Flooding in Bangladesh: A Race Against Time

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Abstract

Flooding is the most common type of natural disaster and is a major problem in Bangladesh that especially harms the disadvantaged. People are uniquely vulnerable to flooding in Bangladesh due to its low elevation, numerous rivers, coastal location, and high rainfall intensity. I estimate the number of people vulnerable to sea-level rise by overlaying a raster of the population over a raster of elevation. The population of Bangladesh is then broken into five risk groups based on their elevation above sea level. Nearly 4% of the population of Bangladesh, over six million people, live less than one meter above sea level. This puts them in the highest risk group, and the sea will rise one meter in the not-too-distant future. High economic growth has made Bangladesh, previously one of the poorest countries in the world, able to take substantial action to address the flooding problem.

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Flooding in Bangladesh: A Race Against Time

Introduction

The Bhola Cyclone was a truly devastating storm that struck East Pakistan, present-day Bangladesh, and India's West Bengal on November 3rd, 1970. According to Patra Madhusmita et al (2013), the Bhola Cyclone was the deadliest tropical cyclone killing 300,000 to 500,000 people in Bangladesh. This calamity occurred not because the storm was abnormally strong, but because of its devastating trajectory that created a storm surge and massive flooding far inland. Another factor was the lack of warning given to the population. According to Naomi Hossain (2017), the warning factor has since been addressed and no subsequent cyclone, even significantly more powerful ones, has approached this staggering death toll.

The Bhola Cyclone and the lack of aid sent from West Pakistan helped to trigger the Bangladesh War of Independence from Pakistan. This conflict was devastating and included a Pakistani genocide against the Bengali people with a death toll estimated in the hundreds of thousands. According to Naomi Hossain (2017), this conflict ended when India declared war against Pakistan and aided the independence of Bangladesh. Natural disasters can cause political upheaval, especially if the government is perceived to be incompetent or uncaring in its response.

Figure 1 Bhola Cyclone Aftermath (Chakraborty 2021)

Figure 1 shows a picture of the scale of the destruction of the Bhola Cyclone. It brings to mind images of the Second World War, and also illustrates that Bangladesh was one of the poorest countries in the world at the time of its creation. One of the factors that made Bangladesh so poor was its flood-prone topography.

Flooding has been a risk to humanity since antiquity and is the most common type of natural disaster. Rising waters do not just kill people; they also displace people and destroy property. Property damage caused by flooding is common and often happens across a wide area. Thus, it is hard to get flood insurance, especially if one lives in a poor area vulnerable to flooding.

Flooding harms the disadvantaged more than those with various privileges such as insurance. According to Margret Arnold et al (2022), people with disabilities or mobility

issues are much more likely to die in floods. The poor often lack the funds to rehouse themselves after their homes are destroyed leading to homelessness or unsafe living conditions. According to Ahmed Hossain et al (2021), these unsafe conditions can further traumatize and harm people that were the victim of displacement related to flooding. People are uniquely vulnerable to flooding in Bangladesh due to its low elevation, numerous rivers, coastal location, and high rainfall intensity.

Climate change is making flooding worse. Rising sea levels, warming water, and a slowing jet stream are making flooding more common and damaging. Higher seas mean that the same storm surge can reach further inland, and a slower jet stream increases the duration of rainfall events. According to Patra Madhusmita et al (2013), warming water makes cyclones more powerful and more likely to reach land with most of that power intact. These factors increase the chance and severity of damaging flooding in Bangladesh.

New capabilities of the nation of Bangladesh give hope. A rapid economic rise gives the nation increasing capabilities, and responsibilities, to address the problem of flooding. Major expensive steps to reduce Bangladesh's flooding woes still need to be taken, but one benefit of not undertaking serious flood prevention measures is that there remains some low-hanging fruit that can be addressed inexpensively. Revitalizing the coastal mangrove swamps would be a major anti-flooding step. In addition, it would also preserve the indigenous flora and fauna. Another inexpensive remediation would be to regulate how close to major rivers people could live; many Bengalis live directly below a river protected only by an earthen levee (Islam & Tsujimoto, 2011). These levees fail

frequently leading to a new tragedy almost every year. According to Islam & Tsujimoto (2011), earthen levees have another negative side effect even when they do not fail. They speed water flowing downstream to where there is no levee, or upstream in the case of storm surge. The point at which the levees decrease in height can be the site of massive spillover and devastating flooding. This creates an incentive to build higher levees all along rivers as no one wants to live next to the shortest levee. Higher levees exacerbate this problem as a spillover event will dump more water out of the breached levee.

Literature Review

Flooding in Bangladesh is an old problem, and many volumes have expounded upon the subject. The geographic structure of Bangladesh and its implications will be discussed along with recent developments in the situation that have raised the stakes. The potentially high cost of failure to control flooding will also be revealed.

> A variety of major flood-related impacts of climate change on Bangladesh are predicted. This includes variability of seasonal monsoon precipitation, increase in the intensity of climate-related disasters such as cyclones, sea-level rise in the Bay of Bengal, and increasing river discharge from melting glaciers and snow-pack in the Himalayas. (Khan 2012: 162)

Inconsistent rainfall amounts from monsoons threaten the agricultural output of all of Bangladesh which is heavily reliant on monsoon rainfall. Too much rain causes dramatic floods; too little rain causes drought. More intense snow melt can cause flooding in the far interior of the country in the short term, with less consistent river flow

in the long term. More severe cyclones can cause dramatic flooding, made up of rainfall and storm surge, in the low-lying regions.

