releases 200 metric tons of carbon from CO_2. Equally 41% of the world's fossil fuel emit from the Mexico, Roraima and Brazil due to wildfires. South Asia, Africa, Central and South America are also known to have millions of hectares of unconsumed biomass from killed trees which keep emitting carbon (Page *et al.*, 2002).

Greenhouse effect and global warming

Greenhouse gases are also emitted due to burning of vegetation during wildfires caused by unsuitable agronomic practices (Phulpin *et al.*, 2002; Laurance *et al.*, 2001). It is found that there is an interaction among greenhouse gases accumulation in the atmosphere and occurrence of wildfires (Lapola *et al.*, 2009; Balch *et al.*, 2011). It is estimated that there is an increase of additional 1.5 °C temperature causing global warming and decrease in 64% of annual precipitation due to Amazon wildfires (Cox *et al.*, 2004). This situation favors the Amazon to be bare ground with high values of dry season, decreased precipitation and temperature increase (Betts *et al.*, 2004).

Effects on local tribes

Hundreds of humans suffer and dead due to accidents (ships, automobiles and plane crash) and smoke related illness caused by smoke produced covering the area over the Amazon, Indonesia and Brazil. Prolonged exposure to smoke, its constituents and concentration directly cause respiratory and cardiovascular diseases in humans living in the affected areas (Cochrane, 2002).

Impact on environment and climate feedbacks

Amount of vegetation and rate of transpiration reduces due to wildfires, which ultimately lowers the humidity levels, affect rainfalls and increases the chances of future fires in affected area (Laurance & Williamson, 2001). The ability of forests to retain water also reduces causes flooding, soil erosion, soil degradation, seasonal water shortages and regional draughts. Aerosols from burned forests cause reduction in relative humidity and temperature disturbs regular cleansing process and increases intensity of lightning strikes (Ramanathan *et al.*, 2001).

2. CONCLUSION

This review article focused on the wildfires in the Amazon rainforest and it is an important study because it highlighted the main causes which results in the wildfires and the impacts which are caused in the environment due to these wildfires very clearly. Indeed, if strategies could not be implemented in near future, it can have catastrophic effects on Amazon. It will be a threat to human life, indigenous species and atmosphere, as it is clear from the fire event occurring in 2019. It is estimated that till 2050, only 16% of the Amazon's forests will remain due to deforestation and continues fire events (Ruiz *et al.*, 2019; Brando *et al.*, 2020; Cardil *et al.*, 2020). To avoid large scale forest fires, there should be forest safety policies, long-term post-fire monitoring and recovery, mapping of forest fire risk and potential fire impact, implementation of education and awareness programs for agriculturalists especially the inhabitants and native dwellers of the Amazon, application of penalties, direct control of biomass burning, public and financial policies to inspire small-scale agricultural projects (Nepstad *et al.*, 2014; Barlow & Peres, 2008; Le *et al.*, 2017; Silva *et al.*, 2018).

3. CONFLICT OF INTEREST

All authors have declared that there is no conflict of interests regarding the publication of this article.

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