Annex 5

Case Study Annex

Case Study 2.A

The Urban Heat Island of Antwerp

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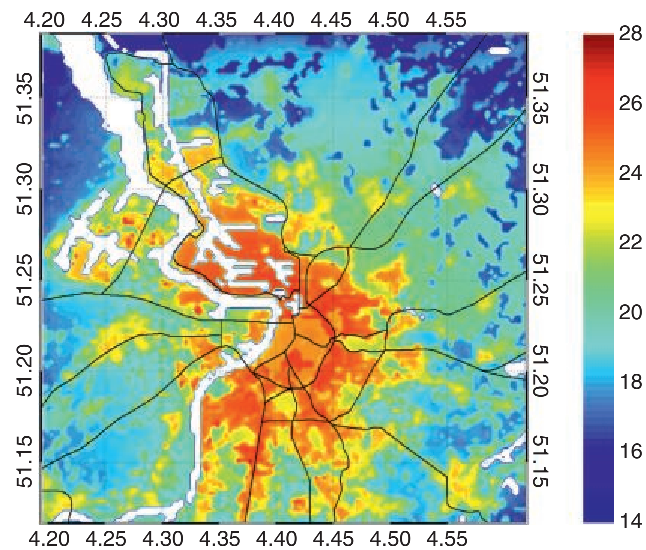
City of Antwerp

Keywords	Heat stress, urban climate model, mitigation, adaptation, climate science
Population (Metropolitan Region)	1,015,000 (Demographia, 2016)
Area (Metropolitan Region)	635 km² (Demographia, 2016)
Income per capita	US$41,860 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Cities tend to be warmer than their rural surroundings, a phenomenon called the *urban heat island,* exposing urban residents to much higher levels of heat stress than people living in the nearby rural areas. At the same time, climate projections indicate that the frequency, intensity, and duration of heat waves is very likely to increase, and it is expected that, toward the end of this century, cities will be groaning under the strain of drastically increased levels of heat stress.

Assessing the Urban Heat Island of Antwerp

Commissioned by the city administration of Antwerp (Belgium), the research center VITO started to map the current and future heat stress situation in the city. Since climate projections at the scale of urban agglomerations are lacking, a new urban climate model (UrbClim^{TM}) was developed that operates at an unprecedented horizontal resolution of a few hundred meters (De Ridder et al., 2015). First, work was done to evaluate the UrbClim model with meteorological measurements from five automatic weather stations, which were installed both inside and outside the city center to assess the ability of the model to reproduce the urban heat island effect. From this, we learned that the model achieves accuracy comparable to that of existing traditional models, but at a speed that is more than a hundred times higher. As a result, UrbClim is capable of covering periods long enough (tens of years) to deduce relevant climate statistics.



Case Study 2.A Figure 1 *Annual average number of heat wave days in the Antwerp area for the period 2081–2100, under the RCP8.5 climate scenario.*

This fast model was successfully exploited, coupling UrbClim to Global Climate Models (GCMs) contained in the CMIP5 archive of the Intergovernmental Panel on Climate Change (IPCC), and conducting simulations representing present (1986–2005) and future (2081–2100) climate conditions (considering the RCP8.5 scenario). Based on the results for the present period, it was found that the urban area experiences *twice as many heat wave days* than the rural surroundings. Subsequently, when analyzing the climate projections, it was found that, toward the end of the century, *the number of heat wave days is expected to increase by a factor of nearly ten*. Given the higher number of urban heat wave days to start with, city inhabitants will be facing almost one month of heat wave conditions each year (see Case Study 2.A Figure 1).

Mitigation and Adaptation Measures

Motivated by these results, the city of Antwerp decided to implement mitigation and adaptation measures to tackle the problem of heat stress. To achieve optimal results, the measures are implemented simultaneously on three scales: (1) citywide, (2) local, and (3) the individual.

Citywide Scale

The construction of buildings in the city of Antwerp is regulated by a building code, which all inhabitants and developers need to adhere to when renovating or constructing a building for which a city permit is required. In this code, specific instructions are added that will help to reduce the heat stress in the city over time:

- For all roofs with a slope of less than 15% and a surface area of more than 20 square meters, it is obliged to install a green roof on top. This will drastically lower the temperature of the roof and, by retaining and evaporating rain water, the air temperature will be cooled. Additionally, green roofs provide extra isolation for the building.
- All private gardens and open parking lots need to be green and permeable. Only 20 square meters can be paved in gardens of 60 square meters and only one-third in gardens of 60 square meters. All outdoor private parking lots need to have a permeable grassed surface.
- The majority of the buildings in the city center have historical plaster facades. When renovated, these building fronts need to be painted in the original light, preferably white color. White buildings reflect more sunlight and will not warm up as easily as dark buildings, thereby reducing the heat radiation from these buildings.

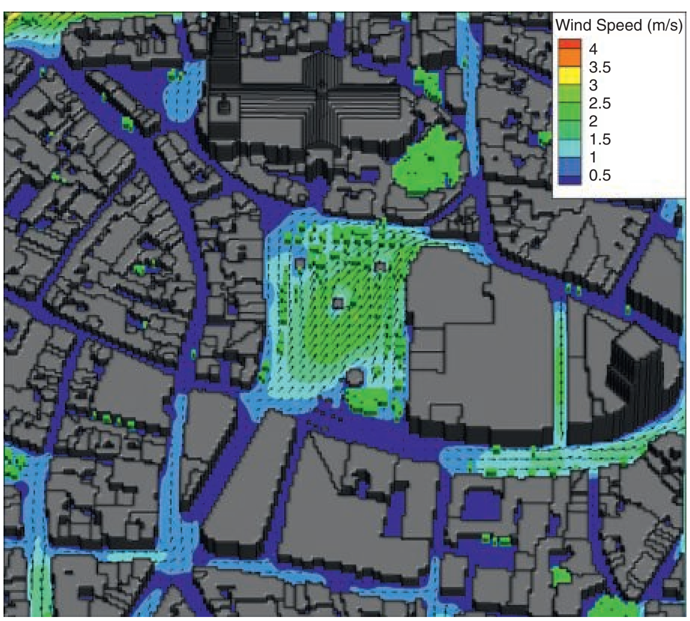
Local Scale

Regularly, large squares, parks, and neighborhoods in the city are renovated. A new goal is to optimize the thermal comfort of the people visiting these places. To be able to do this, detailed information is needed on the local microclimate. Therefore, VITO applied a meter-scale computational fluid dynamics (CFD) model (see Case Study 2.A Figure 2) to map the focus areas and assess the effectiveness of potential adaptation measures. It is important to consider not only the air temperatures because human thermal comfort is also affected by radiation, humidity, and wind speed. An internationally recognized indicator for thermal comfort that takes these variables into account is the predicted mean vote (PMV) (Fanger, 1982), which scales between −4 (strong cold stress) and +4 (strong heat stress).

Since simulations with a CFD model are both computationally expensive and time-consuming, it is not possible to do this for every renovation project in the city. Based on several sensitivity experiments and a review of the scientific literature, VITO listed the expected impact of a number of adaptation measures on both the 2 meter air temperature and the PMV value during a typical warm summer afternoon (Table 1). These numbers can be used as first-order estimates for cities in a comparable climate zone as Antwerp. The precise effect will depend on the local situation and should ideally be assessed with new CFD simulations or measurements.

Individual Scale

As mentioned earlier, the Antwerp urban area experiences twice as many heat wave days than the rural surroundings. This is problematic, since so-called heat health action plans are triggered using rural temperature forecasts only (as in most countries). In order to remedy this issue, VITO has set up a short-term (5-day) heat forecast system based on a



Case Study 2.A Figure 2 *Example of the output of the CFD model for the neighborhood of the cathedral of Antwerp.*

Table 1 *Estimate of the effect of several adaptation measures on mean 2 meter air temperatures and Predicted Mean Vote values during a warm day in summer. The reference situation is a location covered with asphalt and concrete.*

Adaptation measure	Mean 2 m Air Temp.	PMV value
Ref: Asphalt/concrete	=	4
Increase albedo	−0.5°C	3.5
Grass area	−0.5°C	3
Green roof/wall	−0.5°C	3
Large fountain	−1°C	3
Tree with dense crown	−0.5°C	2
Several water sprayers	−1.5°C	2
Row of trees	−1°C	1.5
Water nebulizers	−2°C	1
Large park with water	−1.5°C	0

combination of the regular European forecast model and UrbClim, which delivers specific information for each neighborhood of Antwerp taking into account the urban heat island effect. Since the information is much more detailed, the aid resources, targeting mostly the vulnerable elderly and children, can be devoted more efficiently to those places where they are needed most. Furthermore, heat wave warnings will be displayed on light panels in the streets and on the city's website where citizens can find more information on what to do in case of a heat wave.

More information can be found at the website of the Urban Climate Service Centre (http://www.urban-climate.be).

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Case Study 2.B

Application of Satellite-Based Data for Assessing Vulnerability of Urban Populations to Heat Waves

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Keywords	Heat wave, social sensitivity, health impacts, urban heat island, adaptation, vulnerability, remote sensing
Population (Metropolitan Region)	1,567,442 (U.S. Census, 2015)
Area (Metropolitan Region)	347.3 km² (U.S. Census, 2010)
Income per capita	US$56,180 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

Extreme heat, exacerbated by the urban heat island (UHI) effect, is a leading cause of weather-related mortality in the United States and many other countries (Wilhelmi et al., 2012). From 2006 to 2010, an average of 620 U.S. residents died each year owing to heat stroke and/or sun stroke (Barko et al., 2014). The U.S. National Climate Assessment (NCA) and the IPCC Fifth Assessment identify warmer and more extreme temperatures as one of the impacts of anthropogenic climate change (USGCRP, 2014; IPCC, 2014). Compounding the rising air temperatures and increased variability that is occurring with climate change, UHI effects can add 6–8°C to urban air temperatures when compared to surrounding rural areas for many mid-latitude cities (Imhoff et al., 2010). High population densities in urban areas and their social stratification mean that vulnerability to climate change is also high in certain neighborhoods (Romero Lankao and Qin, 2010). Evidence shows that urban populations with higher levels of sensitivity and lower levels of adaptive capacity generally suffer

Table 2 *Advisory group members.*

	Name	Organization
Academic and Private Sector	Dana Tomlin	Department of Planning, University of Pennsylvania
	Robert Cheetham	Azavea (geospatial analysis firm)
	Shannon Marquez	Drexel University
	Raluca Ellis	Franklin Institute
	Thomas Bonner	Philadelphia Electric Company (PECO)
Policy and Urban Planning	Jeff Moran	City of Philadelphia Department of Public Health
	Palak Raval-Nelson	City of Philadelphia Department of Public Health
	Keith Davis	City of Philadelphia, City Planning Commission
	Mark Wheeler	City of Philadelphia, City Planning Commission
	Scott Schwarz	City of Philadelphia Water Department
	Mami Hara	City of Philadelphia Water Department
	Sarah Wu	City of Philadelphia, Office of Sustainability

greater impacts from a range of climate-related hazards (Reckien et al., 2013; Cutter and Emrich, 2006; Laska, 2006) including heat stress (Ueijo et al., 2011; Johnson and Wilson, 2009).

