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Research Article

Disturbance of Mangrove Forest Due To Climate Change: The Prospects of Sundarban

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ABSTRACT

Mangrove forest has a significant importance in protecting natural di aster, environmental sustainability and in local economy. In Banglades only mangrove forest Sundarban also servicing for environmental su tainability, protecting tropical cyclone, local employment generation ar so on. Thus, its natural properties are being hampered through peop involvement and natural calamities. Moreover, Rapid population grow and climate change stimulating these disturbances of natural properti of Sundarbans. This paper aim at how climate change is disturbing ma grove forest in Bangladesh and how this disturbance may be threatful f future environmental sustainability. Interrelation between clima change and disturbance of Sundarbans has been established throu various exiting literature review and for quantifying the amount of di turbance remote sensing data has been applied and future threat of e vironmental sustainability has been assessed by comparing regener tion capacity of Sundarban after a tropical cyclone and amount of di turbance by a tropical cyclone. Result found that climate change increa ing the frequency of natural calamities and affecting significantly c mangrove forest due to its complex bio-diversity and strategic locatic before regeneration of disturbance. On the other hand, threat of ma groves as well as environment is associated with temperature rising, i melting and sea level rising are increasing because of frequent occu rence, magnitude as comparing with regeneration capacity.

Keywords: *Climate Change, Natural Calamities, Sundarban, Disturbance and Regeneration.*

Introduction

Bangladesh's Sundarban mangrove forest is known as the world's largest single tidal phragmites forest cover. This forest cover is located on Bangladesh's Bay of Bengal delta, which is formed by the convergence of the Brahmaputra, Meghna and Ganges rivers which is vulnerable to disaster (Iftekhar & Islam, 2004).

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On the other hand, Bangladesh is a disaster-prone country. Nearly in every single year, natural calamities like cyclones, tropical cyclones, coastal erosion, floods, storm surges, and droughts strike the country and causing massive damage to life and property (Ali, 1999). Global climatic change stimulating these disasters and negative consequences on environment as well as society and economy of Bangladesh. In the mean-time, the native carbon cycle along with other natural cycles and forces have been rapidly altered as a result of rapid population growth and extreme human actions. If GHG emissions raise the global average temperature by 2 degrees Celsius over pre-industrial levels, catastrophic repercussions such as sea level rise, heat waves, ice melting and so on might occur, wreaking havoc on our environment (Chandler et al. 2002; Otto et al. 2018; Kalra & Kumar, 2019). All these types of problems are associated with tropical cyclone in Bangladesh which hits mainly coastal region. Thus, make mangrove forest vulnerable to higher disturbance.

Tropical cyclones that have a devastating impact on the biological and ecological diversity structure of mangrove forests in the tropic as well as the area's environmental sustainability (Elsner et al., 2008). Thus, Sundarban is highly vulnerable to tropical cyclone due its locational position and complex biodiversity. Mangroves are among the most diverse ecosystems on the planet (Friess et al., 2019) and which are generally, placed in the tropical and sub-tropical regions (Thomas et al., 2017). Mangroves are indeed important for providing a variety services and benefits of ecosystem, including cyclone protection, floods and surges from storm produced by cyclones (Sun & Carson, 2020; Menendez et al., 2020), sequestration and carbon storing (Donato et al., 2011; Mukul et al., 2021), supply of food, fuel, lumber, and construction supplies to sustain local lives (Biswas et al., 2009; Uddin et al., 2013; Abdullah et al., 2016). However, mangrove forest in Bangladesh is being disturbed by tropical cyclones and global climate change constantly increasing this disturbance through sea level rise, higher storm surge, imbalance ecosystem and so on. This paper explore the disturbance of Sundarban mangrove forest due to climatic change and identify future threat of Bangladesh for this disturbance in terms of environmental sustainability due to tropical cyclone.

Literature Review

Typhoons are rotating tropical storms. When they arise in the Indian Ocean, they are referred to as "cyclones" in English (Hossain & Mullick, 2020). Tropical cyclones that affect south Asia, form over the surrounding waters, particularly in the Bay of Bengal.

