<Executive Summary>

Impacts of Climate Change upon Asian Coastal Areas: The Case of Metro Manila

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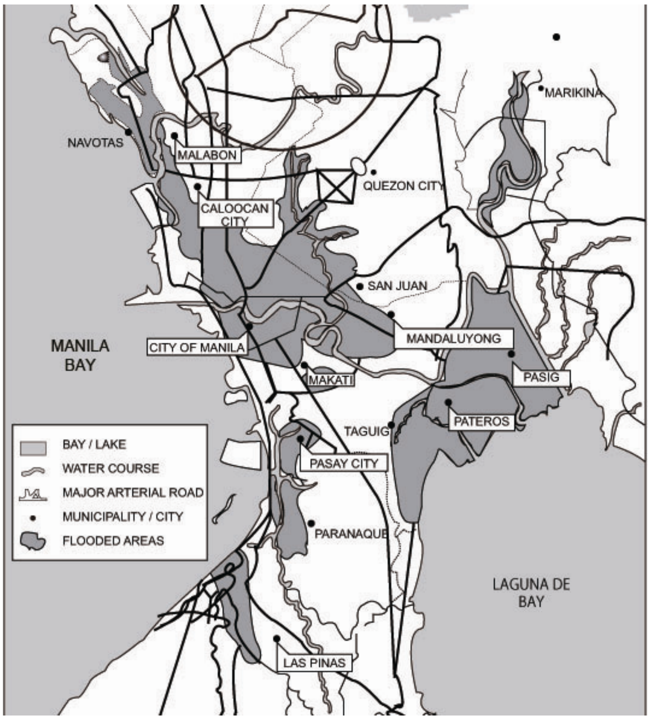
1 Introduction

Climate models supporting the Intergovernmental Panel on Climate Change's (IPCC's) 2007 *Fourth Assessment Report* predict that climate change will increase local temperatures and precipitation in monsoon regions in Asia, where the number of large cities is increasing and existing urban areas are expanding particularly along the coasts. Expected to be the most prone to frequent flooding as a result of global warming, these areas will experience the most complex direct and indirect effects of climate change.

In this context, Metro Manila, typical of Asian megacities, was chosen as a case study to comprehensively simulate the impacts of future climate change and to identify necessary actions. Metro Manila is the centre of the nation's political, economic and socio-cultural activities. Its strategic location beside Manila Bay has supported the capital city's growth and expansion into large suburbs over the last several decades. Metro Manila, whose per capita gross regional domestic product (GRDP) is by far the highest in the country, maintains its position as the premier economic centre of the nation as home to the headquarters of domestic and international business establishments. The regional economic growth of Metro Manila is expected to continue to lead the national economy. At the same time, since Metro Manila is in a low-lying area facing the sea, a large lake (Laguna de Bay) and embracing two river systems, it is prone to flooding disasters (see Figure 1).

Figure 1 Flood-prone areas in Metro Manila



Source: Muto et al. (2010)

1) KAMANAVA area

Several types of flooding affect Metro Manila: storage flooding, overbanking and interior flooding. The KAMANAVA area, for example, is vulnerable to storage-type flooding; the Pasig-Marikina River Basin is prone to overbanking; and the West Mangahan area experiences interior flooding (see Figure 2).

The KAMANAVA area is low and flat with

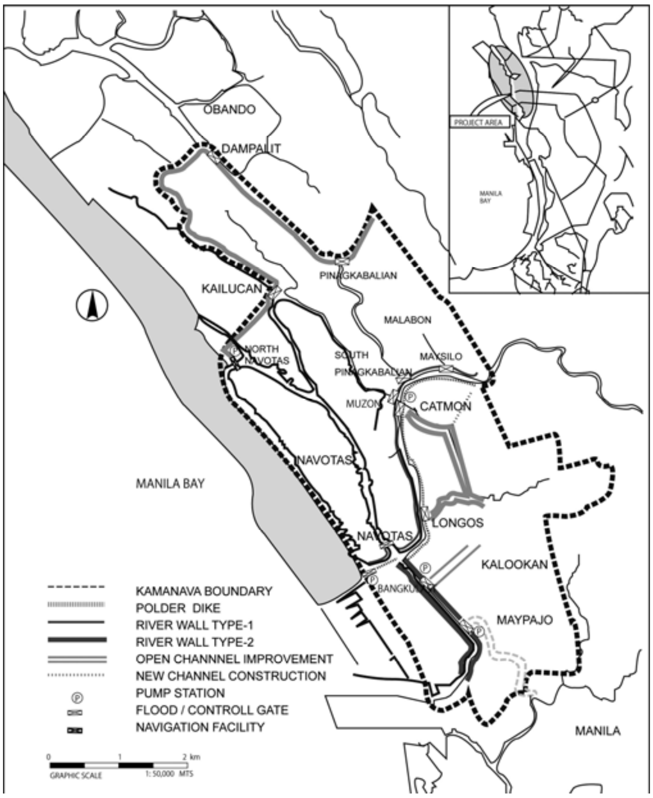
elevations ranging from around sea level to 2m to 3m above sea level. Its current population is in excess of 1 million in an area of approximately 18.5 square kilometres. Before the 1960s, the KAMANAVA area was made up of widely spread lagoons used as fishponds, but it was partially filled to its current configuration, which consists mainly of commercial districts and residential areas, along with fishponds.

The Japan International Cooperation Agency (JICA)-financed KAMANAVA Area Flood Control and Drainage System Improvement Project has the design scale of a ten-year return period. The project works include construction of a polder dike, heightening of river walls on the Malabon and Marala Rivers, construction of a submersible radial navigation gate facility, construction of flood gates, construction of control gates, construction of pumping stations, and improvement and new construction of drainage channels.

