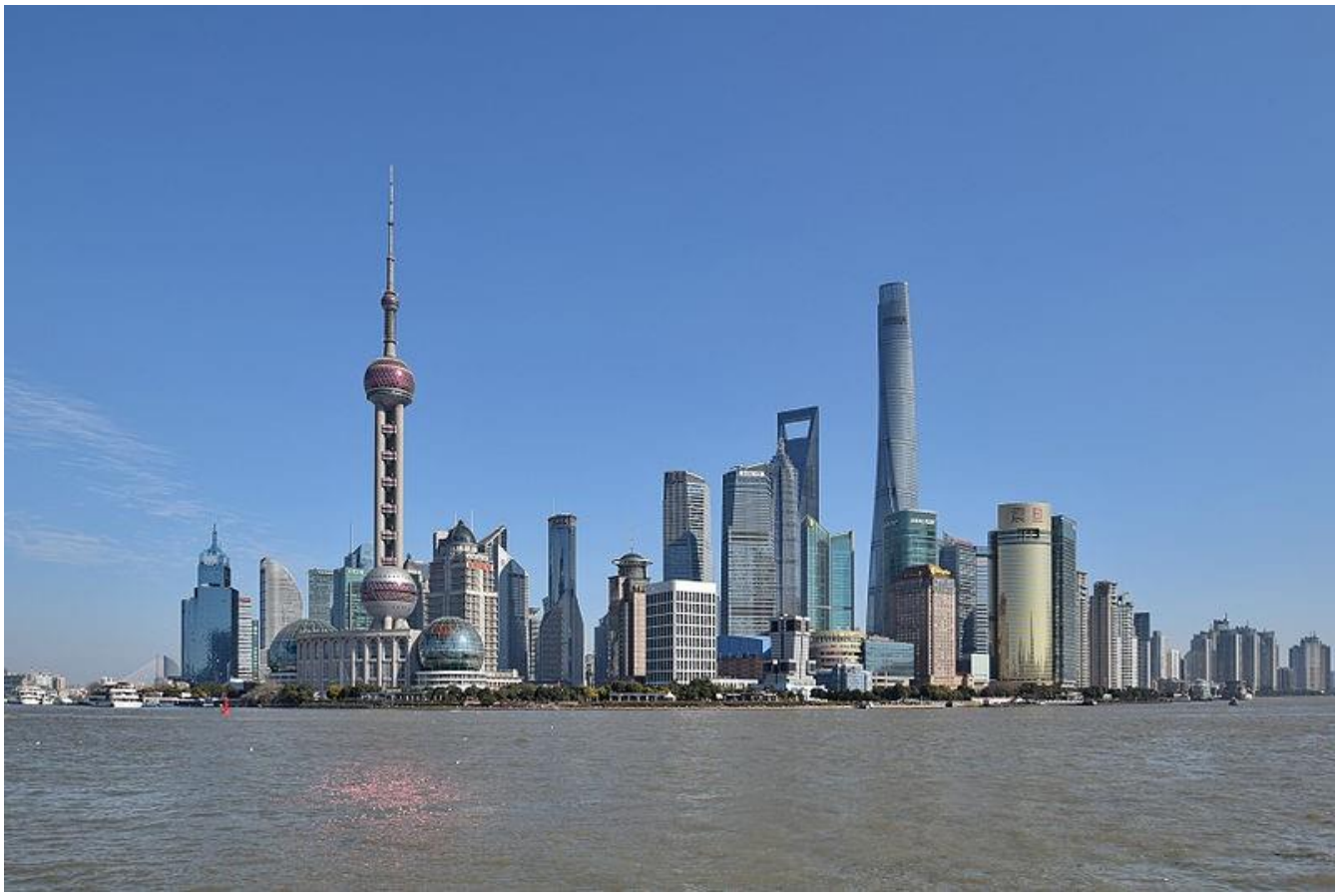
Sinking Cities, Rising Seas

A perfect storm of climate change and bad development choices

5 October, 2018



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Foreword

On 8 October 2018, the IPCC will publish its long awaited report on limiting climate change to 1.5ºC. The report will underscore the increasing vulnerability of planetary systems to increasing temperatures. One recent study notes that limiting warming to 1.5ºC is at the high end of what we currently experience, while 2ºC would take us into a climate regime unparalleled in human history[1].

