WWF

for a living planet®

VOTE EARTH!

Mega-Stress for Mega-Cities

A Climate Vulnerability Ranking of Major Coastal Cities in Asia

Table of Contents

Executive Summary

Asia is arguably among the regions of the world most vulnerable to climate change. Climate change and climatic variability have and will continue to impact all sectors, from national and economic security to human health, food production, infrastructure, water availability and ecosystems. The evidence of climate change in Asia is widespread: overall temperatures have risen from 1°C to 3°C over the last 100 years, precipitation patterns have changed, the number of extreme weather events is increasing, and sea levels are rising. Because many of the largest cities in Asia are located on the coast and within major river deltas, they are even more susceptible to the impacts of climate change. In response, this report highlights the vulnerability of some of those cities - with the goal of increasing regional awareness of the impacts of climate change, providing a starting point for further research and policy discussions, and triggering action to protect people and nature in and around Asia's mega-cities from mega-stress in the future.

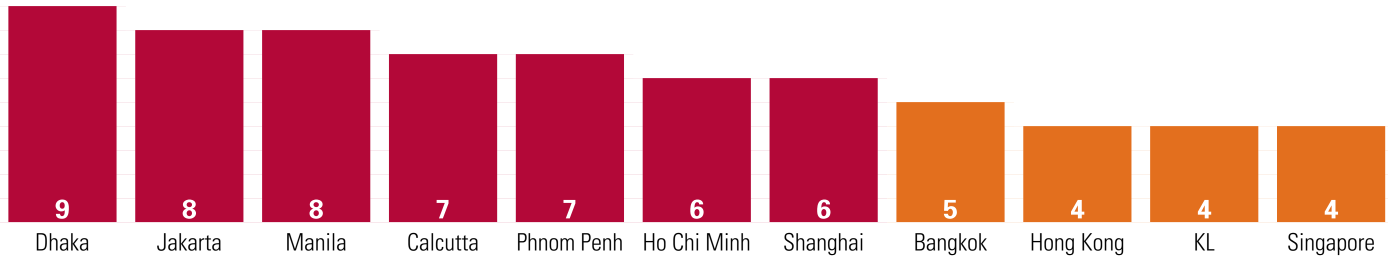
Cities cover less than 1% of the planet's surface, and are home to around 50% of the world's population, and many of them see a rapid growth trend. Taken together, all cities and urban areas worldwide use 75% of the world's energy and are responsible for 75% of global greenhouse gas emissions. Without major breakthroughs on energy efficiency and emission reductions in cities, we will fail to avoid dangerous climate change in urban as well as rural areas. Cities are hotspots of innovation and technology and have therefore traditionally been the places where many of the solutions to the world's problems have been developed, making all cities potential leaders in the global effort for a low carbon future.

This report, however, focuses on climate variability and adaptive capacity of cities. It is divided up into four sections: context, methodology, scorecards, and policy. While we highlight the major climate change effects impacting 11 key Asian cities, this summary is by no means an exhaustive review. The cities chosen for this report represent large, mostly coastal cities which are all threatened by climate change. These particular cities were chosen because they represent a good cross section of coastal Asia and the impacts of climate change were assessed as significant. We encourage governments and all other relevant stakeholders to use this report as a catalyst for further discussions on the issue of climate change in the region, deciding where additional research is needed, and what the appropriate polices should be.

For each scorecard, we provide a short profile of the selected city, highlight the observed climatic change, summarize the major climate impacts the city is facing, and suggest some adaptation strategies that may decrease the city's vulnerability. For this analysis, the vulnerability of the cities is a function of their exposure, sensitivity, and adaptive capacity. These three categories were averaged to get the overall vulnerability score. It should be noted that WWF has approached the issue of vulnerability in this report with the most simplistic analysis possible, and we appreciate that there are many additional factors to consider and alternative methods for assessing vulnerability.

Below we highlight the overall vulnerability scores and rank them. However, apart from the overall ranking taking into account all the assessed criteria, this report also summarizes a number of other comparisons including which city is most at risk of environmental threats, which city is most socio-economically sensitive to climate change impacts and which city has the lowest adaptive capacity.

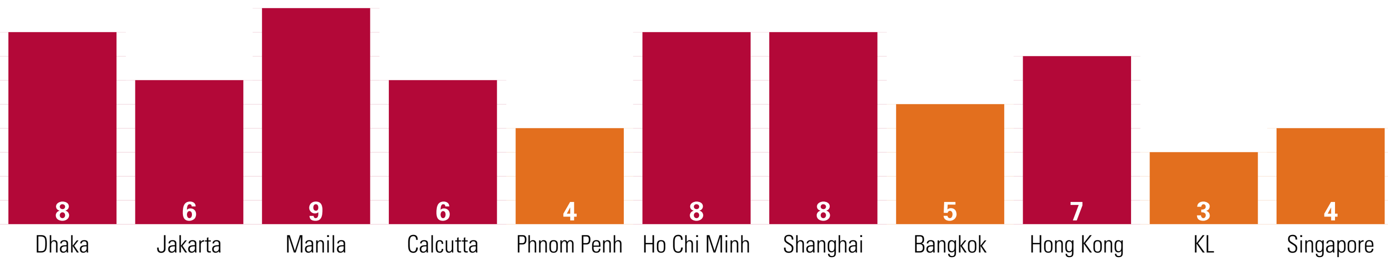
Overall Vulnerability



Overall Climate Vulnerability Ranking

Of the 11 cities examined, Dhaka in Bangladesh is most vulnerable to climate change impacts. This large, relatively poor city sits just meters above current sea levels, is regularly impacted by tropical cyclones and flooding, and has very limited adaptive capacity. Jakarta in Indonesia and Manila in the Philippines are also highly vulnerable cities and tied for the second rank, largely because of the size of the cities, degree of exposure (both experience frequent flooding), and relatively low adaptive capacity. Calcutta in India and Phnom Penh in Cambodia are tied for third most vulnerable city, largely because Calcutta is prone to salt-water intrusion and sea-level rise effects, while Phnom Penh has very low adaptive capacity. Ho Chi Minh City in Vietnam and Shanghai in China are tied for fourth most vulnerable city, because both are very susceptible to sea-level rise, even though Vietnam and China may have slightly higher adaptive capacity when compared to some of the other cities. Bangkok in Thailand is the fifth most vulnerable city, mostly because it has a relatively high socio-economic sensitivity to impacts (i.e., it has a large population and contributes a large proportion towards Thailand's gross domestic product). Kuala Lumpur in Malaysia, Hong Kong in China, and Singapore in the Republic of Singapore are all tied for the sixth most vulnerable city, mostly because all three have slightly more adaptive capacity than the other cities, even though the climate impacts are still significant.

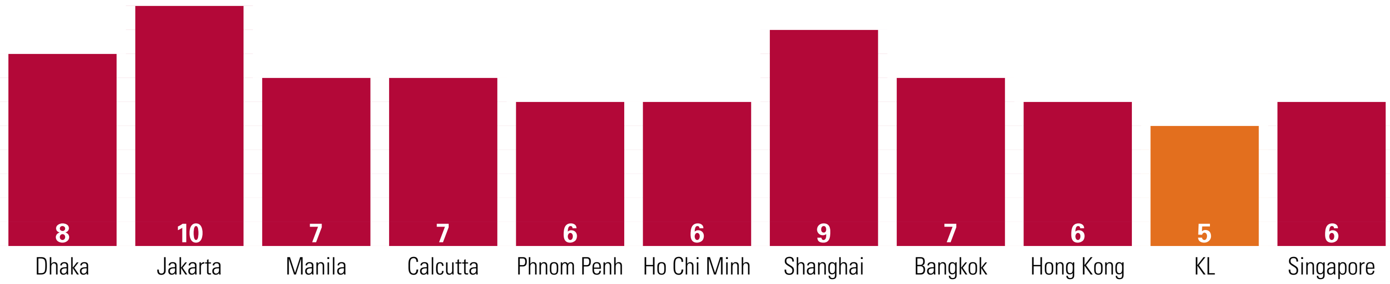
1. Exposure



At Risk: Comparing Exposure To Climate Impacts

All examined cities will be significantly impacted by climate change, but when examining the selected impacts (tropical storms, sea-level rise and flooding and drought), the report found that some of the cities may experience more frequent or more intense events than others. For this report, exposure is the average of the three highlighted environmental categories including the susceptibility of the city impacted by 1 m sea-level rise and 2 m storm surge (as illustrated in the satellite photos at the end of each city chapter), historical frequency of extreme weather events including flooding and drought, and frequency of tropical storms and surges. When examining just the exposure to these impacts, we see a slightly different picture from the overall vulnerability ranking. Manila, largely due to its exposure to tropical cyclones and flooding, tops the list as most exposed. The recent tropical storm Ketsana illustrates this exposure of Manila and the surrounding area to environmental threats. With flood waters reaching nearly 7 m and hundreds of deaths during this one storm, Manila is truly vulnerable. Dhaka, Ho Chi Minh City, and Shanghai tie for having the second highest exposure to climate change impacts, largely because of their susceptibility to flooding and tropical storms. Hong Kong ranks the third highest in terms of exposure to climate change impacts. However, Hong Kong has relatively high adaptive capacity and therefore is overall less vulnerable. Calcutta and Jakarta are ranked as having the fourth most exposure, with Bangkok coming in close in the fifth spot. Not surprisingly, Phnom Penh, Singapore and Kuala Lumpur are ranked at the low end of the exposure scale, but this is not implying that they are not at risk to climate change impacts. All cities examined already see substantial threats with loss of life and significant damage costs, and the situation is projected to worsen in the future.

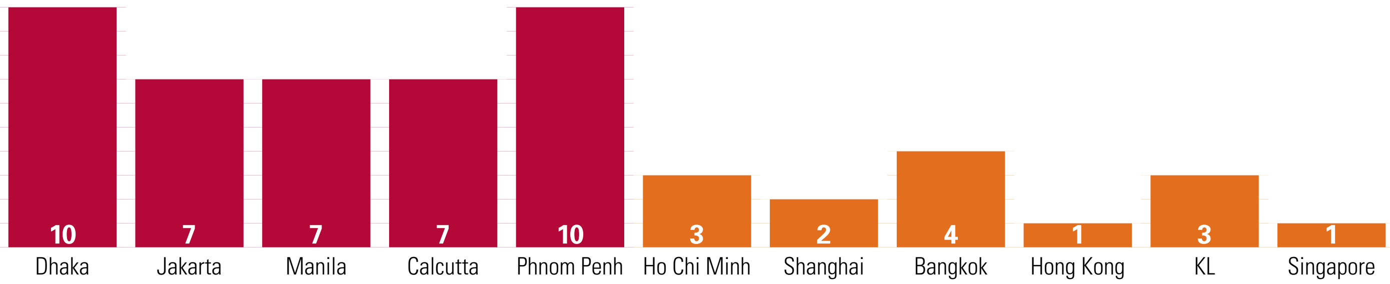
2. Sensitivity



Sensitivity Ranking: People, Assets And GDP Under Threat

The relative sensitivity of the 11 selected cities to climate change impacts is based on population, gross domestic product (GDP), and the relative importance of that city to the national economy. Using these criteria, Jakarta stands out as the most sensitive to climate change impacts. This is largely due to Jakarta's large population and huge contribution towards national GDP. The second most sensitive city to climate impacts is Shanghai for similar reasons. Dhaka is third most sensitive, while Calcutta, Manila, and Bangkok are all tied for the fourth most sensitive. Phnom Penh, Hong Kong, and Ho Chi Minh are fifth most sensitive, while Kuala Lumpur is sixth most sensitive to climate change impacts.

3. Inverse Adaptive Capacity



Preparing To Face The Storm: Adaptive Capacity Comparison

We estimated the adaptive capacity of these 11 cities by examining the overall willingness of the city to implement adaptation strategies (calculated by the number of available adaptation examples and/or responses to previous impacts) and the per capita GDP. It should be noted that a significant caveat of this study is that there are likely quite a number of adaptation examples that cannot be located with desk top reviews. For example, people may come up with their own adaptation strategies in the face of climate change. However, mass media, the internet, and peer-reviewed journals will likely not pick up this information. In essence, the estimates for these 11 cities are just that, estimates based on existing information. For uniformity, we inversed the adaptation capacity numbers so that low adaptive capacity is represented by a larger number (e.g., 10 equates to a very low adaptive capacity). Dhaka and Phnom Penh top the ranking as having the lowest adaptive capacity to climate change. This is not a surprise as both countries, Bangladesh and Cambodia, are classified as Least Developed Countries by the United Nations. Calcutta, Jakarta, and Manila have the second lowest adaptive capacity. Bangkok is next, with Kuala Lumpur and Ho Chi Minh following. Shanghai has the second highest adaptive capacity, and Hong Kong and Singapore tie for having the highest capacity.

Policy Recommendations: How To Adapt Mega-Cities To Mega-Stress

Whether one examines one or all three components of vulnerability, it is evident that climate change will affect Asian cities in many different ways. The latest science as reported by the Intergovernmental Panel on Climate Change (IPCC) and others has highlighted the impacts in much more detail than previously available. This report shows that these cities will be at the front line of climate change impacts. They therefore have a strong imperative to act decisively to avoid the dangerous levels of warming and limit global temperature rise to well below 2°C compared to preindustrial levels. Allowing climate change to continue to go unchecked will cost more lives and more money in the future, but if we act now, we can avert the worst impacts. The costs of avoiding the worst impacts of climate change can be limited to around 1% of global GDP/year, whereas the costs of inaction range from 5 to 20% of global GDP/year. To limit warming to 2°C with more than a 50% chance requires that global emissions peak before 2015 and decline 80 to 95% below 1990 levels by 2050. Therefore, WWF calls on developed countries to cut their emissions by at least 40% by 2020 and by at least 95% by 2050 compared to 1990 levels. To keep the global average temperature increase well below 2°C, the energy system needs to be altered substantially and adaptation needs to start immediately. This is a political challenge that requires decision-making structures to be put in place in order to drive such change. Governments, businesses, and the scientific community should focus their efforts on delivering results, and this report provides some examples of local and regional adaptation action, and local, regional and global policy efforts to support both adaptation and mitigation. WWF hopes this report can be a starting point for further action.

Context

Climate change is arguably the greatest global threat to sustainable development and natural resource management that we face today. The concentration of atmospheric carbon dioxide (CO_2) is now the highest in at least 800,000 years, primarily due to anthropogenic activities such as fossil fuel burning and land-use change. Since the beginning of the 20th century, the average global temperature has risen by about 0.7°C. Unfortunately, even if we were to stop all CO_2 emissions right now, we can expect at least an additional 0.6°C global average warming because of the emissions we've already released into the atmosphere and the inertia of feedbacks in the climate system. Consequently, we are locked into about 1.3°C global warming, and while there is not much we can do about that, it is crucial for the survival of entire nations and cultures to keep temperature rise as far below the danger-threshold of 2°C as possible.

Two years after the release of the IPCC synthesis report, studies are now showing that the worst projections are being realized and that the impacts are being felt around the world more and more. Recent synthesis has even suggested that some regions of the world may already be faced with irreversible biophysical changes due to climate change.

Asia's Extreme Vulnerability

Asia is the most populous and arguably the most vulnerable continent in the world because of the high risk of climate impacts and the relatively low adaptive capacity. Climate change and climatic variability in Asia have and will continue to impact all sectors, from national and economic security to human health, food production, infrastructure, water availability and ecosystems.

The evidence of climate change in Asia is widespread: temperatures in Asia have risen about 1°C to 3°C over the last 100 years, with most of this warming in the North. Precipitation patterns have also changed and there has been an increase in extreme weather events and sea levels have risen.

Impacts Here And Now, Tougher Challenges Ahead

Unfortunately, the full extent of climate change has likely not been fully realized. Climate change projections indicate that temperatures will continue to rise, precipitation patterns will become more variable, extreme weather events, such as intense rain storms, droughts, and tropical storms will increase in frequency and intensity, and sea levels will continue to rise. Some of these changes will be sudden and could drastically re-shape how and where people live.

In fact, climate change has the potential to push some of the most vital parts of our Earth over the edge and lead to irreversible change, and some of these "tipping points" may occur this century (e.g., collapse of the Indian summer monsoon season). Other changes include the shifting of climate zones, such as the tropics and semi-arid regions, and the acidification of the oceans, endangering calcifying organisms like corals, which will affect fisheries and our ability to feed large portions of the human population. Water availability and quality is also changing, with glacier-fed rivers that spill into Asia and supply millions of people with drinking water at risk of drying up. Compounding these effects are changes in precipitation patterns, which are impacting agricultural production and have the potential to push large regions of semi-arid, marginal land out of production.

Coastal Areas And Deltas Especially Threatened

Coastal populations are at high risk of sea-level rise and associated impacts, including increased flooding and salt water intrusion (see Figure 1). In addition to rising sea levels, much of Asia also suffers from considerable subsidence (sinking of the land) due to heavy extraction of groundwater supplies, tectonic activity, and natural ground movement. Coastal erosion, exacerbated by sea-level rise, also threatens vulnerable lands including deltas. In fact, many of Asia's largest cities, like the mega-cities analyzed in this report, were built on such deltas and are consequently some of the most at risk to the impacts of climate change.

The IPCC and others highlight that the mega-deltas of the world are widely recognized as highly vulnerable to the impacts of climate change, particularly sea-level rise and changes in runoff, as well as being subject to stresses imposed by human changes in catchment and delta plain land use. Due to these compounding factors most deltas in Asia are experiencing accelerated rates of relative sea-level rise, which are above the global average. Additionally, many deltas are receiving less sediment because of upstream dams, which also leads to subsidence. Huge areas of land and large numbers of people are being affected by these changes, particularly in Asia.

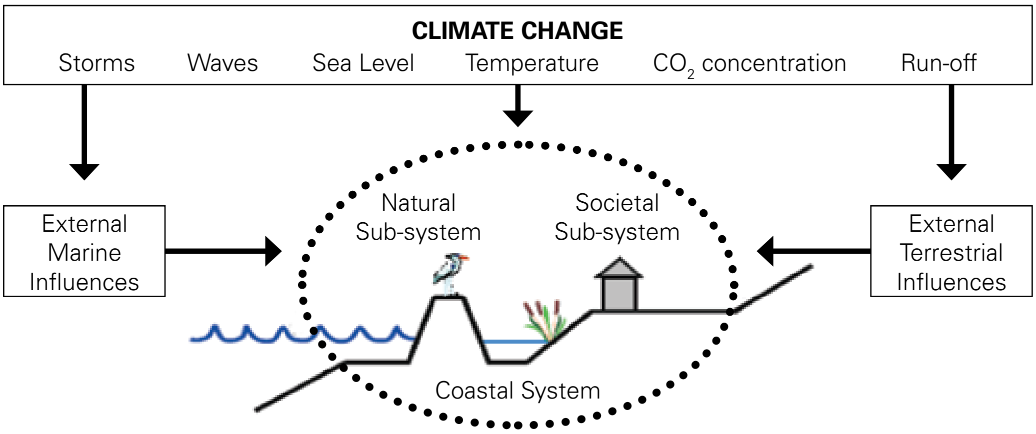


Figure 1.
Climate change and the coastal system showing major climate change factors, including external marine and terrestrial influences. Adapted from IPCC 2007.

