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IMPACTS OF CLIMATE CHANGE ON AMAZON FOREST FIRE

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Abstract

With the temperature rising caused by the global climate change, forest fire season has increased longer and fire severity in the Amazon has been more intense. Some extreme drought events in the Amazon in 2005 and 2010 caused severe fire activities during the fire season. The effects of climate change on forest fires in the Amazon have been discussed in the paper. Warming temperatures have increased the forest dry season; subsequent fires have higher intensity and severity, with fire season expansion in the Amazon forest. Some data and research proved that dry seasons would affect the fire season and fire activity. The consequence of forest fires in the Amazon on environmental conditions, economic development, and human health has been discussed in the paper as well. Greenhouse gas, timber products profits reduction, and harmful smoke release are the three major negative impacts caused by forest fires. Forest fire can produce a large amount of carbon dioxide into the atmosphere and release smoke, which makes environment conditions worse and can harm human health. Additional timber loss due to forest fire causes timber industry loss as well. What's more, fire monitoring, sustainable management, law enforcement, and afforestation are suggested in the paper as solutions in the recommendations section.

Key words: climate change, Amazon, rainforest, impacts, solutions

1. Introduction

The Amazon Rainforest is a large and tropical rainforest in South America, covering the largest proportion of Amazon Basin with an area of 2,100,000 square miles out of 2,700,000 square miles. Nine nations in this region own territory. In addition, the Amazon Rainforest has a large distribution, contained within Brazil with approximately 60 percent of rainforest, followed by Peru with 13 percent and Colombia with 10 percent (Wikipedia, 2014). The Amazon Rainforest is the largest tropical rainforest with richest and most varied biodiversity in the world, comprising millions of species, such as plants, insects, animals, birds, and others. Moreover, many species in this rainforest are still unrecorded by science (Encyclopadia Britannica, 2014). The Amazon rainforest is a major sink for carbon

dioxide as well, and there are a wide variety of trees and luxuriant vegetation to maintain the balance of natural ecosystem. In recent years, the Amazon Rainforest is being affected by lots of biotic and abiotic factors, such as climate change, hunting, deforestation, insects, forest fires and so on.

According to Rachel Nuwer (2013), fire is a quickly growing threat to the Amazon Rainforest over the past decades with the effects of climate change. The future fate of the Amazon rainforest is of concern to us all. The biodiversity and rainforest ecosystem balance become more difficult to maintain under increasing forest fire conditions. While climate change is a big problem and crisis affecting the ecosystem balance of the Amazon Rainforest, the particular effects on forest fire (i.e. intensity, frequency, etc.) and some recommended solutions surrounding climate change and forest fire in the Amazon Rainforest are going to be discussed in this essay. Therefore, the objectives of this paper are to review the literature on this topic and summarize key findings from this literature.

2. Background

Climate change threatens disaster in the Amazon Rainforest. Figure 1 shows the change of drought conditions from 2005 to 2010. It can be obviously seen from the Figure 1 that the drought condition in the Amazonia becomes more and more worse. In 2005, the Amazon Rainforest suffered the worst drought over the century, leading to seventy million hectares of trees in the Amazon rain forest being affected (Fernandes, 2013). The Amazon rain forest is drying out, and the length of the dry season is becoming longer and forest fire risk is increasing because of the global warming caused by climate change. What's worse, these millions trees are not yet recovered when a second, more severe dry spell struck the world's largest rain forest in 2010. According to Joe Romm (2011), droughts co-occur with peaks of fire activity. If climate conditions can't be improved, forest fire could double by 2050 with the increasing temperature approximately1.5°C to 2°C (The World Bank, 2013).

A NASA study (Trumbull, 2013) showed that 3 percent areas of the Amazon Rainforest have been burned by fire in the past 12 years. The study estimated more than 33,000 square miles suffered understory forest fires between 1999 and 2010.