To help local and regional governments understand the vulnerability of urban populations to heat waves, we developed a set of indicators, listed in Table 1. These indicators map the elements of vulnerability and can be used to target adaptation measures and track their effectiveness.

Guided by an advisory group of local planners and experts in the pilot city of Philadelphia, Pennsylvania (listed in Table 2), we constructed the indicators to leverage the benefits of block group-level socioeconomic data and multi-decadal meteorological station data, along with the broad coverage provided by satellite remote sensing land surface temperatures (LST), land cover, and urban vegetation products.

Our methods of calculating and mapping indicators covered the three components of vulnerability: exposure of urban populations to heat waves (using NASA-derived LST and National Climatic Data Center-derived air temperature data [NCDC, 2014]), social sensitivity to heat wave impacts (tied to age, educational achievement, and race, using U.S. Census Bureau data), and adaptive capacity to cope with urban heat waves (using NASA Normalized Difference Vegetation Index [NDVI] and LST to detect results of adaptive urban "greening" projects). We calculated these indicators for a ten-year period for satellite-based data and a thirty-year period for ground-based temperature data, for Philadelphia.

Since heat-wave health impacts are tied to the duration and intensity of extreme heat, we identified heat wave periods, defined as exceeding the 85th percentile of historical average July and August temperature for Philadelphia (81°F) for three or more consecutive days. We calculated the number of heat wave days per year separately for ground-based weather stations identified as urban (6 locations) versus suburban/rural (13 locations). The monitors show that the total duration (number and length combined) of heat waves per year have been increasing from 4 to 12 days per year in urban areas and staying relatively constant at 5 days per year in suburban/rural areas from 1980 to 2010.

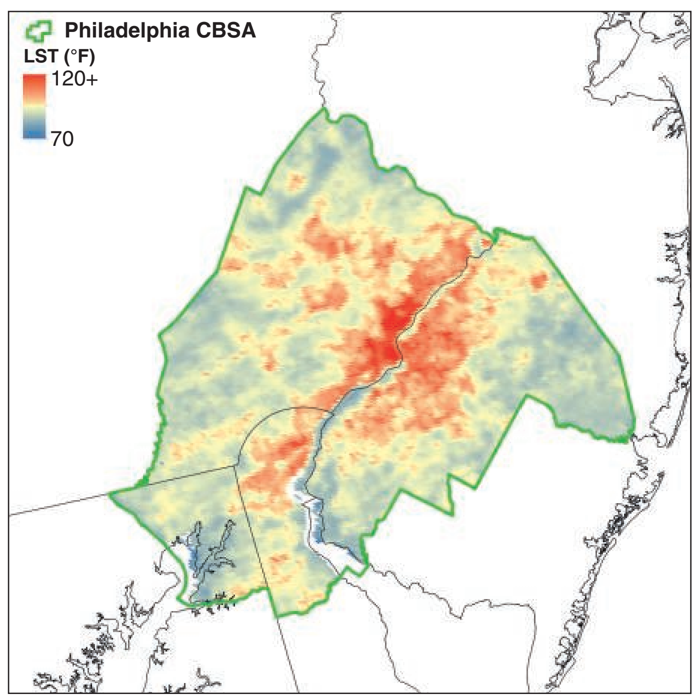
Table 1 *Indicators of vulnerability of urban populations to heat waves.*

Issue	Indicator name
Exposure	• *Urban Heat Wave Indicator:* An estimate of the intensity and total duration of heat waves for a city • *Urban Heat Island Indicator:* An estimate of the average land surface temperature (LST) difference between urban areas and rural areas for periods of extreme heat
Sensitivity	• *Urban Socioeconomic and Hotspot Indicator:* Classification of sensitivity of census units based on socioeconomic census and urban greenness data
Vulnerability	• *Vulnerability of Urban Populations to Heat Health Impacts Indicator:* Overlap of highly exposed and highly sensitive populations
Adaptive Capacity	• *Urban Adaptation Effectiveness Indicator:* Measured reductions in LST or increases in Normalized Difference Vegetation Index (NDVI) in neighborhoods related to UHI reduction measures

Complete spatial coverage of measures of LST using NASA Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua data confirm elevated temperatures and upward trends in areas flagged as urban, while opposite trends are seen in surrounding suburban and rural areas. Case Study 2.B Figure 1 shows higher LSTs in urban areas, using the example of average July LSTs in 2012. Note that LST, while correlated to ambient air temperature, is not an exact indicator of sidewalk level temperature of interest in this study since the relationship between land and sidewalk-level air temperatures depends on surface type, building height, and other factors (Zhang et al., 2014).

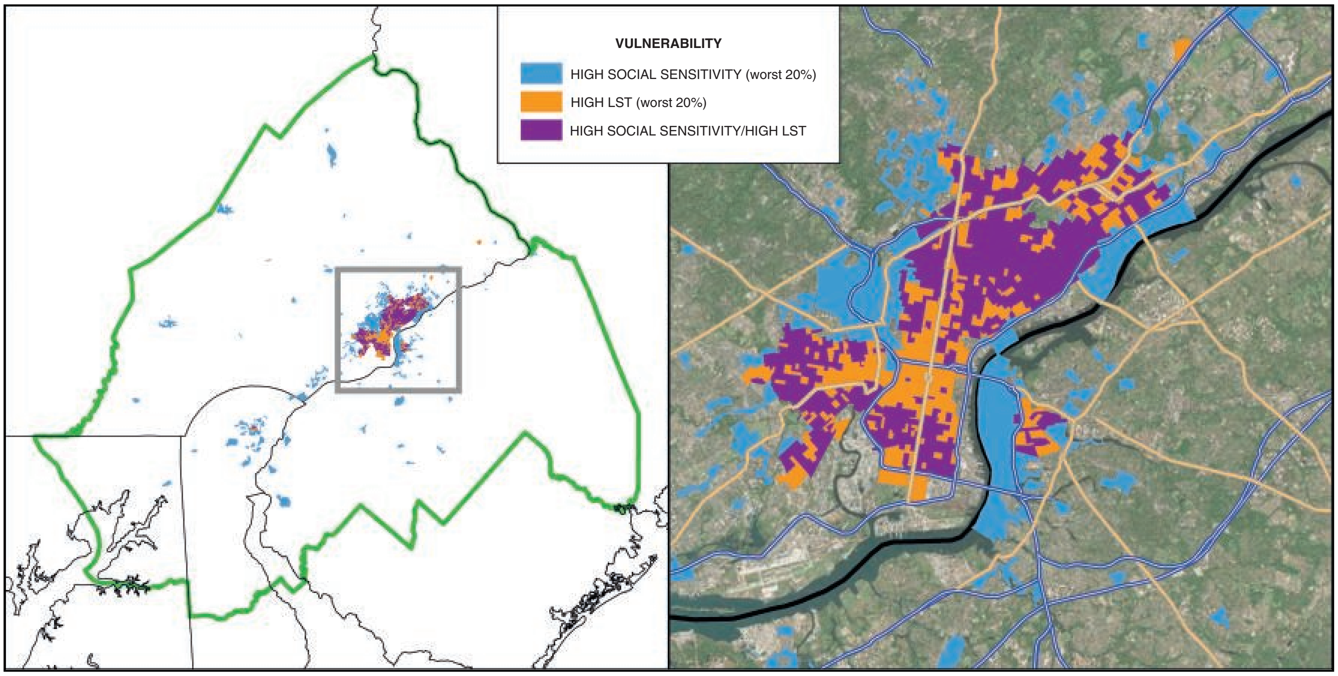
We also mapped areas of high social sensitivity to guide adaptation efforts. Sensitive populations in Philadelphia were identified through U.S. Census American Community Survey (ACS) data and defined using the following population parameters (Ueijo et al., 2011, Johnson and Wilson, 2009):

- % below the poverty line
- % of households with a person over 65 living alone
- % of housing units built before 1960
- % of the population that did not graduate from high school



Case Study 2.B Figure 1 *Land Surface Temperature.*

Source: NASA Aqua MODIS LST, 2012



Case Study 2.B Figure 2 *Overlaying the areas with highest LST (2012, shown in orange) and the residential locations of the most sensitive populations (shown in blue) reveals the most vulnerable populations overall to heat wave impacts in Philadelphia (shown in purple).*

An overall Social Sensitivity Index was calculated for each census block group, dividing each sensitivity factor into deciles and averaging the factors. The results in Case Study 2.B Figure 2 show the location of the most sensitive population to heat waves.

Approximately 10% of Philadelphia's population lives within the most vulnerable areas to heat wave health impacts based on our established thresholds for vulnerability, thus facilitating targeting of cooling adaptation measures. One such cooling adaptation measure with a long-term benefit could be increasing urban vegetation, which can provide shade and localized cooling effects (a measure of adaptive capacity of the city to reduce vulnerability). We mapped vegetation in Philadelphia (using NASA MODIS NDVI) to identify which areas currently contain higher and lower levels of vegetation. Tracking changes in NDVI over time could highlight increases in vegetation, particularly resulting from a targeted urban greening or cooling program, or decreases in vegetation, potentially leading to increases in vulnerability. Isolated examples of urban cooling measures were provided by Philadelphia officials, but none is yet at the scale that can be measured by the satellite data used (1 km). A "reverse" example was found of the increase in LST and decrease in NDVI associated with building a large warehouse in a formerly green area, which also provides useful information on potential negative impacts of zoning policies and land-use changes.

The indicators can be used by local decision-makers in Philadelphia to better understand patterns of vulnerability, target adaptation measures, and measure results (LST reduction or NDVI increase) from existing adaptation measures (e.g., tree planting, green/white roofs). Subkilometer-scale data are needed to make these indicators more applicable in mixed decision-making urban landscapes, although the availability of such products is limited, especially for the relatively short time frame (within a few months of data collection) that is most useful to city managers.