Even with the current 1ºC of warming climate, vulnerabilities to climate impacts are becoming increasingly obvious – as in this year's northern hemispheric heat wave and the lethally catastrophic storms Mangkhut and Florence demonstrate.

Many of the world's biggest cities are coastal, and face the threats of rising sea level - expected to be more than 40cm by 2100 if warming is not limited to 1.5ºC and more than 50cm if we don't keep it under 2 ºC.[2] However, this climate impact does not act in isolation: in addition to facing rising waters, as the examples below show, many cities are actively sinking. This increase their overall vulnerability to sea level rise and to damaging storm surges, something that increased the devastating impacts of Typhoon Haiyan in the Philippines. Through a number of factors, including some poor development decisions, many cities are already highly vulnerable to storm surges and flooding. Climate change acts as a further multiplier of existing and future vulnerabilities.

The growth in urban populations is substantial: by 2030, more than 59% of the global population is predicted to be living in urban centers[3]. Asia is the region with the largest urban population and an estimated 54% live in low-lying coastal zones[4]. This growth increases the human vulnerability to climate impacts.

Collective, collaborative and unprecedented efforts to limit warming by reducing greenhouse gas emissions as quickly and deeply as possible, in line with limiting warming to 1.5ºC with a high probability is essential to reduce this climate vulnerability. This will require the world to achieve net zero emissions[5] by 2050. However, current pledges for action add up to a frightening 3ºC of warming. This, alongside the existing vulnerabilities, makes it all the more imperative that major investment in adaptation and flood risk reduction measures are implemented, with funding most urgently needed for the poorest countries and the most vulnerable communities.

This paper looks at 8 city case studies from around the world, exploring some of the underlying reasons for vulnerability, and then the additional impact that climate change will have on their people. These cities include some of those most vulnerable to climate change[6].

Jakarta

Jakarta reportedly holds the record for the world's fast sinking city, at a rate of around 25.4cm per year. Around 40% of the city now lies below current sea levels.[7] Coastal districts, like Muara Baru have sunk as much as 4.27m in recent years.[8]

As a baseline, its location is naturally flood-prone: the northern part of the city lies on plains that range from -2 to 50m above sea level, with an average elevation of only 8m. Thirteen rivers flow through the city.[9] However, human impacts add new dimensions to the vulnerability.

Jakarta's fundamental problem is the extent of net ground water extraction. Over half of the population of 10.3 million people lack access to piped water and the surface water is heavily polluted, so they dig illegal wells to extract groundwater. Despite rains and the rivers, incoming water does not replenish the soils, as over 97% of Jakarta is covered in impermeable asphalt and concrete. The resulting subsidence of the soils is exacerbated by a lack of sediment being brought downstream by rivers, which normally offsets some of the anthropogenic water extraction. Natural flood buffers, such as mangroves have been removed to make way for shanty towns and apartment buildings, which are also increasingly being built in marginal lands, such as flood plains and coastal marshes[10]. While the loss of groundwater undermines Jakarta from underneath, the sheer weight of its buildings pushes from above, causing further sinking. The rivers sometimes flow upstream because of the deformation of the land.[11]

And all this is before the 40-50cm of sea level rise predicted, should the Paris Agreement temperature goals be achieved. And much for ambition is needed for those goals to be close to being achieved.

Bangkok

Bangkok is another city whose hydrological vulnerability to rising sea levels has been exacerbated by its own water use. Three years ago, in 2015, its government published a report which concluded that the city could be underwater in the next 15 years[12]. The city has an elevation of around 1.5m above current sea level and is sinking towards it at a rate of about 2cm per year[13].

As elsewhere, Bangkok's sinking feeling has ironically been made worse by its reaching for the skies. The sheer weight of its buildings are pressing into the riparian sediments and compacting them as the sustaining water is depleted from them. Thailand's National Reform Council notes that there are about 700 buildings with 20 floors or more and 4,000 buildings with 8-20 floors in the city, putting considerable pressure on the land on which they sit. The NRC recommended building a US$14.3 billion sea wall to protect the city[14].