To form and evolve, they must meet at least five criteria low pressure at sea water surface, plentiful moist air which accomplished of skyward moving toward atmospheric layer, minimal wind shear; the rate at which wind direction and intensity of wind fluctuate with height in the atmosphere, more than 26–27 degrees Celsius ocean water surface temperatures and the rotational force of the Globe to turn the arrangement into a spinning vortex. The major source of energy for cyclonic storms in South Asia is strong evaporation over warm water, rather than opposing temperatures between cold and warmer air currents, as in mid-latitude storms (Greg O'Hare) which is the result of climate change. On the other hand, global climate change resulting global warming which is responsible for making low pressure at surface for cyclonic storm. Thus, Nearly every single year, cyclones wreak havoc on Bangladesh's coastal districts (Hossain & Mullick, 2020).

Additionally, Bangladesh is often hit by severe tropical storms as a result of its unusual geographic position. The Bay of Bengal's funnel-shaped northern section intensifies the storm surge of tropical storms, harming tens of thousands of people. However, it is a matter of hope that several research have explored the role of Sundarbans in decreasing wind and storm surge strength during cyclones (Dutta et al., 2015; Akber et al., 2018). On the other hand, Harun-or- Rashid et al. (2009), claimed that variance in the soil seed bank and above ground flora in three distinct environments in Sundarbans mangrove forest. In the meantime, Azad et al. (2019), examined two distinct locations, the floristic arrangement, biodiversity and abundance in the Sundarban forest after eight years of occurrence of super cyclone in 2007 (Sidr). On the other hand, the key measures of environmental sustainability have been identified as physical and ecological biodiversity along with the conservation of this biodiversity in an area (Kates et al.,2001), despite the fact that various international organizations have emphasized the need of assessing biomass and floristic variation in the tropical forests are (Stork et al., 1997). However, these indicators are being hampered for protecting cyclone hit in the coastal area. Damage to adjacent coastal lands is attenuated mainly by reducing (i) water flow velocity, reduces damage to neighboring coastal areas and (ii) surge height, which controls the extent and depth of flooding. However, the degree of mangrove protection is determined by the density of tree planting and the diameter of trunks and roots, among other factors (Dasgupta et al., 2019). Besides, factors like wind speed, storm surges, and proximity from cyclone's eye are all variables that contribute to the disruptions produced by cyclones (Lugo 2008). These all factors are related to negative consequences of climate change. However, the degree and configuration of forest turbulences produced by tropical cyclones occurrence in the Sundarbans mangrove forest are unknown and a long-standing dataset dedicated to cyclones in the tropics and mangrove forest disturbances is needed (Mandal & Hosaka, 2020).

Research Question and Methodology

This study desires to explore two research question namely, how climate change and disturbance of mangrove forest is interrelated? and how this disturbance will affect environmental sustainability in Bangladesh?

The methodology involves in this study is both qualitative and quantitative. For answering the first research question, various exiting literature and data has been analyzed and reviewed. In contrast for answering second research question, the amount of disturbance and type of disturbance has been quantified using remote sensed data and GIS application. Total amount of vegetation, water and bare area before Super Cyclone and after occurrence and changes and regeneration time has been analyzed to show the future threat on environment.

Data Analysis Process

At first, landsat images for USGS various year has been downloaded. After extracting all the files some different bands have been received which representing different types of surface area. After that it has been inputted into ArcMap 10.7 software for NDVI analysis. The process of NDVI analysis is-

For measuring vegetation disturbance, NDVI value = {(IR - R)/ (IR + R)}

Here,

IR = Infrared band pixel value

R = Red band pixel value.

This index produces values ranging from -1.0 to 1.0, mostly signifying greenness, with negative values originating from water and snow, clouds, water and snow, and tends to zero values originating from rocky character and barren soil.

The equation in the ArcGIS software uses the following to generate output: NDVI value = {(IR - R)/ (IR + R)}* 100 + 100

The output is an 8-bit entity with a range value of 0–200 that may be readily produced with a specified color ramps or color mapping.