The indicator methodology was vetted with stakeholders for different display and visualization options, such as through an interactive tool, and was applied in a second pilot city (New York) as a test of scale-up. That scale-up test showed that modifications to methods (such as the selection of temperature thresholds and designation of urban and suburban locations) may be required based on local contextual factors.

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Case Study 2.C

Temporal and Spatial Variability of Moscow's Urban Heat Island

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Keywords	Urban heat island, urban climatology
Population (Metropolitan Region)	16,570,000 (Demographia, 2016)
Area (Metropolitan Region)	5,310 km² (Demographia, 2016)
Income per capita	US$9,720 (World Bank, 2017)
Climate zone	Dfb – Cold, without dry season, warm summer (Peel et al., 2007)

Moscow is a very large megalopolis where, according to data from the year 2010 (Russian Federal State Statistics Service, 2010) more than 11 million people live. In July and August 2010, there was a blocking anticyclone over Moscow as well as the central part of European Russia, with anomalously hot weather conditions for a long time. This heat wave lasted from July 4 until August 18. During this period, the warmest day for Moscow in the 143-year period of direct meteorological measurements was recorded on July 29 (+39.0°C in the city center; Konstantinov et al., 2014; Kislov and Konstantinov, 2011). This heat wave led to a rise in mortality rate up to 11,000 (Shaposhnikov et al., 2015), so it was decided to investigate the urban heat island (UHI) phenomenon of Moscow and its climatology due to its propensity to amplify heat wave intensity.

We chose for the basic UHI characterization "UHI intensity." This is defined in Equation (1) as the simple difference between air temperature at an urban station and mean air temperature in a rural area.

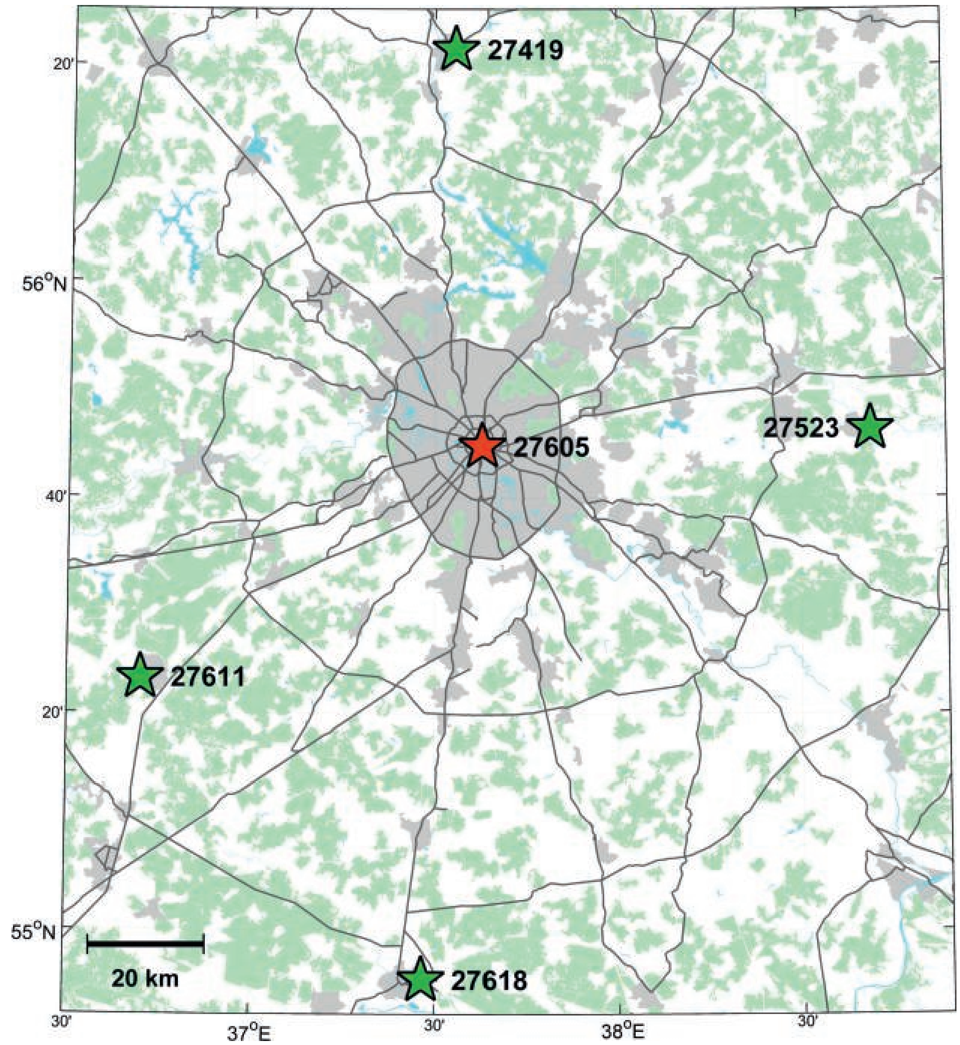
$$\mathbf{UHI}_{\text{intensity}} = \mathbf{T}_{\text{urban}} - (\mathbf{T}_{\text{ruralNord}} + \mathbf{T}_{\text{ruralSud}} + \mathbf{T}_{\text{ruralEast}} + \mathbf{T}_{\text{ruralWest}})/4 \qquad (1)$$

The map of the WMO meteorological stations in the Moscow region (Balchug is an classical urban station situated near the Moscow River and the Kremlin) and the elevation can be seen in Case Study 2.C Figure 1. The time period for the investigation was from January 1, 2000 to December 31, 2012. This period was chosen due to the availability of high-quality data for all stations.

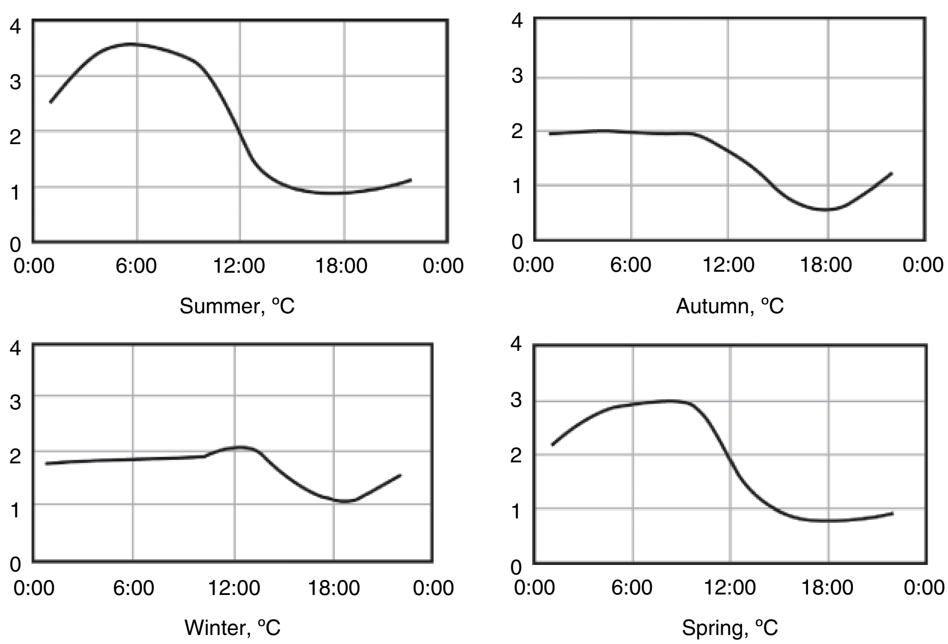
Diurnal variation of UHI intensity in different seasons is shown in Case Study 2.C Figure 2. The peak intensity is during the summer and at night. In classical urban climatology (Oke, 1988), the biggest air temperature differences between a city center and its suburbs occur (in the temperate climate zones) in the autumn and at night. Apparently, this phenomenon in Moscow is caused by high-density development in the city center and warm summer conditions.

In autumn and winter, UHI intensity is lower than in the warm seasons. Cities with continental climates display higher UHI than those in environments where sea breezes may have a cooling effect.

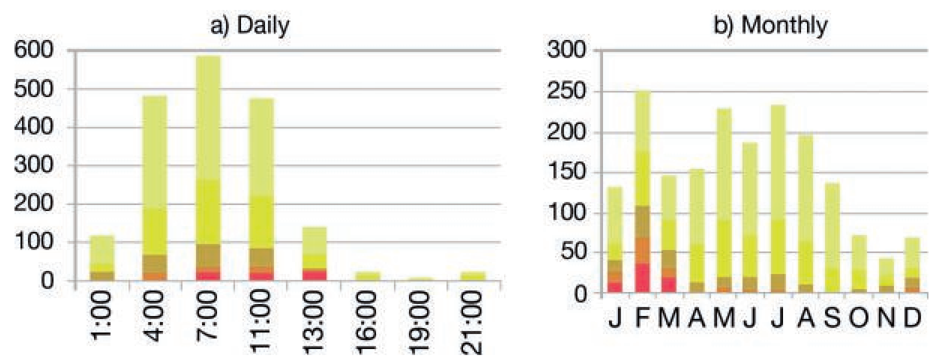
The climatology of extreme UHI intensity values (defined as cases with air temperature differences higher than 5°C) is described in Case Study 2.C Figure 3. The frequency and total number of extreme values are higher in the morning and in winter months (especially February). This might be caused by anticyclonic conditions, the probability of which rises at the end of the winter (due to intensification of the Siberian High). The total number of cases with extreme UHI intensity values in February and in the summer months is similar. The month with the lowest