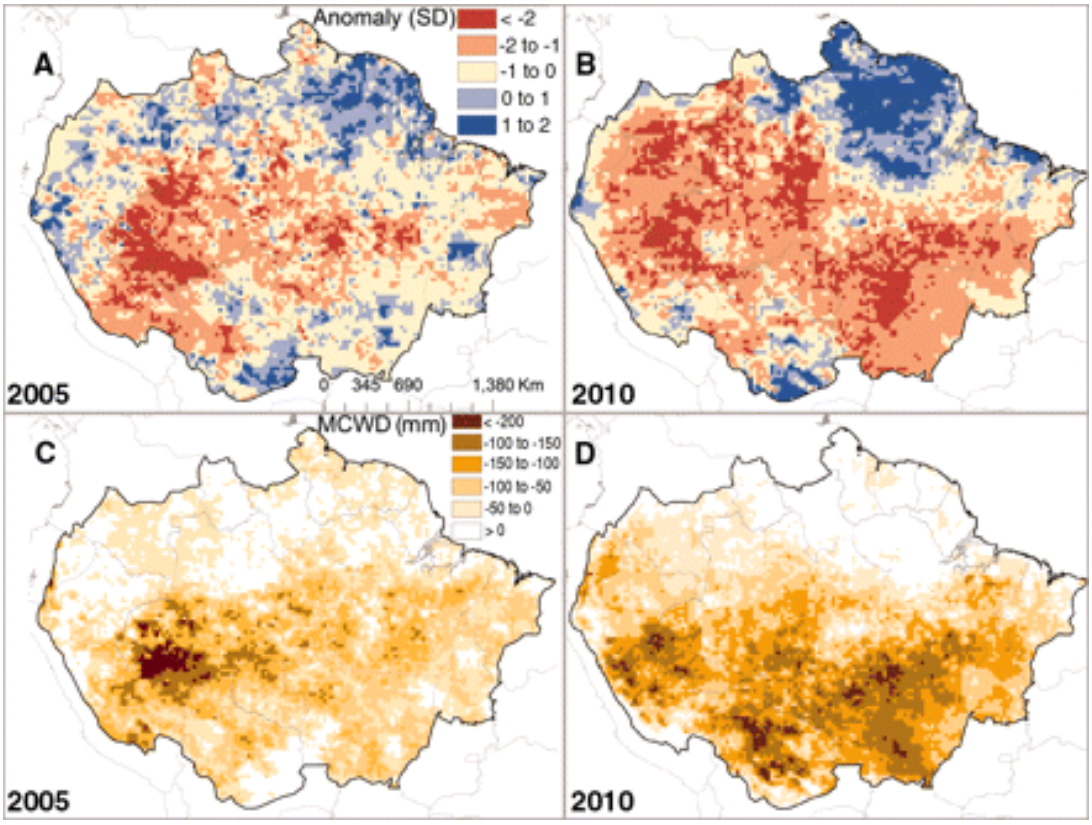

Figure 1 Rainfall deficits in the 2005 and 2010 Amazon droughts (From Lewis et al., 2011). (A and B) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st century in Amazonia. (C and D) The difference in the 12-month (October to September) Maximum climatological water deficit (mm) from the decadal mean (excluding 2005 and 2010), a measure of drought intensity that correlates with tree mortality. (A) and (C) show the 2005 drought. (*Source from: AAAS, 2011*.)

3. Summarize of Findings from the Literature

Climate change will increase the fire severity in fire seasons, for several reasons. Firstly, rising temperature will increase the evaporation, leaving less water contained in the trees or plants and providing good environment conditions for fire-spread between trees or

plants, which can contribute to higher fire intensity and severity. Secondly, climate change causes higher temperatures in the tropical Atlantic, leading to rainfall shifts that leave much areas of the Amazon drier and more vulnerable to drought. The relationship between the higher temperature and the change of precipitation patterns in the Amazon regions is uncertain, but lots of climate models present that rising temperature could cause warmer sea surfaces in the north Atlantic and tropical east Pacific, changing the atmospheric circulation and reducing precipitation in some regions (Good et al., 2008; Harris et al., 2008). Thirdly, climate change is one of the factors that increases understory fires in the Amazon Rainforest in addition to deforestation and land management. According to Hansen (2013), Morton said the forest area affected by understory fires was several times greater than the deforestation area for expansion of agriculture in years with most understory fire activity, such as 2005, 2007, and 2010.

3.1 Fire Season

According to researchers from NASA and the University of California, Irvine, the 2013 Amazon forest fire season had the potential to be a devastating one, and the severity is higher than in 2011 and 2012 for many the Amazon forests in the southern Hemishere (NASA, 2013). The approach they took is to look at sea surface temperatures in the Atlantic and in the Pacific and to relate those two patterns to fire observed by NASA satellites over last decade. Figure 2 shows the fire severity model produced by researchers to predict the Amazon forest fire risk in 2013. Dials indicate regions in the southern Amazon forest. Green color means below-average fire activity while red and orange colors present above-average fire activity during the dry season in 2013 compared to the 2011 and 2012 average fire activity. We can see from the Figure 2, almost all regions' forest fire activity is higher than average in 2011 and 2012 excepting Maranhao and Peru. Mato Grosso and Pará are the two

majority regions with higher burning activity among the Amazon regions. Other important regions in the Southern Amazon are proposed to have higher average burning activity as well, such as the Brazilian states of Rondônia and Acre, and the Bolivian departments of Santa Cruz and Pando (NASA, 2013).

