Land Mass Change along the Bangladesh Coastline

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Introduction

Motivation

Bangladesh is a small country in Asia with a massive population. Always somewhere in the top 10 lists of countries with the highest population (158 million), the country boasts one of the highest population density values in the world; the country is roughly the size of Georgia - 56,977 square miles - but has the population of California, Texas, New York, Florida, Illinois, Pennsylvania, Ohio, Georgia, and Michigan combined. The capital of this country, Dhaka, has a population estimate of about 19 million people, roughly the same as New York City, L.A., Chicago, Houston, Philadelphia, and Phoenix combined, even though it's the size of Waco. There is 115,000 people per square mile in Dhaka, whereas the population density of New York City is 27,000 people per square mile.

Figure 1. Location of Bangladesh (shown in green) relative to India.

Figure 2. Geography of Bangladesh, with the capital Dhaka starred.

I am also originally from Dhaka, Bangladesh, and my primary motivation for this course project was to use the GIS skills learned in class to be able to tell a story about a significant problem that Bangladesh faces: Dhaka's rapid population growth.

Due to a lack of data, the project scope was modified to tell a story about another significant issue facing the Bangladeshi population: fear of losing land mass due to climate change.

In 2010, a National Geographic Society report concluded that Bangladesh was among the countries most vulnerable to climate change. Fears have grown over the last few years that Bangladesh, a country in a low-lying coastal region, would lose its land mass and millions of people would be displaced.

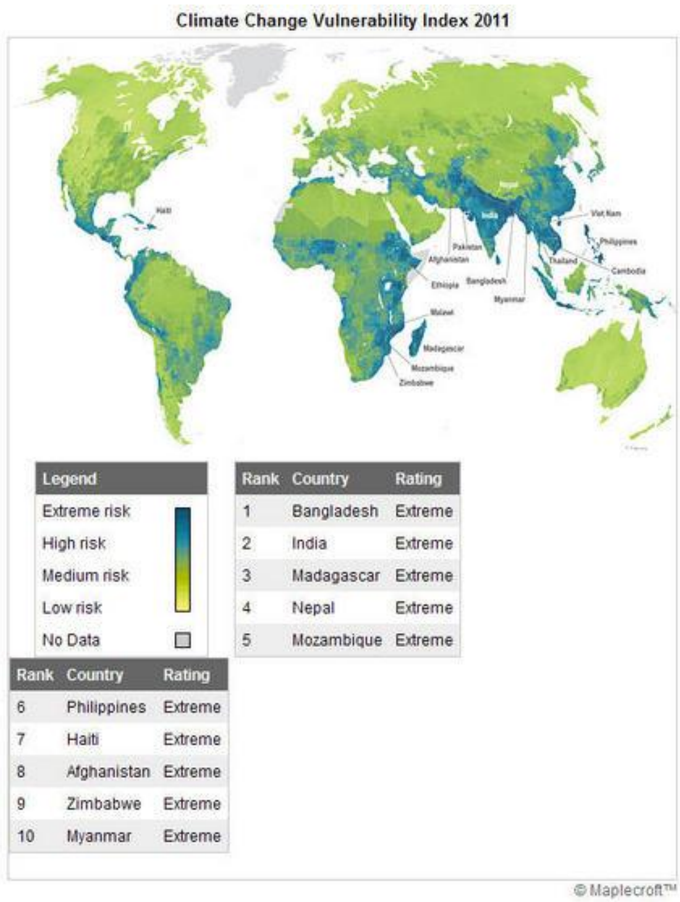


Figure 3. 2011 Climate Change Vulnerability Index

The motivation for the project shifted from telling a story about rapid population growth in one of the densest regions in the world to telling a story about land mass changes in a country deemed to be at highly vulnerable to climate change impacts.

Objective

The final objective of the project is to tell a story about Bangladesh's land mass changing along the coastlines, and answer the question as to whether Bangladesh is truly at risk of sinking into the ocean. Furthermore, after determining whether a risk of sinking is currently present, this paper aims to gain an understanding of what factors lead to certain land accretion or erosion behaviors, i.e. are there relationships between Bangladesh's land mass change patterns and major weather events in the region.

