Jinghong(David) He
Professor Kineke
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A Sense of Place: Shanghai

China has a vast population of approximately 1.4 billion and 18,000 km coastlines (Zhu et al, 2004). During the past 40 years, Chinese economic reform had driven more and more people from inland cities and villages to work in coastal cities (Fig. 1). Internal migration in mainland China is one of the most extensive in the world, and perhaps the largest in human history (Chan and Bellwood 2011). The reason behind the migration of people are complicated, but the significant factors could be more employment, education, and business opportunities, and a higher standard of living. Now, at least a third of the Chinese population lives in the coastal area (Anon. 2015). These coastal provinces also provided a GDP of 51, 991.5 billion Chinese Yuan (approximately 7, 560 billion US dollars) in 2017, which was 62.8% of the total GDP of China. Now, most prosperous cities in China are at the coast (China National Bureau of Statistics 2018). Yet, in the past 30 years, the sea level showed an average rise of about 9 cm in China (China News, 2009). How did sea level rising affect Chinese coastal cities in the past? How will the rising sea level affect these cities in the future? What were their past solutions? Is there any possible strategy for the future? In this article, I will take Shanghai, the biggest city by population in China (Geohive 2016), as an example to illustrate these questions.

In Chinese, the two Chinese character Shanghai ("上海") means "above the sea," thus Shanghai is indeed closely related to the ocean. Shanghai is located in the Yangtze River Delta, on the south edge of the estuary of the Yangtze River (Fig. 2). Between the Yangtze River Delta to the north and Hangzhou Bay to the south, the Old City and modern downtown are located in the center of an expanding peninsula. This region was formed by the Yangtze's natural deposition and by modern landfilling projects. Downtown Shanghai is split by the Huangpu River, a tributary of the Yangtze. The historical old town was located on the west bank of the Huangpu (Puxi), while the central financial district Lujiazui has grown up on the east bank of the Huangpu (Pudong). Shanghai's location on an alluvial plain means that the vast majority of its 6,340.5 km^2 land area is flat, with an average elevation of 4 m (Shanghai Municipal People's Government). Therefore, Shanghai is usually being flooded because of its relatively low altitude.

The reasons behind the flooding in Shanghai are also very complex. The significant factors that cause flooding could be intense rains, high tides, typhoons, and usually a combination of two or even all three factors.

Shanghai has a humid subtropical climate (Köppen Cfa) and experiences monsoon season during summer, usually from June to August. High rainfall can cause widespread flooding, and widespread rains could cause high upstream river flow. Most of the rivers in China was based on Ice and snow melt water supply, which happens more serenely during summer due to a higher temperature. Although the Yangtze river is the sixth-largest river by discharge volume in the world, it usually doesn't affect the flooding in Shanghai. However, many rivers, canals, streams, and lakes within and around Shanghai would have a higher water level under both climate and weather influence (Shanghai Municipal People's Government).

High tides also played an essential role in the flooding of Shanghai. Many coastal cities had been suffered from tidal river flooding, and Shanghai is not an exception. There are many tidal rivers in the region. Take Suzhou Creek as an example. Suzhou Creek is a tributary of Huangpu River that passes through the city center (Fig. 3). It is a typically tidal river (Shanghai Academy of Social Sciences 1994: 5-8). According to the thermal expansion theory, the sea level is even higher in summer. As high tides impound downstream flowing freshwater, reversing the flow and increasing the water level of the lower section of the river, the city center got flooded.

Typhoons hit all along China's coast and can send storms inland for several hundred kilometers. Depending on the severity of the storm, this results in high wind, vast amounts of rainfall in a short amount of time, and storm surges (Naumann 2018). Shanghai experiences the influence of typhoons every year. Although typhoons never hit Shanghai directly, approximately ten typhoons affect Southeastern China coast in 2013 (China Meteorological Agency 2017).

Luckily, since people realized these three major factors, they started to think ways to accommodate it. The three solutions that Shanghai has already used were the reconstruction of the drainage system, building dams on rivers, and building higher sea walls and river embankments.