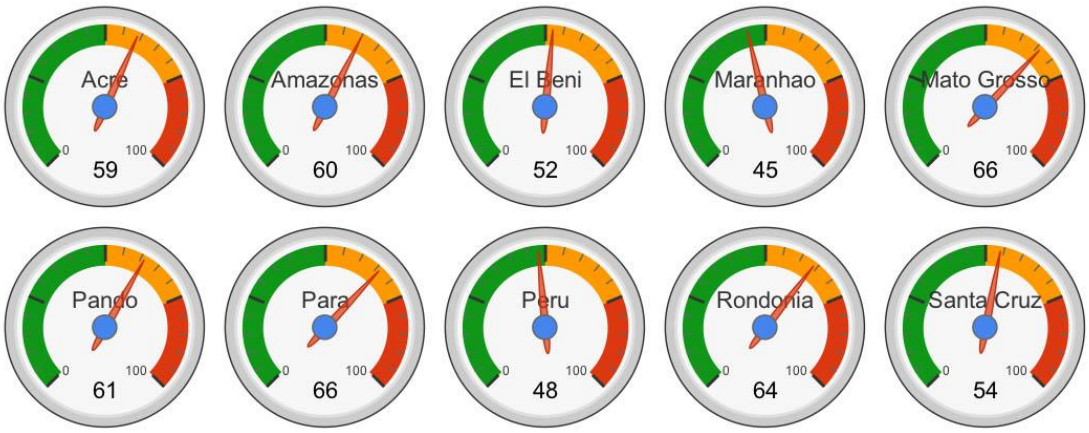

Figure 2 Outputs of the Fire Severity Models for Amazon Regions in 2013. *(source from: NASA 2013)*

3.2 Fire Severity

Climate change increases the length of dry season over southern Amazonia since 1797, increasing the fire severity (Fu et al., 2013). A new study indicates that compared with projections made by the climate models used in the latest report by the Intergovernmental Panel on Climate Change (IPCC, 2013), stronger and longer seasonal drying lead to the southern regions of the Amazon rainforest experience a much higher risk of dieback, increasing the fire severity and intensity (Science News, 2013). Figure 3 shows the relationship between the dry season ending (DRE) and forest fire danger index (FFDI) and fire counts. The main fire season for the Amazon Rainforest is the period August to October,

and a delayed DSE will extend the fire season, causing the fire counts increase during October and November. As the Figure 3 shows, with the increase of dry season, the fire activity increases as well as FFDI becomes higher. A higher FFDI means there is a favorable meteorological condition in forest for fire. Once increased fire activity occurs in the Amazon Rainforest, the consequence will worsen, especially for the Amazon Rainforest with large areas of forest, leading to more challenges on forest fire fighting. Some other studies have suggested that climate change could significantly dry forests in the Amazon Basin and Africa, increasing their risk of forest fire (Butler, 2012).