Data

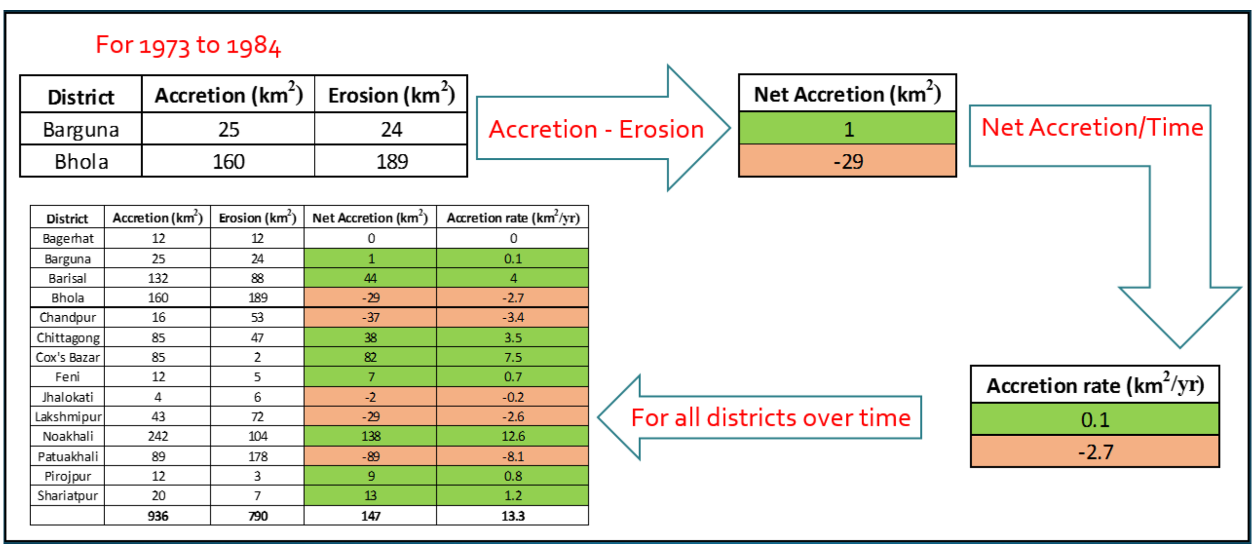
Erosion-Accretion data along the coastline of Bangladesh between the years 1973 and 2015 were provided by the Center for Environmental and Geographic Information Systems (CEGIS) in Dhaka, Bangladesh. The data were provided for 14 coastal districts along the Bangladesh coastline, at 4 different time ranges – 1973 to 1984, 1984 to 1996, 1996 to 2006, and 2006 to 2015. This data were provided in the form of Landsat images. The data were used to determine the land mass changes year to year in Bangladesh, to determine risk of sinking land.

Data related to major earthquakes and cyclones occurring in the region were also obtained from United States geological Survey Earthquake Catalog and Unisys Weather. These data were used to find patterns between major weather events in the region and erosion-accretion patterns.

Methodology

To determine whether Bangladesh should be concerned about sinking land at this point in time, the Erosion-Accretion data was tabulated and mapped using ARCGIS. Shapefiles gleaned from Landsat images were also analyzed with ArcGIS geoprocessing tools to determine total areas of erosion and accretion. From these, total area values for Erosion-Accretion were calculated, as well as net rates of land mass change over the years.

This was done in the following way: the erosion-accretion values obtained from the data showed values for 14 different coastal districts, all near the Meghna river estuary. From this data, which show erosion mass and accretion mass in each district, the value for erosion was subtracted from accretion to determine net accretion. This net accretion value was divided by the total time range of the data points to determine net accretion rates per year. This process was followed for all districts across all points in time. The process is shown below in flowchart form.



District	Accretion (km^2)	Erosion (km^2)	Net Accretion (km^2)	Accretion rate (km^2/yr)
Bagerhat	12	12	0	0
Barguna	25	24	1	0.1
Barisal	132	88	44	4
Bhola	160	189	-29	-2.7
Chandpur	16	53	-37	-3.4
Chittagong	85	47	38	3.5
Cox's Bazar	85	2	82	7.5
Feni	12	5	7	0.7
Jhalokati	4	6	-2	-0.2
Lakshmipur	43	72	-29	-2.6
Noakhali	242	104	138	12.6
Patuakhali	89	178	-89	-8.1
Pirojpur	12	3	9	0.8
Shariatpur	20	7	13	1.2
	936	**790**	**147**	**13.3**

Figure 4. Flowchart showing data analysis of erosion-accretion data.