The estimates of the pace of future global warming are uncertain. Methane is an extremely potent greenhouse gas. Methane, also known as CH_4, trapped in permafrost is the largest contributor to this uncertainty. "Atmospheric CH_4 is the greenhouse gas responsible for the second-largest increase in direct radiative forcing since 1750" (Lan et al 2021). The exact levels of future methane are hard to predict, and this leaves exact warming projections with very large confidence intervals. In a study by Lan et al, they determined that methane is being released from permafrost by looking at carbon 13 attached to the methane. Carbon 13 which is used by this study to measure where the methane came from holds a special signature that allows a scientist to determine which methane molecules came from what source. This study supports the idea of permafrost melting and releasing methane, including some very old sources being unfrozen and released.

According to Lauren Khan (2012), Bangladesh has approximately 800 rivers flowing through the country. In Bangladesh there is a wet monsoon season with too much water that leads to severe floods, followed by a dry season that sometimes results in drought.

The rivers allow storm surges to flow far inland, causing flooding and spreading salt and manufacturing byproducts in the soil. According to Khan, this damages agricultural yields and can exacerbate drought and flooding which can devastate crops.

The river system moves through major urban regions and, when rivers flood, cities are flooded as well as farmland.

Not only is water rising, but the Brahmaputra delta, which makes up a significant portion of Bangladesh, is sinking which reduces the timetable for anti-flooding action.

> Risks are expected to climb. Global warming is raising sea levels around the planet by 2-3 millimeters each year. That only adds to bigger problems in the Ganges-Brahmaputra delta, which is sinking so rapidly that the local, relative sea level may be rising by up to 2 centimeters each year. And Bangladesh's population of more than 150 million people is projected to grow by a further 50 million by 2050, putting more people in harm's way. (Schiermeier 2014)

Schiermeier's population estimate is probably slightly too high given recent reductions in the birth rate of Bangladesh. Estimating sea level rise based on past sea-level changes yields a decidedly optimistic estimate as sea levels could rise much faster in the future.

Coastal protection is an important component of overall flooding protection, which specifically protects against storm surge, a rise in the water level as a result of a cyclonic storm moving near land. Tidal channels are parts of the ocean that stretch inland, like a reverse peninsula. Inside a tidal channel with a narrowing shape, the effects of the tides are magnified. "'Tidal amplification has big implications for coastal protection' for areas with long tidal channels, building more embankments could cause higher tides and exacerbate saltwater intrusion" (Schiermeier 2014). Tragically, earthen embankments protecting areas near the coast or rivers have been one of the few things the government

of Bangladesh has done about flooding. According to Schiermeier, this action may be counterproductive in the long run.

According to Bimal Paul and Harun Rasid (1993), one major problematic after-effect of flooding from the ocean is that, while the water recedes or evaporates, the salt, for the most part, does not. Salting fields has been an extreme scorched earth tactic of armies since antiquity. Floods semi-permanently destroy agricultural land and damage the nation of Bangladesh, especially its coastal farmers. This problem has prompted some clever solutions. “Scientists with the Bangladesh Rice Research Institute in Gazipur have developed salt-tolerant rice to grow in flood-prone plains” (Schiermeier 2014). This domestic innovation allows farmland to be flooded and still grow rice, the staple crop of Bangladesh. While this innovation is helpful, it does not prevent disastrous flooding.

> Scenes of disaster are not unusual in Bangladesh. About 6,000 square kilometers of the massive Ganges-Brahmaputra delta, the largest delta in the world, lies less than two meters above sea level. On average, 6,000 people in Bangladesh die each year in storms and floods. In April 1991, a single cyclone, the worst in recent decades, wiped out well over 100,000 lives in the delta and left millions of people homeless. (Schiermeier 2014)

Rising seas are a real threat to people living on the Brahmaputra delta for a variety of reasons. The most obvious of which is that the sinking delta and rising ocean will at some point be at the same elevation causing much of the Brahmaputra delta to sink into the sea. Another nearer-term threat is the increasing penetration of storm surges into this vulnerable area. Storm surges have the potential to accelerate the sinking of portions

of the Brahmaputra delta by adding weight which compacts the soil, pushing the land down further.

“Natural disasters are increasingly affecting a larger segment of the world's population. These highly disruptive events have the potential to produce negative changes in social dynamics and the environment which increase violence against children” (Cerna-Turoff et al 2021). Natural disasters have a large number of detrimental knock-on effects, including dramatic economic, social, and psychological effects. One of the factors leading to child abuse after disasters are that people expect help from their society and government, and if that help is needed and not received, people feel angry and desperate.

> One proposed reason is that men, frustrated by economic loss and hardship, misdirect their anger at sexual partners and children. Men identified insufficient cash assistance after the 2015 Nepal earthquake and economic loss from not harvesting crops before floods in Laos as reasons for why they were physically violent. After flooding in Bangladesh, men who received aid or took out personal loans were more than twice as likely to be physically or emotionally violent with their children than those who could rely on personal savings. (Cerna-Turoff et al 2021)

Widespread violence against children is a sign of major tears in the social fabric of Bangladesh. “Cyclone Amphan swept into Bangladesh's southwestern coast at the end of May 2020, wreaking havoc on food security and economic stability, as well as possibly worsening mental health” (Ahmed Hossain, et al 2021). When one's livelihood

is washed out to sea along with one's home, basic needs are often not met and serious physical and psychological symptoms are almost guaranteed to develop like malnutrition, depression, anxiety, and general damage to one's body as extreme chronic stress takes hold. According to Hossain, these problems can affect up to three future generations and possibly beyond. The negative effect of an unstable childhood on all manner of things like income, mortality, and stress levels is clear. According to Cerna-Turoff (2021), children put stress on a family that has seen a reduction in the standard of living.