Subsequently, there is a strong desire for more synthesis of climate change impacts to Asian cities and a framework of solution-oriented adaptation measures. In response, WWF provides the following report, which draws heavily on existing climate change research, including the IPCC and others.

Big Cities: Major Part Of The Problem, Key To The Solution

Many of the world's cities play an important role in tackling climate change because they are as much a part of the problem as they are a part of the solution. Cities cover less than 1% of the planet's surface, and are home to around 50% of the world's population, and many of them see a rapid growth trend. Their share of responsibility when it comes to climate change is massive: when compiled, cities and urban areas worldwide use 75% of the world's energy and are responsible for 75% of global greenhouse gas emissions.

Without major breakthroughs on energy efficiency and emission reductions in cities, we will fail to avoid dangerous climate change in urban as well as rural areas. However, cities are hotspots of innovation and technology and have therefore traditionally been the places where many of the solutions to the world's problems have been developed, making cities potential leaders in the global effort for a low carbon future. This is also true for some of the Asians cities covered in this report, which work hand in hand with cities in other parts of the world, identifying and implementing solutions through cooperation.

Taking A Stand Against Climate Change: Asia's Cities In Action

Bangkok, Dhaka, Hong Kong, Jakarta and Shanghai have joined the C40 group, a network of major cities from around the world that are joining forces to tackle climate change. Highlighting the importance of cities when it comes to the development and implementation of climate-friendly solutions, the mayors of these cities urge their national governments to give them a significant role in making a low carbon future happen. They want Heads of States to engage more closely with mayors, whose roles of responsibility mean that they are often very well placed to deliver cuts in emissions. The C40 also urge governments to empower and adequately equip city leaders, so that they have the authority and the resources required to take action within cities.

Many of the cities covered by this report also took a stand against climate action during Earth Hour, the global WWF event on 28 March 2009 that saw hundreds of millions of people, about 4000 towns and cities in 88 countries, as well as 20,000 companies and 1000 iconic landmarks switch off their lights for one hour to call for a fair, ambitious and binding climate treaty. In Bangkok, for example, Thailand's Prime Minister personally pressed the button when famous landmarks like the Grand Palace and the Temple of Dawn switched off. In Hong Kong, most of the skyscrapers in the city's famous skyline went dark. Jakarta switched off various iconic buildings and landmarks including the National Monument, while Shanghai plunged the Oriental Pearl Tower into darkness. In Kuala Lumpur, numerous celebrities witnessed the famous Petronas Twin Towers switch off, with similar actions taking place in Manila, Singapore, Ho Chi Minh City and many other places around Asia and the world, making Earth Hour the biggest demonstration for climate action to date.

Criteria compared for each city:

Environmental Exposure

- Storm threat (tropical cyclones, storm surge)
- Sea-level rise and subsidence
- Water (Flooding/drought)

Socio-Economic Sensitivity

- People per city
- Wealth (Gross Domestic Product)
- Contribution to national GDP

Adaptive Capacity

- Existing examples
- Per capita GDP

Methodology

This report highlights the most significant climate change impacts that will affect some of Asia's largest metropolitan areas including Ho Chi Minh (Vietnam), Bangkok (Thailand), Phnom Penh (Cambodia), Shanghai (China), Hong Kong (China), Dhaka (Bangladesh), Calcutta (India), Jakarta (Indonesia), Manila (Philippines), Kuala Lumpur (Malaysia), and Singapore (Republic of Singapore). It also attempts to identify some of the most feasible and economical near-term adaptation options for these areas and suggests some constructive policy recommendations.

The report builds on information from existing research and analysis. Information was compiled largely from the IPCC's latest reports, specifically, "Working Group I: The Physical Science Basis" and "Working Group II: Impacts, Adaptation and Vulnerability". This report also draws heavily from a very recent report by Anshory and Francisco (2009), "Climate Change Vulnerability Mapping for Southeast Asia". The Anshory and Francisco report provided the foundation of the vulnerability assessment and much of the environmental and socio-economic data.

This report divides the vulnerability assessment into short sections for each city, providing a summary of the local situation for that particular city (i.e., city profile and observed climate change), significant climate change impacts (including but not limited to sea-level rise, flooding, drought, tropical storms and storm surge), and lastly a section on potential adaptation options. Each city section also includes a satellite image superimposed with 1 m sea-level rise and 2 m storm surge color layers that aim to illustrate what could happen in the future if no protection occurs.

In all, this report attempts to synthesize the climate change vulnerability of key major metropolitan areas (megacities) in Asia. When assessing the vulnerability ranking and the environmental and socio-economic scores, each city had a total maximum of 60 points (10 points possible per each of the six categories). Raw data was standardized into a scale of 0 to 10 to allow for cross comparisons between data sets and cities. The purpose of using a diverse array of criteria is because climate vulnerability is a function of not only the physical changes in the climate, but also socio-economic factors, including number of people per city, assets threatened and costs and adaptive capacity and costs.

Peer-reviewed literature and syntheses was used to assess the various impacts and adaptive capacity whenever possible. However, due to the relatively recent awareness of climate change and the diverse array of impacted sectors, many reports and information are likely not published in the peer-reviewed process or available by traditional means. While utilizing in-country colleagues as much as possible, the collection of information and data for this report may be limited by the availability and dispersal of this information. The information provided within this report is by no means an exhaustive assessment, but instead summarizes some of the more significant and well-known impacts that will likely worsen in the future if greenhouse gas emissions continue to rise.

Impacts that this report assesses:

- Temperature change
- Precipitation change
- Sea-level rise
- Extreme weather events (flooding, drought, tropical storms, storm surge)

For this analysis, the vulnerability of the cities is a function of the exposure, sensitivity, and adaptive capacity. These three categories were averaged to get the overall vulnerability score. Exposure is the average of the three highlighted environmental categories (see box) including the susceptibility of the city to be impacted by 1 m sea-level rise, historical frequency of extreme weather events, including flooding and drought, and frequency of tropical storms and surges. Sensitivity is based on population, GDP, and the relative importance of that city to the national economy. Adaptive capacity is calculated by examining the overall willingness of the city to implement adaptation strategies (calculated by the available adaptation examples and/or responses to previous impacts) and the per capita GDP. It should be noted that a significant caveat of this study is that there are likely quite a number of adaptation examples that cannot be located with desk top reviews. For example, people may come up with their own adaptation strategies in the face of climate change. However, mass media, the internet, and peer-reviewed journals will likely not pick up this information. In essence, the estimates for these 11 cities are just that, estimates based on existing information. For uniformity, we inversed the adaptation capacity numbers so that low adaptive capacity is represented by a larger number (e.g., 10 equates to a very low adaptive capacity).

Apart from the overall vulnerability ranking that takes into account all the assessed criteria, this report also summarizes a number of other comparisons including which city is most at risk of environmental threats, which city is most socio-economically sensitive to climate change impacts and which city has the lowest adaptive capacity. It should be noted that WWF has approached the issue of vulnerability in this report with the most simplistic analysis possible, and while we appreciate that there are many additional factors to consider and alternative methods for assessing vulnerability, we also hope that this report can provide a starting point for further discussions on climate change impacts, sensitivity, adaptation, and appropriate policies and measures to respond to the threat.

For this report, we use key IPCC definitions:

Adaptation

Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

Anticipatory adaptation

Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.

Autonomous adaptation

Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

Planned adaptation

Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptive capacity

The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Resilience

The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Vulnerability

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Dhaka, Bangladesh

Vulnerability Score = 9

Environmental Exposure	**8**
Storm threat	4
Sea-level rise	9
Flooding/drought	10
Socio-Economic Sensitivity	**8**
Population	6
Assets threatened	10
Inverse Adaptive Capacity	**10**

City Profile

Dhaka is the capital and center of political, cultural and economic life in Bangladesh. With a population of over 13 million, it's also one of the largest cities in Southeast Asia. In fact, Dhaka is reportedly the 9th largest urban center in the world, by far the most densely populated, and growing at one of the fastest rates in Asia. Dhaka's population is estimated to be 25 million by the year 2025. Dhaka is situated on the Buriganga River or "Old Ganges" within the Ganges-Brahmaputra megadelta. The city proper covers an area of 154 km^2, however the Dhaka district has an area of nearly 1500 km^2.

Dhaka is truly a cosmopolitan city and the center of Persio-Arabic and Western cultural influences in the Eastern Indian subcontinent. With an ever increasing population, Dhaka has significant problems with congestion, pollution and a relatively low level of public services, lowering its already low adaptive capacity. Poverty is massive in Dhaka. The annual per capita income of Dhaka is estimated at US$500, with 48% of households living below the poverty line. Many people come from rural areas in search of employment and survive on less than US$10 a day. As a result the city has massive issues with solid waste and consequently one of the highest rates of deaths from infectious diseases of any city in Asia. However, the city attracts more and more people, large foreign investments, and increasing volumes of commerce and trade. Dhaka has by far the most developed infrastructure in Bangladesh and has recently seen the modernization of transport, communications and public works.

The gross domestic product (GDP) of Bangladesh in 2008 was about US$82 billion and was growing by about 4 to 6%. The purchasing power parity (PPP) is about US$224 billion (2008) and the GDP per capita was about US$1500 in 2008. The service sector is about 52% of total GDP, thus by far the largest sector. Industry makes up about 29% of GDP, while agriculture constitutes about 19% (2008). Bangladesh exports a significant amount of labor to other parts of the world, including Saudi Arabia, Kuwait, UAE, Oman, Qatar, and Malaysia. Workers' remittances are estimated at US$4.8 billion in 2005-06.

Dhaka is characterized by a hot, wet and humid tropical climate. The city experiences a monsoon climate with average temperatures ranging between 18°C in January and 29°C in August. The vast majority (80%) of precipitation occurs between May and September and averages about 1,800 mm per year.

Observed Climate Change

The IPCC highlights that Bangladesh is warming with an increasing trend of about 1°C in May and 0.5°C in November during the 14 year period from 1985 to 1998. More rain has fallen too - on average, decadal rain anomalies have been above long term averages since 1960s.

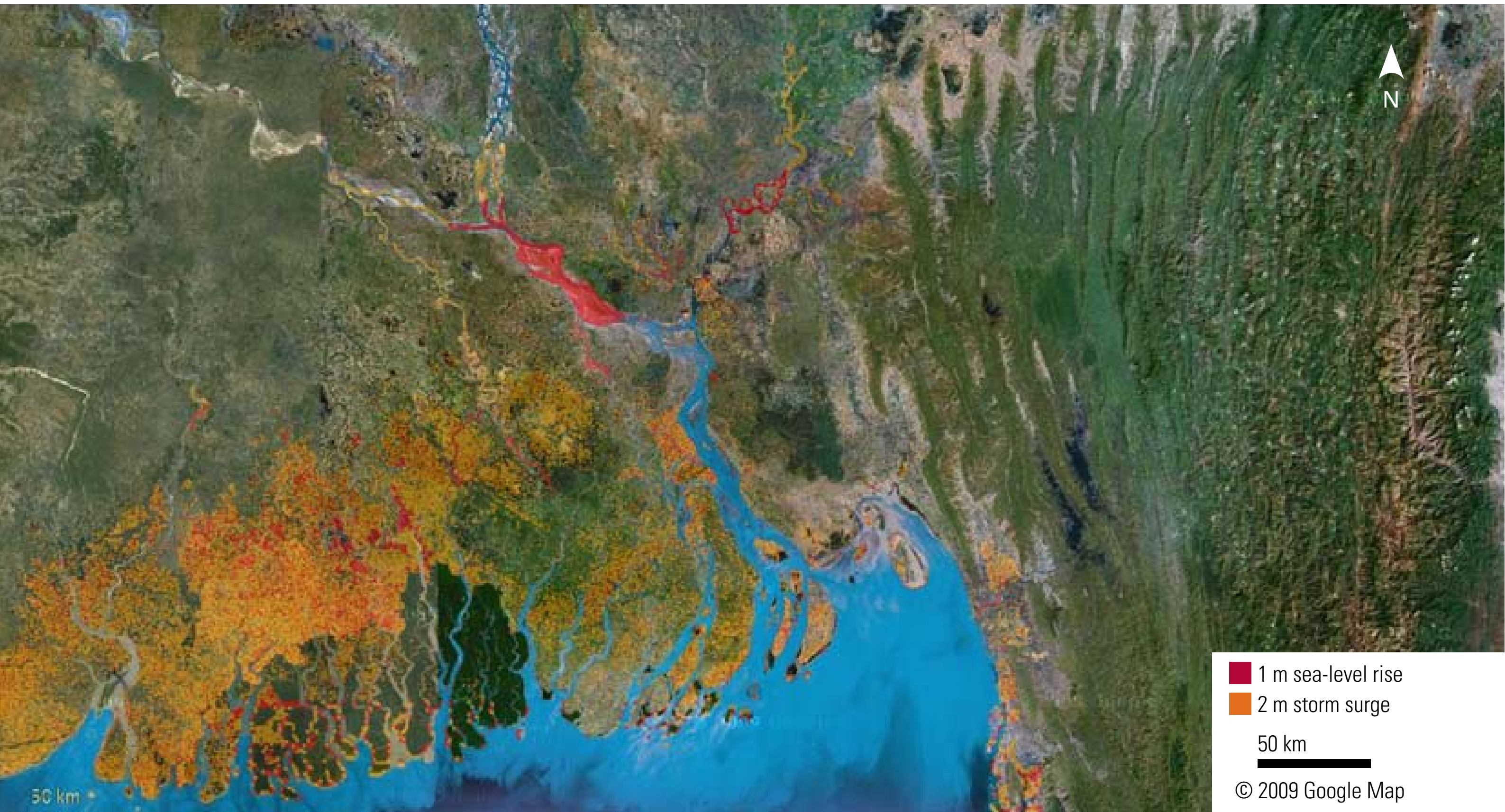
Impacts

Sea-level rise, storm surge, and flooding are the biggest threats to Dhaka, and the city ranks 8 out of 10 for exposure. It is estimated that with a 1 m rise in sea level, Bangladesh would lose approximately 1,000 km^2 of cultivated land and much of its sea product culturing area. Exacerbating the effects of sea-level rise, Bangladesh and Dhaka sit only meters above current sea levels and unfortunately the city is sinking due to subsidence, estimated at 0.6 to 1.9 m. Due to this subsidence and sea-level rise, the IPCC projects that salt-water intrusion could reach up to 100 km from the coast, impacting thousands of people. Salt-water intrusion will impact the availability and quality of freshwater and rice production, a huge source of food for the region. In fact, climate change projections suggest that production of rice and wheat might drop by 8% and 32%, respectively, by midcentury. Salt-water intrusion will not only impact freshwater availability but also the natural ecosystems, such as mangroves that currently buffer the coast from storm surges. There is an estimated 10,000 km^2 of mangroves within the Ganges- Brahmaputra megadelta. These critically important ecosystems currently limit the effects of sea-level rise and storm surges, but massive storm surges have already occurred. In fact, tropical cyclone-induced 6-m storm surges have lead to 500,000 deaths in 1970 and 150,000 deaths in 1991, and misplacing millions of people. Future losses could be even more without current mangrove forests to buffer the effects.

Other climate impacts include flooding due to extreme rainfall during the monsoon seasons and drought during prolonged dry periods. While observed climate data indicates that on average, more rain has fallen, it is not uncommon for the majority of annual precipitation to fall during just a few extreme events. In fact, devastating floods in 2004 affected 38% of Bangladesh, destroying more than three-quarters of crops and leaving 10 million people homeless. The socio-economic sensitivity of Dhaka is high (10 out 10). The projected increased intensity of tropical cyclones will exacerbate Dhaka's vulnerability. In fact, Dhaka already has a high degree of vulnerability because it is exposed to so many impacts. 174 natural disasters happened between 1974 and 2003. Additionally, many of Dhaka's residents are currently homeless and are forced to live on and cultivate nearby flood-prone land, thus further driving up their vulnerability. They have limited access to safe housing and even less access to more profitable livelihood opportunities. Soil degradation, erosion, deforestation, pollution, diseases, and heavy extraction of groundwater all add to Dhaka's vulnerability.

Adaptation

Bangladesh is very poor and the country as a whole has very little adaptive capacity to deal with climate impacts. Dhaka is in a somewhat better position because the majority of the wealth is concentrated there and it is the country's economic, political, and cultural center. However, implementing wide-scale adaptation options for all of Dhaka's 13 million residents will be extremely challenging. Further complicating Dhaka's ability to adapt to climate impacts is the trend that many water bodies and wetlands around Dhaka are being filled to construct multi-storied buildings and other real estate developments. Increasing ground water use also compounds vulnerability and complicates decision-making for viable adaptation options. There are good examples of adaptation at the community level throughout Bangladesh, such as diversifying crops, water management schemes and growing food on floating beds. While these examples can be found in Bangladesh, they are not widespread and large, multi-regional projects such as the integrated water management should be monitored closely and potentially replicated to other sectors quickly. Consequently, without adequate protection Dhaka's poor will be exposed to a high degree of risk from floods and extreme weather events, such as tropical cyclones and associated storm surges.



Jakarta, Indonesia

Vulnerability Score = 8

Environmental Exposure	**6**	●●●●●●○○○○
Storm threat	2	●●○○○○○○○○
Sea-level rise	8	●●●●●●●●○○
Flooding/drought	9	●●●●●●●●●○
Socio-Economic Sensitivity	**10**	●●●●●●●●●●
Population	10	●●●●●●●●●●
Assets threatened	9	●●●●●●●●●○
Inverse Adaptive Capacity	**7**	●●●●●●●○○○

City Profile

Jakarta is the economic, cultural, and political center of Indonesia. It is also capital of Indonesia and has the largest true city population in Southeast Asia, estimated at 8.5 million. Jakarta's metropolitan area, called Jabodetabek, is the sixth-largest in the world with over 24 million. Jakarta covers 662 km^2 and is located on the northwest coast of Java at the mouth of the Ciliwung River on Jakarta Bay. Jakarta also includes the Thousand Islands, located just north of the city in Jakarta Bay.