The second formula, the negative value means the values bellow 100 and hundred represents zero value. Under the zero value means water or ice. The values between 100-110 represents barren cover areas of rocky feature, sand and snow. Finally, the values above 110 represents the greenery. The value has been divided into two parts: one is vegetation cover area and non- vegetated area. The non-vegetation cover area contains all 0 to 110 NDVI values and vegetated area contains all 110 to 200 NDVI values. We also calculated the area of both category by ArcMap 10.5 software. The projection system is UTM WSG 1984 Zone 45N. After completing the process, the image has been converted from raster file to vector file and calculate the area of different types of land use. Besides Microsoft excel is used for calculating data and analyzing data.

Degradation of Mangrove Forest: Associated Factors and Forces

Despite the fact that mangroves only cover 0.7 percent of the global total coastal area, they contribute 10% of net basic production and

25% of carbon burial (D. Alongi, 2007). Mangroves have the ability to aid in the land-building process, which will most likely accelerate as sea levels rise. (D. M. Alongi, 2008). Over 3/2 of the world's mangroves are distributed in 18 countries including Bangladesh which spread over 14 million hectares, comprising less than one percent of the total coastal regions (Barbier, 2016). It has been quantified that around 35% of mangroves disappeared in the latter two decades of the twentieth century, owing mostly to their direct conversion to other land uses (Jia, et. al, 2018; Osland et al., 2018) such as aquaculture, agriculture, urbanization and the effects of changes in river basin hydrological and river sediment inputs, to name a few (Barbier, 2016; De Lacerda, Borges, & Ferreira, 2019; Feller, Friess, Krauss, & Lewis, 2017; Thomas et al., 2017). Although the degree of mangrove forest deterioration has decreased significantly over the last two decades, rates of up to 3.1 percent per year in some countries are still worrying, and this might result in the loss of features and functions in less than 100 years. Furthermore, just 6.9% of the world's mangrove forests are protected, making it critical to establish additional conservation areas in order to slow the rate of destruction (de Almeida, et. al, 2016; Sanderman et al., 2018).

Besides, Thomas (2017), found the transition of mangrove forests to aquaculture/agriculture, which accounts for 11.2 percent of overall changes, was determined to be one of the most prevalent sources of human drivers generating changes, according to Landsat data from 1996 to 2010. It is considered 8.3% in Southeast Asia. Although the spatial pattern of forest losses is recognized, the scope of the operation is not. Some places (for example, Panama) experienced localized losses, whereas aquaculture was discovered on a far greater scale elsewhere (example- Mahakam delta, Kalimantan, Indonesia). Although the most significant was worsened by such losses, the observed natural process was widespread throughout Southeast Asia (Regionally 12.5 percent). Degradation has been found most commonly in highly efficient settings, such as on exposed banks and even at both the openings and mouths of rivers. This factors are also result of climate change.

Additionally, according to a recent research, tropical cyclones are responsible for 45 percent of the documented mangrove area disturbances in the literature emphasis (Sippo et al., 2018). Although damaging, tropical storms have a short-term impact on mangrove environments because certain tree species can readily recover, while others rely on advanced regeneration or post-storm seeds. It is common feature of mangroves are that disruptive ecosystems that are typically regarded as ecologically robust, implying that they can survive with and recover from cyclonic structural disruptions. (D. M. Alongi, 2008; A. Lugo & Cintro, 1981). Where TC fragility is more acute, mangrove structural diversity is limited to smaller canopies with few emergent canopies (A. E. Lugo & Snedaker, 1974). Where cyclone disturbance is uncommon, structural biomass and complexity can grow over time (Allen, Ewel, & Jack, 2001; Simard et al., 2019). Therefore, frequency and magnitude of tropical cyclone are crucial factors for regeneration of mangroves.