> Children could not understand the financial strain on their households, and in demanding superfluous goods, it triggered caregivers to lash out in frustration and guilt. In addition, children were occasionally physically violent against each other due to economic stress. (Cerna-Turoff, et al 2021)

Two of the principal causes of violence are stress and inequity, both of which can be caused by natural disasters. Urbanization stresses people, but it also stresses drainage systems.

> Urbanization plays a significant role in the loss of vegetation and soils. The vegetation is important for holding down the soil, and it also protects the soil from being washed away during heavy rains. But, when the vegetation is removed, rainwater simply rushes to the lowest point within a catchment, where it accumulates and causes flooding. (Utepov 2021)

Rapid urbanization is increasing flooding because of runoff from roofs and paved streets. These sources of runoff absorb no water and generally move water quickly away from where it fell creating flooding in ditches, roads, and rivers. These rivers can rise

with startling speed, especially when they are confined to an artificial riverbed with vertical walls rather than being situated in a valley with a gradual upward slope. Urban growth creates large quantities of runoff from rainfall which often simply flows down major streets to the nearest river, damaging roads, shops, and homes.

Managing this urban runoff is a top anti-flooding priority. Adequate ditches to manage flooding would be an inexpensive way to reduce flooding damage outside of the flooding of rivers. Preventing rivers from flooding takes more work because water needs to be captured and then drained slowly into the rivers. Natural wetlands do this job excellently, but even when they are not present, creating drainage ponds with wetland plants around them does a lot to prevent flooding. A system of ponds, wetlands, ditches, and drainage fields can channel the water that would cause massive flooding damage into man-made reservoirs that hold large quantities of water that can later be used for agriculture or to water the plants integrated into the water control system during the dry season. Reservoirs are the long-term solution to intense seasonality of rainfall and have been successfully used since antiquity. Building, maintaining, and operating a reservoir system large and complex enough to protect a significant amount of Bangladesh from seasonal rainfall oscillations would require large amounts of labor, land, capital, and expertise. Many other countries and regions have undertaken similar projects. The Netherlands has used a complex flood management system for centuries, which has reclaimed land, prevented flooding, facilitated transportation, and create power. Bangladesh might hire consultants from the Netherlands with vast institutional experience in the flood control field like HKV consultants or a similar firm from another

flood-prone country with a good flood prevention track record. A consultant like this could share specific details on how to prevent flooding on a larger scale in both land area and monetary costs.

> PSNA is a flood prone district of Thailand in a large delta similar to Bangladesh. However, existing anti-flood structural infrastructure is inadequate for protecting PNSA district against repetitive floods, while worsening flood situations in the peri-urban area. Therefore, a more sustainable anti-flood strategy should integrate structural measures (i.e., permanent anti-flood structures) with non-structural strategies to effectively cope with repetitive flooding. The non-structural anti-flood strategies include, for example, educating local residents about flood adaptive actions, social media-based advance flood warning, and flood-preventive financial incentives. (Thanvisitthpon 2019)

This is the same type of infrastructure and information systems the nation of Bangladesh will need to build if they want to significantly reduce flooding. Levee systems, generally built by local governments and communities, work well on a local level but ultimately just dump the water on a community with a weak, short, or poorly maintained levee in case of dramatic flooding. Levees alone are not a viable solution to create truly adequate drainage. “Construction of anti-flood structure infrastructure in PNSA increased flood intensity and duration in three neighboring districts as more floodwater was diverted to the peri-urban area” (Thanvisitthpon 2019). This is similar to what is currently going on in Bangladesh and, to solve this problem, reservoirs must be created that can moderate increasingly volatile rainfall amounts.

One city that needs a system like the one outlined above is Dhaka. Dhaka is a city of 21 million people that is not very far above sea level and uses poorly reinforced levees to protect many of its citizens. These levees are often used, not to protect citizens, but to claim land from the rivers which are then used to create slums in constant danger of being flooded by the river which is often located above the settlements.

A large agricultural area of northeastern Bangladesh is also very low in elevation and is vulnerable to snowmelt related flooding. Additionally, the Chittagong region is also vulnerable to cyclone-related flooding as demonstrated by the 1991 cyclone that directly hit Chittagong. Most of Bangladesh is vulnerable to some type of flooding. This vulnerability is being exacerbated by climate change which is generating more powerful floods from all causes. Currently, the government of Bangladesh is not prioritizing flooding protection as, according to Khan (2012), protective mangroves are being removed from the coast and urban areas are expanding with insufficient drainage infrastructure.

As seen in Figure 2, Dhaka has two major rivers flowing through it, which are not very far above sea level. These rivers can lead to a storm surge hitting the capital despite its considerable distance from the coast.