The topography of Jakarta varies, with the northern part just meters above current sea level and lying on a flood plain. Subsequently, this portion of the city frequently floods. The southern part of the city is hilly. In addition to the Ciliwung River, there are about 12 other rivers that drain the hilly southern part of the city into the sea. The Ciliwung River is the most significant river and divides the city West to East.

Jakarta has historically been a key trading port in the region and continues to be economically important. Jakarta's economy depends heavily on financial services, which contribute almost a quarter of the national GDP. Consequently, Jakarta scored 10 out of 10 for sensitivity because of this huge contribution towards national GDP and the city's large population. Trading, manufacturing, and tourism also make significant contributions. Jakarta's manufacturing sector includes electronics, automotive, chemicals, mechanical engineering and biomedical sciences. While there is significant wealth in Jakarta, the city has massive problems because of the extreme population growth, high levels of poverty, and inequitable distribution of wealth. Jakarta has struggled to provide basic needs such as water, shelter and waste management for some of its poorest residents.

Jakarta has an equatorial tropical climate (hot and humid). Temperatures are very consistent, ranging from an annual average low of 23°C to an annual high of 32°C. Jakarta gets significant amounts of precipitation, totaling almost 2,200 mm annually. Jakarta's wet season peaks with an average 400 mm of precipitation during January and a dry season average rainfall of 70 mm during August. The city is humid throughout the year.

Observed Climate Change

Indonesia has become warmer over the last century, with temperatures increasing by about 1°C during the wet season and 1.4°C during the dry season. Annual precipitation overall has decreased by 2 to 3% across all of Indonesia over the last century. However, there is significant spatial variability, with a decline in annual rainfall in the southern regions of Indonesia (e.g., Java, Lampung, South Sumatra, South Sulawesi, and Nusa Tenggara) including Jakarta and an increase in precipitation in the northern regions of Indonesia (e.g., most of Kalimantan, North Sulawesi). There has also been a shift in the seasonality of precipitation (wet and dry seasons); in the southern region of Indonesia the wet season rainfall has increased while the dry season rainfall has decreased, whereas the opposite pattern was observed in the northern region of Indonesia.

Impacts

Climate change has and will continue to impact Indonesia. A recent mapping vulnerability assessment suggests that the western and eastern areas of Java Island (including Jakarta) are at particular threat to droughts, floods, landslides, and sea-level rise. Jakarta is at high risk of climate impacts because it is frequently exposed to significant flooding and landslides and it is one of the most densely populated areas in Southeast Asia. The wet season in Jakarta has become wetter and therefore the city experiences more flooding, which is compounded by clogged sewage pipes and waterways and the fact that much of the city is at or near sea level. Previous floods have wrecked havoc on the city. Major flood events in 1996 and 2007 submerged 5,000 hectares of land with losses from infrastructure damage and state revenue estimated at US$572 million. These two floods also killed at least 85 people and forced about 350,000 people from their homes. Approximately 70% of Jakarta's total area was flooded with water up to 4 m deep in parts of the city. Unfortunately, more severe and frequent flooding is projected for the near future and sea-level rise will compound the impacts, making it more difficult and expensive to respond. Consequently, for this analysis, Jakarta ranked a 6 out of 10 for environmental exposure.

Sea-level rise also threatens Jakarta and the city is at risk of losing more land quickly. Specifically, sea levels in Jakarta Bay are expected to rise at a rate of 57 mm per year, which could submerge as much as 160 km^2 of northern Jakarta by 2050 and permanently inundate some areas. Unfortunately, the poor will be the hardest hit. According to a sustainable development report on climate change much of Jakarta's population, an estimated 1.2 million people, are currently concentrated in vulnerable coastal slum communities. Lack of infrastructure in these slum communities leaves residents highly vulnerable to climate change-related events. Adding to the impacts affecting Jakarta, sea-level rise has also caused salt water intrusion into coastal freshwater and groundwater resources, leading to more water shortages brought about by declining rainfall and overexploitation of groundwater. Saltwater intrusion in the shallow and deep aquifers of Jakarta has reportedly reached 10 to 15 km inland. Rising sea levels have also accelerated inundation and land subsidence in coastal cities and communities, resulting in considerable losses to tourism and aquaculture industries.

Adaptation

Jakarta is highly vulnerable to climate change and must take mitigation action now in order to contribute to the reduction of global greenhouse gas emissions. This is crucial to prevent future climate impacts and improve chances for adequate adaptation action to withstand climate change. Subsequently, Jakarta has a number of good adaptation examples and therefore scored 7 out of 10 for adaptive capacity. However, by implementing additional adaptation measures, millions of lives can be spared and millions of dollars saved. Improved urban planning and infrastructure, such as water and waste services, can not only minimize climate impacts but also increase sustainable development. Adaptation actions include the creation of new green open spaces, improvement of waste management (including behavioral change of Jakarta citizens in treating their waste) and maintaining and improving infrastructure including water and sewers. In order to cope with the impacts that are already inevitable, adaptation should be employed as soon as possible and the IPCC has suggested the following to enhance social capital and reduce the vulnerability to climate change: increase education and technical skills, increase income levels, improve public food distribution, and improve disaster preparedness and management and health care systems through sustainable and equitable development. For Jakarta, adaptation measures that address sea-level rise, increased extreme weather, and threats to ecosystems and biodiversity should be a high priority. Increased water storage and better early El Niño warning systems could also help residents prepare for climate change. The long-term effects of sea-level rise demand that Jakarta considers the effects of 1,000-year storm-surges and, in response, provides substantial protection of current socio-economic activities and highly vulnerable parts of the city.

Sustainable management of coastal zones through Integrated Coastal Zone Management (ICZM) could also provide effective coastal protection and maximize the benefits provided by coastal zones. Conservation of mangroves can also help protect against storm surges, coastal erosion and strong wave actions as demonstrated by the Indian Ocean tsunami of 26 December 2004.

While there are multiple issues that may hinder adaptation, such as poverty, insufficient information and knowledge on climate impacts and limited information on the costs and benefits of adaptation, Jakarta needs to build on existing adaptation examples before the full extent of climate change is felt by its poorest and most vulnerable citizens.

Manila, Philippines

Vulnerability Score = 8

Environmental Exposure	**9**	●●●●●●●●●○
Storm threat	10	●●●●●●●●●●
Sea-level rise	8	●●●●●●●●○○
Flooding/drought	10	●●●●●●●●●●
Socio-Economic Sensitivity	**7**	●●●●●●●○○○
Population	5	●●●●●○○○○○
Assets threatened	9	●●●●●●●●●○
Inverse Adaptive Capacity	**7**	●●●●●●●○○○

City Profile

Manila is the national capital and the financial, commercial, and industrial center of the Philippines. Manila's metropolitan area, which is comprised of 17 local government units, has a population of about 11.5 million people (2007), covers about 636 km^2, and has a density of just over 18,000 people per km2, thus translating to a socio-economic sensitivity to climate change impacts of 7 out of 10. Manila ranks as the fifth largest urban area by population in the world and second in Southeast Asia (Jakarta is first). If the surrounding suburbs in the adjacent provinces of Greater Manila are included, the population swells to around 20 million. This area creates 32% (US$124 billion (PPP) in 2007) of the national GDP. Due to Manila's protected harbor, it is also the main seaport for the Philippines and a major manufacturing center, producing chemicals, steel, textiles, clothing, and electronic goods. Manila is similar to many large cities around the world and is characterized by economic extremes with a huge disparity between the few who control much of the wealth and the massive number of people who are below the poverty line. Reportedly, 97% of the total GDP in the Philippines is controlled by 15% of the population.

Manila's primary waterway is the Pasig River, which meanders through the metropolis, passing through Manila before draining into Manila Bay. The metropolitan area is built on the alluvial deposits of the Pasig River and on some reclaimed land from Manila Bay. The average elevation of metropolitan Manila is a mere 10 m.

Manila is one of the major tourist destinations in the Philippines and the city attracts over 1 million visitors per year. In 2000, net tourism income totaled US$2.1 billion and is growing fast. It is projected that at the current growth rate, Manila's tourism volume will surpass that of Singapore by the year 2020.

Lying just north of 14 degrees longitude, Manila has a tropical wet and dry climate (also referred to as a tropical savanna climate). Average temperatures range from lows of 21°C in January to highs of 33°C in April and May. Precipitation varies throughout the year but typically December through March is generally dry and June to October is generally wet. Average precipitation is about 200 mm a year.

Observed Climate Change

The Philippines has seen an increase in temperature. Between 1961 and 1990, mean annual temperature has increased about 0.61°C, maximum temperature has increased 0.34°C, and minimum temperatures has increased 0.89°C. Subsequently, the frequency of hot days and warm nights has also increased, while the number of cold days and cool nights decreased. There has also been an increase in the annual mean rainfall since the 1980s and an increase in the number of rainy days since the 1990s. Like so many other regions in Southeast Asia, Manila has also experienced an increase in the year to year onset of rainfall.

Impacts

The Philippines could see temperatures rise anywhere between 1.2 and 3.9°C by 2080 with increasing climate impacts, such as tropical cyclones, sea-level rise, floods, and droughts. Manila ranked a high exposure score (9 out of 10) because it is threatened by a number of climate impacts. Cyclones will likely impact the northern and eastern parts of the country the most, whereas floods, landslides and droughts may plague the rest of the Philippines. Overall, annual rainfall has increased and when combined with tropical storms, has led to extreme rain, floods, and landslides in 1990, 2001, 2004, and 2009. Manila is particularly vulnerable to flooding from both extreme rains and tropical storms, as just seen with the latest tropical cyclone Ketsana (Ondo) in September 2009, which by latest accounts has affected over 4.3 million people, displaced nearly 500,000 and killed over 337. The recent storm damage is estimated at US$230 million. On a country-wide scale, cyclone-triggered floods are not uncommon. For example, the 2001 Camiguin flood was triggered by tropical typhoon Nanang and affected more than 35,000 people and killed 157. Total damage was estimated at US$96 million. There are other recent examples of deadly landslides including the 2006 Guinsaugon, Leyte landslide, which was triggered by super typhoon Reming, killing 1,126 people. During that same storm, the Legazpi, Albay landslide killed 1,399 people. These two landslides affected more than 800,000 families and are considered the world's second and third deadliest disasters of 2006.

Droughts, extreme rain and storms are projected to get more intense and variable in the future in the Philippines and can be strongly influenced by increasingly frequent inter-annual climate extremes (e.g., El Niño Southern Oscillation [ENSO] events). Droughts are normally associated with El Niño events in the Philippines, and the 1997 to 1998 event provides some insight into what more is to come under climate change.

During this event, the Philippines experienced severe water shortages, massive crop failures, huge forest fires, and coral bleaching. Consequently, Metro Manila's main reservoir of water, the Angat dam, saw declining input. Storage was reduced by 10%, resulting in water rationing in some areas. It also affected hydroelectric plants that provide power to surrounding cities. Unfortunately, the combination of drought years with rising sea levels means that already stressed water areas will get worse.

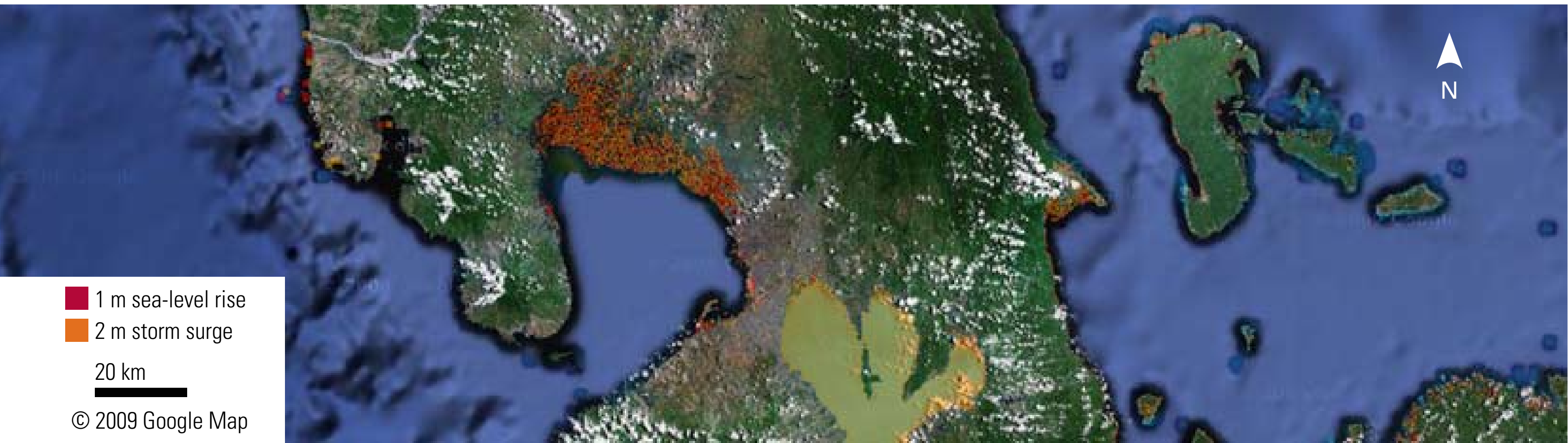
During the last 20 years, the intensity of tropical cyclones has significantly increased, causing extensive damage to property, assets, and human life. They are projected to further increase in frequency and intensity. Adding to the damage, storms are usually accompanied by torrential rains that cause landslides and flash floods, killing people and destroying property and agricultural crops. According to statistics, 80% of disasters occurring in the Philippines over the past 100 years have been weather-related, with typhoons and floods contributing the most. Sea-levels around Manila are also rising and an increase anywhere from 0.4 to 1.0 m by the end of century is expected, partially due to local subsidence and continued ground water extraction. This degree of change could displace over 2.5 million people and inundate over 5,000 ha of the Manila Bay coastal area. These risks will be further intensified if storm surges associated with intense storm activity increase. Coastal erosion is also increasing and is exacerbated by the increase in storms, beach sand mining, and destruction of coral reefs, mangroves and sand dunes.

Adaptation

Due to the high risk of tropical storms, floods, droughts, and sea-level rise, adaptation is critical for Manila and the rest of the Philippines. Relevant adaptation measures may include early warning systems to alert residents of approaching tropical cyclones so that they may avoid high impact areas and better prepare emergency supplies. Other adaptation measures may include designing and building appropriate infrastructures to better protect citizens and allow for massive evacuation if necessary. Installation and maintenance of weather prediction (e.g., Doppler radar to predict precipitation) and hazard warning systems, especially during rainy and tropical storm seasons, is generally a good idea to minimize damage and loss of life. The Philippines can also learn from other case studies. In Cairns, Australia, for example, cyclone experience and education may have contributed to a change in risk perceptions and a reduction in the vulnerability of residents to tropical cyclone and storm surge hazards.

Protecting and restoring natural ecosystems is another progressive adaptation measure, which has proven to be highly cost-effective. Unfortunately, large-scale conversions of coastal mangrove forests to shrimp aquaculture, fish ponds, and salt beds have occurred during the past three decades in the Philippines. Nonetheless, with adequate protection and restoration these ecosystems can help minimize wave energy from storms and buffer the coastline from impacts. Coral reefs have also proven to be hugely beneficial for the protection of coastline and also provide many with food and livelihoods. Many of these natural systems are at a critical threshold, and if appropriate capacity is put into conservation and sustainable development, they can be protected. Revisiting/re-designing Manila's urban plan (or lack thereof) is also critical. Relocating communities in high-risk areas as well as critical waterways (i.e., communities can impede water drainage during storms) is also important. Likewise, reforesting watersheds and mountains surrounding Metro Manila will significantly reduce surface run-off, which was a main contributor to the recent September flooding.

Poor adaptation measures, sometimes referred to as maladaptation, are a risk. Even activities that are meant to prevent erosion, such as building of sea walls and ripraps, have been found to have contributed to the problem, so caution is needed. Manila scores 7 out of 10 for inversed adaptive capacity, so the protection of natural systems, such as mangrove forests and coral reefs and other no-regret adaptation strategies can and should be implemented immediately.



Calcutta, India

Vulnerability Score = 7

Environmental Exposure	**6**	●●●●●●○○○○
Storm threat	3	●●●○○○○○○○
Sea-level rise	8	●●●●●●●●○○
Flooding/drought	7	●●●●●●●○○○
Socio-Economic Sensitivity	**7**	●●●●●●●○○○
Population	7	●●●●●●●○○○
Assets threatened	6	●●●●●●○○○○
Inverse Adaptive Capacity	**7**	●●●●●●●○○○

City Profile

With more than 15 million people, Calcutta is the third largest metropolitan area in India and the 8th largest urban area in the world. Calcutta includes the city proper, Kolkata, which is the capital of the Indian state of West Bengal. Situated on the banks of the River Hooghly, Calcutta is within the Ganges Delta and thus only meters above current sea level. Having to expand the city to accommodate for the swelling population, Calcutta has reclaimed significant amounts of the surrounding wetland. Consequently, the city sits on alluvial deposits and within a considerable seismic zone, and thus is prone to earthquakes.

Calcutta used to be the capital of India and was once the center of industry, culture, and politics. While it had experienced a significant economic downturn since the 1950s, it has recently made an upturn and is now growing. Similar to other metropolitan areas in India, however, Calcutta has problems with widespread poverty, infrastructure, and pollution, particularly air and water pollution. Calcutta is eastern India's main center for business, commerce and finances and a major commercial port. It is also the only city in the region to have an international airport, which - if shut down due to extreme weather events - could significantly disrupt regional travel. Calcutta ranked 7 out of 10 for socio-economic sensitivity to climate impacts. Following independence, Calcutta has experienced a steady economic decline until just recently and Calcutta's economic upturn has been led largely by IT services, which have grown at a staggering 70% yearly, twice the national average. Needless to say, there has been a surge in the demand for housing, with new developments hastily popping up throughout the area.

Calcutta's climate is typical of the region. It has a tropical wet-and-dry climate also referred to as tropical savanna climate. As a result, temperatures are rather constant with an annual mean temperature of 27°C. Further, mean monthly temperatures only range from 19°C to 30°C. Wet seasons are characterized by hot and humid weather, while dry seasons typically experience 40°C temperatures during May and June. Calcutta also experiences seasonally heavy rains, which can lead to flooding. Average precipitation is 1,582 mm and usually comes off the Bay Bengal during June and September. August sees the highest amount of rainfall averaging over 300 mm.

Observed Climate Change

Similar to Bangladesh, Calcutta has seen significantly warming temperatures and changes in rain patterns. Specifically, temperatures have increased about 0.68°C over the last century, with increasing trends in annual mean temperature and more pronounced warming following the monsoon season and during winter. While the total number of rainy days has dropped along India's east coast, more rain seems to fall during the already wet summer monsoon season.