Yet, the reconstruction of the drainage system does not turn out as successful even until early this year. For instance, Shanghai maintained 8,000 kilometers of pipes in 2011 and renovated drainage pipes on 14 roads and 28 drainage systems from 2012 to 2015. Shanghai's drainage system can handle rainfall of up to 36 millimeters per hour, and the capacity is 55 millimeters per hour in some critical areas for instance train station and airport (Shanghai Daily 2012). And the drainage system might be overwhelmed after hours of rain. These pictures show how Shanghai was experiencing urban water-logging during wet seasons (Fig. 4-5).

However, building dams and floodgates on rivers were useful. It could save the city from the risk of saltwater intrusion at estuaries in and can control the river discharge significantly by providing flood storage place in upstream. For example, the Suzhou Creek Flood Gate is located on estuaries of Suzhou Creek (Fig. 6). It serves almost the same purpose as MOSE Project. When high tides arrived, it would close and cut off the connection of the city's inner waterways with the sea. Another example could be the Three Gorges Dam which is one of the dams located on Yangtze River. Like many dams and other water facilities located on upstream, it can control the river discharge significantly by providing huge flood storage place. With the help of these dams and gates, the flooding situation really became better in these years.

The construction of the seawalls and river embankments seems more useful. During the last 20 years, an enormous system of seawalls has been built along the coast of mainland China. Protect the city from the direct invasion of storm surge, 532 km seawalls have been constructed along the Changjiang Estuary and Hangzhou Bay area (Liu et al, 2014) (Fig. 7-9). Shanghai has also built about 500 km water embankments along Huangpu River (Liu et al, 2014) (Fig. 10-12). These structures had been proved successful during high tides and typhoons and at least not meaningless during heavy rains that significantly increased water levels in rivers. However, the idea of these structures had destroyed the marsh structures and the local ecosystem also exists (Bryn 2014). In the long term, it is hard to decide whether these structures are beneficial to society or not.

Still, the future does not seem optimistic to us. By 2100, the rising sea level range from 0.2 meters to 2.0 meters (NASA 2018). Under the current circumstance, it is almost impossible for sea level to rise only 0.2 meters, and the real situation might be even worse than a 2 meters increase. In the past 30 years, Shanghai has a sea level rise of 11.5 cm, and most sea walls being recently constructed have an average height of 6-7 m. Yet some of the water embankments was not constructed as tall as these sea walls. According to the prediction by Climate Central, the most valuable city center, Lujiazui, would be under water by 2100 (Strauss 2015) (Fig. 13). Besides, recent studies have proved that Shanghai is actually sinking because of its overuse of the groundwater resources (Ruggeri 2017). This even relatively worsens the situation of global sea level rise.

Although the situation is tough for us, the hope still exists for us. First, Shanghai could keep focusing on their reconstruction of the drainage system. On this problem, Beijing has figured out a practical way of building huge concrete reservoirs underground to solve the problem of intense rains. By 2015, these giant reservoirs could hold 210, 000 m^3 water (Xinhua News 2015). Second, Shanghai can continue to increase the heights of their sea walls and water embankments. Finally, Shanghai could redirect the Huangpu River and all the rivers flow through the city by digging canals. Although the Bund and the Lujiazui Skyline will permanently lose the waterways that separate them, it is better than being flooded all the year.

In conclusion, the rising sea level is a huge problem along China’s coastlines. However, it is not even one of the most urgent environmental issues that China is facing. Air pollutions, water pollutions, desertification, biodiversity, and cancer villages are all more urgent than sea level rise, and many of them are even hazardous. The relationship between human and the environment is a significant topic being discussed in China and around the globe. But, the central government of China is ignoring these problems to keep their fast pace in increasing GDP. Yet, what is the purpose of this economic boom at the price of reducing human lives?