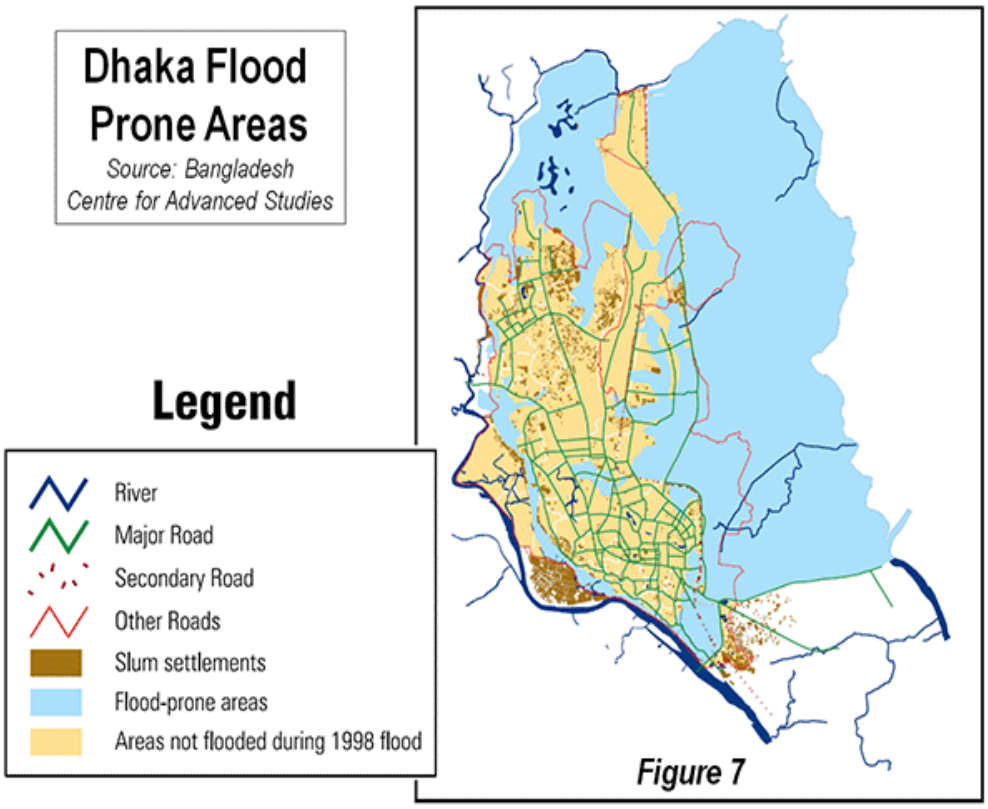

Figure 2 Dhaka Flood Prone Areas (Cox 2012)

Quantitative

This section will focus on data that was created and collated for this project.

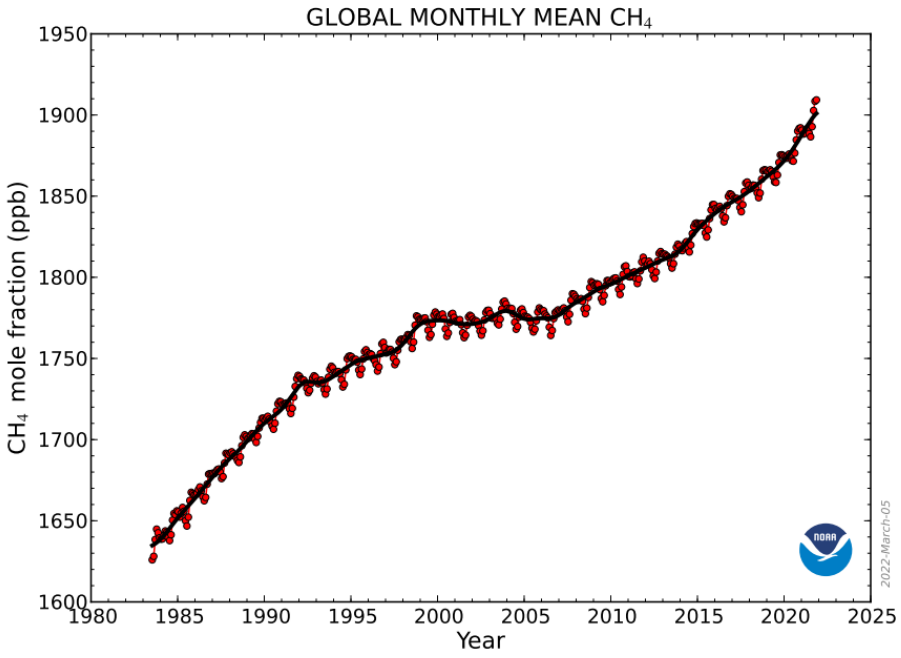

Figure 3 Global Monthly Mean Methane (NOAA 2022)

Figure 3 shows a 40-year increase in atmospheric methane. The plot has an increase with a positive second derivative which is cause for concern. A self-reinforcing increase in the temperature of the earth with its own internal feedback loop is a terrifying scenario that some scientists have envisioned. This feedback loop would be caused by melting permafrost releasing methane which then causes more global warming and more methane emissions, on and on, until we get a double-digit increase in temperature. This is a worst-case scenario and not likely if current projections are correct, even if methane trapped in permafrost is taken into account.