Since essential measures were made to avert present mangrove forest degradation, net yearly mangrove deterioration would need restoration of about 100,000 hectares per year (Lewis III, Brown, & Flynn, 2019). Furthermore, mangroves function as an intertidal habitat that is particularly vulnerable to climate change impacts, such as sea level rise, warming surface water, rising temperatures, changes in atmospheric structure, and changes in precipitation (De Lacerda et al., 2019; Jennerjahn et al., 2017). Climate change is widely acknowledged as the most major factor affecting mangroves in many parts of Latin America and the Caribbean as well as South Asia (De Lacerda et al., 2019). Therefore, anthropogenic and natural stresses may combine in additive or synergistic ways, causing quick and significant changes in mangrove ecosystems (Feller et al., 2017). Mangroves are recognized to be a highly adaptable ecosystem that can adapt to changing conditions and so play an important part in creating climate change strategies (Osland et al., 2018).

Relation between Climate Change and Mangrove Forest Disturbance

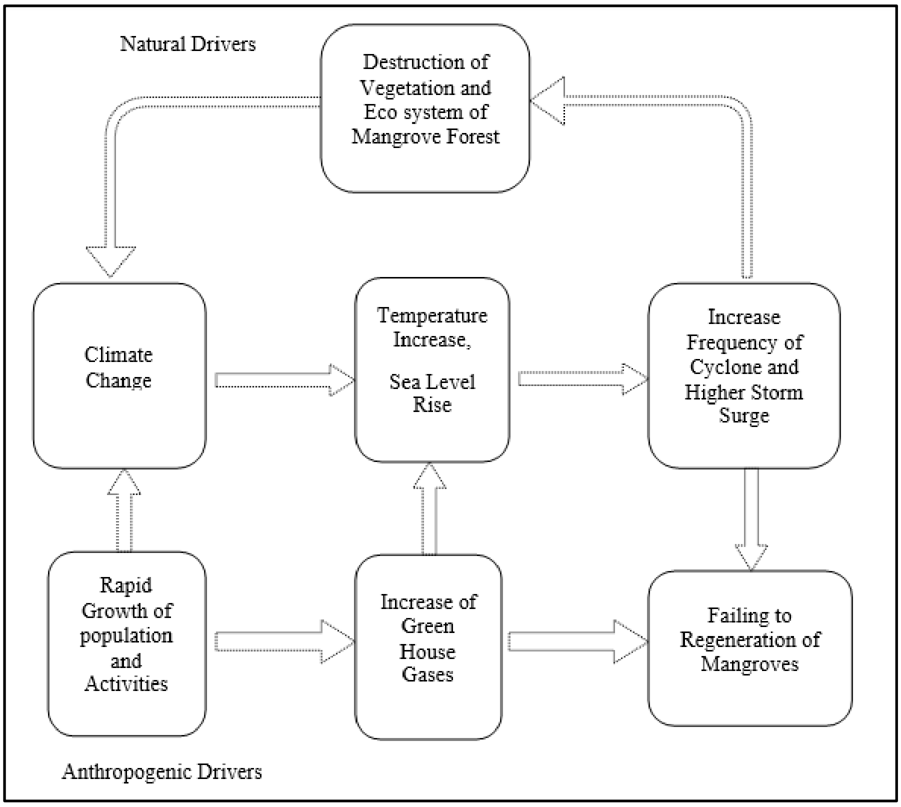

Figure 1. Relation between climate change and mangrove forest disturbance

Cyclonic Disturbance on Sundarban Magrove Forest: Future Threat for Bangladesh

Tropical cyclones occurring virtually in the Sundarban mangrove forest region, in which wind speed and cyclone crossing route being the characteristics that influence Sundarbans properties. Wind speed is lessen by the forest but forest get hampered greatly like destruction of vegetation, bio-diversity loss, increase of bare area etc. Most importantly, cyclone in this area disturb to regeneration of mangrove.