To determine whether these patterns of erosion and accretion throughout Bangladesh's history can be associated with major weather events in the region, the pattern shifts were compared to historical data for major weather events such as earthquakes and cyclones.

Results and Discussion

Following the methodology previously described, ArcGIS was used to draw maps showing eroded and accreted land.

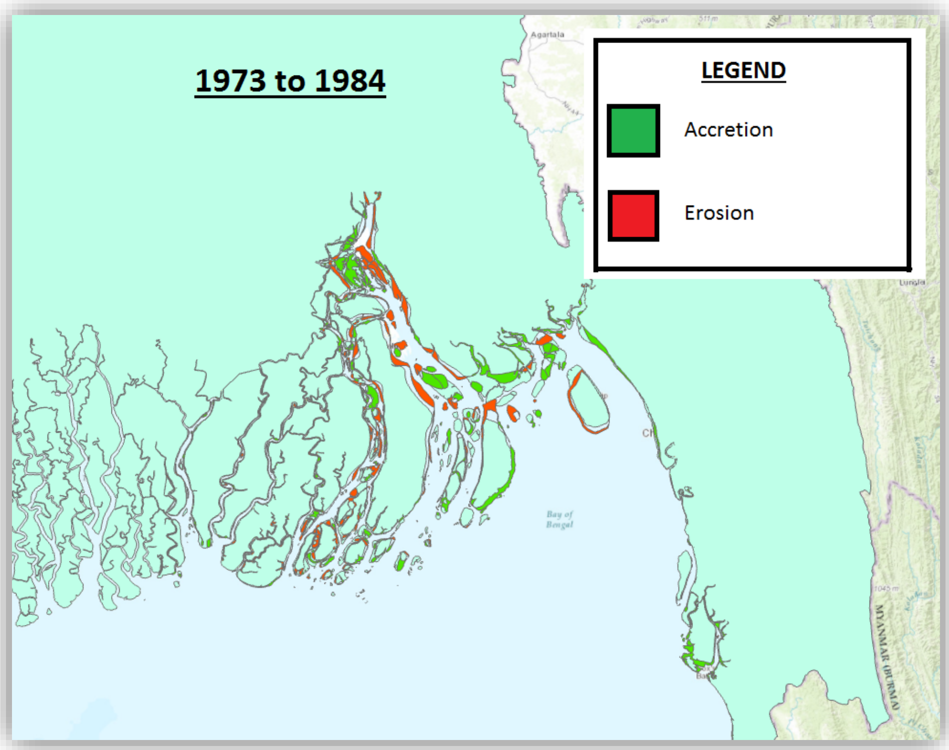


Figure 5. Erosion-Accretion Map from 1973 through 1984.