Bangkok has not been politically passive to its subsidence. Extreme land subsidence has been successfully reduced through a Ground Water Act in 1977, which acted to regulate and restrict groundwater extraction, with the most severely sinking areas more controlled. Charges for use of groundwater were brought in in 1985, such that now only 10% of total water use is from aquifers. The subsidence continues, but at a slower rate.[15] Water is additionally being actively pumped back into the ground to address the drying of the underlying sediments[16]. Despite, this, the city remains highly vulnerable to rising seas.

Lagos

Lagos's closeness to water is reflected even in its name, which derives from the Portuguese for 'lakes'. Even as a city built on the coast and including a number of islands, the city's closeness to water is becoming increasingly intimate, as sea levels rise from climate change and other hydrological vulnerabilities assert themselves. Lack of adequate drainage exacerbated the 2011 floods, where three weeks of torrential rain led to the city being engulfed by floods.[17] Some estimates suggest that a sea level rise of 20cm could cause 740,000 people to lose their homes across Nigeria[18]: clearly the need to limit warming as much as possible is of paramount importance to avoid these people being internally displaced.

Like other cities, excessive ground water extraction, leading to subsidence, is an issue, even though there are reports that industrial chemicals contamination of the water is an problem in some localities[19]. A new law seeks to fine or imprison residents who drill boreholes without government authorization, but has been controversial[20] as access to water is a problem, not least as 70% of the city's population live in informal settlements.[21]

The city's government has permitted the development of a new island based on 10km^2 of filled in land bordering Lagos directly, with the aim of creating jobs and addressing some of Lagos' other economic challenges. Eko Atlantic aims to host a new capital for Africa to include a new financial district, private power grid and shopping boulevard. This new creation will be surrounded by a protective sea wall. However, this wall may serve to worsen the impacts of the rising sea and storm surges on neighboring islands by pushing the force of the water away from the new development and towards other lower lying islands – and the rest of Lagos[22]. Non-sustainable development, combined with climate impacts, may not prove a good combination for the city.

Manila

The theme of groundwater extraction contributing to subsidence is also relevant to the Philippine capital, Manila and its 12.9 million people. Ground water use is causing sinking of around 10 cm per

year, or ten times the rate of sea level rise through melting land ice and thermal expansion[23]. Since the city has an average elevation of around 5m, it seems to be living on borrowed time. The subsidence not only increases the absolute risk of flood, but also the areas affected: high tides can penetrate further inland and floods may recede more slowly[24]. This means that there is increased risk of salination of soils that were previously fertile.

The water-crop relationship is not that simple, however. Rice is a major crop of the area to the north of Manila and it consumes more water than any other crop, and modern high yielding varieties more so than those traditionally grown[25]. Illegal expansion of fishponds into tidal channels increases the risk of floods, as well as causing the drying of the top layers of sediment when they are constructed. Since people complain that their wells stop flowing during periods when large rice plantation irrigation and fishponds are active, it would suggest that these, rather than domestic use might be the larger culprit, but this is hard to measure, as the users do not allow measurement of their water use. Also to blame, and rather less justifiably, are the private golf courses and swimming pools of the affluent that are maintained with unregulated water.

Dhaka

Bangladesh's capital is another low-lying, river-side city beset by a sinking feeling caused by unsustainable extraction of groundwater. As in other cities, including Jakarta, the drive for exploiting groundwater is promoted by the levels of pollution of its rivers. The city is sinking at a rate of about 1.4cm per year, with most urbanized areas a mere 6-8m above sea level[26]. It is not just the hydrology that is changing however, plate tectonics also appears to be playing a role. Movements of the Indian plate and Burman sub-plate are causing subsidence of the Dhaka land mass, but since the slow movement of the plates only causes around 3-5mm per year of sinking, it is clear that human water extraction is several times more important a cause of subsidence.[27]

Sea level rise already appears to be causing migration: people have already been displaced from the lowest lying villages in the river deltas, and these have contributed an additional 1.5 million people of the 5 million slum dwellers[28] in a city where the overall population is around 17.6 million. And sea level rise appears to be happening at a rate ten times greater than the global average in the Bay of Bengal, southwest of the city.[29]

Bangladesh has worked to reduce its vulnerability by creating an early-warning system and building storm shelters, resulting in vast reduction in storm-related deaths. However, additional sea level rise from climate change may challenge these efforts to breaking point.