Table 1 (Primary model of flooding risk based on elevation)

Risk Group	Description	Population	Proportion of population	Proportion of area
1	Elevation>7	76702669	0.46574	0.50752
2	Elevation(5-7]	57175689	0.34717	0.30020
3	Elevation(3-5]	1954353	0.11867	0.09197
4	Elevation(1-3]	4899237	0.02975	0.04314
5	Elevation[0-1]	6367427	0.03866	0.05716

Elevation is in Meters and Population is in Persons.

Our model of flooding risk was created by layering a raster of population density over a raster of the elevation of Bangladesh. The different elevations were then split into five risk groups with five being the highest risk. This elevation-based approach is limited by the fact that living high above sea level does not guarantee one's safety from floods. Many people in mountainous areas are affected negatively by floods. One major flaw of this approach is that it disregards the many people at higher elevations that are still at high risk of flooding. If 6,367,427 is taken as a minimum number of people that will be displaced by a sea-level rise of 1 meter, then Bangladesh will have to permanently resettle millions, maybe tens (estimated according to an average sea-level rise forecast). According to Schiermeier, the Brahmaputra delta, which makes up much of coastal Bangladesh, is sinking into the Bay of Bengal which, combined with sea level rise, could sink this heavily populated part of Bangladesh in the next 50 to 100 years. This sinking, if it should continue, will speed up the timetable for mass displacement events well into our lifetimes.

Figure 4 Risk Grouping of Bangladesh

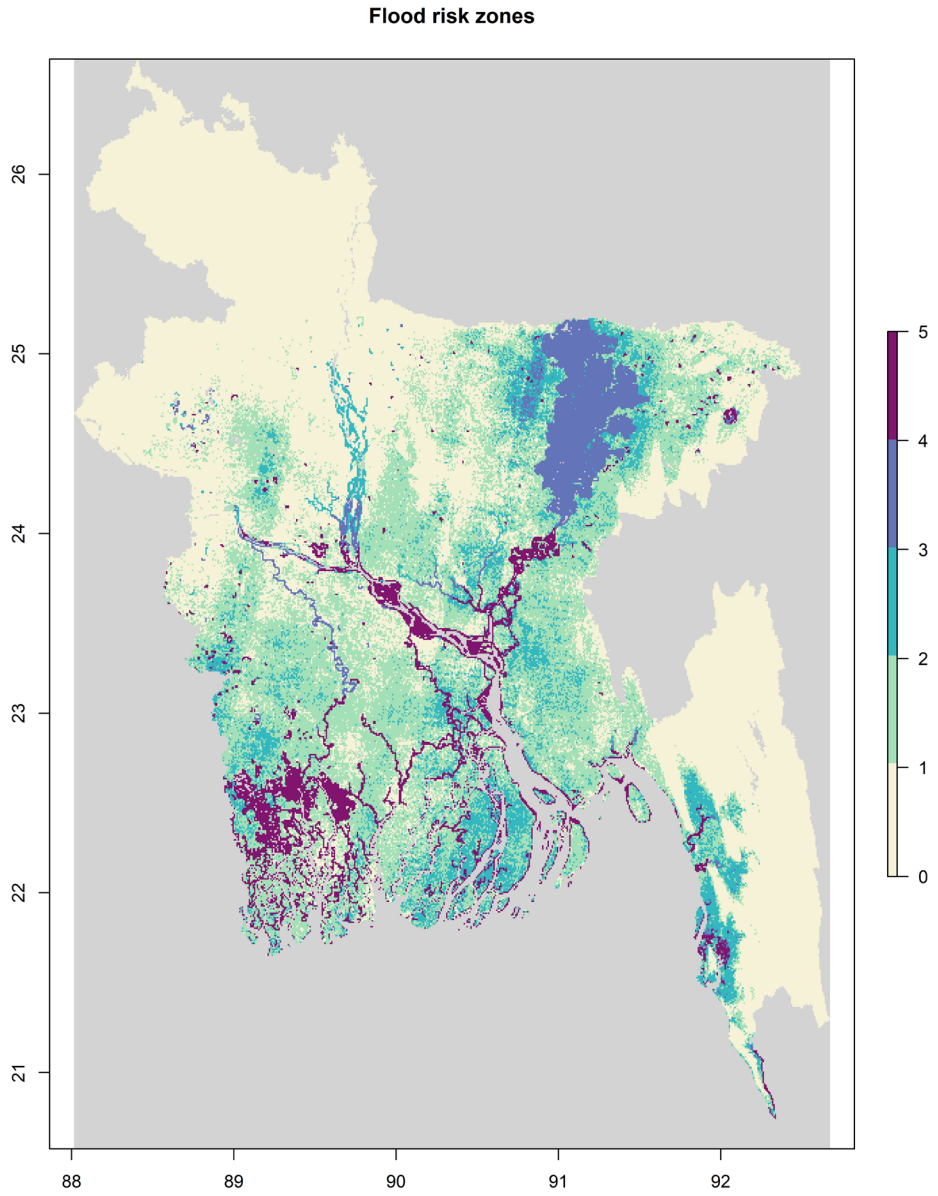

Figure 4 is created from the table of risk groupings above with purple being the highest risk and tan being the lowest risk. The at-risk areas center around major rivers and stretch far inland.