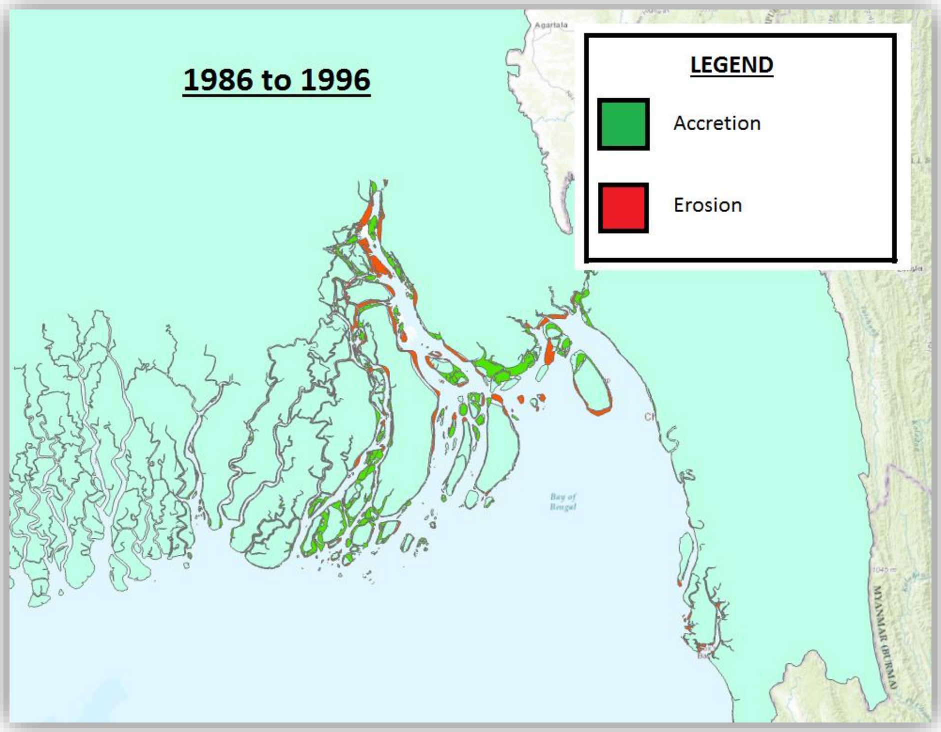


Figure 6. Erosion-Accretion Map from 1984 through 1996.

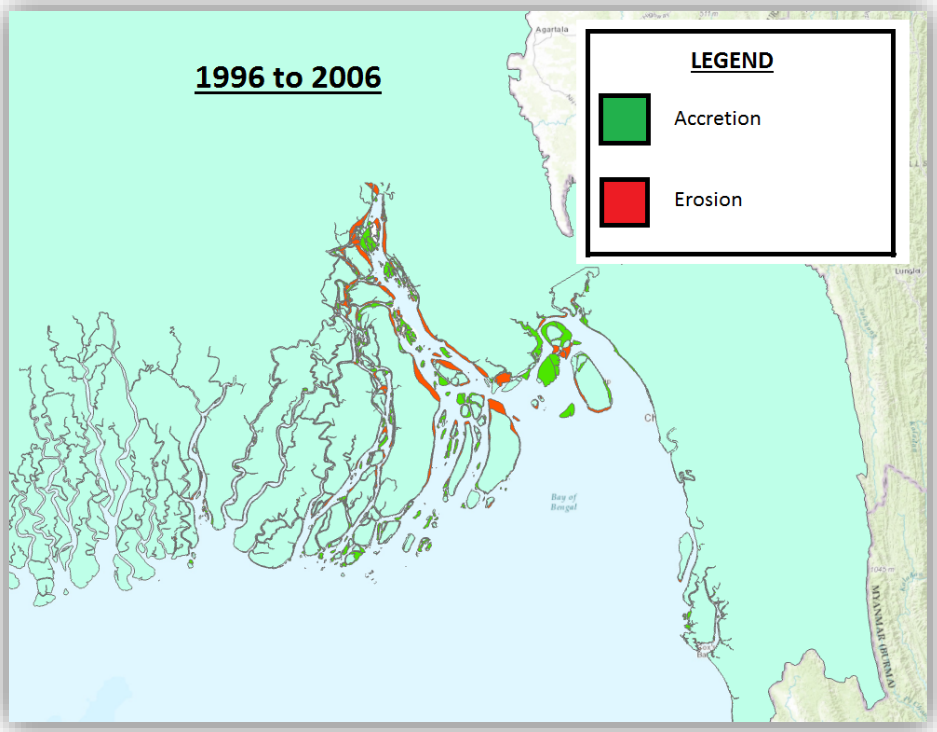


Figure 7. Erosion-Accretion Map from 1996 through 2006.