Impacts

Due to Calcutta's location and size it is particularly at risk of climate change impacts. Calcutta's environmental exposure is ranked at 6 out of 10. Sea-level rise and storm surges will inundate large proportions of the city and surrounding areas over the next few years. In fact, a 1 m rise in sea level could potentially inundate 5,763 km^2 in India. In addition to sea-level rise, a ground subsidence of 0.6 to 1.9 mm per year is adding to the risk in the Ganges Delta. Due to the combined effects of sea-level rise and subsidence, the Ganges Delta will likely see salt water intrude 100 km from the coast, greatly impacting ground water supplies. Compounding the effects of salt water intrusion, over-exploitation of groundwater in and around Calcutta has lead to a drop in its level, leading to further intrusion of sea water and thus making the subsurface ground water saline. Droughts have been more frequent in the last few decades and are projected to get worse, which will lead to even more salt-water intrusion and thus deteriorate surface and groundwater quality. In fact, India may reach a state of severe water shortage and stress before 2025 when the water availability per capita is projected to drop below 1,000 m^3 per year, compared to the level in 2001 of 1,820 m^3 per year.

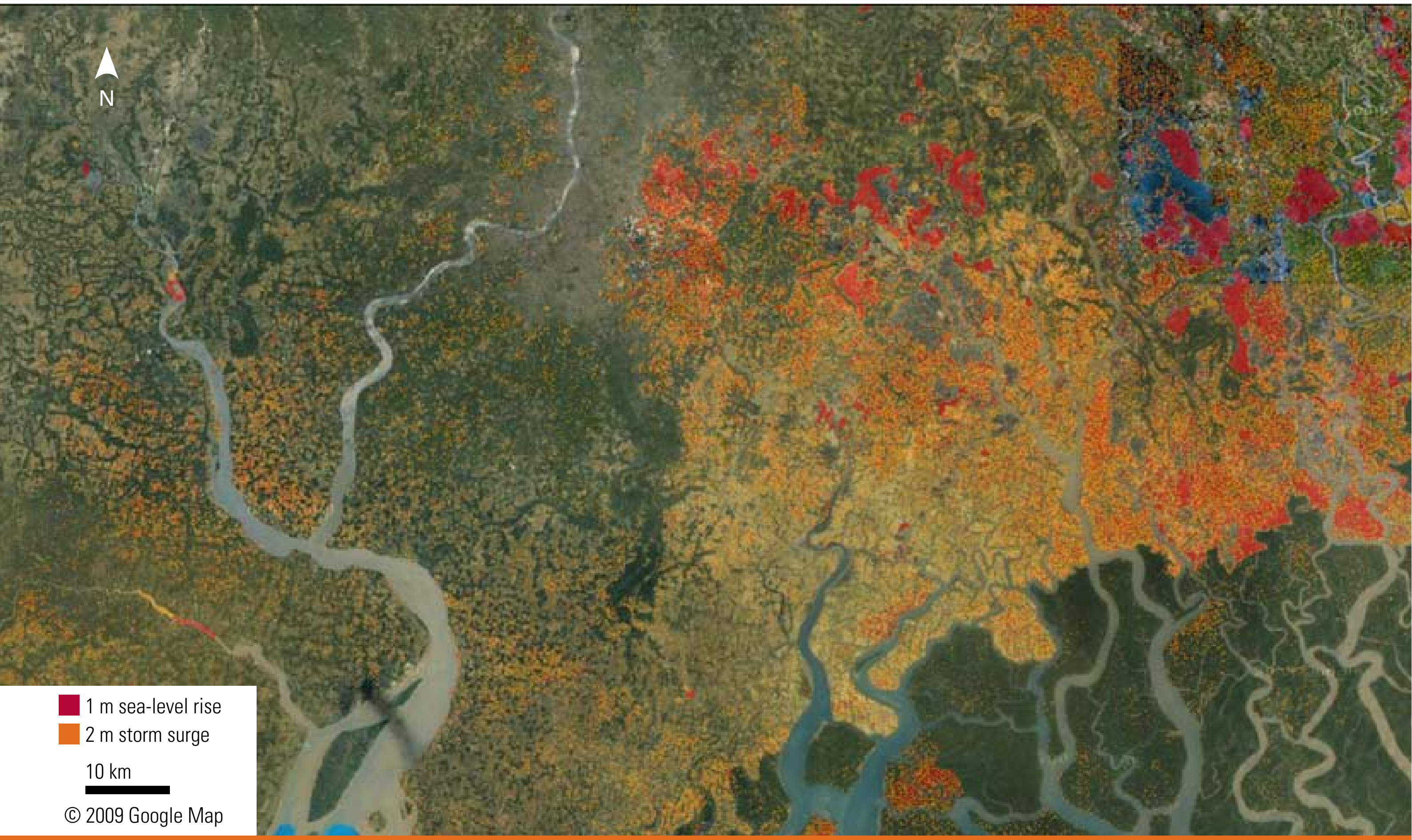
The IPCC projects a decrease in winter precipitation over the Indian subcontinent, which would reduce the total seasonal precipitation during December, January and February and lead to less water storage and greater stress during the lean monsoon period. In contrast, more intense but fewer rainfall events will lead to increased severity and frequency of floods during the monsoon. These extreme rain events do not allow the water to percolate down into the soil, will increase direct runoff and will result in reduced groundwater recharging potential. Extreme rainfall lead to serious and costly floods in northeastern India during 2002, 2003 and 2004, leading to a loss of hundreds of lives, setting rainfall records, and costing the region (including Bangladesh, Nepal, and India) more than US$250 million. Other extreme weather events such as the observed increase in the frequency of hot days and multiple-day heat waves during the last century has lead to more deaths in recent years and provides a sign of what more is expected with further climate change. The observed and projected increase in the frequency of severe tropical storms will also lead to more damage and costs in Calcutta.

While Calcutta has a relatively low percentage of agricultural land, climate change impacts to crops will impact the availability of food within the city and the ability of people to meet their dietary needs. The IPCC highlights that due to thermal stress and water scarcity in some regions in Asia, rice production could decline by nearly 4% by the end of the century and that substantial losses are likely in rain-fed wheat throughout Southeast Asia. For example, a 0.5° to 1.5°C rise in temperature would reduce wheat and maize yield potential by 2 to 5% in India.

Adaptation

Calcutta is vulnerable to climate change and ranked 7 out of 10 for its inverse adaptive capacity (meaning that it has low adaptive capacity). However, India's economy is growing and there are a number of "no-regret" adaptation options that can be implemented now, which will minimize the future costs of not acting. For example, because water stress is a multi-dimension issue, improved water management strategies will minimize future problems with continued over extraction of ground water, sea-level rise, salt water intrusion and an increase in storm surges. India may even consider examining case studies from other countries and share lessons learned with their own projects. Regional population projections suggest that Calcutta's population is going to continue to grow and water shortages will be become more of an issue. Action now on improved water management may save millions of dollars and lives in the future.

Due to the threat of increased frequency and intensity of tropical storms, storm surges, and salt water intrusion, increased protection, enforcement and restoration of mangroves and wetlands is highly encouraged. These types of strategies are relatively low cost, high benefit actions that can be implemented immediately with current technologies. Calcutta is low in elevation and needs increased coastal protection, and these ecosystems provide buffers against storms and storm surges in addition to food and livelihoods for millions of Indians.



Phnom Penh, Cambodia

Vulnerability Score = 7

Environmental Exposure	**4**
Storm threat	2
Sea-level rise	1
Flooding/drought	10
Socio-Economic Sensitivity	**6**
Population	1
Assets threatened	10
Inverse Adaptive Capacity	**10**

City Profile

Phnom Penh is the capital of Cambodia and an economic, industrial, commercial, cultural, tourist and historical center in the country. With more than 14% (2 million) of Cambodia's population and covering 375 km^2, Phnom Penh is Cambodia's largest city. Population growth has been forecasted at almost 4% annually. However, the Phnom Penh City government states that in 2002, 25% of the city's residents were under the poverty line. Phnom Penh sits at the intersection of three rivers: the Tonlé Sap, Mekong, and Bassac rivers. These rivers not only provide fresh water to millions of people, they also move goods and services, provide food and livelihoods and other ecosystem services.

Cambodia is a relatively poor country, but Phnom Penh has seen significant economic growth in recent years, triggering an economic boom with new hotels, restaurants, bars, and residential buildings springing up around the city. Additionally, because Phnom Penh is the historical and cultural center of Cambodia, it is also a very popular tourist destination. Cambodia's GDP in 2007 was approximately US$8.6 billion, or about US$606 per capita, and it is estimated that Phnom Penh contributed a staggering 28% of the national GDP. Annual growth for the country was about 10.2% in 2007. Tourism is Cambodia's fastest growing industry, with over one million visitors in 2004, the vast majority visiting Phnom Penh. However, the effect of the recent global economic downturn has yet to fully materialize and the implications are yet unknown.

Phnom Penh's annual temperatures range from 18° to 38°C but overall the climate is hot year-round with two seasons: dry and rainy. These two distinct seasons are typically referred to as monsoons and control the city's climate. The wet season, referred as the Southwest Monsoon, blows inland from the Gulf of Thailand and Indian Ocean from May to October and brings moisture-laden winds. The wettest months on average are from September to October with temperatures up to 40°C and high humidity. The dry season, referred to as the Northeast Monsoon, brings dry air to the city and lasts from November to April. The driest months are usually from January to February and temperatures can drop to 22°C.

Observed Climate Change

Overall, Southeast Asian temperatures have increased 0.1 to 0.3°C per decade between 1951 and 2000. While there has been a decreasing trend in precipitation between 1961 and 1998, with the number of rainy days declining, the frequency of occurrence of more intense rainfall events in many parts has increased. This leads to more severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased.

Impacts

Warming temperatures and changes in precipitation patterns will significantly impact Cambodia and specifically, Phnom Penh. In fact, in a recent mapping assessment Cambodia was identified as being particularly vulnerable to climate change because of climate impacts such as droughts, floods, and sea-level rise and the country's relatively low adaptive capacity. While Phnom Penh has slightly more financial capacity to respond to climate change impacts, its relatively low elevation, proximity to the ocean and the Mekong River make it particularly vulnerable. For this report, Phnom Penh got an overall score of 4 out of 10 for environmental exposure to climate change, with flooding and drought being the main threats. Extreme rains have lead to record flooding in 2000, killing more than 350 people and displacing hundreds of thousands of others in the Mekong Delta. It is estimated that these floods also affected 1 million people in Cambodia, Laos and Thailand. According to a recent report on climate change in Asia, during this same flood, the river banks of the Mekong in and around the capital were fortified with sandbags, but some outer areas of Phnom Penh were flooded and a state of emergency was declared. Officials said the flooding, which began with unusually widespread and heavy monsoon rains in late July, was the worst to hit Cambodia in 70 years. Vast areas of farmland were destroyed (e.g., 80% of Cambodia's rice harvest) and considerable damage occurred in 11 out of the country's 24 provinces. Additionally, because Cambodian farmers typically only grow a few types of crops they are also particularly vulnerable to climate change. In fact, during the

2002 flood and drought, almost 1 million Cambodians received food aid because their crops were wiped out.

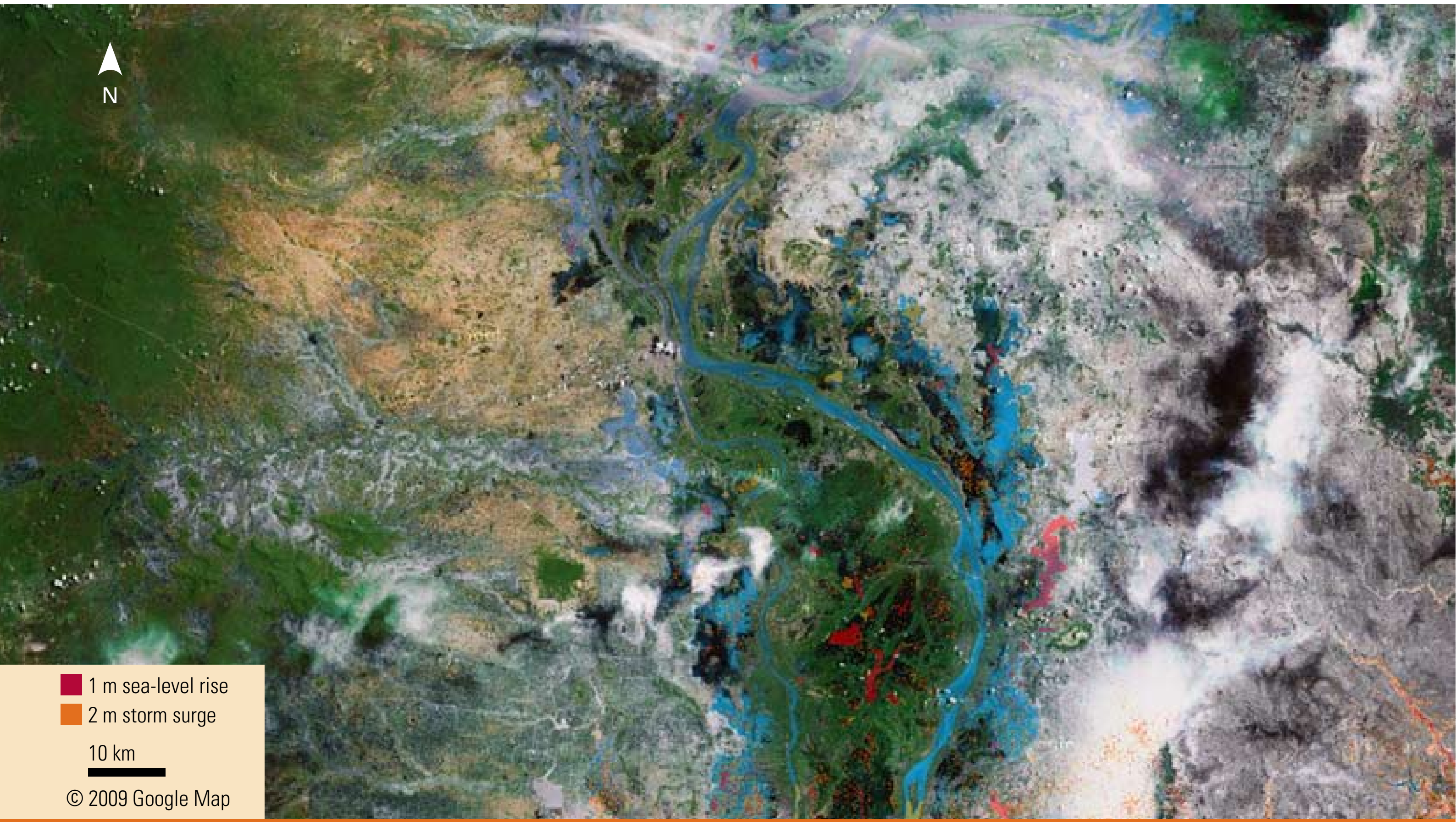
Unfortunately, flooding is not the only threat to Phnom Penh and its residents. Changing precipitation patterns may also adversely affect the quantity and quality of water supplies to the city and result in negative consequences for millions of people. Other threats include the impact of tropical cyclones, which have already increased over the last few decades and are projected to further increase in frequency and intensity. Rising sea levels will also affect Phnom Penh's fresh water availability by increasing saltwater inundation of low-lying areas and contributing to coastal erosion. Unfortunately, loss of natural coastal land, including mangrove forests, will lead to further erosion and damage as mangroves provide a buffer against storms and storm surges.

Adaptive Capacity

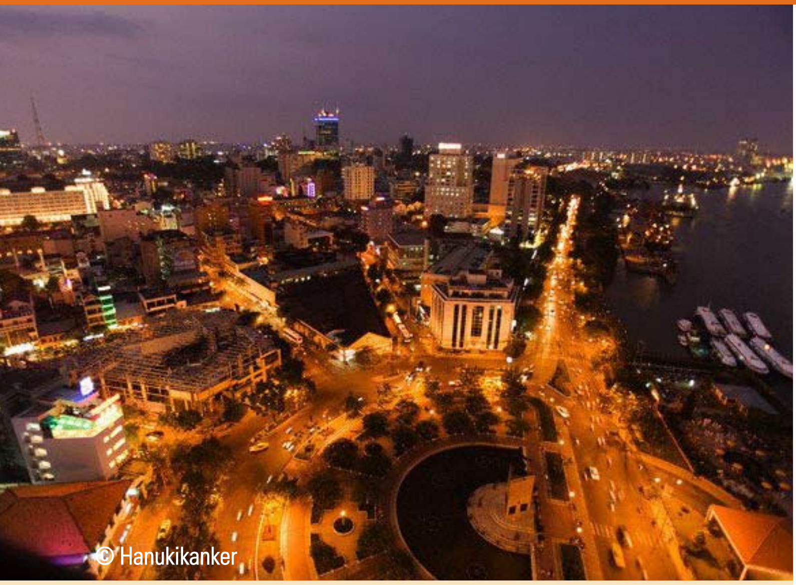
According to a recent vulnerability assessment examining Southeast Asian countries, Cambodia ranks among the most vulnerable to climate change largely due to its low adaptive capacity. In response, organizations have attempted to increase the resilience of Cambodia by supporting sustainable development and community-based adaptation. These efforts have focused on supporting community rice banks and rainwater reservoirs in an attempt to build resilience against possible future food shortages due to drought and flooding. The extreme weather events (i.e., droughts and floods) of 2000, 2001, and 2002 have illustrated how subsequent impacts can compound and devastate large numbers of Cambodians. While Phnom Penh is slightly more capable to responding to climate change because of its significant GDP and resources, it is particularly vulnerable and received a socio-economic score of 6 out of 10 and an inverse adaptive capacity score of 10, suggesting that the city has extremely low adaptive capacity compared to the other Asian cities.

There are many ecosystem-based adaptation options and policies that can be employed now to improve adaptive capacity. For example, the Cambodian government can push for additional protection, enforcement and restoration of mangroves, which act as buffers against storm and tidal surges and provide essential spawning grounds for marine fish. Mangroves are currently being cut on a large scale for the production of charcoal, aquaculture and housing, which increases the vulnerability of the coastal region, but inexpensive fuel and building alternatives exist and the true value of mangroves needs to be recognized. Further research into appropriate levels and cost of coastal protection will also help officials prepare for the future.

Phnom Penh's population is expected to double in the near future and this increase will put further demand on the food supplies and the limited availability of cropland area. More research into adaptation options, such as, crop diversification, changes in planting dates for various regions, and more tolerant crop varieties is needed. Adequate disaster relief resources, like crop, food, and water banks will also increase the adaptive capacity. The World Food Programme (WFP) suggests that instead of just distributing food relief to affected people after a disaster, WFP is promoting food for work, which is a form of community-based capacity building. For example, after previous disaster events, WFP has provided over 1,700 metric tons of food for disaster mitigation projects such as reservoir rehabilitation, community ponds, dikes, and dams for irrigation purposes.