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Figures:

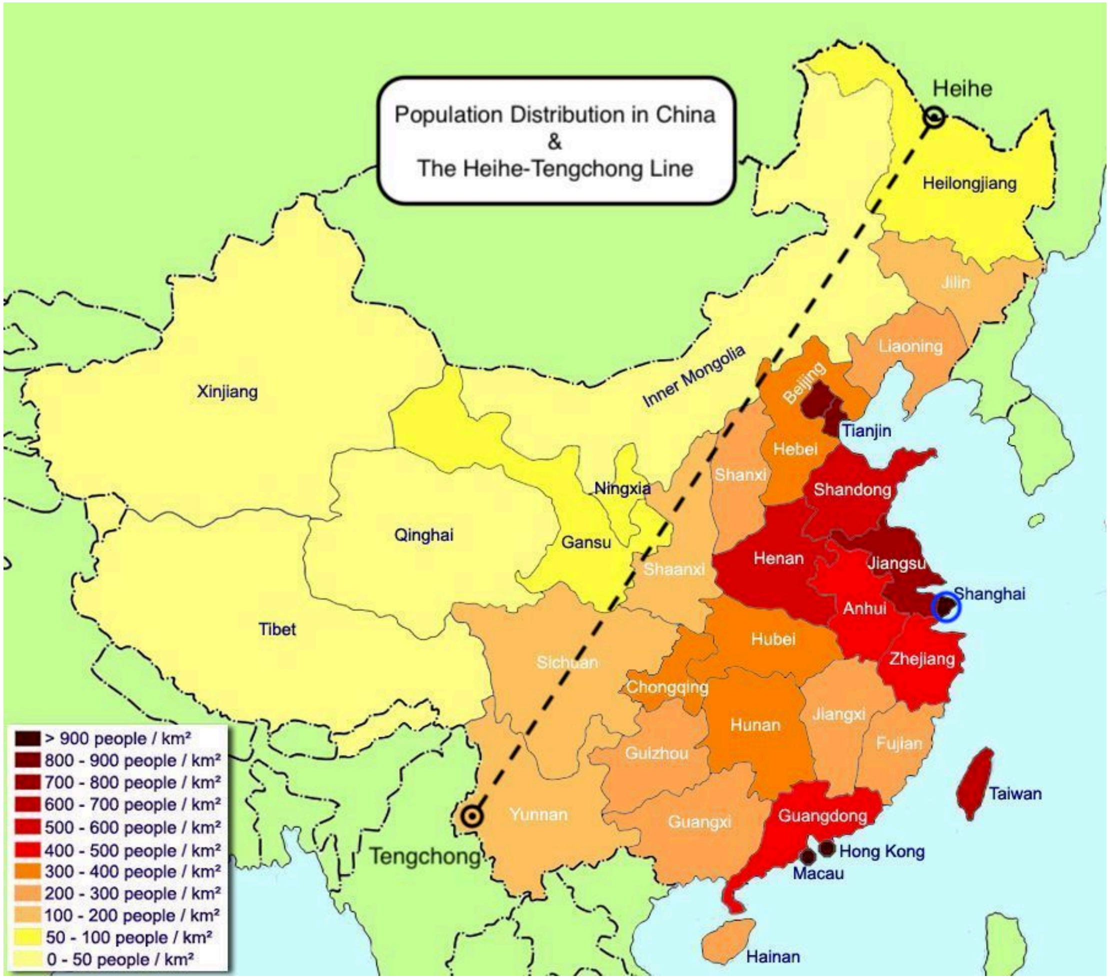

Fig. 1[1]: Chinese Population Distribution.

[1] Fig. 1 is adapted from: https://baike.baidu.com/item/中国人口/4417422. Translated, remodified, and converted by Jinghong He.