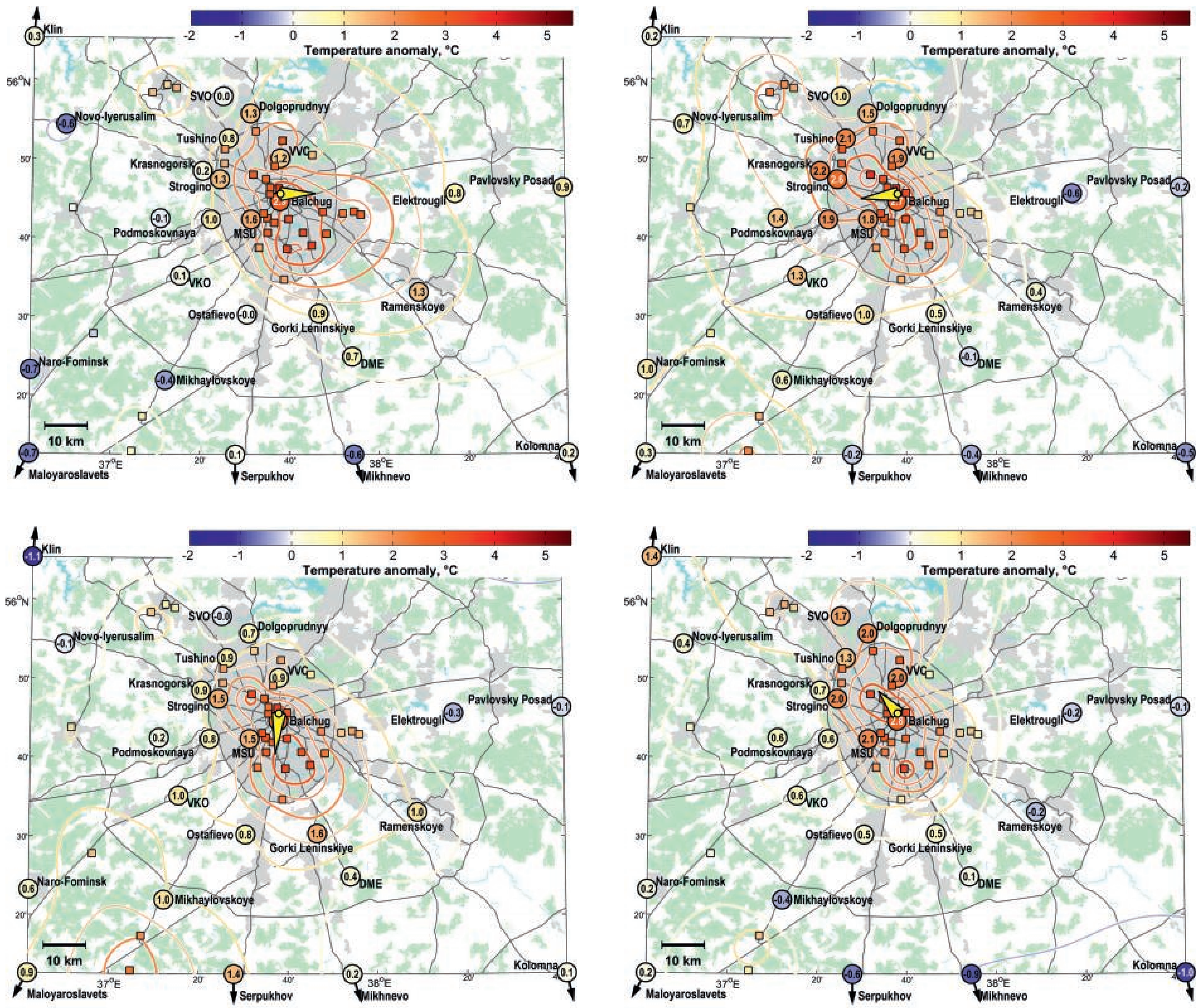
Case Study 2.C Figure 1 *Moscow region's meteorological stations map. Distance between urban and rural stations: 72 km, 92 km, 68 km, 69 km. Data available for period 2000–2012.*



Case Study 2.C Figure 2 *Diurnal urban heat island intensity variations for different seasons in Moscow (2000–2012).*



Case Study 2.C Figure 3 *Extreme urban heat island (UHI) intensity values: Number of cases with UHI $_{intensity}$ 5°C daily (a) and monthly (b). Color scale reflects five intervals with intensity increase: [5–6); [6–7); [7–8); [8–9); [9-∞) – from light yellow to red.*



Case Study 2.C Figure 4 *Spatial urban heat island zone displacement due to cases with unified wind direction averaged for the warm season of 2014: (a) western wind, (b) eastern wind, (c) northern wind, and (d) southern wind.*

UHI intensity frequency is November, which also is unusual in comparison with classical theory (Oke, 1988).

Finally, according to the physics of the UHI phenomenon, it can be slightly "blown with the wind," as shown at Case Study 2.C Figure 4. During the warm season of 2014 (May–September), averaged situations with weak (0–1.5 m/s) winds demonstrate that the displacement of the UHI zone is clearly observed, in agreement with theory (Landsberg and Maisel, 1972).

Conclusion

Moscow demonstrated a strong UHI, with a mean annual intensity of 1.8°C in 2000–2012. (Kukanova and Konstantinov, 2014) The strongest UHI conditions occur in the spring and summer months, but frequency of extreme UHI intensity values (5°C) is higher in winter months (especially February). Spatial displacement of the UHI may occur in warm months due to wind influence.

Acknowledgments

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Case Study 2.D

Adaptation of the STEVE Tool (Screening Tool for Estate Environmental Evaluation) to Sydney Conditions

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Keywords	Urban heat island, urban planning, STEVE Tool, urban climate science
Population (Metropolitan Region)	4,540,000 (United Nations, 2016)
Area (Metropolitan Region)	2,037 km^2 (Demographia, 2016)
Income per capita	US$54,420 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Australia is particularly vulnerable to the extreme weather events associated with anthropogenic climate change. The City of Sydney and other local government areas that comprise Australia's largest conurbation – the Sydney metropolitan area – are actively collaborating on mitigation and adaptation strategies.

Cities must deal with an additional phenomenon, which exacerbates the effects of global warming. The urban heat island (UHI) effect occurs when a city area experiences significantly warmer temperatures than the surrounding countryside. This localized warming is due to the absorption and trapping of incident solar radiation by buildings and paved surfaces, together with the anthropogenic heat production characteristic of densely urbanized areas. Rising city temperatures can lead to adverse conditions such as risks to public health, poor air quality, and high energy use. Several recent studies have elaborated prediction models in order to quantify and address this phenomenon (e.g., Grimmond et al., 2010, Mirzaei and Hahighat, 2010). A sustainable approach to urban development appears as a key driver to ameliorate UHI effects and reduce building energy consumption.

Research has found that temperatures in Sydney have been rising for the past 40 years above what would be expected through global warming. By 2050, the global warming effect in combination with the UHI phenomenon could increase Sydney temperatures by up to 3.7°C (Argüeso et al., 2013). Along with the many efforts being made to address the UHI effect in Australian cities, the present study aims to investigate how the urban planning process in the city of Sydney can actively incorporate climatology data in order to reach a more sustainable urban development and measure its impact on the environment. This research has been undertaken thanks to a collaborative agreement with researchers from the National University of Singapore who have developed a web-based application (STEVE Tool: The Screening Tool for Estate Environment Evaluation) able to bridge the gap between urban climatology and the urban planning process.

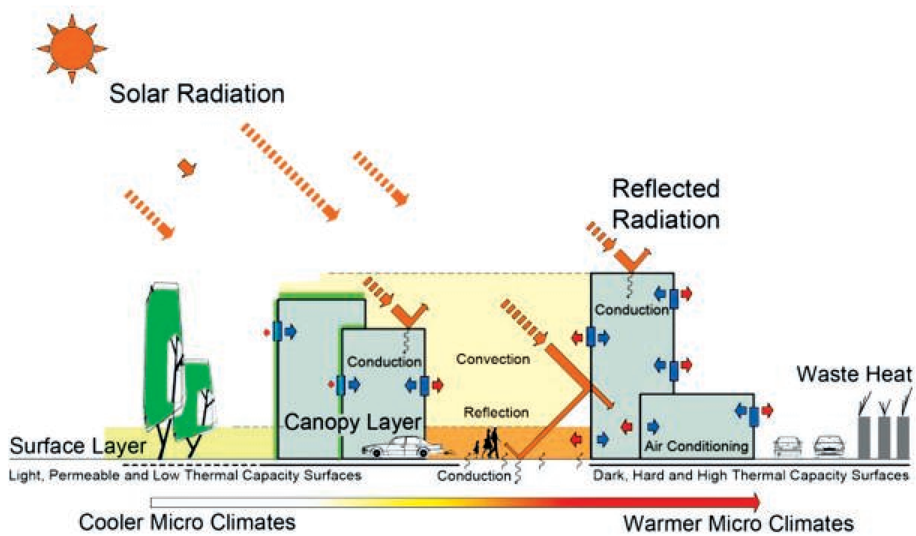
The STEVE Tool is a software tool that can estimate the outdoor thermal comfort (temperature and humidity) performance of developments based on urban form, vegetation, and weather data. It incorporates an empirical model for air temperature prediction with the main objective of evaluating the impact of development on the air temperature and, ultimately, on the UHI phenomenon. It consists of three interfaces: estate existing condition, estate proposed masterplan, and a calculator for air temperature prediction. Based on input of urban morphology and climate data, the STEVE Tool can calculate the air temperature of an existing or planned urban development.

This application has been initialized for Singapore conditions. However, the tool itself appears amenable to initialization for any latitude, provided the data are available. To investigate the tool's adaptability to the Sydney urban context, two scenarios were tested for the same central Sydney location. The first one corresponds to the site before redevelopment, with no vegetation and low building density. The second scenario responds to the site masterplan, incorporating new buildings and landscape features. The hypothesis is that urban morphology and greenery can modify the air temperature and potentially help mitigate the UHI effect.