Ho Chi Minh, Vietnam



© Hanukikanker

Vulnerability Score = 6

Environmental Exposure	**8**	●●●●●●●●○○
Storm threat	6	●●●●●●○○○○
Sea-level rise	10	●●●●●●●●●●
Flooding/drought	8	●●●●●●●●○○
Socio-Economic Sensitivity	**6**	●●●●●●○○○○
Population	4	●●●●○○○○○○
Assets threatened	7	●●●●●●●○○○
Inverse Adaptive Capacity	**3**	●●●○○○○○○○

City Profile

Ho Chi Minh is the largest city in Vietnam. The metropolitan area, which consists of Ho Chi Minh City metro area, Thu Dau Mot, Di An, Bien Hoa and surrounding towns, is populated by more than 9 million people. The Greater Ho Chi Minh City Metropolitan Area is projected to have a population of 20 million inhabitants by 2020. Ho Chi Minh City center is situated on the banks of the Saigon River and stretches south to the South China Sea with 15 km of coastline.

Ho Chi Minh City is the most important economic center in Vietnam and accounts for a high proportion of Vietnam's economy, giving the city a socio-economic sensitivity of 6 out of 10. With 7.5% of Vietnam's population, Ho Chi Minh accounts for about 20% GDP and 28% of all industrial output in 2005. Ho Chi Minh's GDP in 2007 was estimated at US$14.3 billion, or about US$2,180 per capita. In 2007, about 3 million foreign tourists, about 70% of the total number of tourists to Vietnam, visited the city.

Ho Chi Minh City has a tropical climate with two distinct seasons: rainy and dry. The rainy season has an average rainfall of about 1,800 mm annually and about 150 rainy days per year, usually beginning in May and ending in late November. The dry season lasts from December to April. The average temperature is 28°C; the highest temperature sometimes reaches 39°C around noon in late April, while the lowest may fall below 16°C in late December.

Observed Climate Change

Annual average temperature had increased by 0.7 degrees over the last 50 years. The dry season is getting drier and the wet season is getting wetter. Vietnam is highly sensitive to climate variability (such as El Nino).

Impacts

The average elevation for Ho Chi Minh City is 19 m, with a substantial portion of the city being at threat from sea level rise and associated storm surge. A recent analysis by the World Bank on the potential impact of rising sea levels of 84 coastal, developing countries ranked Vietnam among the top five countries most affected by rising sea levels, and this is reflected in the city's relatively high exposure rating of 8. With a 1 m rise in sea level, 11% of Vietnam's population, 10% of GDP, and 29% of Vietnam's wetlands will be affected. Additionally, a 1 m rise in sea level could incur losses totaling US$17 billion per year and the loss of more than 12% of the most fertile land. Additionally, a comprehensive vulnerability mapping assessment of Southeast Asia also ranks the Mekong River Delta in Vietnam among the most vulnerable regions. Rising sea levels will have negative impacts on coastal agriculture, reducing the number of viable rice crops in the Mekong delta. In fact, food security and loss of livelihoods is a significant threat in the Mekong Delta, with a looming loss of cultivated land and nursery areas for fisheries as a result of inundation and coastal erosion. Needless to say, the poor are highly vulnerable.

Sea-level rise may inundate large portions of Ho Chi Minh City and will lead to salt water penetration far upstream in dry season, especially during droughts. It is estimated that for the entire Mekong Delta, salt water intrusion could reach 60 to 70 km inland and inundate 15,000-20,000 km^2 with just 1 m of sea-level rise. Salt water penetration will lead to the salinization of ground and surface waters and will endanger Ho Chi Minh's water supply and millions of residents.

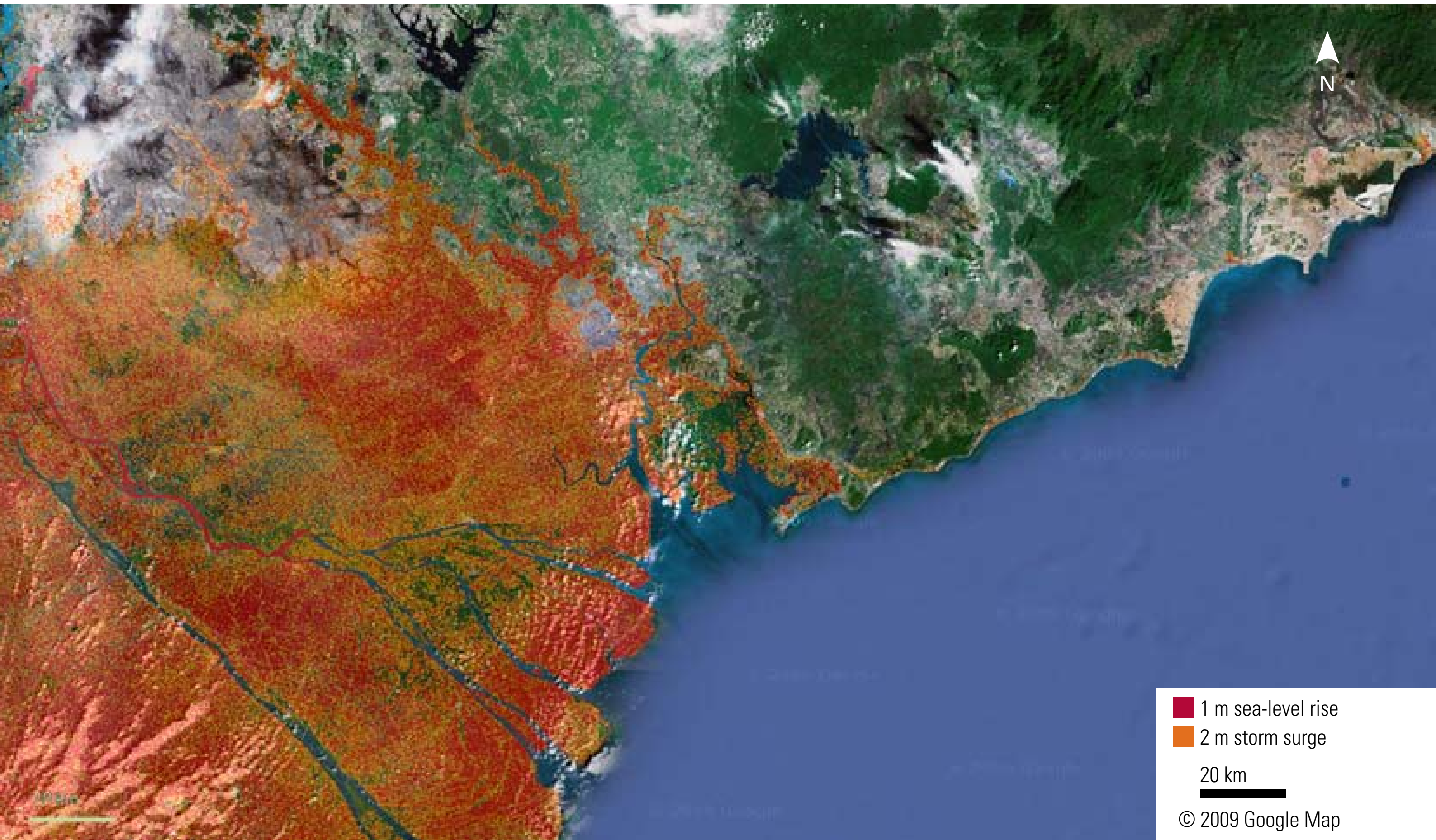
In addition to the threat of sea level rise, inundation, storm surge and the salinization of ground water, other climate impacts threaten Ho Chi Minh City, including flooding and erosion. Because the city is situated on the banks of the Saigon River, it is prone to periodic flooding, flash floods from extreme rain events and landslides. Previous flash floods have destroyed entire sections of the city, costing millions of dollars in damage, and usually affect the poor the most. For example, storms and floods in Vietnam during 2007 killed an estimated 435 people and caused US$917 million in damages.

The IPCC highlights that the maximum monthly flow of the Mekong is estimated to increase by 16 to 19% in the delta, with lower values estimated for years 2010 to 2038 and higher value for years 2070 to 2099, compared with 1961 to 1990 levels. In contrast, the minimum monthly flows are estimated to decline by 26 to 29% in the delta, suggesting that there could be increased flooding risks during wet season and an increased possibility of water shortage in dry season. Flooding could seriously affect the aquaculture industry and infrastructure, and decreases in dry season flows may reduce abundance of some key species.

Ho Chi Minh City is also in the path of typhoons and tropical storms. Previously these storms have destroyed thousands of hectares of farmland and disrupted transportation. They cost billions of dollars and are projected to get worse. Unfortunately, recent studies suggest that the frequency and intensity of tropical cyclones originating in the Pacific have not only increased over the last few decades but are expected to continue to increase in frequency and intensity.

Adaptive Capacity

Ho Chi Minh City residents will have to adapt to climate change, and while the city does have a slightly higher adaptive capacity, responding to sea-level rise and dealing with extreme weather events, such as floods, will be extremely costly. Because Ho Chi Minh City is relatively low in elevation, there are not many options to relocate to higher land. Therefore increased coastal protection will become ever more important. It is projected that with 1 m of sea-level rise, 2,500 km^2 of mangroves will be completely lost and 1,000 km^2 of cultivated farm land and sea product culturing area will become salt marshes. Further protection and even restoration of these mangrove forests is critical for the protection of Ho Chi Minh City and other coastal areas. Because sea-level rise will force rural people into the city, thereby stressing already limited resources, consideration of the effects of sea-level rise and other climate impacts should be included in all Ho Chi Minh City planning from infrastructure designs to water supply and treatment. Fortunately, Vietnam has started. The country ratified the Kyoto Protocol in 1999, and a Climate Change Office has been set up within the Ministry of Natural Resource and Environment (MONRE). In fact, the Science, Technology and Environment Committee of the Parliament has started to examine the impacts of climate change on the national development sustainability, and MONRE is supposedly preparing a national targeted program to cope with climate change and sea level rise for the period 2009 to 2015. Initiatives, such as the Asian Cities Climate Change Resilience Network, are developing case studies of climate change resilience-building projects, including health systems to combat the spread of dengue fever, and infrastructure improvements to control flooding. However, increased international capacity such as expertise and aid are needed if Vietnam is to successfully cope with climate change and sea level rise.



Shanghai, China

Vulnerability Score = 6

Environmental Exposure	**8**
Storm threat	7
Sea-level rise	10
Flooding/drought	7
Socio-Economic Sensitivity	**9**
Population	9
Assets threatened	8
Inverse Adaptive Capacity	**2**

City Profile

Shanghai is the largest city in China with over 20 million people. It covers over 6,400 km^2 and is expanding. Sitting roughly equal distance from both Hong Kong and Beijing, Shanghai is an estuary city located on the Yangtze Delta. Shanghai is the world's largest cargo port with 560 million tons of cargo in 2007. Additionally, Shanghai's container traffic surpassed Hong Kong's to become the second busiest port in the world, behind Singapore. Consequently, Shanghai's socio-economic systems are highly sensitive to climate change and thus scored 9 out of 10 for this study.

Shanghai's average elevation is just 4 m above sea level. To the east of Shanghai is the East China Sea. The city is bisected by the Huangpu River, a tributary of the Yangtze. Shanghai is situated on the soft mud of the delta and natural subsidence is estimated at 2 to 2.6 m, which contributes to the city's high exposure score of 8 out of 10.

Being a major center of business, Shanghai hosts hundreds of thousands of business visitors (up to 700,000 from Taiwan alone). While Shanghai and Hong Kong compete for the title of economic center of China, Shanghai has a GDP of over US$200 billion and a PPP of US$371. Per capita GDP is US$10,500 (nominal) and is growing at almost 10% a year. This GDP is considerably higher than in some other Asian cities analyzed, and therefore one of the reasons that Shanghai ranks as one of the more adaptive cities in this study.

Shanghai has a humid subtropical climate and experiences four distinct seasons. In winter (December – February), cold northerly winds from Siberia can cause nighttime temperatures to drop below freezing (average low is about 1°C during January), and although not usually associated with snow, the city can receive one or two days of snowfall per year. Summer (June – August) in Shanghai is very warm (average high is about 32°C during July) and humid, with occasional downpours from sudden thunderstorms. Precipitation varies but most falls during the summer months. On average there are about 112 rainy days per year, totaling over 1,100 mm annually . While Shanghai has not been hit hard recently, the city is also susceptible to typhoons.

Observed Climate Change

As with many other Asian countries, China has seen significant climate change. According to the IPCC, observed temperature increases during recent decades have ranged between less than 1°C to 3°C over the last 100 years (more pronounced warming has been observed at the Northern latitudes). Further, warming during the last 50 years has been more pronounced in winter than summer, and the rate of increase has been more pronounced in low temperatures than in high temperatures. While specific climate data was not available for Shanghai, the IPCC does report that annual rain has increased in the past decade in Western China, along the Changjiang River and at the south-east coast.

Impacts

Climate change is a major threat to Shanghai and is best illustrated by the substantial damage that occurred in 2006. The combined effects of sea-level rise, storm-surge, coastal erosion, and salt water intrusion significantly impacted Chinese coastal economies, including Shanghai. For example, in 2006, salt water intrusion and coastal erosion impacted a large portion of the Yangtze Delta region.

Specifically, salt water intruded into Shanghai's water supply and greatly reduced the quality of groundwater. Unfortunately, this salt water intrusion also impacted local ecosystems, such as wetlands, which can greatly improve water quality by naturally filtering pollution and debris. These coastal areas also provide habitat for aquatic species like fish, which also support a significant portion of food and livelihoods for Shanghai's poorest residents.

The events in 2006 also illustrate how damaging tropical storms and typhoons can be. One such storm, tropical storm Bilis, affected nearly 32 million people, and around 3.4 million were relocated. This one tropical storm damaged over 1.3 million hectares of crops and caused an additional 250,000 hectares to go unharvested. Additionally, nearly 900,000 houses either collapsed or were damaged. The IPCC suggests that the frequency and intensity of storms in this region will likely increase with climate change and as in 2006, damages will rise. Unfortunately, the Yangtze delta is particularly vulnerable to typhoons, and resulting storm surges as high as 5.2 m have been measured in the past.

Sea-level rise is being compounded by subsidence throughout the Yangtze River Delta (also referred to as the Changjiang Delta). The current subsidence is estimated at 2.0 to 2.6 m, and as more and more people are being drawn to Shanghai, the increased use of groundwater is resulting in accelerated subsidence. Further, projections of sea-level rise range from 50 to 70 cm by 2050. Models indicate that with 0.3 m sea-level rise, the area inundated will be 54,500 km^2. Flooding is another significant climate change threat in the Yangtze River Delta. In fact, there has been an observed increase in the frequency of extreme rain events with more floods in the past decade and it is projected that this will continue with further climate change. Shanghai is vulnerable to climate change, and the events of 2006 show how the combination of tropical storms, sea-level rise, coastal erosion and salt-water intrusion will impact China's megadelta metropolitan areas.

Adaptation

Shanghai and the Yangtze River Delta account for a substantial proportion of China's total GDP. In fact, it is estimated that the economy of the entire Yangtze Delta is about the same as a medium-sized developed country, encompassing a GDP (when measured to purchasing power parity) of some US$2 trillion US, which is 21% of the Chinese economy according to the International Monetary Fund. Because of widespread development in the region, the Yangtze River Delta may be the largest concentration of adjacent metropolitan areas in the world, covering an area of 99,600 km2 and home to over 80 million people (2007). Needless to say, protection of Shanghai and other important urban centers in the Yangtze River Delta is of critical economic and humanitarian importance.

Shanghai has implemented some adaptation strategies including what the IPCC refers to as an effective heat watch and warning system, which will likely be helpful in reducing the impacts of climate change on human health. However, the poor air quality in Shanghai's industrial areas adds to the city's overall vulnerability and will likely contribute to widespread heat stress and smog-induced cardiovascular and respiratory illnesses in the region. There is also currently some coastal protection in place. However, it has been assessed as insufficient and substantially more protection will be needed to buffer higher sea levels and future tropical storms and storm surges. The IPCC also highlights that Shanghai is more vulnerable to extreme events because the city is heavily dependent upon these artificial coastal defenses with systemic failures leading to widespread problems. Shanghai would be wise to upgrade design criteria for flood embankments and barrages in preparation of future flooding and storms. Coastal adaptation should also include no-regret options that have low costs and high benefits, such as protecting and restoring coastal ecosystems like mangroves.

Bangkok, Thailand

Vulnerability Score = 5

Environmental Exposure	**5**	●●●●●○○○○○
Storm threat	2	●●○○○○○○○○
Sea-level rise	7	●●●●●●●○○○
Flooding/drought	7	●●●●●●●○○○
Socio-Economic Sensitivity	**7**	●●●●●●●○○○
Population	5	●●●●●○○○○○
Assets threatened	9	●●●●●●●●●○
Inverse Adaptive Capacity	**4**	●●●●○○○○○○

City Profile

Situated on the bank of the Chao Phraya River, Bangkok is the largest urban area and capital city of Thailand. In fact, covering over 1,500 km^2, it is one of the largest cities in the world. Some regard Bangkok as the political, social and economic center of not only Thailand but all of Asia. Bangkok is one of Asia's major business, financial, and cultural centers and the city influences all sectors, from the arts to politics, fashion, education and entertainment.

Bangkok has a diverse population of approximately 6 million and the greater Bangkok area has a population of nearly 12 million (2008). Bangkok is reportedly the most built-up area in Southeast Asia, stretching from the northeast along Bangkok to the industrialized eastern seaboard of Thailand. Bangkok is sometimes referred to as the "Venice of the East," because it is situated 30 km from the mouth of the Chao Phraya River and the Bay of Bangkok, sitting among a number of canals and passages that divide the area into separate patches of land.

Bangkok is the economic center of Thailand, producing US$220 billion or 44% of the country's GDP. This massive proportion of Thailand's total GDP is reflected in Bangkok's GDP per capita, which is well over US$20,000. While this per capita GDP is one of the highest in Southeast Asia, it does not reflect the vast difference between the few wealthy and the many poor that inhabit Bangkok. Subsequently, Bangkok ranked a 7 out of 10 for its socio-economic sensitivity to climate change.

Thailand overall attracts 14.5 million foreign tourists a year (2007) and it is estimated that Bangkok itself attracts almost 11 million (2007), about 3 million more than New York City. Subsequently, tourism contributes about 5% of Thailand's GDP and is a significant contributor to Thailand's economy.