2) Pasig-Marikina River Basin

The Pasig-Marikina River System has a catchment area of 651 square kilometres, including the catchment area of the San Juan River. It is composed of the ten cities and municipalities of Mandaluyong, Manila, Marikina, Quezon, San Juan, Antipolo, Cainta, Rodriguez, San Mateo and Pasay. The downstream part of the river system belongs to Metro Manila, but the upper part is under the jurisdiction of Rizal Province. The section of the river system between the river mouth (Manila Bay) and the Napindan Channel confluence point is called the Pasig River, while the Marikina River lies upstream. The Marikina River is also connected with Laguna de Bay Lake at the Rosario Weir through the Mangahan Floodway.

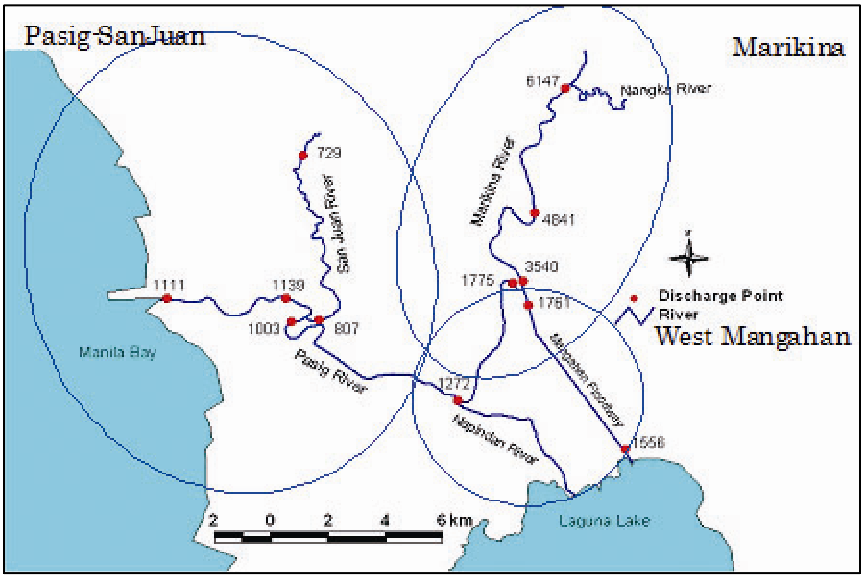
Figure 2 KAMANAVA Area Flood Control and Drainage System Improvement Project



Source: Muto et al. (2010)

Excess flood runoff overflows from the Pasig and Marikina riverbanks. Similarly, storm water flowing in drainage and creek networks creates inundation. Excess runoff water from the Marikina River is diverted to the lake through the Mangahan Floodway during floods to protect Metro Manila’s city core. The flood runoff stored in Laguna de Bay is slowly released to the Pasig River through the Napindan Hydraulic Control Structure (NHCS) in Napindan Channel when the water level recedes in the Pasig River and ultimately drains into Manila Bay (see Figure 3). Another broad flood control project, the JICA-financed Pasig-Marikina River Channel Improvement Project was formulated based on a scale of 30-year return period.

Figure 3 Pasig-Marikina and West Mangahan areas



Source: Muto et al. (2010)

3) West Mangahan area

The total area west of the Mangahan Floodway is 39 square kilometres, covering the five cities of Makati, Pasig, Pateros, Taguig and Taytay. Here, are a number of drainage channels discharge into Laguna de Bay Lake or the Napindan River, such as the Tapayan, Abasing, Taguig-Pateros and Hagonoy drainage channels.

The West Mangahan drainage area topography is flat and is a typical interior flood-prone area along Laguna de Bay Lake. Flooding in the area is caused by storm rainfall and high water levels in the lake. There are several drainage channels and rivers; storm water runoff is stranded due to high lake water levels. As a result of the urbanization of former paddy fields, inundation now also affects towns, communities and numerous subdivisions.

Flooding in this area usually begins when the water stage of Laguna de Bay rises to approximately 11.5m; most of the area is submerged at a water stage of approximately 13.5m, although the lake is not affected by storm surges. The Mangahan Floodway was constructed in 1985 to divert floodwaters from the Marikina River into Laguna de Bay at a design discharge of 2400 cubic metres per second, with the flood flow regulated at the planned Marikina Control Gate Structure. The north-western portion of the lake is flanked by Metro Manila, while the provinces of Rizal and Quezon bound its north-eastern and south-eastern borders. Laguna, Batangas and Cavite provinces border the lake to the south and south-west (see Figure 3). The construction of the JICA-financed flood control project in the area west of the Mangahan Floodway was completed in 2007. The project work included a lakeshore dike, bridges at two sites (in Mangahan and Napindan), a parapet wall with a top elevation of 14.1m, floodgates at eight sites, four pumping stations, and regulation ponds at four sites.