Figure 5 Highest Risk Only Populated Places

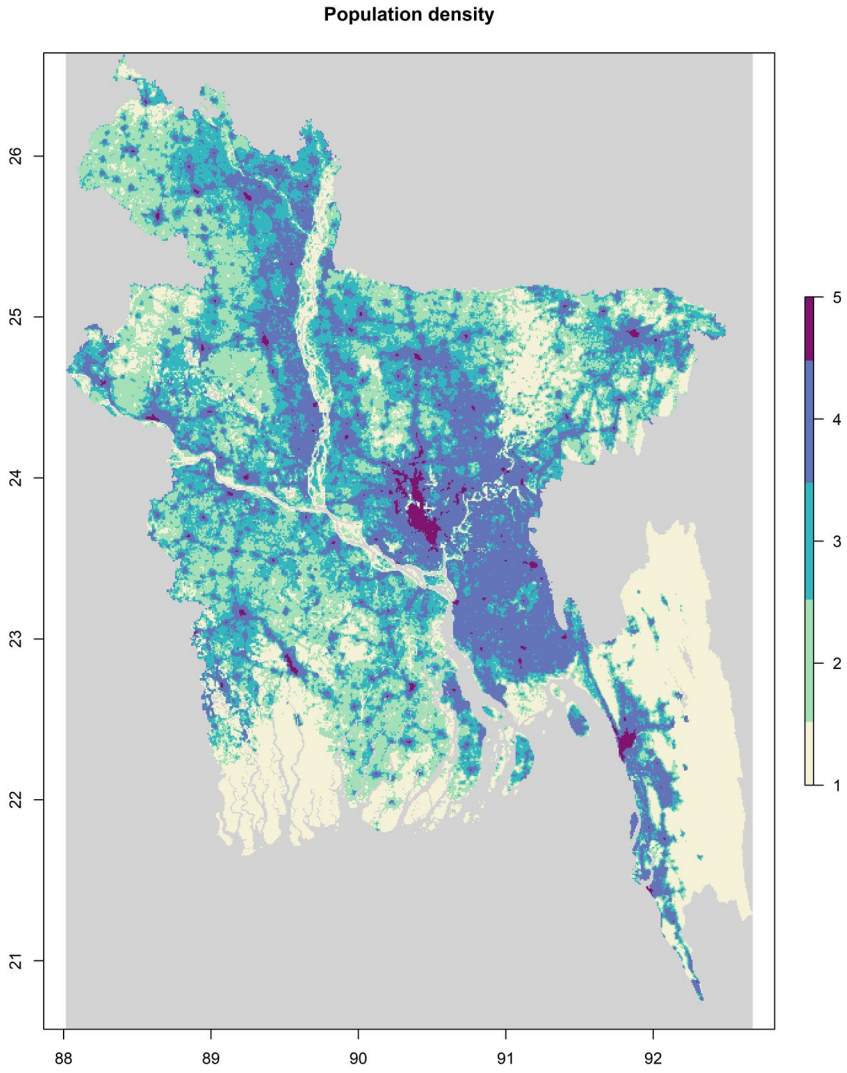

Figure 5 shows the population density of Bangladesh. The most densely populated areas are along major rivers, in the coastal area around Chittagong, and in the area around Dhaka.

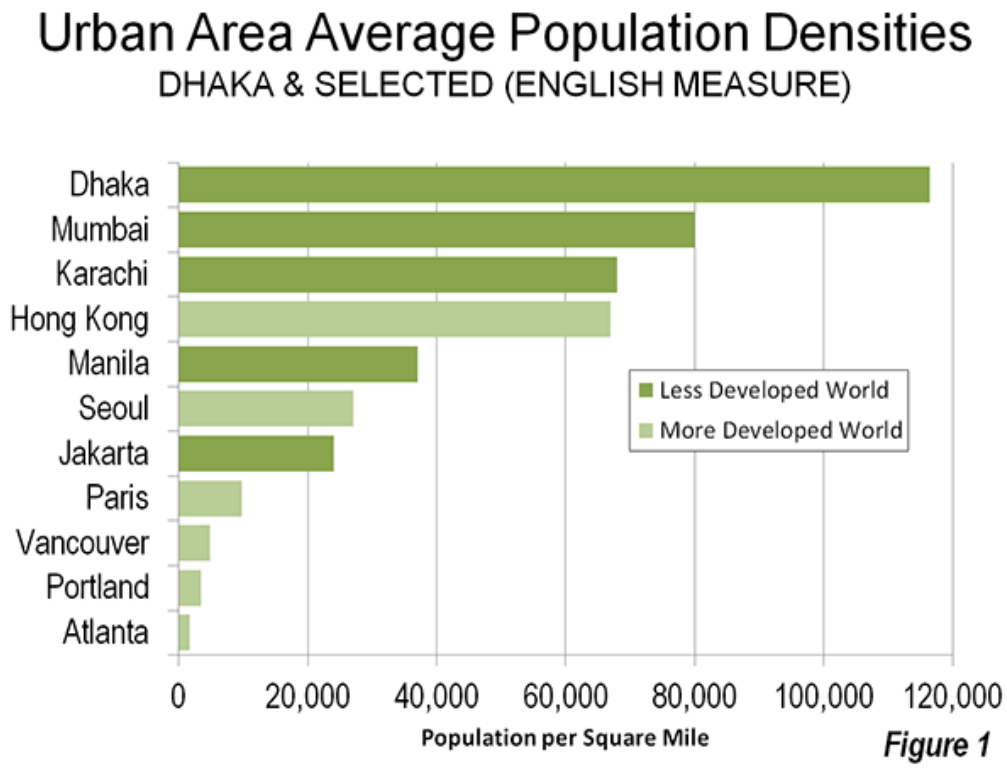

Figure 6 Urban Area Average Population Densities (Cox 2012)