Shanghai

Shanghai, and its 23.7 million inhabitants, is another victim of its own groundwater use causing sinking subsidence in the city. The effect was first noticed in 1921 when the first surveys were undertaken and since then, the center of the central business district has subsided by 2.6m[30]. Like other delta cities, it also suffers from a lack of sediment recharge because sediment is trapped by upstream dams or is extracted for building material.

The sediments on which the city has been built are not responding just to the water extraction, but to the sheer weight of the infrastructure built upon them. In 2012, an 8m long crack opened up at the foot of the 632m tall Shanghai Tower project, near to other two massive towers at 492 and 420m tall[31]. The balance of the impact of water and building weight on the overall subsidence appears to be disputed as to whether building weight is a “minor cause”[32] or accounts for up to 40% of the sinking[33]. Whatever the balance, Shanghai’s cumulative total losses from subsidence in the period 2001-2010 were approximately 2 billion dollars[34].

Shanghai has pursued notably strong measures to reduce or even reverse the sinking. In 1995, the city required each well to have an official permit and a year later it had invested in a GPS system to monitor the sinking[35]. There has been a substantial shift from using ground water to extracting from the local rivers for most uses, so the annual sinking rate is now down to 1cm as opposed to a business as usual rate of around 9cm[36]. In addition, pumping 5.2bn gallons of water a year into the aquifers has not only helped slow the subsidence, but in some areas reversed it: some land is now 11cm higher than it was[37] (or the difference in sea level rise between limiting warming to 1.5ºC or 2ºC).

London

London’s sinking is largely a vestige of the last ice age. The “glacial isostatic adjustment” it is experiencing is a result of the weight of the glaciers pressing down on Scotland 11,000 years ago. These depressed the north and allowed the south of the UK to relatively soar. However, since the UK’s glaciers have melted, Scotland is on the rebound, at a rate of around 1mm per year, and the south of the country is simply sinking back into the rising sea.

London is sinking at twice the rate of Scotland partly due to the continuing depression of the London Clay Formation and in the draining of many stretches of land. The increasing vulnerability of London’s 10.3 million residents is evident from the increased use of its primary flood defense, the Thames Barrier. Opened in 1984, the Barrier was designed to protect London from a once-in-100-year risk of high flood levels up to 2030, thereafter still remaining within acceptable limits. In 1984, its annual use was predicted to be 2-3 times a year. Its current rate of use is 6-7 times per year. With

another 40-50cm of sea level rise from climate change, even in good scenarios for climate action, will Parliament keep its supremacy, or will the waves rule Britannia?

Houston

Houston faces natural vulnerabilities, but some of its problems are self-inflicted. The city sits on the banks of the Buffalo Bayou and its three tributaries, which flow slowly over the flat lands of the gulf coastal plain, making the area vulnerable to flooding. Furthermore, downtown Houston currently stands a mere 15m above sea level[1] and is sinking further, even as the sea level rises. An area of the city has already been lost: Brownwood, an up-market residential peninsula began to sink and a 1983 hurricane rendered it uninhabitable.[2]

The 12,500 km^2 of the greater Houston-Galveston area has already experienced a lowering of the land surface by as much as 3m[3] and the northwest of the city continues to sink by as much as 2 inches per year[4]. The subsidence has meant that areas that weren't prone to flooding have become so[5] and that drainage topology has changed so that water outflow rates are decreased, increasing flooding risk. This subsidence is in part a result of long-term industrial ground-water withdrawal from shallow aquifers to provide water for its 5.5 million population. Sea level rise and storm surges will only exacerbate these effects.

In addition, Houston's production of oil and gas is - literally - contributing to its own downfall, as extraction of the minerals leads to further subsidence. Ironically, being a fossil producer is undermining Houston's already-limited resilience to climate impacts, including sea level rise. Ironically, Brownwood was home to many oil and gas executives.[6]

Conclusion

In each case, the location of the city was chosen without any idea of the future scale of population living there. Bad development decisions, and a lack of recognition of the carrying capacities of the land are being exacerbated by sea level rise from human-induced climate change. To protect the inhabitants of these cities, the causes of the subsidence, where possible, should be addressed and measures to increase the cities' resilience should be urgently

[1] http://www.experts123.com/q/how-high-is-the-elevation-of-houston-above-sea-level.html

[2] https://www.houstonchronicle.com/news/houston-texas/houston/article/Brownwood-The-suburb-that-sank-by-the-Ship-4379765.php

[3] https://pubs.usgs.gov/of/2003/of03-337/extraction.html

[4] https://www.houstonchronicle.com/news/houston-texas/houston/article/For-years-the-Houston-area-has-been-losing-ground-7951625.php

[5] ibid

[6] ibid

implemented. Protection of the poorest and most vulnerable communities must be a priority. Of greatest urgency, these case studies underscore the need for greater and more rapid greenhouse gas emissions reductions to reduce the amount of sea level rise – and the threats that it poses.