Bangkok has two seasons: tropical wet and dry climate. Average temperatures in Bangkok range from lows of 21°C during December and January to highs of 35°C during April. Average precipitation ranges from 10 mm during December and January to 320 mm during September.

Observed Climate Change

Temperatures in Southeast Asia have increased 0.5 to 1.5°C between 1951 and 2000. While there has been a decreasing trend in precipitation between 1961 and 1998, with the number of rainy days declining, the frequency of occurrence of more intense rainfall events in many parts has increased. This leads to more severe floods, landslides, and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased.

Impacts

Sea-level rise is a major climate change threat to Bangkok. The city lies just 2 m above current sea level and the IPCC states that subsidence or sinking of the Chao Phraya River delta is being enhanced by human activities such as excessive ground water extraction and a diminishing supply of river sediments because of upstream dams. This subsidence is estimated at 0.2 to 1.6 m. A recent study estimates that sea level will rise by 10 to 100 cm in the next 50 years in the upper Gulf of Thailand. Consequently, salt water will make it many kilometers inland in the Chao Phraya River delta, thus impacting Bangkok's freshwater supply. This will affect everything from farmland productivity to the availability of drinking water. Salt water intrusion is also exacerbated by stronger and more frequent storms surges. The loss of land due to a sea-level rise of 50 cm and 100 cm could decrease Thailand's GDP by 0.36% and 0.69% (US$300 to 600 million) per year, respectively. The hardest hit sector will likely be manufacturing, which in Bangkok could amount to about 61% and 38% of the total damage, respectively. Bangkok's environmental exposure was ranked at 5 out of 10 for this study.

Coastal erosion is another significant threat in Thailand and with the expected rise in sea-level, there will be further loss of valuable land. In some places along Thailand's 2,667 km shoreline, erosion is occurring at a rate of 15 to 25 m per year. This will not only impact Bangkok and its surrounding suburbs, but also will affect the economically important tourism industry. Unfortunately, Bangkok's natural coastal protection – mangroves – is also being affected by coastal erosion, in addition to being cut at an alarming rate. For example, Bangkok's only seaside district, Bang Khunthian, once comprised 5 km of muddy coastline with abundant mangrove forests and has lost more than 483 ha of mangroves over the last 30 years. These mangrove forests buffer the effect of storm surges by absorbing and dissipating the wave's energy and when the mangroves are gone people are more vulnerable. An example of this exposure is in the small coastal village of Khun Samutchine, in Samut Prakan province south of Bangkok. Because of coastal erosion and other factors, many of the people living here have had to abandon their coastal homes and move inland, losing much of what they owned.

Because Bangkok is so low in elevation and sits on the banks of the Chao Phraya River, flooding is another major climate change threat to Bangkok. Historically, Bangkok has always been prone to periodic flooding. However, with the projected increase in extreme rainfall protecting the city against floods during the monsoon season will be even more difficult and costly. As mentioned, Bangkok lies within the Chao Phraya River delta and thus sits on a series of canals. During the rainy season, river volume swells significantly and the river overflows the banks, resulting in massive floods.

Adaptive Capacity

Climate change poses significant threats to Bangkok. Because of its relative wealth, however, Bangkok has higher adaptive capacity than most other large cities in Southeast Asia and therefore ranked 5 out of 10 for adaptive capacity. Bangkok has already implemented a number of flood control and prevention options. Specifically, the Bangkok Metropolitan Administration (BMA) has recently installed higher banks and pumping stations in strategic areas of the city to regulate water in canals and rivers that tend to overflow during the rainy season and extreme weather. Water gate facilities have also been installed in some parts to prevent salt water intrusion and to control floods.

The combination of severe floods and subsequent droughts threatens food security in the region and is a concern of the Thai government. In response, rice storage silos have been built on high ground in some regions. There is also community-based training on emergency response and how to prepare for extreme events. A proactive example from Vietnam is to establish early flood warning systems for local communities. This could not only save lives but also substantially reduce damage costs.

Due to the effects of sea-level rise and storm surges, Bangkok would also be wise to better protect existing mangrove forests and restore ones that have been lost due to cutting. These forests provide significant protection during storms and are key marine habitats for fish. Protection and restoration of mangroves can result in high benefit for relatively low cost of implementation.

Hong Kong, China

Vulnerability Score = 4

Environmental Exposure	**7**	●●●●●●●○○○
Storm threat	7	●●●●●●●○○○
Sea-level rise	7	●●●●●●●○○○
Flooding/drought	6	●●●●●●○○○○
Socio-Economic Sensitivity	**6**	●●●●●●○○○○
Population	3	●●●○○○○○○○
Assets threatened	8	●●●●●●●●○○
Inverse Adaptive Capacity	**1**	●○○○○○○○○○

City Profile

Hong Kong, officially the Hong Kong Special Administrative Region, is a territory of the People's Republic of China. Hong Kong faces the South China Sea and is approximately 1,100 km^2 in area, consisting of Hong Kong Island, Lantau Island, Kowloon Peninsula, the New Territories as well as some 260 other islands. Hong Kong has long been renowned for its deep natural harbor, tall surrounding hills and as a cosmopolitan mixing pot of Eastern and Western cultures. This diversity is well reflected in Hong Kong's cuisine, cinema, music and traditions. Hong Kong is 60 km east of Macau and on the opposite side of the Pearl River Delta, which is where the vast majority of the current air pollution originates from. Hong Kong is mostly hilly and even mountainous in spots (e.g., the highest elevation is 958 m) with less than 25% of the territory's total area being developed. Hong Kong has population of about 7 million people and a density of over 6,200 people per km^2, making it one of the highest density cities in the world. Hong Kong has made an effort to restrict further land reclamation along Victoria Harbor and has ensured that about 40% of the total land area is reserved as green space and nature reserves.

Hong Kong is a major international financial center and has a highly developed capitalist economy stemming from history as a UK colony. Hong Kong's economy is relatively sensitive to climate change and therefore ranks a 6 out of 10. Hong Kong hosts one of the greatest concentrations of corporate headquarters in the Asia-Pacific region and is considered as one of the freest economies in the world. Hong Kong's main source of income comes from tourism, import and exports, as well as financial services. While tourism is very strong in Hong Kong –over 25 million visitors in 2006 – the increase in popularity of other Chinese cities is providing stiff tourism competition.

Hong Kong's climate is a humid subtropical climate similar to Shanghai. Because it is farther south, however, temperatures are warmer. Summer is hot and humid with temperatures averaging 31°C during July and August. Winters are mild, with temperatures averaging 14°C during the coldest month, January. Precipitation is heaviest during July and August (374 and 444 mm, respectively) when warm air blows from the southwest. This is also the time of year that typhoons are most likely and when precipitation is heavy, which can result in flooding and landslides.

Observed Climate Change

The IPCC highlights that observed temperature increases during recent decades in China have ranged between less than 1°C to 3°C over the last 100 years (more pronounced warming has been observed at the Northern latitudes). Warming during the last 50 years has been more significant during winter rather than summer, and the rate of increase has been more pronounced in low temperatures than in high temperatures. The IPCC also highlights that annual rainfall has increased in the past decade in Western China and along the south-east coast.

Impacts

Hong Kong sits across from the Pearl River Delta (also referred to as the Zhujiang River Delta) and is considered a part of the overall megadelta. In all, the population is estimated at 60 million, with Hong Kong contributing about 7 million. Because of Hong Kong's economic ties and close proximity to the Pearl River Delta, this report includes the effects of climate change impacts throughout the delta area but only considers Hong Kong's population and per capita GDP for the other vulnerability components. The most significant climate impacts to affect Hong Kong and the surrounding area include sea-level rise, storm surge, flooding, salt water intrusion and extreme weather events, such as tropical cyclones. Subsequently it ranks a 7 out of 10 for exposure. In addition to slight ground subsidence, sea level is estimated to rise 40 to 60 cm by 2050 in the Pearl River Delta. Additionally, the area that would be inundated by 30 cm of sea-level rise is estimated at 5,500 km^2, increasing coastal flooding areas by 5 to 6 times. Sea-level rise of 0.4 to 1.0 m could lead to an additional 1 to 3 km of salt-water intrusion, further impacting agriculture and industry along the Zhujiang estuary.

Increased climatic variability is predicted throughout the region and the resulting changes in precipitation may translate into longer and more severe droughts during the dry season and more frequent and intense flooding during the wet season. According to the IPCC, there has been an increase in the frequency of extreme rains in parts of China and damages have increased by about three times and eight times respectively in the 1990s, relative to those in the 1980s and 1970s, and these trends are likely to continue into the future. During the dry season, increased frequency and intensity of droughts will add to the effects of salt-water intrusion and further deteriorate surface and groundwater quality. The frequency and intensity of tropical cyclones originating in the Pacific have also increased over the last few decades - a trend which is expected to continue. Specifically, the number and intensity of strong cyclones has increased since the 1950s with 21 extreme storm surges from 1950 to 2004, of which 14 occurred between 1986 and 2004. Damages from these storms and the associated costs of storm surges have also risen significantly. In fact, the direct damage cost caused by tropical cyclones in Asia has increased more than five times in the 1980s as compared with those in the 1970s, and about 35 times in the early 1990s compared to the 1970s. Because more storms are projected for the future, costs are likely to continue to rise. Increases in the frequency and intensity of extreme weather events will also negatively impact aquatic ecosystems, making existing coastal areas more vulnerable and challenging subsistence-based livelihoods further.

Climate change will also impact the health of Hong Kong residents. Warming temperatures will reduce the number of cool winters in Hong Kong. Studies suggest that the combination of climate change and rapid urbanization will warm Hong Kong so much that the city's cool winters could vanish from an average of 21 "cold days" (days when temperatures are below 12°C), to zero within 50 years. Observational records show that between 1961 and 1990, there was an average of 21 cold days every winter. In contrast, the number of hot summer nights (nights when temperatures are above 28°C) has risen almost four times since the 1990s, which will likely continue with climate change and lead to heat stress for Hong Kong's residents.

Adaptation

The Pearl River Delta is one of the largest manufacturing centers in the world and of extreme economic importance to China, accounting for a substantial proportion of China's total GDP. Because the region is low in elevation and exposed to climate risks, mitigation and adaptation should be top priorities. Because the Pearl River Delta is a manufacturing center, powered by dirty coal plants, the area is extremely polluted. Poor air quality in the Pearl River Delta's major cities such as Guangzhou, Hong Kong, and Shenzhen is contributing to a major public health crisis – over 300,000 people die prematurely from air pollution in China every year. However, shifting to more sustainable forms of energy in the Pearl River Delta will have a positive impact far beyond the delta. As one of the richest and most influential regions in China, developing best practice in the Pearl River Delta will positively influence energy planning in other parts of the country. Additionally, cleaning up pollution (air, soil, and water) is relatively easy, and if authorities switch to cleaner ways of electricity generation, such as wind, solar, and geothermal, then the region will be more resilient to the effects of climate change.

Hong Kong, like many coastal Asian cities, has converted large areas of mangrove forests to shrimp aquaculture in the past three decades. Fortunately, this trend can be changed quickly by implementing additional protection, enforcement and restoration policies so that mangroves can continue to provide a buffer against storm and tidal surges and deliver essential spawning grounds for fish. Mangroves are currently being cut on a large scale for the production of charcoal, aquaculture and housing, which increases the vulnerability of the coastal region, but inexpensive fuel and building alternatives exist, and the true value of mangroves needs

Kuala Lumpur, Malaysia


© Daniel Berthold

Vulnerability Score = 4

Environmental Exposure	**3**
Storm threat	1
Sea-level rise	1
Flooding/drought	7
Socio-Economic Sensitivity	**5**
Population	3
Assets threatened	7
Inverse Adaptive Capacity	**3**

City Profile

Kuala Lumpur is Malaysia's capital and largest city in terms of population size and economy. Covering an area of 244 km², Kuala Lumpur has an estimated population of 1.8 million (2009), and when including the surrounding suburbs the greater Kuala Lumpur area known as the Klang Valley, the population swells to about 7.2 million. Kuala Lumpur has the fastest growing population and economy in Malaysia and is a center for finance, insurance, real estate, media and the arts. Kuala Lumpur ranked a 5 out of 10 for socio-economic sensitivity to climate change impacts.

Well known as the home of the tallest buildings in the world, the Petronas Twin Towers, Kuala Lumpur is also the cultural and economic center of Malaysia and home to Malaysia's Parliament. Kuala Lumpur roughly translates to "muddy confluence" because it is situated at the confluence of the Klang and Gombak rivers. Kuala Lumpur lies within the Klang Valley bordered by the Main Range Mountains and the Strait of Malacca. Kuala Lumpur has an average elevation of 22 m.

Kuala Lumpur's GDP is estimated at US$7.5 million in 2000 with an average annual growth rate of 4.2%. The per capita GDP for Kuala Lumpur in year 2000 is US$8,800, an average annual growth rate of 6.1%. The service sector comprises about 83% of total employment and includes the following: finance, insurance, real estate, business services, wholesale and retail trade, restaurants and hotels, transport, storage and communication, utilities, personal services and government services. The remaining 17% comes from manufacturing and construction. Tourism also plays an important part in Kuala Lumpur's economy, providing income and employment to many.

Kuala Lumpur's climate is equatorial, officially referred to as tropical rainforest climate. Temperatures are generally uniform and range from average lows of 22°C during January and February to average highs of up to 33°C during March and April. Precipitation averages 2,266 mm per year and is heaviest during the months of March, April, October, November, and December. Flooding is a frequent occurrence in Kuala Lumpur whenever there are heavy precipitation events and can significantly impact the city center. Air pollution from forest fires during the dry season and extreme climatic events, such as El Nino, can be a major source of pollution for Kuala Lumpur.

Observed Climate Change

Kuala Lumpur's temperature change has been similar to changes in other places across Southeast Asia. Generally, the temperature has warmed 0.5 to 1.5°C since the 1950s. There has been an overall decrease in precipitation throughout Southeast Asia with the total number of rainy days declining but with more intensive rain storms in some areas. There has also been an increase in the number of hot days and warm nights and a decrease in the number of cold days and nights between 1961 and 1998.

Impacts

Extreme weather events, such as intense rain storms and floods have been and will likely be a major problem for Malaysia and specifically, Kuala Lumpur. The IPCC highlights that there has been an increased occurrence of extreme rains causing flash floods in the past and that things will get worse under climate change scenarios. Previous floods have caused considerable damage, including massive landslides and loss of life and property. Increasing urbanization and population growth in the Kuala Lumpur metro area will drive the opening of more areas for development. As hill slopes get encroached upon, there is an increased risk of landslides and property damage during heavy rainfall. Increases in heat wave duration and severity is also projected to worsen in the future and will significantly impact Kuala Lumpur's poor residents, since they have little or no capacity to cope with added heat stress. Kuala Lumpur's poor will also have a difficult time dealing with rising temperatures and increased rainfall variability (induced by inter-annual climate cycles, such as the El Niño Southern Oscillation), which has lead to increased frequency of occurrence of climate-induced diseases and heat stress. There is also an expected increase in endemic morbidity and mortality due to diarrheal disease associated with floods and droughts in the region.

Drought frequency has been high in some regions of Malaysia, particularly Sabah state, and with continued, heavy extraction of surface water resources could become more of an issue the near future for Kuala Lumpur (e.g., depletion of water reservoirs). Droughts in Southeast Asia have also been triggered by El Nino events. During the 1997 to 1998 event, they lead to massive crop failures, water shortages, and vast forest fires. Climate change will also likely expand the area under severe water stress in Malaysia, making it more difficult for poor residents to survive during extreme events.

Kuala Lumpur will likely not be impacted by sea-level rise nearly as much as some other places in the region, and therefore only ranked a 3 out of 10 for environmental exposure. However a recent analysis suggests that sea-level rise could affect 7% of Malaysia's population and 6% of the national GDP. The combined effects of sea-level rise, coastal erosion and large-scale conversions of coastal mangrove forests to shrimp aquaculture have occurred during the past three decades along the coastlines of Malaysia.

Adaptation

Kuala Lumpur is arguably Malaysia's most important metropolitan area and adaptation to climate change is crucial for continued economic growth and for ensuring sustainable growth. Furthermore, with over 16 million foreign visitors in 2005 and a considerable contribution towards the national GDP, adaptation is needed to maintain Malaysia's status as a key tourist destination. It has been shown that adapting to climate change now will be much less expensive and relatively easier than waiting until climate change impacts worsen.

Because of the expected increase in water stress, Malaysia, and specifically, Kuala Lumpur, should consider protecting current surface and groundwater resources, improving infrastructure to allow for use of recycled water and harvesting rain water. Other important strategies include improving the management and maintenance of existing water supply systems, protecting and conserving water catchment areas, developing flood controls, such as the Stormwater Management and Road Tunnel (SMART Tunnel), drought monitoring systems, and reforming water policies, including pricing and irrigation systems. Even though this study could not find many adaptation examples within Kuala Lumpur, the city has much more adaptive capacity than the rest of the country and ranked a 3 out of 10. Further, there are many good case studies from other countries in Southeast Asia, and Kuala Lumpur should share its own experiences.

For coastal resources, Kuala Lumpur should consider increased protection of its economic infrastructure, increasing public awareness and education to enhance the protection of coastal and marine ecosystems, including mangrove forests, better coastal planning and zoning (i.e., sustainable development), and integrated coastal zone management so that all sectors are in communication with one another and that policies and laws are recognized and enforced.

Singapore, Republic of Singapore


© Formulax

Vulnerability Score = 4

Environmental Exposure	**4**
Storm threat	1
Sea-level rise	6
Flooding/drought	5
Socio-Economic Sensitivity	**6**
Population	2
Assets threatened	10
Inverse Adaptive Capacity	**1**

City Profile

Singapore, officially the Republic of Singapore, is an island city-state located at the southern tip of the Malay Peninsula. Singapore is by far the smallest nation in Southeast Asia at 710 km^2. However, with over 4.7 million residents and a density of 6,672 people per km^2, Singapore is the third densest country in the world. Singapore is culturally diverse with Chinese people forming an ethnic majority, along with large populations of Malay, Indian and other ethnicities.

Singapore sits on the mouth of the Singapore River and since the 1960s has developed essentially all surrounding land into an urban landscape with about 23% of land being parks. In fact, Singapore has actually built up some of its land from the sea (e.g., East Coast Park) and may try to add another 100 km^2 by 2030.

Singapore's economy focuses on industry, education and urban planning and has a high standard of living ultimately ranking a 1 out of 10 for inversed adaptive capacity, meaning Singapore has relatively high adaptive capacity. At US$51,142, Singapore is reportedly the 6th wealthiest country in the world in terms of GDP (PPP) per capita (2008). Total GDP is estimated at US$238.8 billion (2008). In fact, Singapore has been ranked as the 10th most expensive city in the world to live in and the 3rd most expensive in Asia. Tourism also provides a significant contribution towards national GDP, with over 10 million visitors in 2008.