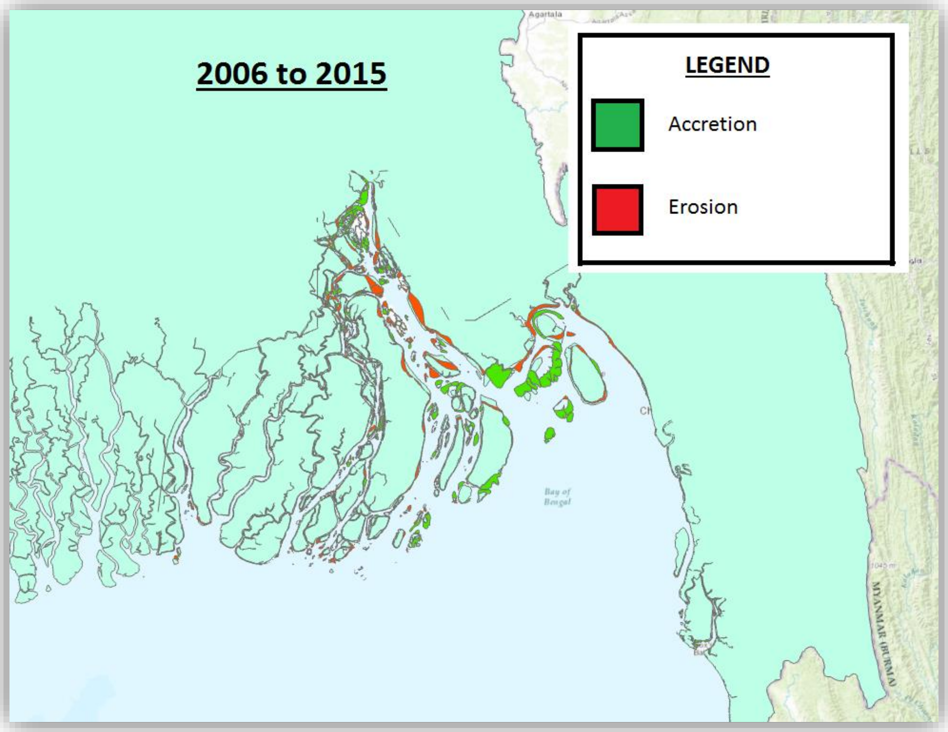


Figure 8. Erosion-Accretion Map from 2006 through 2015.

The data in the maps were also tabulated and are shown below:

Table 1. Erosion-Accretion Data from 1973 through 1984.

	1973 to 1984			
District	**Accretion (km^2)**	**Erosion (km^2)**	**Net Accretion (km^2)**	**Accretion rate (km^2/yr)**
Bagerhat	12	12	0	0
Barguna	25	24	1	0.1
Barisal	132	88	44	4
Bhola	160	189	-29	-2.7
Chandpur	16	53	-37	-3.4
Chittagong	85	47	38	3.5
Cox's Bazar	85	2	82	7.5
Feni	12	5	7	0.7
Jhalokati	4	6	-2	-0.2
Lakshmipur	43	72	-29	-2.6
Noakhali	242	104	138	12.6
Patuakhali	89	178	-89	-8.1
Pirojpur	12	3	9	0.8
Shariatpur	20	7	13	1.2
	936	**790**	**147**	**13.3**

Table 2. Erosion-Accretion Data from 1984 through 1996.

	1984 to 1996			
District	**Accretion (km^2)**	**Erosion (km^2)**	**Net Accretion (km^2)**	**Accretion rate (km^2/yr)**
Bagerhat	15	13	1	0.1
Barguna	34	14	20	1.7
Barisal	83	128	-45	-3.8
Bhola	174	137	37	3.1
Chandpur	41	45	-5	-0.4
Chittagong	78	64	14	1.1
Cox's Bazar	5	45	-41	-3.4
Feni	20	7	13	1.1
Jhalokati	5	6	-1	-0.1
Lakshmipur	70	37	32	2.7
Noakhali	199	106	93	7.7
Patuakhali	268	71	197	16.4
Pirojpur	3	5	-2	-0.2
Shariatpur	13	10	3	0.2
	1006	**689**	**317**	**26.4**

Table 3. Erosion-Accretion Data from 1996 through 2006.

	1996 to 2006			
District	**Accretion (km^2)**	**Erosion (km^2)**	**Net Accretion (km^2)**	**Accretion rate (km^2/yr)**
Bagerhat	11	9	2	0.1
Barguna	16	12	4	0.3
Barisal	99	104	-5	-0.4
Bhola	202	147	55	4.6
Chandpur	34	46	-12	-1
Chittagong	132	48	84	7
Cox's Bazar	25	11	14	1.2
Feni	10	7	3	0.2
Jhalokati	3	3	1	0.1
Lakshmipur	39	65	-26	-2.2
Noakhali	175	116	60	5
Patuakhali	109	60	49	4.1
Pirojpur	2	4	-3	-0.2
Shariatpur	7	26	-19	-1.5
	865	**657**	**207**	**17.3**

Table 4. Erosion-Accretion Data from 2006 through 2015.