End notes

[11] Schleussner C-F, TK Lissner, EM Fischer, J Woland, M Perrette, A Golly, J Rogelj, K Childers, J Schewe, K Frieler, M Mengel, W Hare, M Schaeffer, 2016, "Differential climate impacts for policy-relevant limits to global warming: the case of 1.5ºC and 2ºC"**,** Earth Syst. Dynam., **7**, 327–351

[2] *ibid*

[3] ICRC, 2010, "World Disasters Report; Focus on Urban Risk"

[4] Http://unescap.org/stat/data/syb2011/I-People/Urbanization.asp

[5] Net zero emissions are where emissions into the atmosphere are balanced by uptake of gases eg through forest growth

[6] Hallegatte S, C Green, RJ Nicholls and J Corfee-Morlot, 2013, 'Future Flood Losses in Major Coastal Cities' Nature Climate Change, **3,** 802-806

[7] https://weather.com/science/environment/news/2018-04-06-jakarta-indonesia-sinking-groundwater

[8] https://www.nytimes.com/interactive/2017/12/21/world/asia/jakarta-sinking-climate.html

[9] https://en.wikipedia.org/wiki/Jakarta#Geography

[10] https://www.deltares.nl/app/uploads/2015/09/Sinking-cities.pdf

[11] https://www.nytimes.com/interactive/2017/12/21/world/asia/jakarta-sinking-climate.html

[12] https://weather.com/science/environment/news/bangkok-sinking-subsidence-warming-15-years

[13] ibid

[14] https://www.bangkokpost.com/news/general/631224

[15] https://www.deltares.nl/app/uploads/2015/09/Sinking-cities.pdf

[16] ibid

[17] https://guardian.ng/features/science/confronting-climate-change-doom-in-lagos/

[18] ibid

[19] http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_Nigeria

[20] https://www.premiumtimesng.com/news/headlines/224917-lagos-criminalises-drilling-boreholes-without-permit.html

[21] https://guardian.ng/features/science/confronting-climate-change-doom-in-lagos/

[22] https://qz.com/africa/923142/the-flaw-in-the-construction-of-eko-atlantic-island-in-lagos/

[23] http://www.science.ph/full_story.php?type=News&key=8871:metro-manila-sinking-farms-fishponds-blamed

[24] http://www.gmanetwork.com/news/scitech/science/298939/overpopulated-metro-manila-is-sinking-and-flooding-fast/story/

[25] http://www.science.ph/full_story.php?type=News&key=8871:metro-manila-sinking-farms-fishponds-blamed

[26] Saleemul Huq and Mozaharul Alam http://www.bvsde.paho.org/bvsacd/cd46/cap9-flood.pdf

[27] https://poleshift.ning.com/profiles/blogs/7-of-10-sinking-dhaka-is-sinking-over-half-an-inch-a-year-on

[28] https://www.nytimes.com/2014/03/29/world/asia/facing-rising-seas-bangladesh-confronts-the-consequences-of-climate-change.html

[29] https://pure.qub.ac.uk/portal/en/publications/rapid-rise-in-effective-sealevel-in-southwest-bangladesh-its-causes-and-contemporary-rates(792fcb3f-eb18-45fe-9837-7c7443b559e0).html

[30] https://www.theguardian.com/world/2012/apr/03/china-cities-suffer-land-subsidence

[31] https://www.theguardian.com/world/2012/apr/03/china-cities-suffer-land-subsidence

[32] ibid

[33] http://hua.umf.maine.edu/China/p_Shanghai_Bund_history/01910243wPudong.html

[34] https://www.deltares.nl/app/uploads/2015/09/Sinking-cities.pdf

[35] http://www.china.org.cn/english/2003/Jul/70034.htm

[36] https://abcnews.go.com/Technology/story?id=120074&page=1

[37] ibid