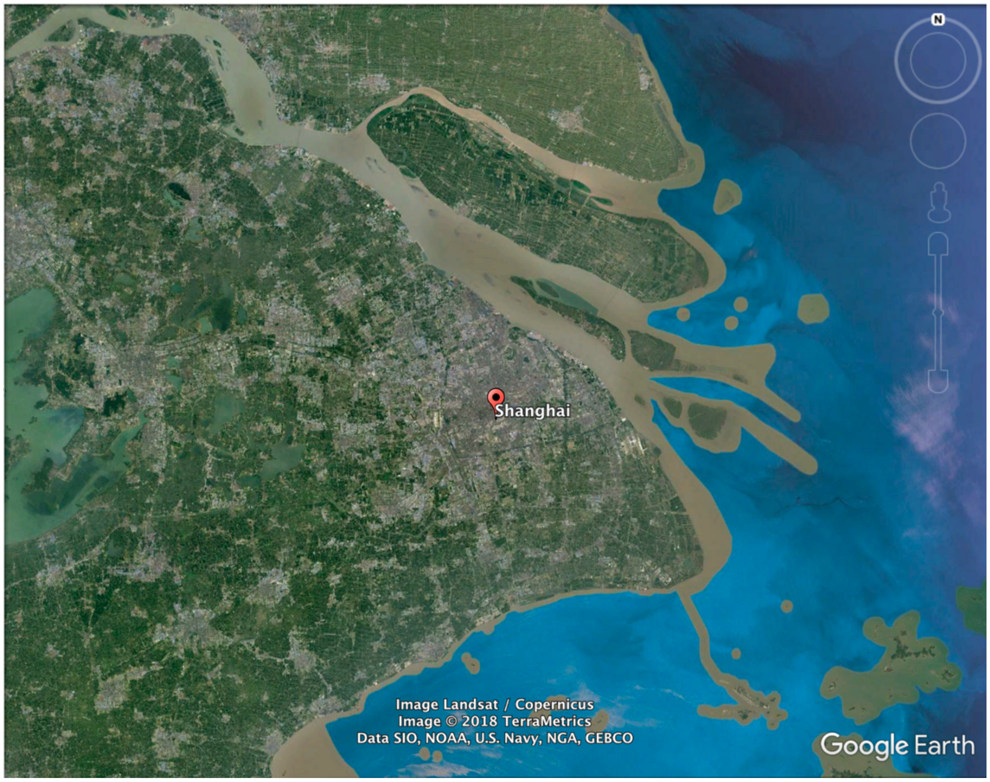

Fig. 2[2]: Geographical location of Shanghai

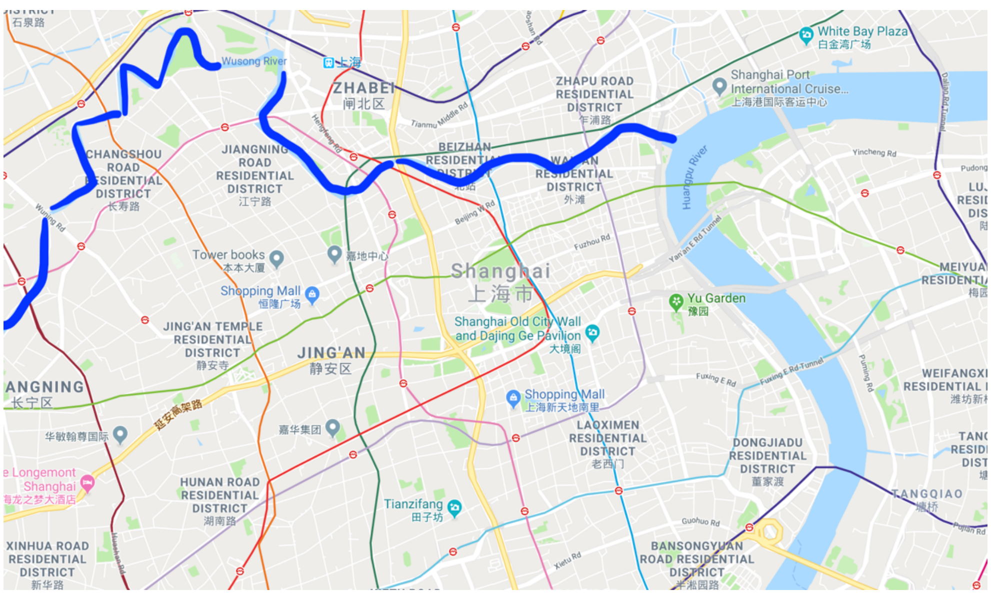

Fig. 3[3]: Suzhou Creek (Wusong River) in Blue line

[2] Fig. 2 is adapted from Google Earth Pro.
[3] Fig. 3 is adapted from Google Map. Modified by Jinghong He.