	2006 to 2015			
District	**Accretion (km^2)**	**Erosion (km^2)**	**Net Accretion (km^2)**	**Accretion rate (km^2/yr)**
Bagerhat	6	9	-3	-0.3
Barguna	6	19	-13	-1.4
Barisal	83	88	-5	-0.5
Bhola	137	154	-17	-1.8
Chandpur	46	23	23	2.6
Chittagong	120	74	46	5.1
Cox's Bazar	21	6	15	1.7
Feni	5	8	-3	-0.4
Jhalokati	2	4	-2	-0.2
Lakshmipur	30	86	-56	-6.3
Noakhali	246	84	162	18
Patuakhali	46	70	-24	-2.7
Pirojpur	1	5	-5	-0.5
Shariatpur	21	10	12	1.3
	770	**640**	**130**	**14.4**

Looking at the maps and tables presented so far, especially at the total accretion values along the entire coastline, it can be seen that Bangladesh (as a whole) has been adding land mass since the first point in time of available data, i.e. 1973. This leads to the conclusion that, although Bangladesh may truly be in an area of high vulnerability to effects of climate change, the population of Bangladesh has no reason to currently be afraid of the country sinking. Not only is Bangladesh not losing land mass along the coast, but it is actually adding mass, at the rate of about 15 kilometers per year.

Now, looking individually at district-level behavior, there were patterns across the different districts that appeared to change from time period to time period. Districts that were experiencing net accretion over a long period of time suddenly shifted to eroding and vice versa. A couple of examples of this behavior follow:

- Patuakhali went from experiencing significant erosion to about two decades of accretion, before reverting back to a pattern of erosion in the most recent decade.
- Chandpur experienced overall erosion for three decades, but experienced accretion in the most recent time period.

One possible hypothesis postulated was that perhaps there were patterns of accretion or erosion based on the geographic location in relation to the Meghna river, i.e. all districts to the West of the Meghna river behaved in a certain way, while those to the East behaved in another. To investigate this, the tables were modified to separately consider Western and Eastern districts. The resulting data table and graphs analyzing net accretion rates are shown on the following page:

Table 5. Net accretion along all districts along Bangladesh's coast over the years, separated by West/East.

		1973 to 1984	1984 to 1996	1996 to 2006	2006 to 2015
East/West of Meghna	**District**	**Net Accretion (km^2)**	**Net Accretion (km^2)**	**Net Accretion (km^2)**	**Net Accretion (km^2)**
West	Bagerhat	0	1	2	-3
West	Barguna	1	20	4	-13
West	Barisal	44	-45	-5	-5
West	Bhola	-29	37	55	-17
East	Chandpur	-37	-5	-12	23
East	Chittagong	38	14	84	46
East	Cox's Bazar	82	-41	14	15
East	Feni	7	13	3	-3
West	Jhalokati	-2	-1	1	-2
East	Lakshmipur	-29	32	-26	-56
East	Noakhali	138	93	60	162
West	Patuakhali	-89	197	49	-24
West	Pirojpur	9	-2	-3	-5
West	Shariatpur	13	3	-19	12
		147	**317**	**207**	**130**