Figure 6 shows Dhaka's extreme level of population density. This density causes numerous problems with managing water flow. People will need to be moved to improve anti-flood infrastructure which increases costs. This density also tempts developers to use cheaply constructed levees to gain more land. The density increases prices of being in Dhaka which means its poorer residents, such as recent immigrants and garment factory workers, must live in places that are obviously at high risk of dramatic flooding. Even though these financially motivated risks are common in rapidly industrializing countries, it is apparent that market forces do not protect the lives of these vulnerable populations. This makes anti-flooding infrastructure necessary to save a great many lives even though market forces do not yet demand anti-flooding infrastructure.

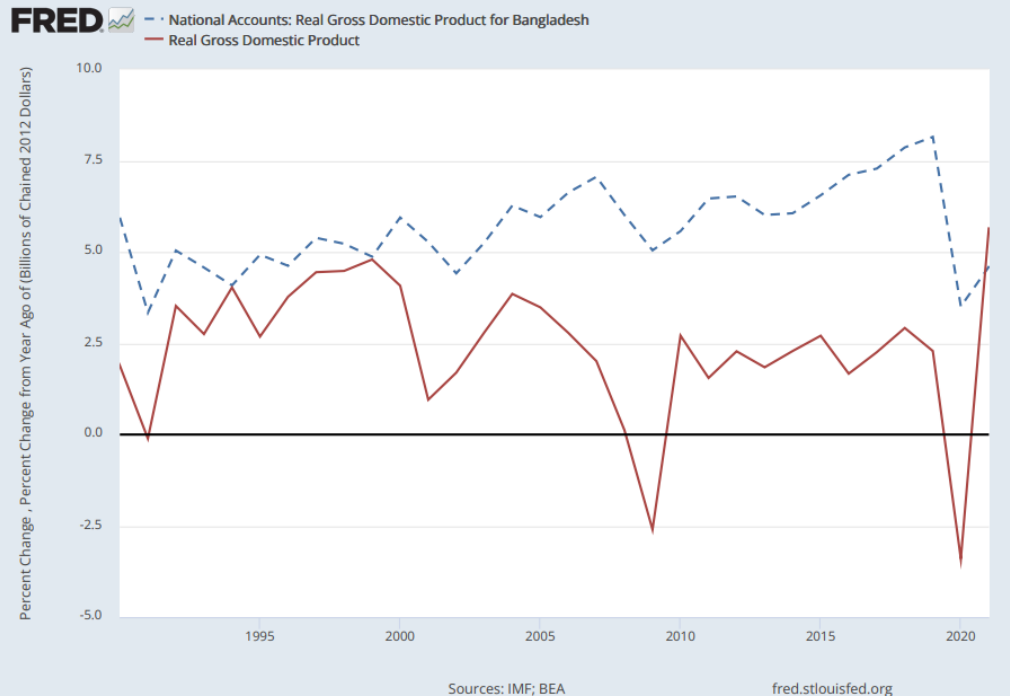

Figure 7 Percentage Change in Real GDP of Bangladesh Compared to The United States (St Lous FRED 2022)

High economic growth has made Bangladesh, previously one of the poorest countries in the world, able to take substantial action on the flooding problem. According to The St. Louis FRED (2022), recently the per capita GDP of Bangladesh has surpassed that of its neighbor India. This action is becoming more necessary as climate change accelerates and Bangladesh urbanizes. According to Khan, the economy of Bangladesh is almost wholly based on the garment industry and low technology agriculture. Subsistence agriculture is what people do when they have no other opportunities and is normally abandoned by most of the population when given the option. While the garment industry has brought Bangladesh out of extreme poverty, there is a limit to how far the garment

industry alone can propel Bangladesh economically. According to Khan, efforts to significantly diversify the economy of Bangladesh have failed so far. To avoid the middle-income trap, Bangladesh must diversify its economy to a point where it can produce goods or services with high human capital investment rather than just cheap labor. The rapidly growing economy can address the flooding problem if a significant share of the wealth goes to protecting Bangladesh from flooding. Bangladesh must harness its new economic power to ameliorate the effects of flooding, or its future economic growth may be crushed. This would be a terrible eventuality and one that could politically destabilize the entire region.

Discussion

Bangladesh is experiencing rapid economic growth, which could enable them to do more to address the future threat of flooding and thereby ensure long term prosperity. However, Bangladesh is in a race against time to create effective anti-flooding protections using their newfound wealth. The increasing urban development which creates economic growth also increases the risk of flooding due to more runoff from urban areas. This situation demands competent and urgent flood mitigation design implementation. Bangladesh must use some of its economic potential to construct integrated drainage systems with sufficient reservoirs.

Internal displacement will become a major problem if many coastal areas are rendered uninhabitable. Internal displacement is when people must leave their homes and municipality because of forces that threaten great bodily harm. Internal displacement is a common problem in war-torn African countries, such as The Democratic Republic of the

Congo, Ethiopia, and South Sudan. Natural disasters also cause internal displacement, especially when they render the land from which people were displaced permanently uninhabitable.