2 Downscaling and flood simulation

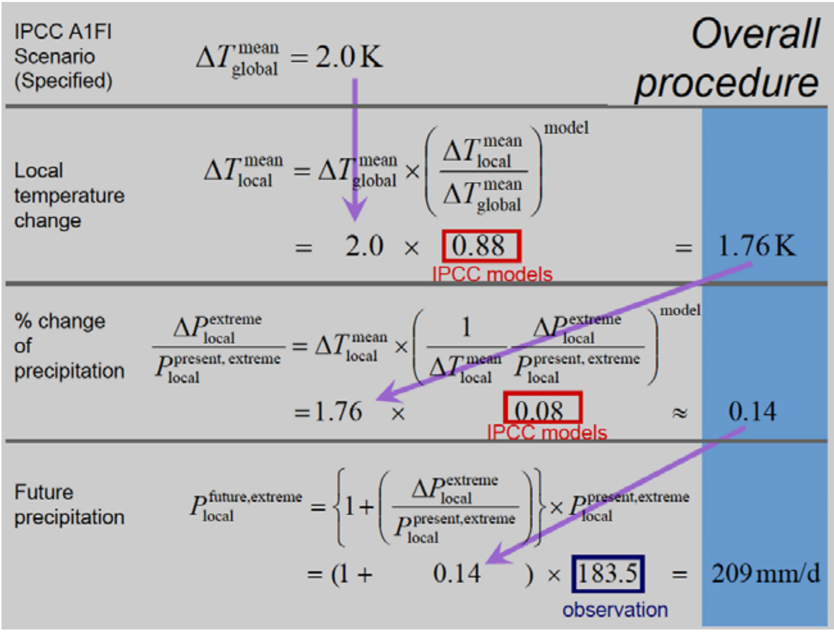
This study is based on global climate projections provided by the IPCC's *Fourth Assessment Report* (AR4), adopting the B1 and A1FI scenarios from the IPCC's *Special Reports* *on Emissions Scenarios* (SRES), and comparing them with the status quo (SQ) scenario. B1 is the scenario projected by the IPCC to represent the least anticipated change, which makes it the most sustainable case. A1FI, on the other hand, represents a large change scenario due to high economic growth. The target year is set as 2050, the halfway mark of the IPCC SRES timeframe. The spatial spreads of flooding for the year 2050 under the SQ, B1 and A1FI scenarios are taken as the basis for impact analyses.

It should be noted that the present IPCC climate models cannot be directly applied to impact studies on local climate change because of various uncertainties: emission scenarios due to economic growth rates and energy efficiency improvements; carbon cycle response to changes in climate; global climate sensitivity; discrepancies in regional climate change scenarios; and changes in ecosystems, etc. Simulations of local climate change are fundamentally more uncertain than global mean values. Local climate is heavily influenced by atmospheric and oceanic circulation, such as prevailing weather situations and wind directions. For example, global mean precipitation changes do not necessarily determine the changes in local precipitation, so it is impossible to conclusively determine future precipitation rate extremes.

Although climate projections are based on global climate models or general circulation models (GCMs), their results contain various biases. If the raw GCM outputs were used for impact studies, the biases would surely contaminate the assessment outcome. Precipitation remains a stringent test for climate models. Many biases in precipitation statistics remain in both precipitation means and variability, especially in the tropics.[1] Comparison between observations and simulations of 20th-century conditions reveals that most models do not accurately simulate precipitation extremes[2].

Despite these various uncertainties, global climate scenarios can be translated to regional climate scenarios, a process called 'downscaling',[3] which is employed for this study (see Figure 4). While there has recently been an increasing recognition of the explicit treatment of uncertainty in environmental assessments, this chapter deals with qualitative rather than quantitative uncertainties.[4] Downscaling requires local-level, bias-corrected climate information. The analyses below discuss development of regional climatic changes in the period up to 2050.[5]

Figure 4 Overall downscaling procedure



Source: Muto et al. (2010)

IPCC SRES scenarios B1 and A1FI provide a basis for discussing changes in local temperature and precipitation in Metro Manila, based on which hydrological conditions, such as sea-level rise, storm surge and land subsidence, are projected.

The matrix in Table 1 is a summary of climatic–hydrological conditions for the SQ, B1 and A1F1 scenarios. Return periods of 10, 30 and 100 years are considered. These conditions provide a basis for flood impact analysis for this chapter. (see Table 1).

Table 1 Global climate scenario setting and conditions of the inundation simulations for Metro Manila

Simulation case		Temperature rise (°C) (downscaled)	Sea-level rise (cm) (global)	Increased rate of rainfall (%)	Storm surge height (m) at Manila Bay
1	Status quo climate (SQ)	0	0	0	0.91
2	B1 with storm level at status quo	1.17	19	9.4	0.91
3	B1 with strengthened storm level	1.17	19	9.4	1.00
4	A1FI with storm level at status quo	1.80	29	14.4	0.91
5	A1FI with strengthened storm level	1.80	29	14.4	1.00

Source: Muto et al. (2010)

In choosing an infrastructure scenario, this chapter focuses on flood control. During the past several decades, the Philippine government has been implementing a series of strategic flood control infrastructure projects protecting Metro Manila, covering the Pasig-Marikina River Basin, the KAMANAVA (Kalookan – Malabon – Navotas – Valenzuela) area, and the area west of Mangahan. Recently implemented flood control projects are included in those identified in the JICA 1990 master plan. In addition, the government has several other flood control projects planned that will complete the implementation of the priority projects identified in the 1990 master plan.

In order to identify necessary adaptation measures, two flood control infrastructure scenarios were considered. The first is the existing infrastructure level, including projects completed by base year 2008. The second is the 1990 master plan scenario, which assumes continued implementation of projects identified in the 1990 master plan until the year 2050. Consequently, the two flood control infrastructure scenarios are added to the climatic–hydrological matrix in Table 2.