The project involved the following steps:

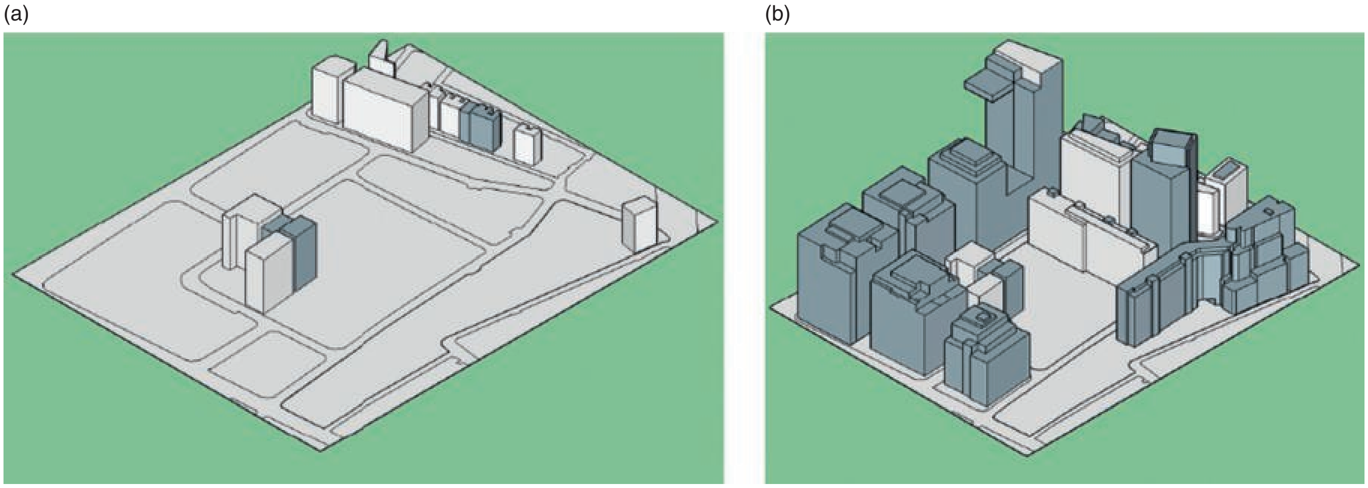
1. **Site selection.** A recently redeveloped area in inner Sydney, the Central Park precinct, was selected for the first application of the STEVE Tool. Central Park is a 5.8 hectare urban renewal project 2 kilometers from the Sydney Central Business District (CBD). Formerly dominated by a brewery operation, the new development features medium- and high-rise mixed-use buildings and a large park.
2. **Creation of a 3D model of the site.** 3D models of the pre- and post-development scenarios (see Case Study 2.D Figure 2) were built following the architectural drawings (noting that as the project is staged, some works are yet to be completed).
3. **Insertion into the model of the species indicated in the proposed landscape plans.** Since the plants specified in the plans are mostly Australian and the STEVE Tool has been originally designed for the Singaporean context, new species had to be added to the tool database. This can be done by providing specific data about the species: girth, Leaf Area Index (LAI), and type of vegetation (whether it is a tree or shrub) for each new item. With the species added, the final model was ready to be tested for different scenarios.
4. **Export of both scenarios to the STEVE web application and comparative analysis of air temperature results.** The final stage of the study will evaluate the differences in modeled air temperature and compare these with empirical data collected in previous projects on this site. The software allows the user to insert climate-related values such as the existing air temperature and the solar radiation for any given location. According to these variations, the STEVE Tool will recalculate the air temperature, taking urban morphology parameters (buildings, vegetation and streets) into account.

The results of this project are based on the study of the influence of two major variables relevant to UHI mitigation: the influence of vegetation and the influence of urban morphology on air temperature. Outcomes are expected to be consistent with previous tests of the STEVE Tool in Singapore. Further applications of the tool in Australia will require deeper modification of the program through the calculation of specific air temperature prediction models for each city's conditions based on collection of empirical meteorological data.

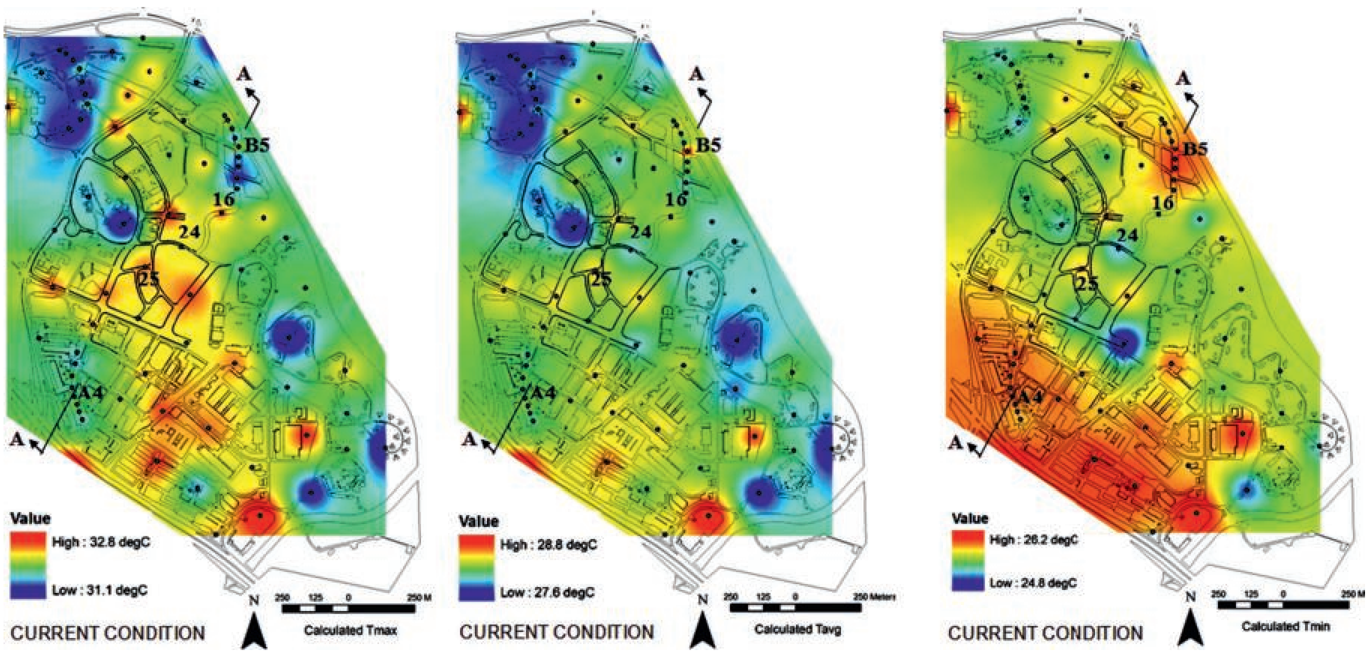


Case Study 2.D Figure 1 *The urban heat island effect in Sydney.*

Source: Sharifi and Lehmann, 2014



Case Study 2.D Figure 2 *Sydney's Central Park: 3D models of the estate's existing condition and the estate's proposed master plan.*



Case Study 2.D Figure 3 *Temperature maps produced by the STEVE Tool for Singapore conditions.*

Source: Jusuf and Wong, 2012

Case Study 2.D Figure 3 shows resulting temperature maps for a similar study undertaken in Singapore, where different climate parameters have been tested for the same urban scenario. The UHI phenomenon can be visualized in the areas colored in red.

Expected Outcomes

The initial conditions scenario shows a low-density urban form with low building heights, which can result in higher daytime air temperatures. As discussed by Jusuf et al. (2011), low building density combined with an absence of vegetation increases solar gain. However, a sparse configuration of buildings (high sky-view factor) facilitates heat release from urban surfaces in the absence of trapping structures.

The post-development scenario responds to the site master plan, incorporating new buildings and landscape features as shown in Case Study 2.D Figure 2. Following the architectural and landscaping plans, the increased building density will be accompanied by the existence of a large park and significant plantings of several tree species. According to Jusuf and Wong (2011), increased building height may not always lead to higher ambient air temperatures when an optimum distribution of greenery, building configuration, and a ratio of paved to unpaved surfaces is met. Higher buildings can provide shade and moderate air temperature, reducing the daytime UHI; conversely, they can increase the nocturnal UHI by trapping heat at night. Vegetation can play a decisive role in developments combining high buildings and substantial open space because it provides shading and evaporative cooling. An additional model of the estate's proposed master plan but excluding greenery will be tested to further evaluate the influence of vegetation on ambient temperature.

Conclusion

The STEVE Tool has the potential to be of major relevance to cities aiming for more sustainable urban form. Through its straightforward implementation, planning professionals can experiment with different design options to help reduce ambient air temperature in densely populated spaces. Together with measures to address anthropogenic heat production, the STEVE Tool can have substantial impact on the mitigation of the UHI effect through facilitating more efficient urban design.

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Case Study 3.A

Integrating Climate Change Concerns in District Disaster Management Plans (DDMP): Case of Gorakhpur

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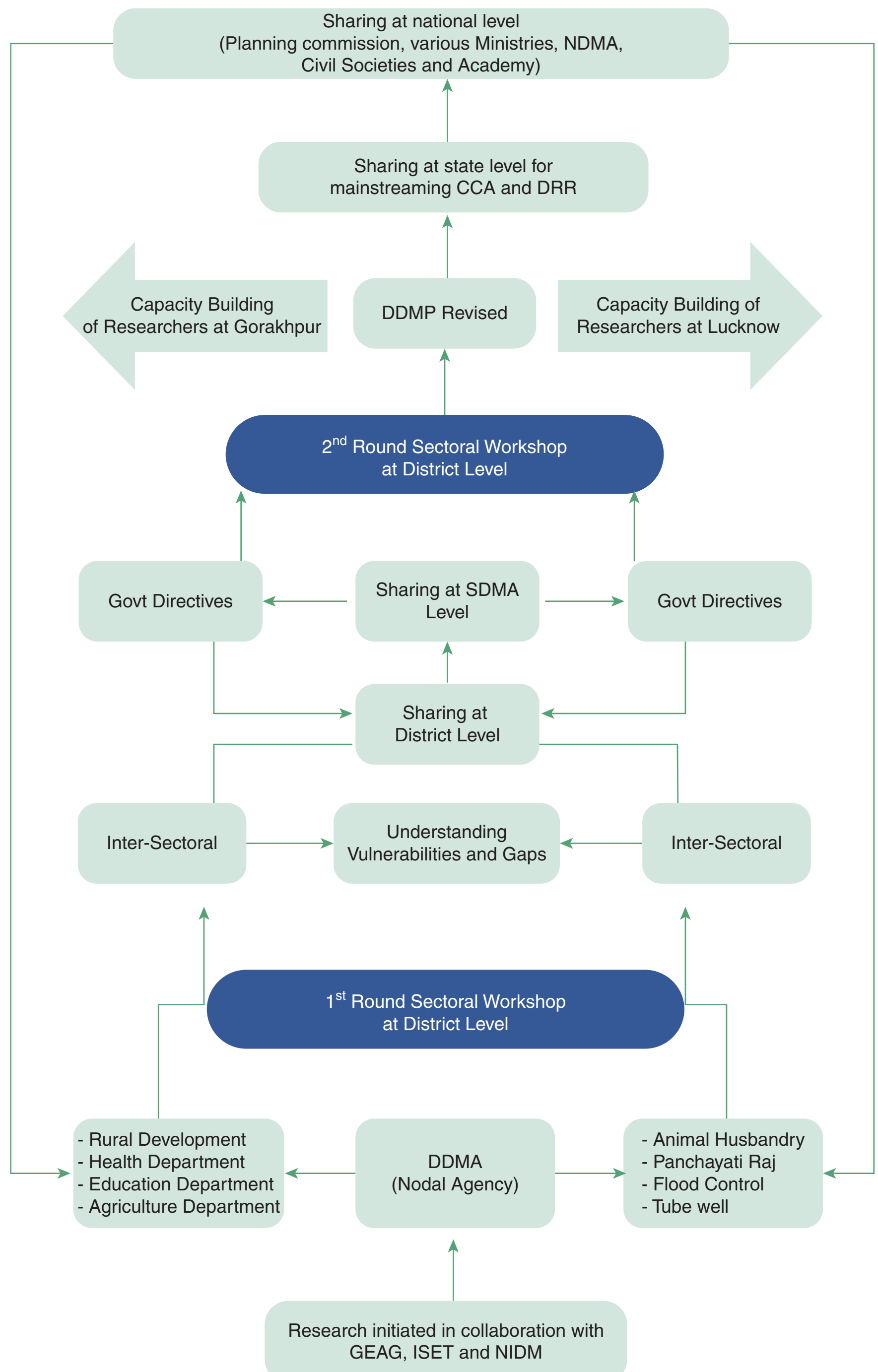
Keywords	Flood, adaptation, disaster risk reduction, disaster management plan
Population (Metropolitan Region)	735,000 (Demographia, 2016)
Area (Metropolitan Region)	54 km^2 (Demographia, 2016).
Income per capita	US$1,680 (World Bank, 2017)
Climate zone	Cwa – Temperate, dry winter, hot summer (Peel et al., 2007)