Sitting less than two degrees way from the equator, Singapore has a typical equatorial climate or tropical rainforest climate with no real distinctive seasons. Because at least 60 mm of precipitation falls each month, there is no real dry season. Singapore's climate is characterized by uniformly warm temperatures, high humidity, and abundant rainfall. Temperatures range from 22°C to 34°C and the relative humidity is around 90% in the morning and 60% in the afternoon. During prolonged heavy rain, relative humidity often reaches 100%. June and July are the hottest months, while November and December make up the wetter monsoon season. From August to October, there is often haze, sometimes severe enough to prompt public health warnings, due to bushfires in neighboring Indonesia.

Observed Climate Change

According to observed climate data, Singapore has warmed about 0.6°C between 1987 and 2007, consistent with the rest of Southeast Asia. Singapore has also seen less rain, with a significant decrease in annual rainfall in the past three decades, but with more intense rainfall during the monsoon season, leading to flooding.

Impacts

The IPCC projects Singapore's temperature to continue to rise by 1.7 to 4.4°C by the end of the century. Additionally, Singapore will likely see continued changes in precipitation and freshwater resources and an increase in sea level. Extreme weather events, such as heat waves, heavy rainfall, and flooding also threaten Singapore, and therefore the city ranked a 4 out of 10 for environmental exposure. Singapore's monsoon season runs from November to January and an increase in heavy rainfall during this season could lead to significant flooding and increased damage costs. Initially, increased rainfall sounds like a positive change for Singapore. However, the majority of rainfall may occur during just a few storms, making it more difficult to trap it in catchment areas and supply the growing demand with sufficient freshwater and food resources. Until recently Singapore imported water from Johor, Malaysia and is still importing food, making Singapore vulnerable to changes in other Southeast Asian countries. In fact, Singapore's agriculture sector only contributes less than 1% to the country's GDP and subsequently any significant damage to crops in neighboring countries will affect agriculture and food supplies. In response to this vulnerability, the government of Singapore has implemented several water projects that are highlighted in the adaptation section below. Climate change projections suggest that changes in Singapore's annual precipitation could range from –2% to +15% with a median of +7%, but with just 138 m^3 of freshwater available to each Singapore resident, a slight change in precipitation will lead to huge changes in freshwater supplies.

Climate change projections also indicate that extreme rainfall and winds associated with tropical cyclones are likely to increase.

At the same time, sea level rise will continue to erode Singapore's limited coastal protection and decrease total shoreline. As an island, Singapore has limited land area and is at high risk to coastal erosion. Subsequently, coastal land loss is a major concern to Singapore and increased erosion has already affected some recreational areas along the coast such as those at the East Coast Park. Sea level is projected to increase about 60 cm by the end of the century which would translate into additional loss of land.

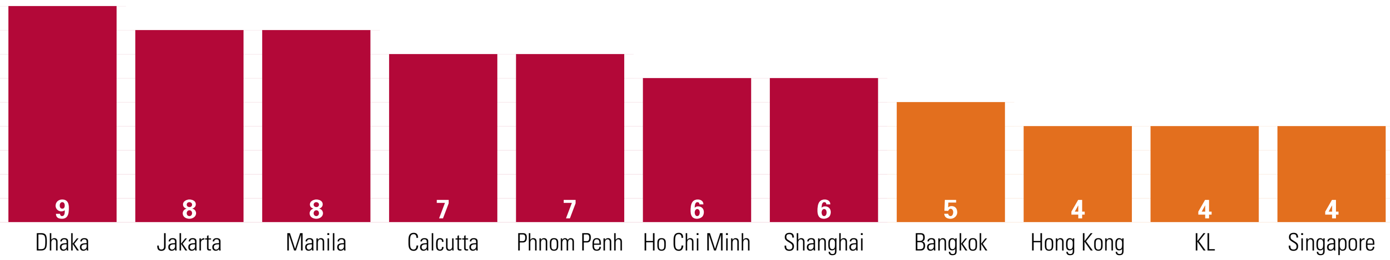
Other climate change threats may include impacts to human health. For example the prevalence and spread of diseases - such as dengue fever - into areas not previously affected is a sign that the climate is changing. Dengue outbreaks in 2005 were three times the previous peak of the disease in 1998 (the disease runs in 6 to 7 peak cycles) and 2007 saw the third highest number of outbreaks ever. Dengue seems to also be spreading to areas of Singapore where it previously was not found.

Adaptation

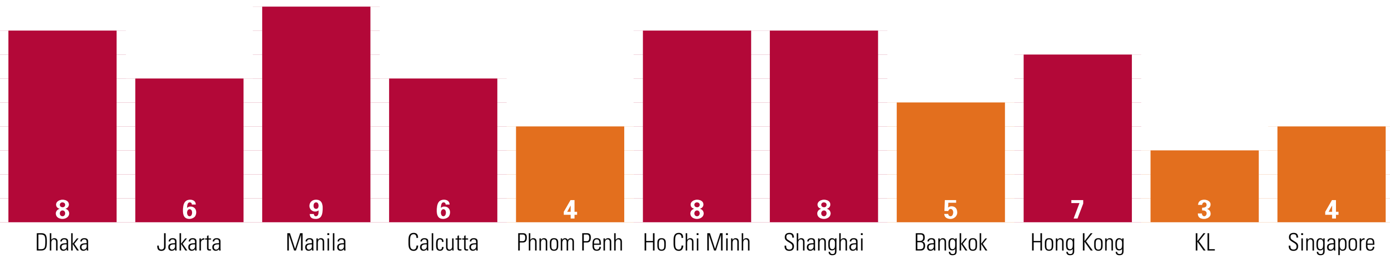
Singapore has a relatively high GDP per capita, high monetary reserve (estimated at US$170 billion in January 2009), and considerable access to new and innovative technologies and therefore is believed to have a relatively high adaptive capacity. However, Singapore is also particularly vulnerable to climate change impacts because it is an island nation, has a dense population in one city and is reliant on other countries for food resources. Subsequently, Singapore ranked a 6 out of 10 for socio-economic sensitivity to climate change. Additionally, water availability is a huge issue in Singapore because of the limited domestic availability of water resources and increasing population growth and economic activity. In response, the government of Singapore plans to increase the water catchment area from half to two-thirds of the nation's land area through three new reservoir schemes Marina, Punggol, and Serangoon Reservoirs. Singapore is also putting considerable resources into technologies that will enhance water, such as recycling and reusing used water. This project, referred to as NEWater technology, currently provides about 15% of Singapore's water consumption and will be increased to meet 30% of Singapore's water needs by 2011. Singapore is also using reverse osmosis on seawater, which will also produce 136 million liters of fresh water a day.

Coastal erosion is already impacting Singapore and will likely worsen with sea-level rise and increased storms. A recent study estimates the annual cost of protecting Singapore's coast to be between US$0.3 and 5.7 million by 2050 and between US$0.9 and $16.8 million by 2100. Coastal protection has been found to be the least-cost strategy to combat sea-level rise in Singapore and researchers have concluded that it would be more costly to allow the coast to become inundated than to defend it. However, adaptation should not replace mitigation, but instead work in tandem with it.

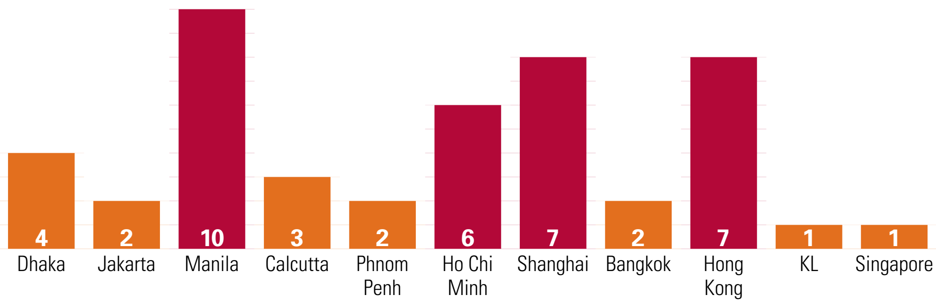
Overall Vulnerability



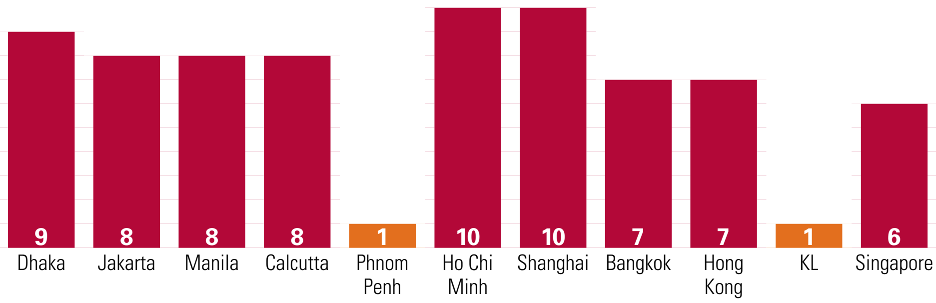
1. Exposure



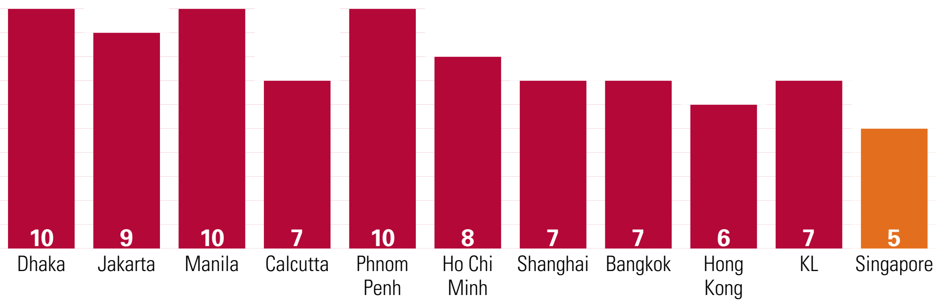
1.1 Storm threat



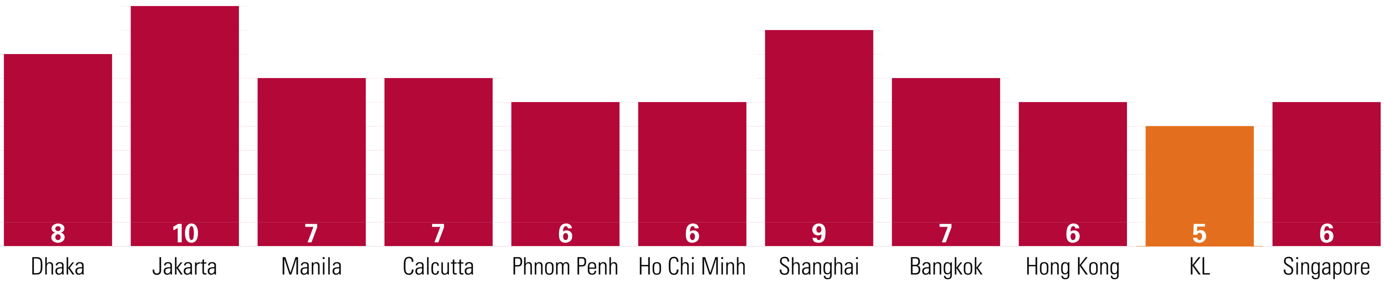
1.2 Sea-level rise



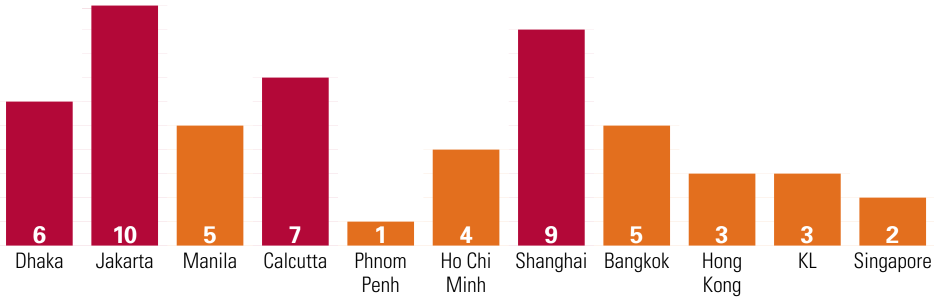
1.3 Flooding/drought



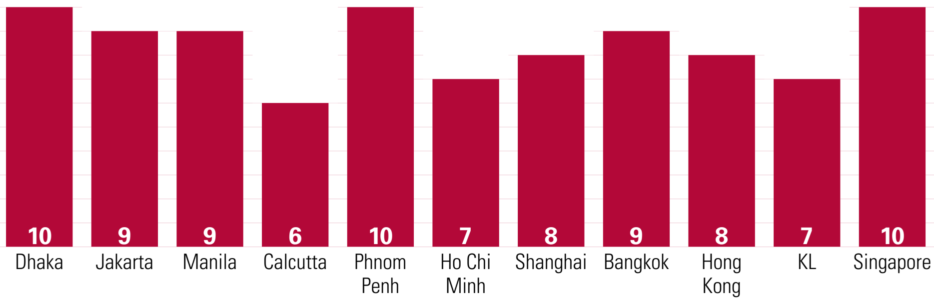
2. Sensitivity



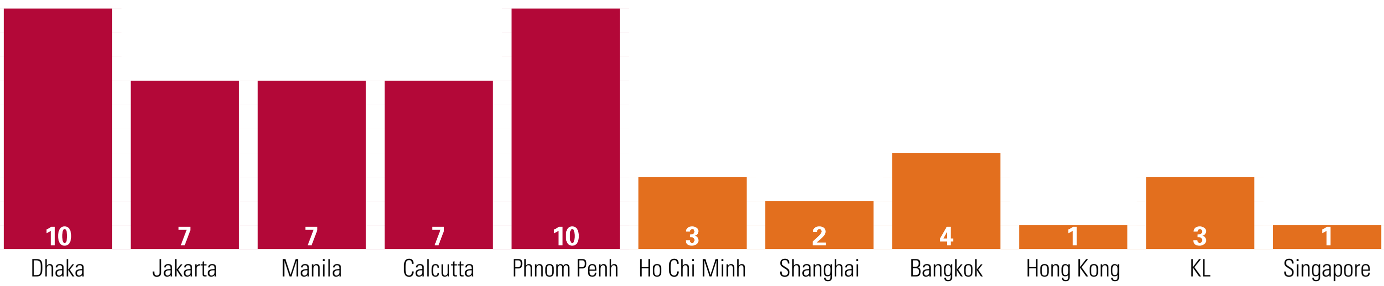
2.1 Population



2.2 Assets Threatened



3. Inverse Adaptive Capacity



Policy Recommendations

It is undeniable, humans have caused climate change and the irreversible impacts resulting from it, and the window of opportunity to limit further damage is quickly closing. As outlined in this report, climate change impacts in Asia are real and happening now. The vulnerability of this region is relatively high and millions of people are being affected.

Fortunately, there are a number of no-regret (win-win) adaptation options that can be implemented immediately and that will help protect people, assets, and natural ecosystems. However, fast action is of the essence as the world has no time left to wait. Climate change and the associated impacts, such as sea-level rise, flooding, droughts and tropical storms will get worse in the future and the costs of responding now rather than later are significantly less. As climate-induced damages escalate, so too do the costs.

In response, the ultimate objective of the United Nations Framework Convention on Climate Change is to stabilize greenhouse gas (GHG) concentrations in order to avoid dangerous climate change. Recent studies indicate that an average global warming of 2°C will result in dangerous and irreversible effects to humans and nature, which rapidly worsen above 2°C warming. The benefits of strong and early mitigation action far outweigh the economic costs of not acting. The costs of avoiding the worst impacts of climate change can be limited to around 1% of global GDP/year, whereas the costs of inaction range from 5 to 20% of global GDP/year. GHG emissions research suggests that the chances of staying below 2°C are getting smaller, but scientists say that it may still be possible. Keeping warming below 2°C with more than a 50% chance requires global emissions to peak before 2015 and to decline 80 to 95% below 1990 levels by 2050. Therefore, WWF calls on developed countries to cut their emissions by at least 40% by 2020 and at least 95% by 2050 compared to 1990 levels.

This report illustrates the high vulnerability of mega-cities in Asia and provides some general adaptation options. It is also a catalyst for societal discussion about the region's vulnerability, the different types of allowable risk, and what can be done to improve the situation. This will hopefully spark not only discussion about this region, but also in and about other vulnerable regions around the world, as well as about the historical inequality between the biggest polluters and the countries that have contributed the least to climate change but suffer most.

Implementing both mitigation and adaptation strategies is crucial. We need to implement ambitious and effective mitigation policies immediately, achieving peak emissions as soon as possible (but no later than 2015) and maintain at least 3% global emissions cuts annually thereafter. If we want to avoid additional irreversible consequences and even more costs then we need to dramatically reduce CO_2-eq concentrations to reach less than 350 ppm as soon as possible. Currently the world is estimated to be at 396 ppm CO_2-eq, including the cooling effects of aerosols in the atmosphere. Another way of illustrating the limited window of opportunity for staying below 2°C is by examining the total allowable amount of carbon in the atmosphere. In order to accomplish this we must limit all CO_2 emissions from fossil fuels to around 1,000 billion tons of carbon in total from 2010 to 2050, and if we do there would be a good chance (over 70%) that the climate would not warm more than 2°C.

To keep the global average temperature increase well below 2°C, the energy system needs to be altered substantially; we need a new energy paradigm. A below 2°C energy future is realistic and the technology exists to dramatically increase the efficiency of our societies, produce energy with zero-to-low CO_2 and drive innovation. The challenge rather is a political one whereby decision-making structures must be put in place in order to drive such change. It is not acceptable to dismiss 2°C without having attempted to change the politics so that we can avoid the associated impacts. Vast resources and decision-making structures have been put into place to deal with military conflicts which may have less likelihood of occurring than the impacts from climate change. Governments, businesses, and the scientific community should focus their efforts on delivering this kind of change, rather than slipping into a world where devastating impacts would be the result.

Time is running out and implementing both mitigation and adaptation strategies are of the upmost importance. It is useful to remember that with both strategies we are not powerless to act on climate change, regardless of our position on the planet or role in governance. There are mitigation and adaptation opportunities for everyone. Vulnerability is important to assess because planning for adaptation is essentially designing response options to key vulnerabilities. However, no plan should be created for a single vulnerability in a single location, rather effective planning requires that the various responses be woven together into a fabric that is composed of actions that work together to provide the greatest adaptive benefit for the greatest number of vulnerabilities or the highest priority vulnerabilities. To limit these vulnerabilities there needs to be a combination of local and regional adaptation action, and local, regional and global policy efforts to support both adaptation and mitigation.