Table 2 Climatic—hydrologic **-** infrastructure scenarios: Summary

Cases	Return period	Climate	Hydrological (storm surge)	Infrastructure: EX : existing MP : 1990 master plan	Adaptation
100-SQ-cu-EX	100 years	SQ	Current	EX	–
100-SQ-cu-MP			Current	MP	–
100-B1-st-EX-wD		B1	Strengthened	EX	With dam
100-B1-st-MP-wD			Strengthened	MP	With dam
100-A1FI-st-EX-wD		A1FI	Strengthened	EX	With dam
100-A1FI-st-MP-wD			Strengthened	MP	With dam
30-SQ-cu-EX	30 years	SQ	Current	EX	–
30-SQ-cu-MP			Current	M/P	–
30-B1-st-EX-wD		B1	Strengthened	EX	With dam
30-B1-st-EX-nD			Strengthened	EX	No dam
30-B1-st-MP-wD			Strengthened	MP	With dam
30-B1-st-MP-nD			Strengthened	MP	No dam
30-A1FI-st-EX-wD		A1FI	Strengthened	EX	With dam
30-A1FI-st-EX-nD			Strengthened	EX	No dam
30-A1FI-st-MP-wD			Strengthened	MP	With dam
30-A1FI-st-MP-nD			Strengthened	MP	No dam
10-SQ-cu-EX	10 years	SQ	Current	EX	–
10-SQ-cu-MP			Current	M/P	–
10-B1-st-EX-nD		B1	Strengthened	EX	No dam
10-B1-st-MP-nD			Strengthened	MP	No dam
10-A1FI-st-EX-nD		A1FI	Strengthened	EX	No dam
10-A1FI-st-MP-nD			Strengthened	MP	No dam

Notes: cu = current; EX = existing infrastructure; MP = 1990 master plan; nD = no dam; SQ = status quo; st = strengthened; wD = with dam.
Source: Muto et al. (2010)

The case code in Table 2 consists of five sets of alphanumeric symbols. The first set (100, 30, 10) indicates the assumed return period; the second set (SQ, B1, A1FI) shows the climate scenario; the third (cu, st) indicates whether storm surge was set at the current (cu) or strengthened (st) level. In the fourth set, EX or MP denotes the infrastructure scenario. Lastly, wD/nD means with or without the hypothetical Maikina Dam.

3 Socio-economic impact

This section conducts socio-economic impact analyses in order to understand the characteristics and magnitude of flood damage expected in the year 2050. For the sake of this analysis, benefits are taken to be the future aggregate-level flood damage avoided by implementing flood control infrastructure improvements. The types of benefits included in this study go beyond conventional flood impact assessments that only deal with direct losses. For example, in conventional analyses of direct losses, damage to buildings is converted into monetary terms based on simple information such as flood depth and building use. Such direct impacts are limited to damage caused by physical contact of the floodwater with humans, property and other objects.

Flooding, however, interacts with the patterns of human activities in the metropolis in more complex ways. Not all tangible losses are direct losses: floods not only affect structures themselves, but also their contents and the activities undertaken within them. Disruption of traffic and business are examples of such losses. Such secondary impacts occur as a result of direct impacts and may occur outside the flood event in space or time. In addition, there are intangible impacts, such as health hazards.

In this chapter, first, direct and tangible losses are assessed, as occurs in conventional flood control project analyses. Secondly, indirect and tangible losses are assessed, where possible with available data. For the indirect and tangible losses, this chapter combines incremental costs of transportation (vehicle operating and time costs), and lost wages and income (sales) triggered by floods. The intangible losses (here, health hazards) are presented separately.

If flood control infrastructure improvements were halted now and the A1FI climate scenario is assumed, a 100-year return period flood could cause aggregate damages of up to 24 per cent of the GRDP, while damages from a 30-year return period flood would be about 15 per cent of the GRDP. If, however, infrastructure improvement based on the 1990 master plan continues and climate scenario B1 is assumed, the projected damages would be only 9 per cent of the GRDP for a 100-year return period flood, and 3 per cent for a 30-year return period flood. (Tables 3 to 5)

Note that the simulation results are some cases among a wide range of future possibilities resulting from “cascade of uncertainties” inherent in the various steps of the methodology.

Table 3 Damage assessment (2008 Philippine pesos): 100-year return period

Cost in 2008 pesos		SQ EX	SQ MP	B1 EX	B1 MP	A1FI EX	A1FI MP
Damage to buildings	Residential	3,688,647,788	1,045,670,772	6,022,893,816	1,326,288,039	7,517,544,912	2,101,690,472
	Commercial	37,699,327,245	15,298,341,749	63,871,514,594	25,506,211,401	68,021,524,157	37,713,082,264
	Institutional	298,785,692	158,994,559	485,447,235	173,893,911	1,874,981,233	253,765,175
	Industrial	8,650,623,155	5,694,313,706	16,556,719,073	5,532,356,399	17,850,618,995	9,193,023,327
Maintenance cost on flood-affected roads	Current roads	8,143,240	3,010,272	9,677,159	4,831,659	10,443,791	5,780,183
	Future roads	360,001	360,001	485,467	485,467	524,226	524,226
Vehicle operating costs (VOC)		50,729,576	22,855,337	62,246,103	36,684,130	68,001,872	43,885,751
Travel time costs		706,986,380	277,477,558	1,082,134,984	197,675,748	1,420,426,406	340,173,579
Loss of business	Assets (this is already included in damages to buildings)						
	Sales	13,403,412,143	6,567,976,899	14,085,687,162	7,745,705,319	14,639,854,088	8,339,388,091
Residents' income loss	Formal residents	214,933,500	67,473,375	230,942,250	95,140,125	481,092,750	105,586,875
	Informal residents	6,050,968	584,668	6,881,952	1,247,540	7,089,432	2,091,824
Total		64,727,999,688	29,137,058,896	102,414,629,796	40,620,519,739	111,892,101,862	58,098,991,768

2008 Metro Manila GRDP							
468,382,396,000							
Percentage of GRDP		14%	6%	22%	9%	24%	12%

Notes: EX = existing infrastructure; MP = continuing 1990 master plan; SQ = status quo.
Sources: Muto et al. (2010), GRDP data from National Statistical Coordination Board