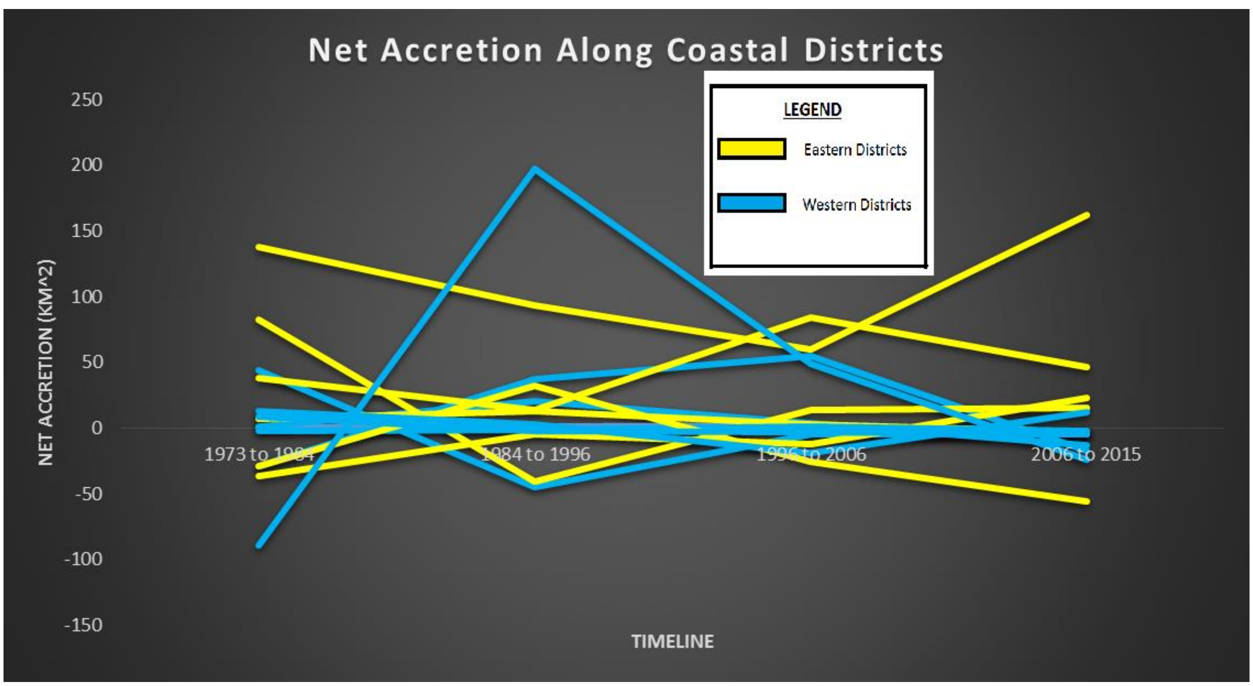


Figure 9. Net accretion along coastal districts, separated by location relative to Meghna River.

Patterns noticed from separating Eastern and Western districts:

- Most Western districts are facing mild erosion.
- Most Eastern districts are experiencing significant accretion

- Still, no straight line patterns exist for most districts, i.e. districts that face erosion are not consistently eroding and vice-versa.

While this did provide more answers, sudden changes in the erosion-accretion pattern cannot be explained. For that, the second half of the project analysis was performed: comparing these patterns to major weather events in the region.

Cyclones

Extracting historical cyclone data from Unisys Weather's Hurricane/Tropical Data storage, a table like the following was created for the years between 1973 and 2015:

Table 6. Sample data table of historical cyclones in Bangladesh

Year	Month	Day	Wind Speeds
1973	11	3	60
	11	14	55
	12	5	60
1974	11	23	75
1975	6	4	-
	11	7	50
1976	10	15	-

The data was compared to the erosion-accretion data to see if there were major cyclones before the end points of the various time ranges. For example, there is a break point in the erosion-accretion data during year 1996, so the cyclone data was checked to see if there were major cyclones on or immediately before 1996, which could change the erosion-accretion pattern.

Analyzing the first break point in 1984, there were no significantly different cyclones in the years prior. "Significantly different" refers to any cyclones that were either more severe than normal or occurring at different times of the year than typical. For that region, "typical" times of the year are in the fall/winter months and "normal" severities are near 50 knots. For the second break point in 1996, the years prior had severe and atypically timed cyclones, in the range of 120 knots in wind speeds. For the third break point in 2006, the cyclone behavior in the years prior went back to "normal" and "typical", but in the year just after the break point (2007), Bangladesh experienced its worst ever cyclone, which could have impacted the erosion-accretion behavior for the rest of the time period (2006-2015).

Comparing this with the available erosion-accretion data, whether or not the behavior changed from before a particular break point to the next was checked. Meaning, for 1996 (the 2nd break point, separating the 2nd and 3rd date range), it was checked to see if districts that were experience erosion prior to the break started to experience accretion afterwards and vice-versa. The results are shown in the following table:

Table 7. Change in Erosion-Accretion behavior between time range break points.