Empirical study investment shows destruction of mangrove forest just after Sidr (2007) and Amphan (2020). Table 1 shows the destruction and Figure 1 shows the destruction type

Table 1. Disturbance of Sundarban After Tropical Cyclone

	Bare Area (Sq. K.m.)	Water (Sq.K.m.)	Vegetation (Sq. k.m.).
Before TC of 2007	52.4435	148.9610	3982.1539
After TC of 2007	167.9127	208.6272	3807.1513
Change	115.4692	59.6662	-175.0026
Percentage	220%	40%	-4%
Before TC of 2020	70.3462	165.8369	3947.1702
After TC of 2020	79.1013	159.6880	3944.4908
Change	8.7550	-6.1489	-2.6794
Percentage	12%	-4%	0%

Source: Author Analysis

Table 1 illustrates the state of change of properties of Sundarban Mangroves after tropical cyclone. After super cyclone Sidr bare area has increased 220% and which has not regenerated up to year 2020. On the other hand, water area also increase significantly after occurrence a major cyclone whereas ultimate change of water area from 148.9610 sq.k.m. in 2007 to 165.8369 sq.k.m. in 2020. In the mean time vegetation area is not significant. It means that regeneration capacity of vegetation area is more than bare or water area. However, ultimate increase of bare area means loss of forest ecology in terms of vegetation and bio-diversity loss. Higher frequency of occurrence of cyclone reduces the capacity of regeneration (Lewis III, Brown, & Flynn, 2019) and negative consequences of climate change accumulates the factors for cyclone occurrence (De Lacerda et al., 2019). In Bangladesh, it is observed that temperature rising, sea level rising, frequent flood etc. are observing at catastrophic characteristics which may involve in frequent cyclone formation in coastal area. Frequent cyclone formation and landfall in mangrove forest destroys the properties of mangroves and enter cyclone to human settlements with higher magnitude of wind speed and storm surge. This situation is not only capable to destroy mangrove environmental sustainability but also destroy the environment around human settlement.

Scientific analysis and climate model forecasts also point to a possible rise in the frequency of tropical cyclones (Emanuel, 2013), extreme sea level rises are more likely, especially in the second half of the century (Gosling et al., 2011), as well as increased frequency of high surge in coastal events. Pertaining to a research for coastal Bangladesh, the area exposed to cyclones might grow from 14 percent to 69 percent by 2050, with a 1–3 m flooding depth with a 27 cm SLR and a 10% increase in wind speed (Dasgupta et al., 2014). Associated with global warming- induced glacier melting in the Himalayas, floods duration, inundation area, and depth are expected to rise (Xenarios, S., & Polatidis, H., 2015).

On the other hand, according to the World Bank (2000), sea levels would increase by 10 cm, 25 cm, and 1 m by 2020, 2050, and 2100, impacting 2%, 4%, and 17.5 percent of global land mass, respectively. Bangladesh has recorded a 1.0 centimeter per year rise in sea level. According to UNEP (1989), Bangladesh's shoreline would rise 1.5 meters by 2030, impacting 22,000 square kilometers (16 percent of total landmass) and a population of 17 million (15 percent of total population).

Therefore, higher sea level means potentiality of higher storm surge, higher destruction and reduced generation of mangroves.

Discussion and Conclusion

Unusual weather variability, such as temperature, severe water shortages, and flood-inducing rainfall events, are expected to continue to afflict developing nations like Bangladesh in the next decades, according to the Intergovernmental Panel on Climate Change. Thus, Bangladesh is vulnerable to temperature and flood increasing related problems. This vulnerability is being crucial for rapid urbanization and others anthropogenic sources of climate change. Main vulnerable area is coastal area and natural elements in the coastal area. On the other hand, mangrove forest is the most vital natural elements in coastal area of Bangladesh which is being affected by recurrence of tropical cyclone due to climatic change. The disturbance of mangrove forest is related to wind speed, storm surge, surge velocity and regeneration capability of the mangroves. When frequency of cyclone increase, regeneration capacity decreases and get loss of vegetation and bio diversity of mangroves. Thus, environment losses its sustainability in mangrove areas. It also negatively affect on other environmental sustainability. In mechanism of mangrove, by reducing water flow, mangrove trees will greatly minimize the exposure of adjacent coastal regions to tropical storms. While coastal zone management staff members are increasingly aware of the value of mangrove forests in natural disaster prevention and ecosystem-based conservation, the absence of location-specific information on mangrove conservation capacities is frequently a barrier. This research evaluates the future threat of environmental sustainability due to climatic change and disturbance of mangrove forest.

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