Table 4 Damage assessment (2008 Philippine pesos): 30-year return period

Cost in 2008 in pesos		P30 SQ EX	P30 SQ MP	P30 B1 EX	P30 B1 MP	P30 A1FI EX	P30 A1FI MP
Damage to buildings	Residential	1,802,689,882	399,849,739	3,660,228,253	549,439,668	4,210,760,389	637,339,590
	Commercial	22,710,938,518	2,273,492,105	35,692,199,142	7,069,333,943	39,538,199,655	10,143,817,110
	Institutional	158,250,637	23,533,947	270,248,699	85,001,479	334,199,868	96,920,697
	Industrial	4,216,676,982	1,330,430,240	9,932,796,023	2,657,311,465	11,606,388,976	3,456,942,255
Maintenance cost on flood affected roads	Current road	5,286,655	1,102,956	6,846,841	1,937,811	7,482,737	2,313,418
	Future road	244,376	244,376	302,185	302,185	329,119	329,119
Vehicle operating costs (VOC)		40,138,658	8,374,141	51,984,296	14,712,729	56,812,303	17,564,506
Travel time costs		374,633,321	31,760,926	421,032,785	74,184,136	573,888,428	85,170,808
Loss of business	Assets (this is already included in damages to buildings)						
	Sales	10,756,786,447	3,281,670,824	11,832,564,006	4,515,810,393	12,434,679,407	5,075,470,880
Residents' income loss	Formal residents	93,848,625	39,640,500	184,246,875	49,636,125	196,321,500	51,926,625
	Informal residents	4,731,076	92,036	5,367,880	111,188	5,750,388	118,636
Total		40,164,225,177	7,390,191,790	62,057,816,985	15,017,781,123	68,964,812,770	19,567,913,643

2008 Metro Manila GRDP
468,382,396,000

Percentage of GRDP		9%	2%	13%	3%	15%	4%

Notes: EX = existing infrastructure; MP = continuing 1990 master plan; SQ = status quo.
Sources: Muto et al. (2010) , GRDP data from National Statistical Coordination Board

Table 5 Damage assessment (2008 Philippine pesos): Ten-year return period

Cost in 2008 in pesos		P10 SQ EX	P10 SQ MP	P10 B1 EX	P10 B1 MP	P10 A1FI EX	P10 A1FI MP
Damage to buildings	Residential	785,486,988	320,880,033	842,295,372	491,606,130	595,395,243	546,225,294
	Commercial	8,641,501,748	610,789,400	9,658,314,207	1,611,046,487	13,750,520,244	2,326,289,074
	Institutional	66,863,814	20,189,999	91,707,535	37,209,916	96,826,650	37,268,296
	Industrial	2,890,401,496	1,173,449,757	2,414,697,965	1,461,799,749	1,756,641,760	1,346,409,219
Maintenance cost on flood-affected roads	Current road	1,162,100	346,199	1,587,787	463,132	2,632,955	543,277
	Future road	44,014	30,219	44,014	31,532	91,969	38,102
Vehicle operating costs (VOC)		8,823,186	2,628,501	12,055,195	3,516,306	19,990,575	4,124,802
Travel time costs		33,199,847	8,380,787	45,754,992	11,655,307	71,672,669	13,646,330
Loss of business	Assets (this is already included in damages to buildings)						
	Sales	2,816,137,180	2,704,662,851	2,961,770,824	2,822,212,152	3,044,628,088	2,881,793,868
Residents' income loss	Formal residents	32,629,500	20,444,625	49,763,250	26,401,500	49,437,000	29,098,125
	Informal residents	85,652	51,072	151,620	51,072	255,892	72,352
Total		15,276,335,523	4,861,853,444	16,078,142,760	6,465,993,284	19,388,093,046	7,185,508,737

2008 Metro Manila GRDP							
468,382,396,000							
Percentage of GRDP		3%	1%	3%	1%	4%	2%

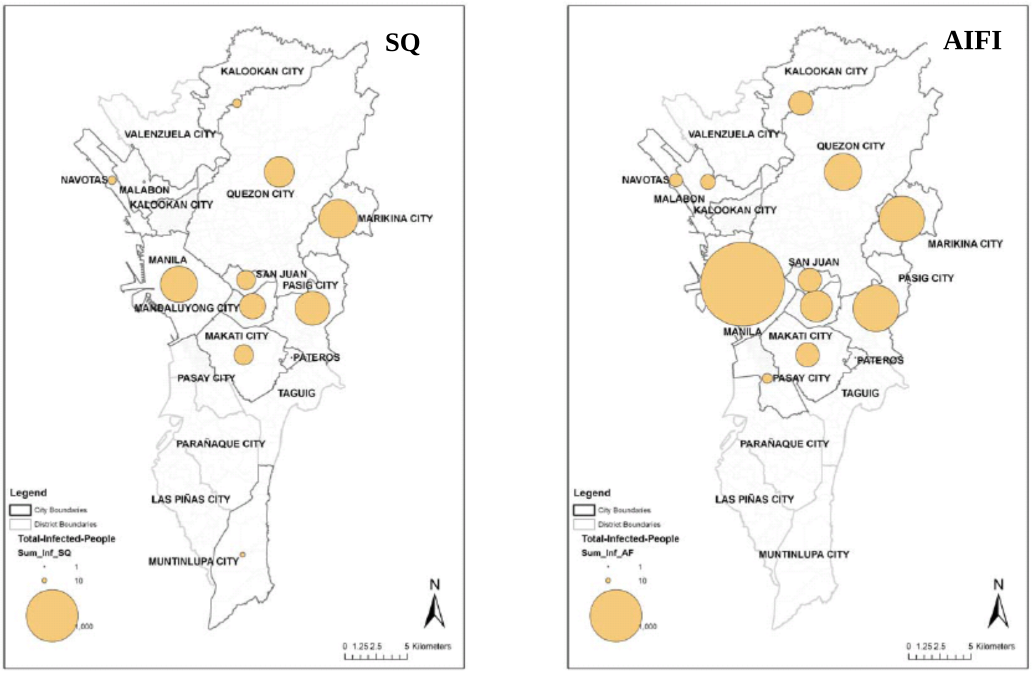
Notes*:* EX = existing infrastructure; MP = continuing 1990 master plan; SQ = status quo.
Sources: Muto et al. (2010) , GRDP data from National Statistical Coordination Board