Gorakhpur is one of the most flood-prone districts in the mid-Gangetic region in eastern India. Although its inhabitants are accustomed to twice yearly flooding during the monsoon seasons, data from the past 100 years show a considerable increase in the intensity and frequency of floods, which are now recurring every 3–4 years and even annually in some areas. The pilot program was initiated to incorporate climate change considerations into disaster management planning. The aim of the initiative by the District Disaster Management Authority was to respond effectively to more frequent and extreme flooding by planning proactively to minimize the loss of life and property damage. The program, spearheaded by Gorakhpur Environmental Action Group (in collaboration with the National Institute of Disaster Management – Government of India and Institute for Social and Environmental Transition [ISET] International), has improved understanding of how climate change impacts will be manifested at the subnational level. The program team presented relevant scientific analysis of climate change projections in a form that conveyed the urgency, relevance, and implications of climate change to the district's plans and programs.

Large-scale inundation has now become a common feature for the people of Gorakhpur. Historical records date back to 1823, and similar destructive floods have occurred in 1839, 1873, 1889, and 1892. The 1998 flood, in which the Ghaghara and Rapti Rivers along with their many tributaries exceeded their danger levels, caused unprecedented damage. The subsequent embankment failures and drainage congestion disrupted normal life for more than 90 days. With large-scale landscape change from human encroachment, improper infrastructure, urban development and embankment construction, and ineffective flood moderation systems in large dams, medium to high intensity flooding has become more frequent even with average rainfall levels.

India's National Disaster Management Act (2005) provides for constitution of District Disaster Management Authorities



Case Study 3.A Figure 1 *Climate change adaptation and disaster risk reduction Integration Process in District Disaster Management Plan, Gorakhpur.*

Source: Wajih, S. A., and Chopde, S., 2014

(DDMAs), which are entrusted with developing and implementing a District Disaster Management Plan (DDMP) in consultation with all relevant departments. Accordingly, the Gorakhpur DDMA has been constituted and has prepared a DDMP. The Plan used to be focused mainly on disaster response coordination among agencies (i.e., after a flood), with some emphasis on pre-disaster preparedness activities. However, it lacked a systematic approach to hazard risk and vulnerability analysis, and it needed to focus more on pre-disaster risk reduction.

As well, various studies note that flooding patterns in the area are changing and climate projections point to significant changes in patterns of extreme rainfall events in the future. For example, an analysis predicts an increase in intensities of rainfall events of up to 33%, especially for events lasting 12 and 24 hours, and for all return periods (2, 10, and 50 years). This is consistent across all six global climate models used in the analysis for Gorakhpur. To be effective, disaster management planning must include both current and projected climate change impacts. Also, preliminary gap analysis using the Climate Resilience Framework (Tyler and Moench, 2012), which helps assess climate exposure, systems, institutions, and change agents, shows an oversimplified understanding in the DDMP of vulnerability issues and their root causes.

The experience is based on the concept of the Urban Climate Resilience Framework developed under Asian Cities for Climate Change Resilience Network (ACCCRN), supported by the Rockefeller Foundation and the objectives of the CDKN-START program:

- Understanding the systemic factors within the flood-prone Gorakhpur District that contribute to resilience or exacerbate vulnerability
- Understanding specific policy innovations that could help to bridge the vertical gap between the integrated national policy framework and local contexts and the horizontal gap between actions within sectorial development programs to integrate disaster risk reduction and climate change adaptation practice

Developing the relevant capacities of city departments and researchers on climate change adaptation and disaster risk reduction.

The Gorakhpur DDMP has been formulated with the cooperation, collaboration, and participation of different departments and public representatives so that the loss during disasters should be reduced pre-, during- and post-disaster (Case Study 3.A Figure 1). The work plan of the respective departments was also incorporated for reducing losses caused by a disaster. The recommendations and the plan were shared at the state and national level in India for further replication and scaling up. The national government developed a training module on the basis of the Gorakhpur DDMP experience that has been shared with more than 600 districts in India.

As a result of strong buy-in and effective coordination, the program has gone beyond simply making recommendations to publishing a climate-sensitive DDMP. The project demonstrates that a suite of effective initiatives led by credible organizations can result in policy change (Wajih and Chopde, 2014). In Uttar Pradesh, a similar alchemy occurred during the program's rollout. The United Nations Development Programme (UNDP), in close coordination with the state government and the State Disaster Management Authority (SDMA), has supported a capacity-building project for 9,000 *Gram Panchayats* (rural village councils) in the state to develop Village Disaster Management Plans. The networking fostered by the process helped sensitize the SDMA to aspects of integrating disaster risk reduction and climate change adaptation. This in turn led the Gorakhpur DDMA to issue an order for integrating disaster risk reduction into departmental annual development plans. This led to the release of several state government orders to further the disaster risk reduction and climate agenda.

Because of the key enabling factors just highlighted, the program was able to exceed its initial goals. But it also faced some challenges at the district level, such as lack of comprehensive understanding of vulnerability and its contributing factors, as well as a lack of a clear and systematic plan in departments to collect and synthesize relevant data on vulnerability, lack of effective horizontal coordination among departments, and lack of availability of climate projections, downscaled and interpreted in a meaningful way.

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Case Study 3.B

Climate Vulnerability Map of Rome 1.0

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Keywords	Rainwater flooding, policy-based adaptation, vulnerability, urban planning
Population (Metropolitan Region)	3,738,000 (United Nations, 2016)
Area (Metropolitan Region)	1,114 km² (Demographia, 2016)
Income per capita	US$31,590 (World Bank, 2017)
Climate zone	Csa – Temperate, hot summer, dry summer (Peel et al., 2007)

Public awareness about climate change adaptation in cities is still limited in Italy: few local authorities have started working toward this aim so far. However, the Italian Ministry of Environment is currently finalizing the National Adaptation Strategy. Moreover, Rome has been included in the first thirty-two cities of the world funded by the Rockefeller Foundation to develop a Resilience Strategy; activities are starting. Therefore, it is likely that, in the near future, the awareness of both citizens and public authorities on adaptation of cities is going to increase.

Within this evolving context, the Department of Architecture of Roma Tre University and the UTMEA department of ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) have started a joint research project aimed at testing a *quick* yet efficient and *reproducible* procedure that can provide – swiftly and with limited resources – a clear framework of the main climate vulnerability issues of a city.

The purpose of this work is not to suggest adaptation policies or measures, but rather to lay the foundation for future, tailor-made adaptation policies by public authorities. In other words, local policy-makers will be able to use the map as a means to better understand their priorities in terms of adaptation needs. Therefore, the outcome of this research is intended for use by policy-makers, but it will eventually benefit citizens, enterprises, and the nonprofit sector by increasing awareness of climate vulnerability.

As of May 2015, the first advanced result of this research is the Climate Vulnerability Map of Rome 1.0 (CVMR 1.0): the map is at its first stage and is still open to improvements. Despite the limited available data, the map seeks to show the degree of climate vulnerability of the city. As the map is improved, the city council will be able to use it as a starting point for its future climate strategies. Moreover, a more detailed work is currently under way on a closer focus: a Roman neighborhood that has recently undergone a serious rainwater flooding event is being studied in order to refine the general methodology by using more detailed and comprehensive data, with the aim of proposing more specific urban policy measures and assessing their possible effects on local resilience.

The chosen methodology is similar, though simplified and adapted to the urban scale, to the one used in *Climate Change and Territorial Effect on Regions and Local Economies* developed by the ESPON 2013 Programme (ESPON, 2011). The main concepts – *Exposure, Sensitivity, Impacts, Adaptive Capacity, Vulnerability* – have been incorporated to allow for future integrations.