Fig. 4[4]: Waterlogging, Shanghai. Shot on June 24th, 2018

Fig. 5: Waterlogging, Shanghai. Shot on June 24th, 2018

[4] Fig. 4-5 are adapted from https://www.google.com/search?q=Shanghai+waterlogging&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiev_fStYrfAhXPo1kKHZyqAsMQ_AUIDygC&biw=1440&bih=837&dpr=2

Fig. 6[5]: Suzhou Creek Flood Gate

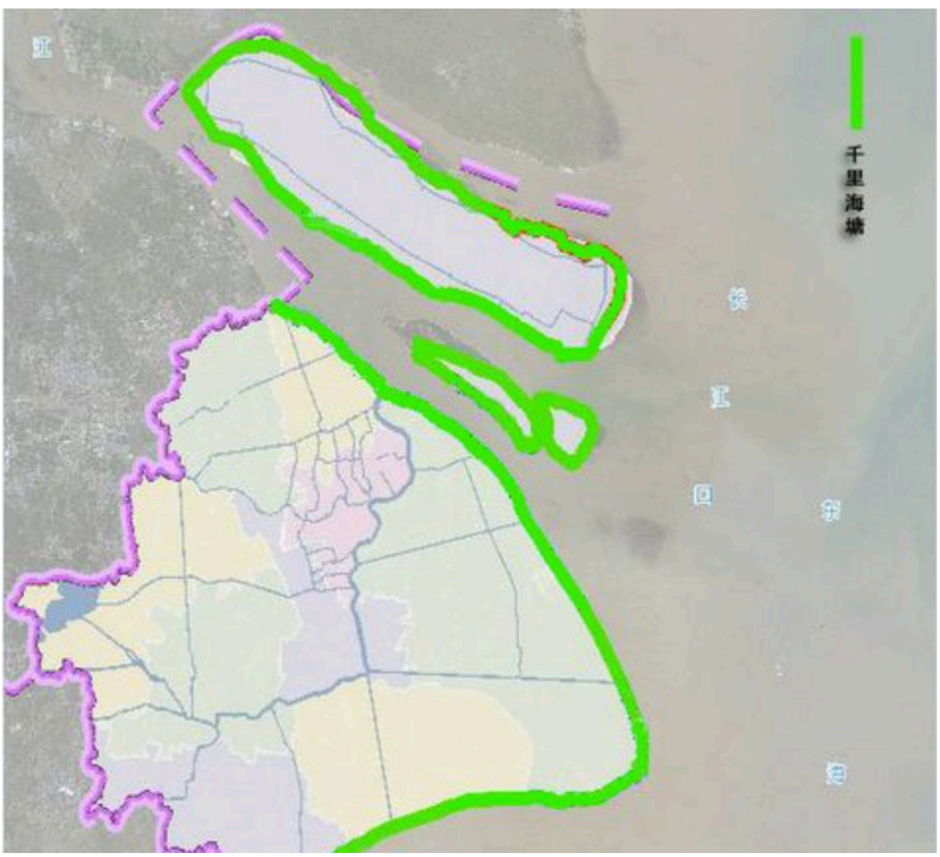

Fig. 7[6]: Distribution of seawalls in green line

[5] Fig. 6 by Xun Zhang.
[6] Fig. 7-12 is adapted from https://www.swedri.com/brand/

Fig. 8: Seawall, Shanghai Pudong International Airport

Fig. 9: Seawall, Chemical Industrial Zone of Shanghai

Fig. 10: Distribution of river embankments in blue line

Fig. 11: River embankments, Shanghai

Fig. 12: River embankments, Shanghai

Fig. 13[7]: Water level projection of Shanghai, 2100

[7] Fig. 13 is adapted from http://www.climatecentral.org/news/global-icons-at-risk-from-sea-level-rise-pictures-19633