4 Health impact

This section aims to characterize and quantify human health risks associated with exposure to pathogens present in floodwater as an example of an intangible risk related to flooding in Metro Manila. Here, exposure scenarios based on different inundation levels are developed in which direct and indirect contact with water is assumed to occur.

The risks of gastrointestinal illness due to E. coli from incidental ingestion of flood water in Metro Manila are calculated for different flood depths. The number of infected people is estimated to be high in densely populated flood areas, such as the cities of Manila, Pasig and Marikina.

Figure 5 Health impact analysis



Note: Number of infected people due to gastrointestinal illness via incidental ingestion of flood water in Metro Manila.

Source: Muto et al. (2010)

5 Vulnerability of the urban poor and firms

The results of analyses conducted to identify vulnerabilities of selected segments of the society and the economy are presented here. First, an analysis at the household level focuses on the experiences of those living in areas affected by flooding, typhoons and tidal surges in the current climate. Household-level respondents found difficulty in distinguishing between typhoon events effectively, as well as in distinguishing between floods, typhoons and tidal surges. Therefore, the impacts discussed combine the effects of floods, typhoons and tidal surges. Next, an analysis of businesses at the firm level focuses on their experience during Typhoon Milenyo (which occurred in 2006) and other flood events.

The surveyed households have a high level of social vulnerability given their common characteristics:

** All live in low-lying and/or swampy wetlands, vulnerable to floods and storm/tidal surges.

** The monthly median income is 8000 Philippine pesos, which translates to approximately only 44 pesos per day per person for food in a typical six-member household (less than US$1 per day per person, given the current rate of exchange and consumer price index).

** Most people live in slum/squatter settlements with no security of tenure in their housing, and inadequate sources of water, electricity, health services, drainage and sanitation.

** Of these 300 households, two-thirds regularly suffer damages due to typhoons floods and tidal/storm surges such as loss of income, health and household assets. They have no access to adequate basic services such as potable water, toilet and sanitation facilities, as well as electricity, and endure inconveniences such as evacuation or having to use their neighbours' toilet or a waterway as a toilet due to typhoons, floods and tidal/storm surges.

The study found a high correlation between the environmental or ecological vulnerability of communities along the river systems (Marikina-Pasig, Malabon-Tullahan and Napindan) and the social vulnerability of the residents in these areas' poor urban households. Thus, the effects of climate change on poor households (e.g. intensified typhoons, floods and storm/tidal surges) are heightened by the location of their homes and their low socio-economic status (i.e. low income, no housing tenure, and inadequate access to water, electricity and drainage/sewage systems).

Amongst the urban poor, the very poorest are extremely vulnerable because they have no alternatives for where to build or relocate their houses, or to find alternative jobs and schools for their children. As reported in the community survey, those who are elderly, sick, disabled or dependent upon others have less capacity to cope with the impacts of climate change. They are least able to cope with the consequences of frequent typhoons, floods or tidal surges, such as sickness, loss of income, inability to pursue their livelihood, and loss of household assets. Women also bear the brunt of taking care of sick children and their homes during floods.

More importantly, the capacity to cope with these disasters is also weakened by the inability of local and national governments to provide necessary infrastructure and services, or to repair and restore existing ones. Among the local governments in the study, only Marikina and Navotas seem to have actively responded with infrastructure development and/or innovation in order to stem the effects of floods and other impacts of climate change.

Many of the firms in flood-prone areas of Metro Manila experienced a temporary halt of operations, especially during Typhoon Milenyo in 2006. The three main reasons were shortage of electricity/power outage (mainly due to strong winds), insufficient numbers of people reporting to work, and low sales. The main reason for employees' absence from work was the unavailability of transport, related to flooding.

6 Adaptation options

This section first describes the methodology employed to derive the adaptation options and their corresponding costs. The adaptation options are selected with the objective of eliminating, as much as possible,[6] the floods shown in the previously presented flood simulations. Next, the results of economic evaluation, economic internal rate of return (EIRR) and net present value (NPV) are presented by combining the adaptation options (cost side) with the damages that can be avoided (benefit side) (see Table 6).

Table 6 Economic internal rate of return (EIRR) and net present value (NPV) results