	Change in Erosion-Accretion Behavior Between 1st and 2nd Range	Change in Erosion-Accretion Behavior Between 2nd and 3rd Range	Change in Erosion-Accretion Behavior Between 3rd and 4th Range
Bagerhat	No	No	Yes
Barguna	No	No	Yes
Barisal	Yes	No	No
Bhola	Yes	No	Yes
Chandpur	No	No	Yes
Chittagong	No	No	No
Cox's Bazar	Yes	Yes	No
Feni	No	No	Yes
Jhalokati	No	Yes	Yes
Lakshmipur	Yes	Yes	No
Noakhali	No	No	No
Patuakhali	Yes	No	Yes
Pirojpur	Yes	No	No
Shariatpur	No	Yes	Yes
Yes	6	4	8
No	8	10	8

From the table above, I was unable to discern any strong patterns that would suggest that cyclones definitively caused certain erosion or accretion patterns.

Earthquakes

Extracting earthquake data from the United States Geological Survey's Earthquake Catalog, a list of earthquakes occurring in the region surrounding Bangladesh since 1973 was obtained. A portion is shown below:

Table 8. Sample data table for historical earthquakes in Bangladesh region.

time	**latitude**	**longitude**	**depth**	**mag**	**gap**	**dmin**	**rms**	**net**	**id**	**place**
2015-12-15T	23.8301	86.5783	14.79	4.5	171	5.101	0.5	us	us10004846	6km E of Gobindpur, India
2015-11-27T	22.5864	94.9855	13.79	4.6	63	3.089	0.57	us	us100041qe	54km NNW of Monywa, Burma
2015-11-25T	26.4076	92.9745	54.52	4.7	60	3.666	0.77	us	us1000419g	30km SE of Tezpur, India
2015-11-25T	29.6929	89.8692	77.42	4.7	102	1.094	0.57	us	us1000415j	47km N of Qiangqinxue, China
2015-11-24T	28.1552	84.7587	8.19	4.6	60	0.661	0.96	us	us100040q1	39km E of Lamjung, Nepal

Most of the earthquakes that have occurred in this region in the time period of concern have been of magnitudes around 4 and 5 on the Richter scale. First, it was checked to see if there were any major earthquakes in the region which corresponded to a change in the erosion-accretion behavior; there weren't any significantly larger earthquakes during this time period.

Next, the number of earthquakes occurring on or near the break point years was summarized, to see if that was related to the erosion-accretion behavior. The following table shows the data obtained.

Table 9. Comparison of number of earthquakes around each time period break point.

Number of Earthquakes in/around 1984	140
Number of Earthquakes in/around 1996	143
Number of Earthquakes in/around 2006	134

Given that the number of earthquakes occurring around those times have stayed relatively constant, this avenue of inquiry did not prove fruitful.

Summary

This project began with the intention of using GIS to tell a story about rapid population growth then evolved into a project that aims to further explore the effect of climate change on Bangladesh's shoreline. Through the use of ArcGIS's geoprocessing tools, erosion-accretion data was used to determine whether Bangladesh was losing or gaining land mass overall. As it turns out, the country is, at this point in time, experiencing land mass additions of about 15 kilometers per year. Thus, fears of a sinking country are not corroborated by the data.

After trying to determine if erosion and accretion behavior differed significantly based on location, it was seen that the Eastern coastline was experiencing accretion overall, while the Western coastline was experiencing more erosion.

Then, the project aimed to gain an understanding of factors that may affect the erosion-accretion patterns, such as major weather events in the region. Two specific types of weather events were selected for further investigation: cyclones and earthquakes. The investigation proved inconclusive for both factors.

Ideas for further research to build upon the information gathered are:

- The Meghna river estuary near the coastline is the conglomeration of three separate rivers which run through the country and join near the Indian Ocean. Investigations could look into whether erosion-accretion patterns are related to discharge rates and activities of the three circuits leading to the estuary.
- Could the flow discharge coming from the Himalayas be impacting erosion-accretion patterns?
- For cyclones, could the impact be related to not just cyclones in general, but which area of the country the cyclones hit?

References:

1. Center for Environmental and Geographic Information Services (http://www.cegisbd.com/)
2. http://weather.unisys.com/hurricane/
3. http://earthquake.usgs.gov/earthquakes/search/