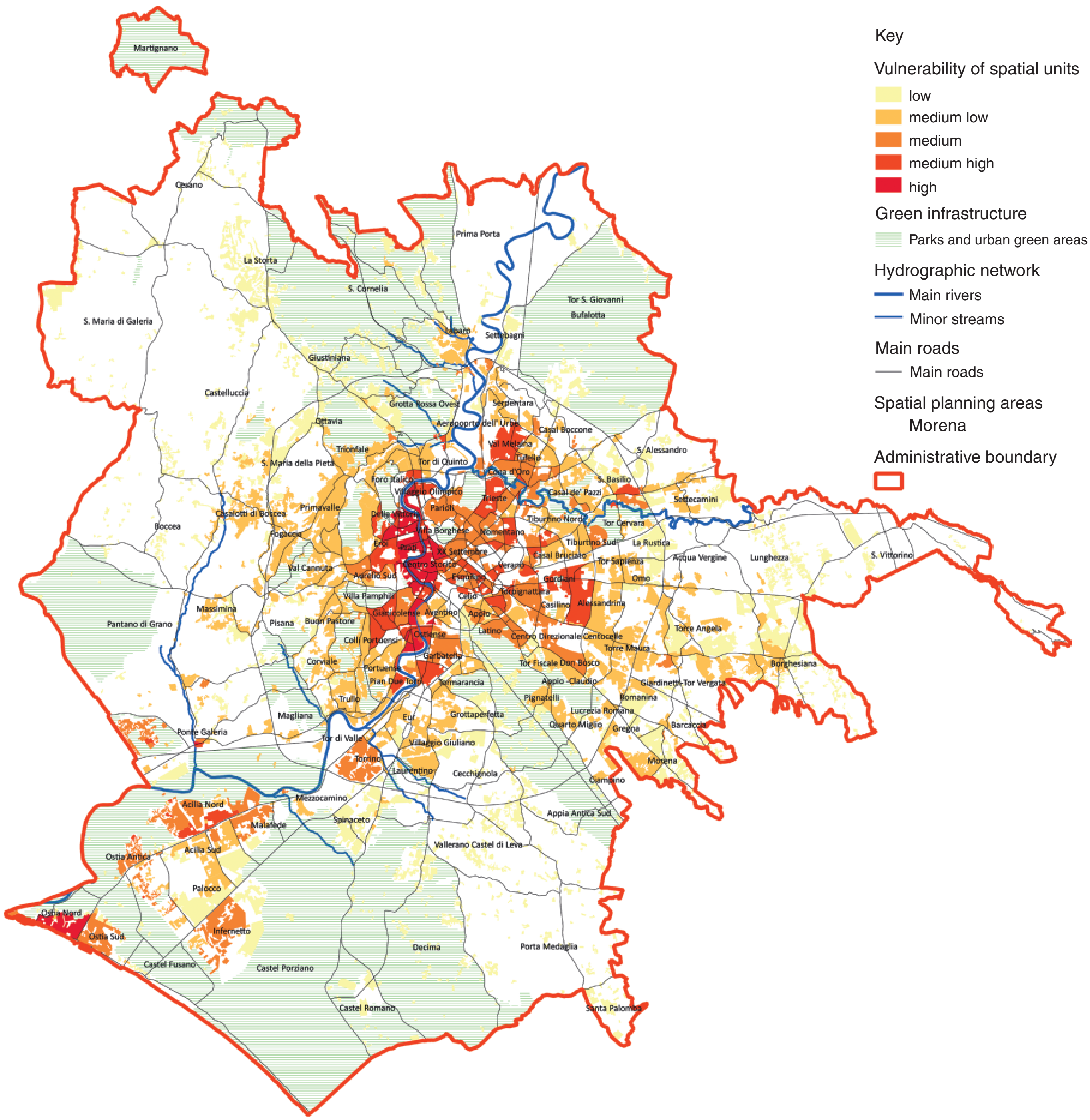
Within this first phase, the focus has been on the identification and mapping, at an infra-urban scale, of those urban characteristics causing sensitivity to climate phenomena and of those that contribute to relieving its impacts and thus improve the city's resilience. Working on an infra-urban scale requires disaggregated data; because these are not always sufficiently detailed, the research group decided to limit the chosen variables and to use proxies when necessary.

Some stakeholders have been involved in the data collection phase: in particular, the Office for Civil Protection of the City Council of Rome has been interviewed and has provided geo-referenced data on rainwater flooding events of the past years. As regards the next phase of the research – focusing on the critical neighborhood mentioned earlier and its possible adaptation measures – the local citizens' associations, political parties, and submunicipal government level will be involved in collecting all local interests on spatial development and urban policies and analyzing them with the purpose of suggesting improvements and modifications in line with adaptation needs.

To better appreciate the spatial variability of climate vulnerability, the administrative area (Municipality of Rome) has been subdivided into spatial units (SUs). These are the minimum units containing spatial and statistical data, with variable dimensions, corresponding to a neighborhood or part of it, and they identify homogeneous parts of the city in terms of function, urban morphology, and building typology. In this phase, only residential, commercial, and industrial settlements have been taken into account. In the future, the SUs could also be used as areas for the implementation of adaptation policies and actions. Thus, the city council and other local actors will be able to implement climate change adaptation in Rome.

As regards exposure analysis, two phenomena have been considered: the increase in summer temperatures and precipitation intensity. Therefore, the exposure of the city to the intensification of heat wave and flood risks caused by extreme rain events has been assessed.

The predictions regarding such phenomena come from climatic models corresponding to emission scenarios, but the spatial resolution of such models makes them of little use at a local scale unless a substantial downscaling is elaborated. Therefore, the research group sought to render the spatial differentials of



Case Study 3.B Figure 1 *Map of the overall climate vulnerability of Rome, considering the main elements of impact, vulnerability, resilience, and exposure to the threats of summer heat islands, heavy rain floodings, river floodings; 2014 update.*

exposure to chosen phenomena by using observed events and risk maps as proxies:

E1 – exposure to summer night temperatures (retrieved by satellite thermal observations in July 2003; MODIS, 2013)
E2a – exposure to rainwater flooding (maps of rainwater floods observed by the city department for civil protection; Comune di Roma, 2007)
E2b – exposure to river flooding (flood risk maps elaborated by Autorità di Bacino del fiume Tevere (Basin Authority of the Tiber River, 2009a and 2009b)

The next step was an analysis of the degree of sensitivity for each SU. Based on the available literature, three sensitivity factors representing urban and demographic characteristics were selected:

S1 – land cover: use, density and continuity of settlements (Regione Lazio, 2003)
S2 – population density (ISTAT, 2013)
S3 – percentage of elderly population (ISTAT, 2013)
S – aggregate sensitivity (sum of the three above factors)

The *impact analysis* relates exposure and sensitivity elements, aiming to highlight the gravity of possible impacts on each SU. The impact levels for each phenomenon have been calculated as a function of the respective exposure and aggregate sensitivity. Three impact indicators have been elaborated:

I1 – heat wave impact
I2a – rainwater flood impact
I2b – river flood impact

The research team decided to replace the term "adaptive capacity" with "resilience" to emphasize that the research refers to the physical structure of the urban socioeconomic system rather than to resources.

Three *resilience* factors, linked to residual natural elements that characterize the different parts of the city, were considered:

R1 – proximity to green infrastructures (degree of adjacency of each SU to green urban areas and wooded areas; derived from Regione Lazio, 2003)
R2 – presence of vegetation (estimated by using the Normalised Difference Vegetation Index derived from satellite images from Landsat, 2013)
R3 – percentage of permeable soil (inverse value of the soil sealing index elaborated by the EEA at a European level; derived from EEA, 2013)

However, since not all resilience factors influence each impact, three phenomenon-specific aggregate resilience indices have been elaborated for the calculation of vulnerability in the final step:

RS1 – Resilience to summer night temperatures (including all factors)
RS2a – Resilience to rainwater flooding (including the first and third factors)
RS2b – Resilience to river flooding (including the third factor)

Finally, three *vulnerability* indices (V1, V2a, V2b) were calculated, referring to the three phenomena plus an index of aggregate vulnerability (V). The single vulnerability indices were calculated by multiplying the impact indices by the respective phenomenon-specific resilience indices, while the aggregate vulnerability index resulted from the sum of the single vulnerability indices. The CVMR 1.0 is the map of the aggregate vulnerability index and is shown in Case Study 3.B Figure 1.

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The MODIS image from 23 July 2003 was retrieved from the online Data Pool, courtesy of the NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://lpdaac.usgs.gov/data_access/data_pool.

The Landsat image from 23 July 2003 is available from the U.S. Geological Survey.

Case Study 3.C

Naples, Italy: Adaptive Design for an Integrated Approach to Climate Change and Geophysical Hazards

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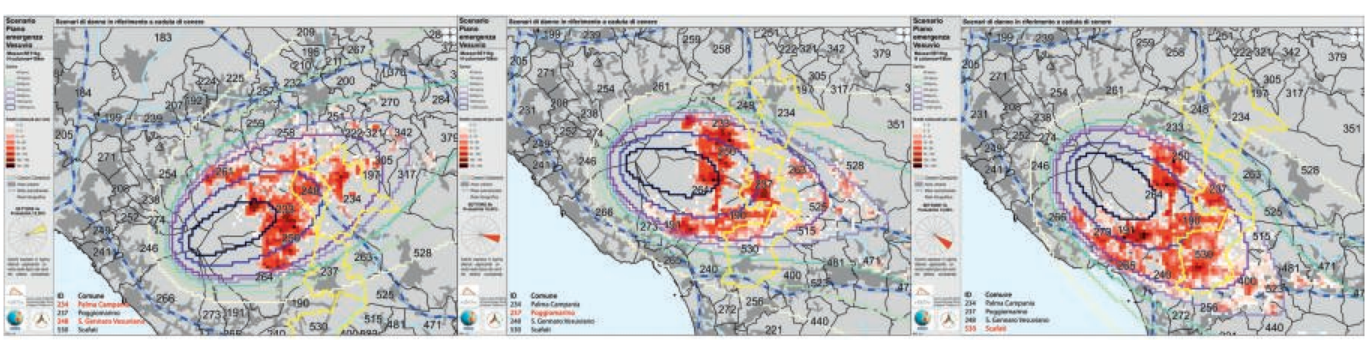
Keywords	Geophysical hazards, volcanic risk mitigation, building technologies, energy efficiency, adaptive design
Population (Metropolitan Region)	3,114,000 (SVIMEZ, 2016)
Area (Metropolitan Region)	1,023 km^2 (Demographia, 2016)
Income per capita	US$31,590 (World Bank, 2017)
Climate zone	Csa – Temperate, dry summer, hot summer (Peel et al, 2007)

Complex eruptive scenarios, such as sub-Plinian or Plinian eruptions, produce extremely variable impacts on constructions depending on the specific time history of the event, on the existing building typologies, and on their level of vulnerability. This specific approach has been recently formalized to evaluate the impact of a sub-Plinian eruption in the Vesuvius and Campi Flegrei area (Zuccaro et al., 2008) through the development of the *PLINIVS Volcanic Impact Simulation Model*, a GIS model for the dynamic simulation of impact scenarios, able to evaluate the cumulative damage distribution in time and space from different eruptive phenomena such as earthquakes, pyroclastic flows, and ash fall.Within the main "mitigation scenarios" identified (Zuccaro and Leone, 2012), aimed at the development of local regulations, a priority action concerns the structural reinforcement of roofing systems or the superposition of pitched roofs to reduce damages from ash fall, especially for areas more distant from the crater not affected by pyroclastic flows, for which, however, overloads between 500 and 1,400 kg/m^2 are expected (Case Study 3.C Figure 1).