	Cases	EIRR	NPV 15% (Philippine Pesos)	Adaptation cost in 2008 (Philippine Pesos)	Duration (days)
1	P100 SQ EX wD	18%	3,735,417,996	13,501,553,721	5
2	P100 SQ MP wD	NA	4,747,146,081	0	3.5
3	P100 B1 EX wD	23%	10,119,764,171	13,604,450,310	5
4	P100 B1 MP wD	140%	7,578,065,582	102,896,589	3
5	P100 A1Fi EX wD	24%	11,941,808,517	13,640,673,269	6.5
6	P100 A1Fi MP wD	141%	10,393,996,079	139,119,548	4
7	P30 SQ EX wD	16%	791,013,521	14,121,102,133	2
8	P30 SQ EX nD	18%	2,921,383,920	10,943,489,020	2
9	P30 SQ MP wD	19%	1,194,339,182	3,177,613,113	1.5
10	P30 SQ MP nD	NA	3,324,709,581	0	1.5
11	P30 B1 EX wD	20%	5,615,755,728	14,232,087,722	3
12	P30 B1 EX nD	23%	7,746,126,127	11,054,474,609	3
13	P30 B1 MP wD	26%	3,506,324,553	3,216,390,949	2
14	P30 B1 MP nD	174%	5,636,694,952	38,777,837	2
15	P30 A1Fi EX wD	21%	7,041,428,985	14,248,304,696	4
16	P30 A1Fi EX nD	24%	9,152,200,101	11,099,925,438	4
17	P30 A1Fi MP wD	31%	5,498,525,059	3,216,390,949	2
18	P30 A1Fi MP nD	160%	7,609,296,174	68,011,692	2
19	P10 SQ EX nD	49%	209,952,438	42,887,291	1.5
20	P10 SQ MP nD	NA because master plan beyond EX does not exist.			
21	P10 B1 EX nD	10%	(349,951,115)	1,003,222,253	1.5
22	P10 B1 MP nD	NA because master plan beyond EX does not exist.			
23	P10 A1Fi EX nD	8%	(581,704,127)	1,409,166,226	1.5
24	P10 A1Fi MP nD	NA because master plan beyond EX does not exist.			

Notes: EX = existing infrastructure; MP = master plan; NA = not available; nD = no dam; SQ = status quo; wD = with dam.
Source: Muto et al. (2010)

The EIRR evaluation and the NPV evaluation produced different results on how adaptation projects should be ranked; but they are similar in suggesting that filling the infrastructure gap identified under the current master plan (for the status quo climate) is the first and foremost priority. If maximizing the avoided damages is most important, following the NPV results is preferable; but if investment efficiency is more of a concern, following the EIRR results is better.

Assuming no dam in the adaptation options, the NPV results prioritize investments in order to protect the city from the 30-year return period under the A1FI climate scenario. The recommended investment package is to, first, continue investments under the current master plan in the Pasig-Marikina River Basin and then add additional investments for full adaptation to the A1FI scenario. This suggests that the flood control investments in the Pasig-Marikina River Basin that fill the gap between the existing infrastructure and the master plan are priority investments in the process to adapt to climate change. This is the option currently chosen by the Philippine government, by implementing the Pasig-Marikina Flood Control Project Phase II, to avoid damages from 30-year flooding.

The EIRR results prioritize additional investments to prepare for P30 flood under the B1 climate scenario after the master plan components for the current climate are completed. The recommended progression is to invest in additional adaptation projects for full adaptation for the B1 scenario, provided that the current master plan in Pasig-Marikina River Basin is completed before the projects are undertaken. This also suggests that the flood control investments in the Pasig-Marikina River Basin that fill the gap between the existing infrastructure and the master plan are prerequisites to adapt to climate change. It is important to note that preparing for ten-year flooding in the status quo climate comes in third place. This suggests that additional investments for the KAMANAVA and West Mangahan areas under the status quo climate are important. This discussion confirms that the ongoing flood control projects in Metro Manila are integrated components of adaptation to climate change. At least in the case of Metro Manila, adaptation investments are not a completely new effort, but a continuation of ongoing flood control efforts both in terms of planning and financing.

7 Policy discussions

7.1 New flood-control infrastructure

As described earlier, new flood control infrastructure is required to adapt to the flood situation in 2050, assuming climate change. Our analysis suggests that filling the infrastructure gap in responding to the current climate is the first and foremost priority. As a next adaptation priority, additional flood control investment in the Pasig- Marikina River Basin was identified. This investment consists mainly of raising embankments along the Pasig-Marikina

River.

7.2 Fine-tuning and improvement of the existing flood control infrastructure

Although the above economic evaluations highlight the priority of currently implemented flood control infrastructure investment, discussions with communities and local governments also call for an assessment of the design of existing structures in order to better respond to the new hydrodynamics faced by flood-prone communities.

1) KAMANAVA area

The KAMANAVA Area Flood Control and Drainage System Improvement Project has a ten-year return period design scale. However, recent observations by residents and *barangay* officials in the area (e.g. Barangay Bangkulasi and Barangay Bagonbayan South) suggest that tides are reaching unprecedented levels, especially when combined with floods from the upstream sections of the Malabon-Tullahan River or with storm surges. As a remedial response, the *barangay* captains are introducing drainage pumps, locally known as ‘bombastics’, in their respective areas to remove floodwater. However, as neighbouring *barangays* are simply discharging water to each other, this remedial response is not significantly reducing water levels in the respective areas.

Therefore, an additional assessment is necessary to understand the relatively recent hydrodynamics, which may not necessarily be due to climate change, and to consider local policies that can create solutions that benefit all of the neighbouring areas. In conducting the assessment, a close coordination with the national government (the Department of Public Works and Highways, or DPWH) is necessary to ensure technical consistency between DPWH-led infrastructure projects (the Kamanava Area Flood Control and Drainage System Improvement Project under national roads) and local government initiatives (pumping, drainage under local roads, land use, social housing, etc.).

2) Pasig-Marikina River Basin

Marikina city is located alongside the Marikina River. With strong political leadership, it has successfully strengthened its capacity to cope with flooding. First, under the Pasig-Marikina River Channel Improvement Project Phase I, the city government successfully relocated almost 10,000 households who were squatting along the Marikina River. Today both sides of the river are cleared and pleasant walkways and bikeways have been constructed, together with dike structures. Drainage of the riverbed is regularly conducted. The city planning office has a comprehensive information database of the hydrodynamics of the city area, setting design standards for local drainage infrastructure projects. Marikina is the only city that can demand that the DPWH conform to the city’s design standards when the DPWH constructs drainage facilities under national roads.