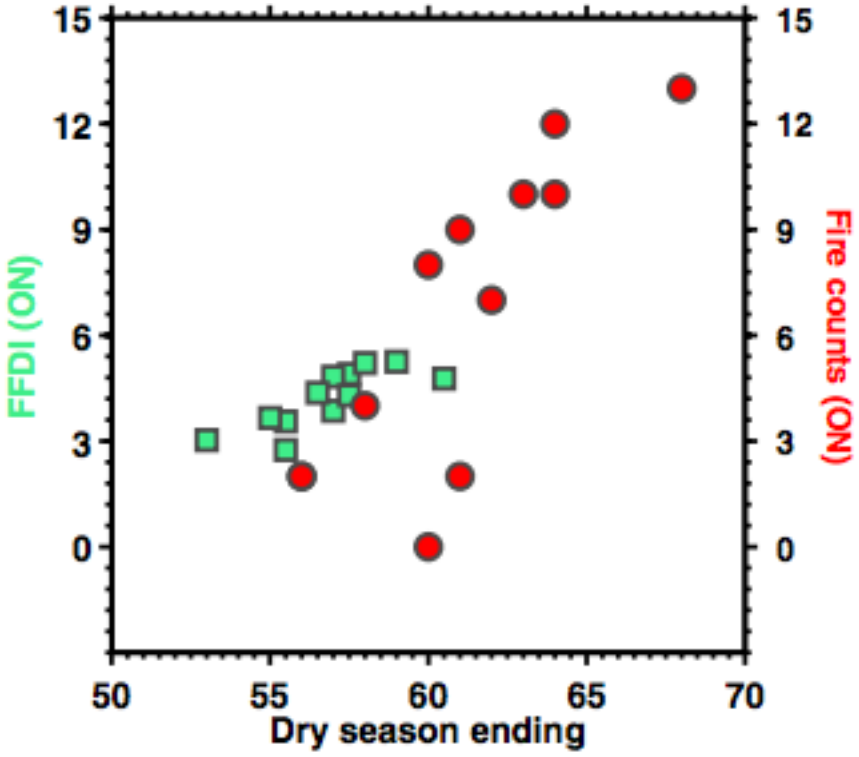

Figure 3 The length in days of the dry season ending (DSE) versus FFDI and fire count in October and November for the period of 2000-2011. The fire counts are derived from the moderate resolution imaging spectoradiometer fire-count data, FFDI is first derived from the ERA-Interim and NCEP reanalysis, respectively, and then averaged to obtain its values shown in the figure. *(Source from: Fu et al, 2013)*

4. Consequences of Changes in Fire Season/Severity on Ecosystem, Environment, Society and the Economy

Increasing fire risk with longer fire season and higher fire severity in the Amazon Rainforest creates a series of problems to ecosystems, environments, and the economy.

4.1 Rainforest Ecosystem Effects

Increasing forest fires in the Amazon break the balance of the rainforest ecosystem. Firstly, surface fires are increasingly common in the Amazon forests due to the increase of dry season. When there are lots of brushes, leaves or dry wood debris, fires can spread out rapidly, affecting surrounding forests areas, especially during drought seasons. The new research shows that knee-high fires can make significant changes in forest species composition (Butler, 2008). Secondly, initial understory fires may increase forest flammability, thereby creating potential long-term changes in the Amazon forest structure (Morton, 2008). Subsequent fires burn with increased severity and intensity, leading to higher tree mortality and the loss of biodiversity, such as decreasing the wildlife habitat, disrupting plant, and destroying animal communities. Forest fires also affect the soil texture, moisture, and nutrients, reducing forest site productivity.

In addition, a study by IMAZON (the Institute for Man and Nature in the Amazon) found that more than one-acre of fire activity is undetected under the forest canopy for every acre burned or cleared which shows up on satellite imagery (Butler, 2012). These understory fires can occur for months with warm temperatures and little rain, leading to fires in these previously burned areas which will be more intense and destructive in the future (Butler, 2012). Some other studies have shown that the Amazon rainforest can quickly transition to savanna after only two or three small surface fires (Mongabay, 2012).

Forest fire impacts on ecosystem resources can be positive as well, depending on the

characteristics of fire site, fire severity, occurring time, and resource values. With the fire season longer, fire severity and negative effects on the Amazon Rainforest ecosystem become higher, but it doesn't mean that any fire in rainforest creates destructive impacts on forest ecosystem. Some benefits can be created by fire, such as reducing fuel loads, disposing of slash, preparing seedbeds, thinning overstocked stands, increasing forage plant production, improving wildlife habitats, changing hydrologic processes, and improving aesthetic environments (DeBano et al.,1998). Compared with the scale of problems created by fire in Amazon, the positive functions of fire can be ignored to some degree.

4.2 Greenhouse Gas Impacts

Fires in the Amazon Rainforest create other environmental problems in addition to affecting the rainforest ecosystem and killing wildlife. The most important environment issue caused by forest fire in the Amazon is the increase of greenhouse gases. When fires are severe enough, the loss of rainforest could cause the release of large volumes of the greenhouse gas carbon dioxide into the atmosphere. The fires release thousands of tons of carbon into the atmosphere, producing more smoke in the Amazon, causing local airport closings and hospitalizations to avoid breathing in smoke (Butler, 2012). In 1987, about 19,300 square miles (50,000 sq. km) of the Brazilian Amazon burned in the regions of Para, Rondonia, Mato Grosso, and Acre during a four-month period (July-October). The burning released carbon dioxide including over 500 million tons of carbon, 44 million tons of carbon monoxide, and millions of tons of other particles and nitrogen oxides (Butler, 2012). With the different length of fire season and fire severity in different year, the amount of carbon dioxide that released will be different. According Butler (Mongabay, 2014), the Amazon experienced extremely drought in 2010, releasing approximately 500 million

metric tons of carbon into the atmosphere due to forest fire. However, during the wet fire season year of 2011, the amount of carbon release due to forest fires decreased by more than 200 million tons of carbon. In other words, during dry 2010 the Amazon exhaled deeply, while in wet 2011 it exhaled slightly.