Increasing risks because of climate change put further pressure on Bangladesh to create flooding defenses. The warming climate is increasing the frequency of rare weather events as the global hydro cycle is continually disrupted by climate change caused by CO_2 and methane emissions. The disruptions to the hydro cycle have a major effect on the distribution of rainfall throughout time and between locations. The specific changes in the hydro cycle are not predictable with a very high degree of certainty. This uncertainty is a further reason to construct an integrated water capture and flood containment system.

Conclusion

Bangladesh must do more to protect itself against flooding as climate change intensifies. If the government of Bangladesh does nothing, its economic growth might be washed away when another powerful Bhola-like cyclone strikes again. A future disaster will be deadly, but the number of zeros in the cost, both in human lives and in dollars, has a lot to do with what action the nation of Bangladesh takes and how many zeros are in the expenditure. Bangladesh needs to spend money to prevent future monetary and human losses.

Creating a comprehensive coastal defense system using natural barriers like mangrove swamps, supplemented with intelligently placed walls and levees, is not something to be deferred to the next generation. Inland flood control systems are also

necessary, but they could be implemented very cheaply in new parts of the rapidly expanding urban areas of Bangladesh. Flood control in the already very densely populated parts of Bangladesh's urban areas would be more expensive and disruptive. Despite the potential benefits, it might not be worthwhile or even feasible. The nation of Bangladesh has some hard choices, and serious stakes are riding on these decisions. Serious action is urgently needed by the national government of Bangladesh to alter the path of water to be beneficial instead of harmful to its citizenry.

In summary, this thesis discussed the history of flooding in Bangladesh and the catastrophic effects of past floods in Bangladesh. Climate change makes this issue more serious over time. Potential solutions to both rainfall and storm surge-based flooding were envisioned, and the example of Dhaka was considered. In the quantitative section, the number of people that will be displaced by sea-level rise was estimated and the unique vulnerability to flooding in Bangladesh was quantified. These issues, and the potential effects of neglecting these issues, were then discussed.

Works cited

Arnold, Margret, et al. “Five Actions for Disability-Inclusive Disaster Risk Management.” *World bank Blogs.* July 24, 2018. Accessed March 15th, 2022

Cerna-Turoff, Ilan, et al. "The pathways between natural disasters and violence against children: a systematic review." *BMC Public Health*, vol. 21, no. 1, 12 July 2021.

Chakraborty, Yajnaseni. “Bhola, the Cyclone that gave birth to a nation.” *Get Bengal.* 28th of May, 2021. https://www.getbengal.com/details/bhola-the-cyclone-that-gave-birth-to-a-nation

Cox, Wendel. “Evolving Urban Form: Dhaka” *New Geography.* August 8th, 2012.

Dlugokencky, Ed. NOAA/GML (gml.noaa.gov/ccgg/trends_ch4/) March 2022. Accessed March 16, 2022.

Federal Reserve Bank of St. Louis and U.S. office of Management and Budget. “Percentage Change in Real GDP of Bangladesh Compared to The United States” Retreved from FRED. Federal Reserve Bank of St. Louis; March 16, 2022.

Hossain, Ahmed, et al. "Household food insecurity, income loss, and symptoms of psychological distress among adults following the Cyclone Amphan in coastal Bangladesh." *PLoS ONE*, vol. 16, no. 11, 2 Nov. 2021.

Islam, Md. Serazul, and Tetsuro Tsujimoto. "Characteristics of flood disasters in low floodplain along a big river due to overflow levee breach." *International Journal of GEOMATE*, vol. 1, no. 1 SERL 1, Oct. 2011.

Khan, A. Lauren. Creative Adaptation: Bangladesh’s Resilience to Flooding in a Changing Climate. *Community, Environment and Disaster Risk Management.* Vol. 11, 2012.

Madhusmita Patra, et al. “JenaHealth Hazards by Sea Cyclones in Odisha, the Supercyclone and the Phailin,Odisha Review” November – 2013 http://magazines.odisha.gov.in/Orissareview/2013/nov/engpdf/31-38.pdf

Naomi, Hossain. “The 1970 Bhola cyclone, nationalist politics, and the subsistence crisis contract in Bangladesh”28 April 2017, https://onlinelibrary.wiley.com/doi/abs/10.1111/disa.12235

Paul, Bimal Kanti, and Harun Rasid. "Flood damage to rice crop in Bangladesh." *The Geographical Review*, vol. 83, no. 2, Apr. 1993.

Schiermeier, Quirin. "Holding back the tide: with the Ganges-Brahmaputra delta sinking, the race is on to protect millions of people from future flooding." *Nature*, vol. 508, no. 7495, 10 Apr. 2014.

Thanvisitthpon, Nawhath. “Impact of Land Use Transformation and Anti-Flood Infrastructure on Flooding in World Heritage Site and Peri-Urban Area: A Case Study of Thailand’s Ayutthaya Province.” *Journal of Environmental Management,* vol. 247, Oct. 2019.

Utepov, Yelbek, et al. "Potential Impact of Land-Use Changes on River Basin Hydraulic Parameters Subjected to Rapid Urbanization." *Tehnicki Vjesnik - Technical Gazette*, vol. 28, no. 5, Oct. 2021.

Xin, Lan, et al. “Improved Constraints on Global Methane Emissions and Sinks Using *δ*13C-CH4.”
Global Biogeochemical Cycles, vol. 35, no 6, 8 May 2021.