Despite this excellent performance, the city of Marikina is not prepared for climate change. According to this study's flood simulation, because of its steep topography, Marikina is one of the areas worst affected by climate change. The types of structures or policies necessary to cope with climate change at the local level have yet to be identified by the city government. At the Metro Manila level, improvement of river embankments to protect against B1 climate scenario conditions is a priority for adapting to climate change.

3) West Mangahan area

The city of Taguig stretches alongside Laguna de Bay Lake. Some large-scale development projects brought high-rise condominiums and shopping centres to the southern part of the city, while the swampy areas in the northern part are a mix of middle-income and low-income residential areas, with some remaining paddies and fishing areas. The West of Mangahan flood control project consists of a long road dike alongside the lake and several pumping stations. Floods are assumed to be brought on by storm rainfall and high water levels in the lake.

Flood simulations in this study, however, show that when taking climate change into consideration, the risk of intensive rain in the inner urban area will increase, causing water to flow from the inner urban area to Laguna Lake. With the presence of the road dike, this will lead to flooding in the northern part of the city of Taguig. In this case, additional pumping structures will be necessary to permit the water to flow both ways.

Partly due to the completion of the road dike, the city of Taguig is busy evaluating unsolicited development plans in the areas previously used as paddies and fishing fields. However, these plans typically do not accompany drainage plans or flood mitigation plans. For the city of Taguig, assessment of the hydrodynamics of the area (with climate change considered) and development of land-use plans that have appropriate drainage and flood mitigation plans, in addition to the appropriate evaluation of environmental considerations, are all urgent.

7.3 Other policy areas for consideration

1) Capacity-building (city planning)

Cities' capabilities of coping with flooding problems under the status quo climate differ widely. In particular, assessing the local hydrodynamics, building design standards for drainage systems, land-use planning and enforcement, and social housing, including resettlement, seem to be the key areas for adapting to climate change. As already exists among cities and municipalities in Metro Manila, continuous upgrading of technical capabilities (including recruiting), as well as learning from examples of excellent management (such as in the case of Marikina) are fundamental to improving city-level capabilities, along with the obvious importance of strong political leadership.

2) Capacity-building (disaster preparedness)

The local governments in Metro Manila have been finding innovative solutions to their flooding and other related problems. However, as is evident in the case of *ad hoc* installations of water pumps (‘bombastics’), solutions designed for a particular area may be counterproductive to a coordinated solution. It is urgent to communicate to the local governments the necessity for collective solutions and to instil strong leadership in the existing coordinating mechanisms (through the the Housing and Urban Development Coordinating Council (HUDCC), the Metro Manila Development Authority (MMDA) or other councils).

Interviews with local communities show that many local governments are active in monitoring water levels, conducting evacuations and providing shelter (including food and medicine) in the case of disasters. However, interviews with poor urban households reveal that many of them are left with minimum care, so they adopt ‘water-based lifestyles’ in which they cope with the flooding any way that they can. This includes adding floors to their structures and raising their appliances onto movable platforms. More importantly, interviews with key information sources has revealed that poor and vulnerable households who do not have a wide network of relatives, neighbours or friends who can support them are also unable to access much support from formal institutions such as health clinics run by local government unit social workers. Effective methods of intervention to help these segments of the society should be strengthened with the help of capable stakeholders such as non-governmental organizations (NGOs) operating in the area of disaster management.

3) Adaptation in combination with mitigation

During discussions with the Metro Manila Development Authority, it was pointed out that it is expecting a new study assessing mitigation effects. The MMDA is leading the efforts to control traffic in Metro Manila. These efforts are expected to increase the mitigation measures that will be taken by the Philippine government. Assessment of the combined efforts covering the intersection of mitigation and adaptation for a given city is our future research topic.

Notes

1 Randall et al (2007).

2 A simple example is to calculate the difference in a model between its 20th- and 21st-century estimates and add that difference to the observed 20th-century climate. This renders the estimated variable (at least partially) independent of the model used to simulate the 20th century. Otherwise, the resulting 21st-century modeled precipitation level could be in error. This could lead to a biased impact assessment if used directly without correction. In the case of a 20th-century model simulation where precipitation is underestimated at 7mm/day, the model could project an increase of precipitation to 9mm/day in the future. Since the 21st-century figure carries along the underestimation of the 20th-century estimate, using it directly would produce precipitation increases that are too small. The simple procedure of adding the difference between the two model simulations to the observed 20th-century value can ameliorate this trouble.

3 Since downscaling is a common technique, there are a number of useful references for experts and non-experts alike. From a technical viewpoint, Chapter 11 of IPCC AR4 is a good start. Its last section is dedicated to regional climate projection methodologies. The *Technical Summary of Working Group I* is also helpful. IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA) produces guidelines on the use of regional scenarios. *Guidelines for Use of Climate Scenarios Developed from Regional Climate Model Experiments* (Mearns et al, 2003) and *Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods* (Wilby et al, 2004) are of particular relevance. For more broad information, various downscaling techniques for non-experts are compiled by the United Nations Framework Convention on climate change in its *Compendium on Methods and Tools to Evaluate Impacts of, and Vulnerability and Adaptation to, Climate Change* (UNFCCC, 2008).

4 There are a number of ways to formally generate probability information at the local scale, including multi-model ensemble and perturbed physics runs (the IPCC's *Fourth Assessment Report* provides a concise review of various papers).

5 Projected climate change up to the year 2050 is highly likely to occur, and has already started to be observed.

6 For the KAMANAVA and West of Mangahan areas, total elimination is impossible because of low elevation. Instead, pumping capacity improvement is considered to minimize the duration of flooding.

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