Below are some international adaptation priority actions:

- Adaptation is the additional burden to developing countries in their national development imposed as a result of activities contributed by developed countries, thus the financial, technical and capacity building support for adaptation activities shall come from developed countries as a legally binding commitment based on their historical responsibilities. Create an adaptation and risk prevention framework for the most vulnerable with an operational and adequately resourced Adaptation Fund. This should also include an insurance and compensation mechanism to cover the loss and damages or responses to unavoidable and catastrophic effects.
- Give countries in the region a greater say in identifying the interventions and targeting the financing according to their own priorities for adaptation.

There are also some national and regional priority actions that will apply to all countries in Asia and that are part of the solutions for all of the key vulnerabilities, including:

- Mainstream adaptation planning and climate resilience into economic development planning over the near, medium and long term – taking into particular account investments in infrastructure and energy stocks. Reassess conservation and development strategies to determine their vulnerability to climate change and redesign them as necessary.
- Develop multi-sectoral national and regional adaptation strategies balancing development and conservation plans to maximize sustainability in the face of climate change.
- Develop stakeholder and community engagement processes with respect to adaptation. Affected parties need to be part of the creation and implementation of adaptation solutions in order for them to be equitable and effective. Fundamentally, it will be local knowledge that generates the innovative adaptation strategies that may prove most successful.
- Extend and strengthen regional networks of community managed areas in places that demonstrated increased potential for resistance and resilience to climate change. These sites should include a range of coastal habitats. They can act as stepping stones for species movement in response to climate change and simultaneously support human responses to climate change.
- Employ ecosystem-based management of the region's seas and coastal areas to protect vital ecosystem services which will be essential to coping with an uncertain and challenging future.
- Protect coastal and marine biodiversity and implement more sustainable fisheries management as no-regrets actions to address current declines in productivity and adapt to future challenges of climate change.

References and Resources

Alam, M., 1996. Subsidence of the Ganges–Brahamaputra Delta of Bangladesh and associated drainage, sedimentation and salinity problems. In: Milliman, J.D., Haq, B.U. (Eds.), Sea-Level Rise and Coastal Subsidence. Kluwer Academic Publishers, pp. 169–187.

Allen, K.M., 2006: Community-based disaster preparedness and climate adaptation: local capacity building in the Philippines. Disasters, 30, 81-100.

Ali, A., 1999: Climate change impacts and adaptation assessment in Bangladesh. Climate Res., 12, 109-116.

Ali, A., 1996. Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water, Air, and Soil Pollution 92, 171–179.

Anderson-Berry, L.J., 2003: Community vulnerability to tropical cyclones: Cairns, 1996-2000. Nat. Hazards, 30, 209-232.

Anthoff, D., Nicholls, R.J., Tol, R.S.J. and Vafeidis, A.T. (2006). Global and regional exposure to large rises in sea-level: a sensitivity analysis. Working Paper 96. Tyndall Centre for Climate Change Research, Norwich

ADB (Asian Development Bank), 2009. The economics of climate change in Southeast Asia: A regional review. ADB, Manila.

Boer, R. and Perdinan. 2008. Adaptation to Climate Variability and Climate Change: Its Socio-economic Aspect. Proceedings of the Workshop on Climate Change: Impacts, Adaptation, and Policy in South East Asia, Economy and Environmental Program for Southeast Asia, Bali.

Boer, R. and R.G. Dewi. 2008. Indonesian Country Report—A Regional Review on the Economics of Climate Change in Southeast Asia. Report submitted for RETA 6427: A Regional Review of the Economics of Climate Change in Southeast Asia. Asian Development Bank, Manila.

Boer, R., and A. Faqih. 2005. Current and Future Rainfall Variability in Indonesia. Technical Report of the AIACC Project Integrated Assessment of Climate Change Impacts, Adaptation and vulnerability In Watershed Areas and Communities in Southeast Asia (AIACC AS21): Indonesia Component. Assessments of Impacts and Adaptations to Climate Change, Washington, DC.

Boer, R., Sutikno, A. Faqih, B.D. Dasanto, and A. Rakhman. 2007. Deteksi Perubahan Iklim dan Dampak Sosio-ekonominya. Laporan Proyek Kerjasama Badan Meteorology Dan Geofisika (Geophysics and Meteorology Agency) dan Institut Pertanian Bogor (Bogor Agricultural University), Bogor.

Boer, R. and A. Faqih. 2004. Current and Future Rainfall Variability in Indonesia. In An Integrated Assessment of Climate Change Impacts, Adaptation and Vulnerability in Watershed Areas and Communities in Southeast Asia, Report from AIACC Project No. AS21 (Annex C, 95-126). International START Secretariat, Washington, District of Columbia. http://sedac.ciesin.org/aiacc/progress/ FinalRept_AIACC_AS21.pdf

Chen, X.Q., 1991: Sea-level changes since the early 1920s from the long records of two tidal gauges in Shanghai, China. J. Coastal Res., 7, 787-799.

Cruz, R.V.O., R.D. Lasco, J.M. Pulhin, F.B. Pulhin and K.B. Garcia, 2006: Climate change impact on water resources in Pantabangan Watershed, Philippines. AIACC Final Technical Report, 9-107. http://www.aiaccproject.org/FinalReports/final_reports.html.

Dasanto, B. D., and B. Istanto. 2007. Indonesia Country Report: Climate Variability and Climate Change. Jakarta. Dasgupta, S, B. Laplante, C. Meisner, D. Wheeler, and J. Yan. 2007. The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis. World Bank Policy Research Working Paper 4136, Washington, DC.

Du, B.L. and J.W. Zhang, 2000:Adaptation strategy for sea-level rise in vulnerable areas along China's coast. Acta Oceanologica Sinica, 19, 1-16.

Duong, L.C., 2000: Lessons from severe tropical storm Linda. Workshop report: The Impact of El Niño and La Niña on Southeast Asia, Hanoi.

Ericson, J.P., C.J. Vorosmarty, S.L. Dingman, L.G.Ward and M. Meybeck, 2006: Effective sea-level rise and deltas: causes of change and human dimension implications. Global Planet Change, 50, 63-82.

Faisal, I.M. and S. Parveen, 2004: Food security in the face of climate change, population growth and resource constraints: implications for Bangladesh. Environ. Manage., 34, 487-498.

Fan, D.D. and C.X. Li, 2005: Complexities of Chinese coast in response to climate change. Advance in Research on Climate Change, 1, 111-114 (in Chinese with an English abstract).

Ge, D.K., Z.O. Jin, C.L. Shi and L.Z. Gao, 2002: Gradual impacts of climate change on rice production and adaptation strategies in southern China, Jiangsu. J. Agr. Sci., 18, 1-8.

Glantz, M.H., Ed., 2001: Once Burned, Twice Shy? Lessons Learned from the 1997-98 El Niño. United Nations University, Tokyo, 294 pp.

Haq, B.U., 1997. Regional and global oceanographic, climatic and geological factors in coastal zone planning. In: Haq, B.U., Haq, S. M., Kullenber, G., Stel, J.H. (Eds.), Coastal Zone Management Imperative for Maritime Developing Nations. Kluwer Academic Publishers, pp. 55–74.

Hara,Y., K. Takeuchi and S. Okubo, 2005: Urbanization linked with past agricultural landuse patterns in the urban fringe of a deltaic Asian mega-city: a case study in Bangkok. Landscape Urban Plan., 73, 16-28.

Hay, J.E., and N. Mimura, 2005: Sea-level rise: Implications for water resources management.Mitigation and Adaptation Strategies for Global Change, 10, 717-737.

Hay, J.E., and N.Mimura , 2006: Supporting climate change vulnerability and adaptation assessments in theAsia-Pacific Region –An example of sustainability science. Sustainability Science, 1, DOI 10.1007/s11625-11006-10011-11628.

Ho, J. 2008. Singapore Country Report—A Regional Review on the Economics of Climate Change in Southeast Asia. Report submitted for RETA 6427: A Regional Review of the Economics of Climate Change in Southeast Asia. Asian Development Bank, Manila.

Hu, D.X.,W.Y. Han and S. Zhang, 2001: Land-Ocean Interaction in Changjiang and Zhujiang Estuaries and Adjacent Sea Areas. China Ocean Press, Beijing, 218 pp. (in Chinese).

Hu, Z.Z., S. Yang and R. Wu, 2003: Long-term climate variations in China and global warming signals. J. Geophys. Res., 108, 4614, doi:10.1029/2003JD003651.

Huang, Z.G. andW.Q. Zhang, 2004: Impacts of artificial factors on the evolution of geomorphology during recent 30 years in the Zhujiang Delta. Quaternary Research, 24, 394-401.

Hulme, M., and N. Sheard. 1999. Climate Change Scenarios for the Philippines. Climatic Research Unit, Norwich.

IPCC. 2007. 2007. Climate Change 2007. Contribution of Working Groups I and II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press Cambridge, United Kingdom and New York, NY, USA

Jiongxin, X., 2003: Sediment flux to the sea as influenced by changing human activities and precipitation: example of theYellow River, China. Environ.Manage, 31, 328-341.

Kelly, P.M. andW.N. Adger, 2000: Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. Climatic Change, 47, 325-352.

Khan, T.M.A., O.P. Singh andM.D. Sazedur Rahman, 2000: Recent sea level and sea surface temperature trends along the Bangladesh coast in relation to the frequency of intense cyclones. Marine Geodesy, 23, 103-116.

Kripalani, R.H., S.R. Inamdar and N.A. Sontakke, 1996: Rainfall variability over Bangladesh and Nepal: comparison and connection with features over India. Int. J. Climatol., 16, 689–703.

Lal,M., G. Srinivasan and U. Cubasch, 1996: Implications of global warming on the diurnal temperature cycle of the Indian subcontinent. Curr. Sci. India, 71, 746-752.

Lal, M., T. Nozawa, S. Emori, H. Harasawa, K. Takahashi, M. Kimoto, A. Abe-Ouchi, T. Nakajima, T. Takemura and A. Numaguti, 2001b: Future climate change: implications for Indian summer monsoon and its variability. Curr. Sci.

India, 81, 1196-1207.

Lenton et al. 2008. Tipping elements in the Earth's climate system. PNAS 105(6): 1786-1793.

Li, C.X., D.D. Fan, B. Deng, and V. Korotaev, 2004: The coasts of China and issues of sea-level rise. J. Coastal Res., 43, 36-47.

Lin, E.D.,Y.L. Xu, H. Ju andW. Xiong, 2004: Possible adaptation decisions from investigating the impacts of future climate change on food and water supply in China. Paper presented at the 2ndAIACC Regional Workshop for Asia and the Pacific, 2-5 November 2004, Manila, Philippines. http://www.aiaccproject.org/meetings/Manila_04/Day2/erda_nov3.doc.

Liu, C.M. and Z.K. Chen, 2001: Assessment onWater Resources Status and Analysis on Supply and Demand Growth in China. ChinaWater Conservancy and Hydropower Press, Beijing, 168pp.

Liu, C.Z., 2002: Suggestion on water resources in China corresponding with global climate change. China Water Resources, 2, 36-37.

Lüthi et al., 2008. High-resolution carbon dioxide concentration record 650,000-800,000 years before present. Nature 453: 379-382.

Manton,M.J., P.M. Della-Marta,M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins, G. Daw and Co-authors, 2001: Trends in extreme daily rainfall and temperature in Southeast Asia and the South Pacific; 1961–1998. Int. J. Climatol., 21, 269–284.

Milliman, J.D., Broadus, J.M., Gable, F., 1989. Environmental and economic implications of rising sea-level and subsiding deltas: the Nile and Bengal examples. Ambio 18, 340–345.

Mirza, M.Q., 2002: Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Global Environ. Chang., 12, 127-138.

NEF. 2007. Up in smoke? Asia and the Pacific: The threat from climate change to human development and the environment. London, UK.

Nicholls, R.J., 2004: Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. Glob. Environ. Chang., 14, 69-86.

Nicholls, R.J., 2006: Stormsurges in coastal areas. Natural Disaster Hotspots: Case Studies. Disaster Risk Management 6,M.Arnold, R.S. Chen, U. Deichmann,M. Dilley, A.L. Lerner-Lam, R.E. Pullen and Z. Trohanis, Eds., The World Bank, Washington, District of Columbia, 79-108.

Nicholls, R.J., and R.J.T. Klein, 2005: Climate change and coastal management on Europe's coast. Managing European Coasts: Past, Present and Future, J.E. Vermaat, L. Bouwer,K. Turner andW. Salomons, Eds., Springer, Environmental Science Monograph Series. 199-226.

Nicholls, R.J., and J.A. Lowe, 2006: Climate stabilisation and impacts of sea-level rise. Avoiding Dangerous Climate Change, H.J. Schellnhuber, W. Cramer, N. Naki enovi , T.M.L. Wigley and G. Yohe, Eds., Cambridge University Press, Cambridge, 195-202.

Nicholls, R.J., and R.S.J. Tol, 2006: Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Philos. T. Roy. Soc. A, 364, 1073-1095.

Nicholls, R.J., S.E. Hanson, J. Lowe, D.A. Vaughan, T. Lenton, A. Ganopolski, R.S.J. Tol andA.T. Vafeidis, 2006: Metrics for Assessing the Economic Benefits of Climate Change Policies: Sea Level Rise. Report to the OECD.ENV/EPOC/GSP(2006)3/FINAL. Organisation for Economic Co-operation and Development (OECD). 128 pp.

Ong, J.E., 2001: Vulnerability of Malaysia to sea level change. Proceedings of the APN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia – Pacific Region, 14-16th November 2000, Kobe, Japan, Asia Pacific Network for Global Change Research, 89-93.

PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration), 2001: Documentation and analysis of impacts of and responses to extreme climate events. Climatology and Agrometeorology Branch Technical Paper No. 2001-2, PhilippineAtmospheric, Geophysical and Astronomical Services Administration, Quezon City, 55 pp.

Perez, R. T., L. A. Amadore, and R. B. Feir. 1999. "Climate Change Impacts and Responses in the Philippine Coastal Sector." Climate Research Journal 12:97–107.

Perez, R. 2008. Philippines Country Report—A Regional Review on the Economics of Climate Change in Southeast Asia. Report submitted for RETA 6427: A Regional Review of the Economics of Climate Change in Southeast Asia. Asian Development Bank, Manila.

Pusat Pengembangan Kawasan Pesisir dan Laut, Institut Teknology Bandung. 2007.

Rawadee and Areeya. 2008. Adaptation Strategies for Coastal Erosion/Flooding: A Case Study of Two Communities in Ban Khun Thian District, Bangkok. Thailand Development Research Institute Quarterly Review 23(1, March):11–8.

Ren, M., 1993. Relative sea-level rise in Huanghe, Changjiang and Zhuijiang (Yellow, Yangtze and Pearl River) deltas over that last 30 years and prediction for the next 40 years (2030). Acta Geographica Sinica/Dili Xuebao 48, 385.

Ren, M., Milliman, J.D., 1996. Effect of sea-level rise and human activity on the Yangtze Delta, China. In: Milliman, J.D., Haq, B.U. (Eds.), Sea-Level Rise and Coastal Subsidence. Kluwer Academic Publishers, pp. 205–214.

Rodolfo, K.S., and F.P. Siringan, 2006: Global sea-level rise is recognised, but flooding from anthropogenic land subsidence is ignored around northern Manila Bay, Philippines. Disaster Manage., 30, 118-139.

Singh, N. and N.A. Sontakke, 2002: On climatic fluctuations and environmental changes of the Indo-Gangetic plains, India. Climatic Change, 52, 287-313.

Solomon et al., 2009. Irreversible climate change due to carbon dioxide emissions. PNAS 106(6): 1704-1709.

Spalding, M., F. Blasco and C. Field, 1997: World Mangrove Atlas. The International Society for Mangrove Ecosystems, 178 pp.

Stern, N. 2007. The Economics of Climate Change: The Stern Review. Cambridge: Cambridge University Press.

Tam, N.Y.Y., and Y.S. Wong, 2002: Conservation and sustainable exploitation of mangroves in Hong Kong. Trees, 16, 224-229.

Tan, J., L.S. Kalkstein, J. Huang, S. Lin, H. Yin and D. Shao, 2004: An operational heat/health warning system in Shanghai. Int. J. Biometeorol., 48, 157-62.

Tran, V.L., D.C. Hoang and T.T. Tran, 2005: Building of climate change scenario for Red River catchments for sustainable development and environmental protection. Preprints, Science Workshop on Hydrometeorological Change in Vietnam and Sustainable Development, Hanoi, Vietnam, Ministry of Natural Resource and Environment, Hanoi, 70-82.

TEI. 1999. A Study on Thailand's Climate Change. Thailand Environment Institute, Bangkok.

TEI. 2000. Report for the Preparation of Climate Change National Action Plan for Thailand. Thailand Environment Institute, Bangkok.

Thanawat, J. 2006. Coastal Erosion in Thailand: Causes and Management. Department of Geology, Chulalongkorn University.

Trenberth, K.E. and T.J. Hoar, 1997: El Niño and climate change. Geophys. Res. Lett., 24, 3057-3060.

UNDP, 2004: Reducing disaster risk: A challenge for development, Disaster Reduction Unit, Bureau for Crisis Prevention and Recovery, 161 pp.

Wassmann, R., N.X. Hien, C.T. Hoanh and T.P. Tuong, 2004: Sea level rise affecting the Vietnamese Mekong Delta: water elevation in the flood season and implications for rice production. Climatic Change, 66, 89-107.

World Bank, 2004: Modelled Observations on Development Scenarios in the Lower Mekong Basin, Prepared for the World Bank with cooperation of the Mekong Regional Water Resources Assistance Strategy, World Bank, Vietnam, 142 pp.

The World Bank.2003. Building Safer Cities. The Future of Disaster Risk.

The World Bank.2008. Global Monitoring Report. MDGs and the Environment. Agenda for Inclusive and Sustainable Development.

Yanagi, T., and T. Akaki. 1994. "Sea Level Variation in the Eastern Asia." Journal of Oceanography 50:643–51.

Yusuf, A.A. and H.A. Francisco, 2009. Climate Change Vulnerability Mapping for Southeast Asia. Economy and Environment Program for Southeast Asia (EEPSEA), Singapore www.eepsea.org.

VOTE EARTH!

Vote Earth to show your support for a fair, ambitious and binding global climate treaty:
http://www.earthhour.org

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

WWF

for a living planet®

WWF International

Avenue du Mont-Blanc
1196 Gland
Switzerland

Tel: +41 22 364 9111

www.panda.org