In addition, as the largest tropical forest in the world, the Amazon plays an important role in maintaining the global carbon balance and regional climate regimes as well (May et al., 2013). However, forest fires will release massive carbon dioxide into the atmosphere, increasing greenhouse gas as well as weakening the forest functions on improving regional climate condition. To some degree, it will make climate conditions worsen regionally.

4.3 Human Health and Economy

A large number of smokes produced by forest fire during fire season or extremely dry years do have a significant negative effect on human health in the Amazon (Mendonça et al., 2004). For example, more than 40,000 people in the State of Acre sought medical care because of a persistent smoke produced during the extreme drought seasons in the Southwest Amazon in 2005 with the abnormal warming of the tropical North Atlantic. If fires occur in the lowerland and spread quickly without control in the drought seasons, it may threaten the local people's lives and lead to considerable poverty.

In terms of economic loss, in 2005, 300,000 hectares of forest in the region experienced burning by multiple fires (Brown et al. 2006; Aragão et al., 2007), causing large timber value loss and non-timber forest products loss. Direct economic losses from widespread fires in 2005 amounted to US$50 million (Brown et al., 2006). Taking non-timber forest products in Amazon as an example, Table 1 demonstrates the value created by the main non-timber forest products (NTFP) in the Brazilian Amazon Rainforest from 1985 to 2008. From Table 1 we can see that most non-timber forest products have the highest value in

1990, and then most products experienced shapely decreased value in 1995 due to the extreme fire activity in 1995. Subsequently, the NTFPs' value increased a little during 2004 to 2008. The economic loss in NTFPs from the 1985 to 2008 is about $26,659,895 with the highest value loss from 1990 to 1995, which was over $143 millions.

Years	1985	1990	1995 (Extreme fire year)	2004-08 (Average)
Carnauba wax	6,273,611	12,299,941	2,648,493	7,000,228
Brazil nuts	19,378,986	7,224,062	5,688,986	19,436,001
Heart of palm - açaí (1)	5,406,838	16,327,742	13,136,006	3,792,167
Piaçava fiber	20,362,390	69,270,337	13,660,332	37,994,790
Babaçu (oil kernel)	40,563,277	30,111,716	38,372,301	47,989,670
Açaí fruit	28,554,855	45,831,745	34,815,441	37,824,060
Erva Mate	24,918,384	92,110,484	34,875,137	39,328,250
Total	223,545,968	293,162,288	150,106,456	196,886,073

Table 1 Value of Principal non-Timber Forest Products in Brazilian Amazon Rainforest from1985 to 2008. Current US$ (IBGE, various years).

The above data only presents the 8 major NTFPs among the richest NTFP resources. However, it indicates the large economic loss caused by forest fire in Amazon. Besides the

economic loss caused by NTFPs, timber industry loss, agricultural loss, and other aspects contribute to the economic loss as well.

5. Implications of Findings for Forest Management Policy and Actions

With continuous increase of forest fire severity, some actions should be done to prevent or reduce the fire disaster on the Amazon Rainforest.

5.1 Fire Monitoring

In order to effectively prevent and control fires, early fire detection and monitoring is an imperative necessarily (Cheng, Jin, 1992). In recent years, more and more people use remote sensing as a tool for forest conservation management. Compared with readily available satellite imagery popularized by Google Earth, some new remote sensing applications provide more functions, such as allowing researchers located anywhere in the world to detect fires using a computer or handheld device (Butler, 2008). Remote sensing can provide more comprehensive information on forest characteristics, such as vegetation cover, forest cover, drought conditions, etc., giving a broad coverage over wide area and helping managers to understand conditions access the whole forest. In sum, forest monitoring is essential for preventing forest fire and reducing fire effects on environment, communities, and the economy, as well as supporting effective measures taken in time while fires occur in the Amazon forest.

5.2 Sustainable Development

Fire monitoring can detect the forest current fire conditions and predict the trends of fire severity and fire season in the next few years. However, sustainable forest management on

forest is required as well to enhance the ability of forest to vulnerable to forest fire. The two major components for sustainable management in Amazon are agriculture and logging. In terms of agriculture, most rainforest fires proceed in adjacent pasturelands and agricultural fields, where fires are used by human to clear land and retain crop (Butler, 2012). During the burning season, tens of thousands of fires are burned by land speculators, ranchers, plantation owners, and poor farmers to clear bush and forest annually (Butler, 2012). These agricultural forests fires can easily and quickly spread out and threaten nearby rainforest, especially under dry conditions when the fire severity will increase, bringing more challenges for fire control and fire- extinguishing. On the other hand, legal and illegal logging in the Amazon forest will create lots of brushes and wood debris, producing a large number of potential fuel resources. Once wildfire or understory fire occurs in forest, these brushes, leaves, and wood debris will increase the fire severity and drive fire spread into nearby forest.

5.3 Law Enforcement

Besides fire monitoring and sustainable management, improving Law Enforcement is also important for slowing down the fire disaster in Amazon. With the depletion of forests in Southeast Asia and central Africa, the Amazon Rainforest is being the key source for tropical timber products (Greenpeace, 2005). In fact, a number of laws have been established in Brazil to encourage human using forest resources sustainably (Butler, 2009). However, the loggers often cut some species protected by law and steal from protected areas and indigenous lands without awareness of limitations and permits of laws (Greenpeace, 2005). Additionally, IBAMA estimates that illegal logging accounts for appropriately 80% of all logging in the Amazon. The large number of trees removed from forest creates lots of potential fuels for fire as well as increasing the disturbance on forest

ecosystem and raising the vulnerability of forest to fires. Fire severity will be enhanced with the quantity of trees cut down in Amazon.

Therefore, government should effectively enforce current logging laws as well as the existing environmental law to weaken the negative impacts of illegal logging activities on potential forest fires.

5.4 Afforestation

To avoid the worst consequences of climate change on forest fire, regional climate conditions should be stabilized by preventing the temperature increase over time. In the long term, the major drivers for climate change should be figured out, and then people should take some specific actions to address it. The presence and absence of vegetation will influence the regional climate, as the current climate and vegetation may coexist in a dynamic equilibrium that will be changed by the alterations in either of the climate and vegetation (Shukia et al., 2008). So, the major driver for regional climate change in Amazon is deforestation, and additional forest loss is caused by forest fire; this means that leading to protecting and restoring forest becomes an essential first response to climate change (Conservation International, 2014).

Forest fires will produce large amounts of carbon and smoke, damaging the forest functions on fixing carbon and nitrogen. Subsequent consequences are making the climate conditions in Amazon worse. Forests are a critical element for global environmental health, as trees have the ability to absorb greenhouse gases through the process of photosynthesis and have a positive impact on climate change. Replanting can rearrange the tree species, planting fire-resilient species with more fire resistant ability. What's more, forest restoration can improve the climate conditions and reduce the forest environment's

temperature, avoiding the long time forest drought, and then reducing fire activity frequency and severity.

In sum, afforestation can weaken fire disaster by improving regional climate and preventing global climate change as well as improving tree species.

6. Conclusion

Climate change causes a global concern nowadays with dramatic impacts on environment, economic development and human health. The Amazon rainforest is the biggest carbon sink in the world with richest biodiversity. It plays an important role in tropical regional climate even global climate change as well. With the trends of climate change with warming temperature, the Amazon forest fire season is becoming longer due to the dry season altered with climate change, causing more severity fire activity in the Amazon rainforest. Serious environmental problems, economic problems and human health problems originated from more severe fire activities occurred in Amazon, such as biodiversity loss, induced invasive species, timber value reduction, and harmful smoke.

In addition, several solutions for reducing fire disaster were introduced in the paper, including monitoring, effective and sustainable management, enforcing law, and replanting in Amazon as suggested by some researchers. Among them, fire monitoring thorough remote sensing techniques is critical to deal with forest fire problem in Amazon, for several reason reasons. On the one hand, the Amazon Rainforest occupies large areas so that the management brings many considerations and challenges. Additionally, replanting trees can not make significant positive effects until they grow up to a well-established stage in terms of age and sufficient size. However, monitoring can detect the current forest fire condition and make predictions of fire condition in next few years by providing warnings to managers so that managers can implement fire prevention strategy.

In conclusion, more in-depth research should be done in terms of Amazon forest fire and its effects on environment, economy and communities in Amazon. However, improving current climate conditions and avoiding temperature rising is the responsibility for people all around the world. Actions should be taken for everyone in their daily life to avoid the further risk caused by global climate change.

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