Based on the cost parameters identified in the development of the model for the assessment of economic impacts of eruptive scenarios (Zuccaro et al., 2013) it is possible to compare the costs for the implementation of ash fall mitigation measures with the "avoided cost" of the reconstruction of collapsed buildings. The cost-effectiveness of the mitigation actions is evident in case of ash fall impact since the avoided costs of demolition and reconstruction are in terms of billions of euros against mitigation costs at least an order of magnitude lower. However, the uncertainty related to the wind direction at the time of the eruption does not make such mitigation scenarios feasible since, in the absence of a destructive event, these represent only a cost factor without significant additional benefits.

The integrated approach to disaster risk and climate change frames the mitigation of volcanic risk in the context of a broader strategy aimed at upgrading the energy efficiency of the built environment (contributing to climate change mitigation) and reducing environmental impacts and soil consumption (increasing adaptive capacity). In this context, the need for widespread and cost-effective actions on the built environment requires that the adopted solutions, both with reference to energy retrofitting and risk mitigation objectives, are based on well-established and reliable technologies.

A design simulation has been carried out in the context of preliminary studies related to the development of the new Urban and Building Code for the City of Poggiomarino (Naples, Italy), considering a sample residential building where the risk mitigation from ash fall is connected to an energy retrofitting that provides an increase in gross floor area through the construction



Case Study 3.C Figure 1 *Most probable ash fall scenarios following an eruption of Vesuvius.*

Source: PLINIVS Study Center, University of Napoli Federico II of an attic space, thus combining the economic benefits deriving from property value increase, the energy savings for insulation of roofs, and the production of energy from photovoltaic panels.

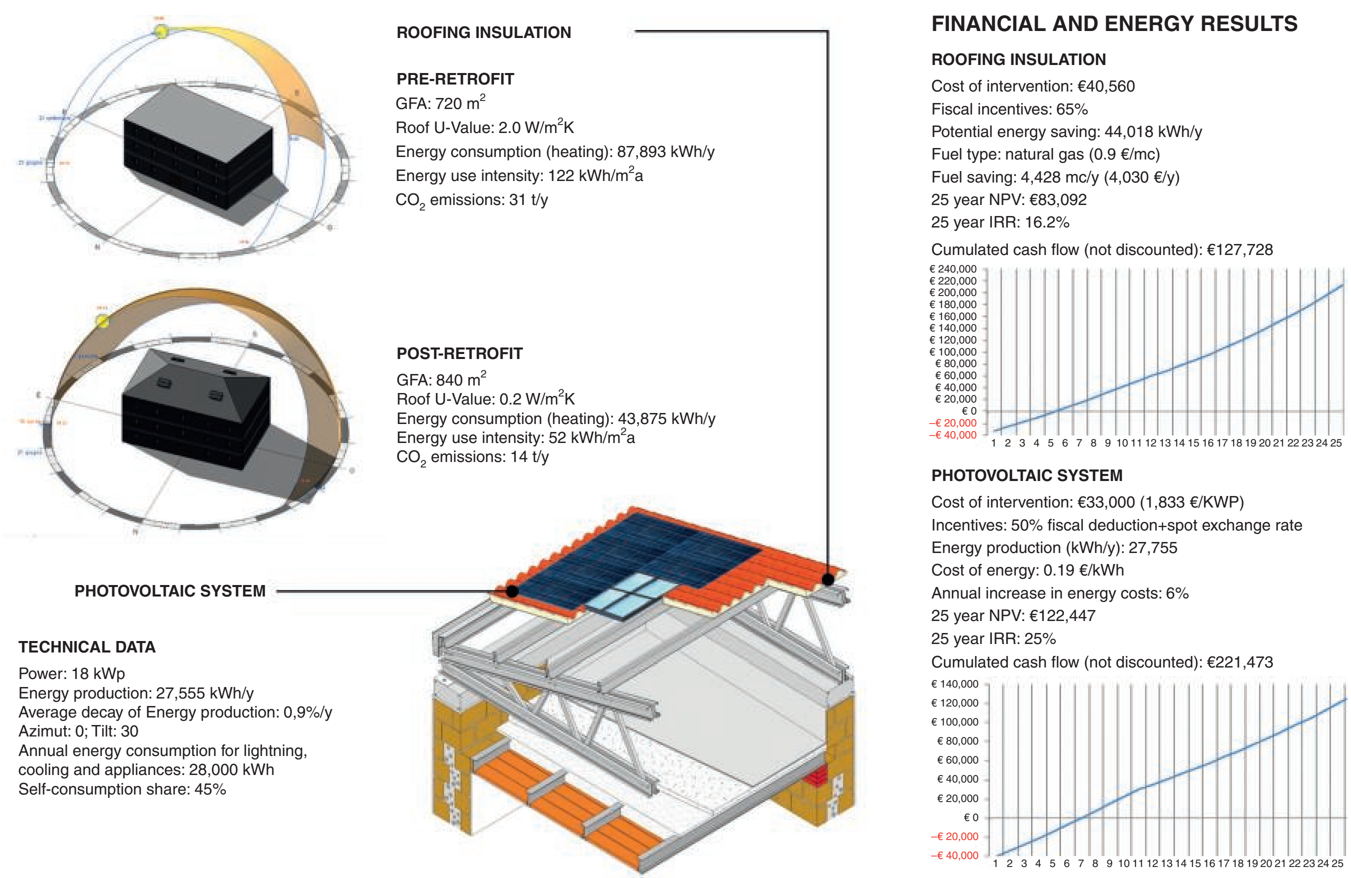
A sloping roof with a cold formed steel structure is overlapped on the existing flat roof thus minimizing the overload on the underlying structure. The insulated and micro-ventilated roof offers high energy performance complementary with the structural retrofitting intervention. Additional economic and energy benefits come from the insertion of high-efficiency photovoltaic modules, with a cost per kWp significantly reduced due to the possibility of integrating the modules in the CFS substructure. The solution does not present any particular complexity in the design and implementation, but it requires the verification of expected loads and connections to the existing structure to provide a further contribution in terms of improving seismic resistance, thus realizing the so-called *box effect*.

Considering a 20-year period, compared to a cost of intervention of €75,000 (US$88,359), it is possible to estimate significant energy benefits, which in economic terms determine an net present value (NPV) of about €205,000 (US$241,516), in addition to the increment in the value of the property due to the increased surface area, equal to about €55,000 (US$64,797). Based on these data, also taking into account the aleatory definition of certain parameters and the need of further details for a complete economic analysis, it is possible to estimate the return of the initial investment in few years, with particularly relevant cash flows added to the primary benefit of the ability of the building to withstand expected overloads from ash fall (Case Study 3.C Figure 2).

Other relevant co-benefits in terms of climate change adaptation come from the opportunity of integrating rainwater harvesting and recycling systems in the building basement and collecting water from the sloped roof to be reused for multiple purposes (e.g., evaporative coolers; toilet flushing; car washing; indoor plant, pet, and livestock watering; lawn and garden irrigation).

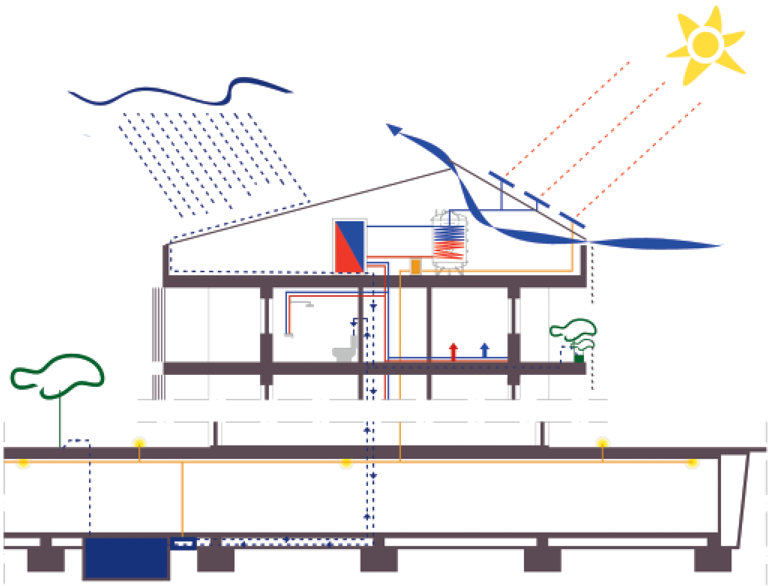
Case Study 3.C Figure 3 shows a possible integrated design approach where new technical systems (solar thermal panels exchange boilers, additional boilers, PV inverters) are located in the attic space, while the lift shaft hosts ducts for connections to the residential units (recycled rainwater for toilet flushes and irrigation; hot/cold water for sanitary uses and radiant floor heating/cooling systems).

This additional retrofitting option is aimed primarily at reducing the amount of water discharged into the sewage system, which aggravates the impacts of flash floods. The increased frequency of extreme precipitation events represents critical risk conditions for municipalities in the Vesuvius area, where the effects of climate change are exacerbated by past and ongoing



Case Study 3.C Figure 2 *Synthesis of adaptive design technical solutions and cost-benefit analysis for the reference building in located in Poggiomarino Municipality.*

Source: Leone and Zuccaro, 2014



Solar thermal panels sizing	Floor	Stairwell	Building
n. of people	7	42	252
Average daily consumption (l)	350	2,100	12,600
Panel surface (m^2)	6	36	**216**
Accumulation volume (l)	400	2,400	
DHW needs average covering	**66%**		

PV panels sizing	
Average annual solar radiation on 30° surface (az. SSE,SSO)	1,662 kWh/m^2a
Calculation value (average system losses: 5%)	1,580 kWh/m^2a
Panels surfaces	108 m^2
Panels number	67
Single panel power (1,0x1,6 m)	308 Wp
Total power	21.3 kWp
Average annual energy production	33,600 kWh/a

Case Study 3.C Figure 3 *Rainwater harvesting/recycling system and additional solutions for technical systems retrofitting for the reference building in Poggiomarino Municipality.*

Source: M. F. Leone

Case Study 3.C Figure 4 *Pluvial flood event in Scafati and Poggiomarino.*

Source: Local Press. Il Gazzettino Vesuviano, 22.01.2014

local territorial dynamics such as urban sprawl and widespread soil sealing (Case Study 3.C Figure 4).

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Case Study 3.D

Surat: The Value of Ad-Hoc Cross-Government Bodies

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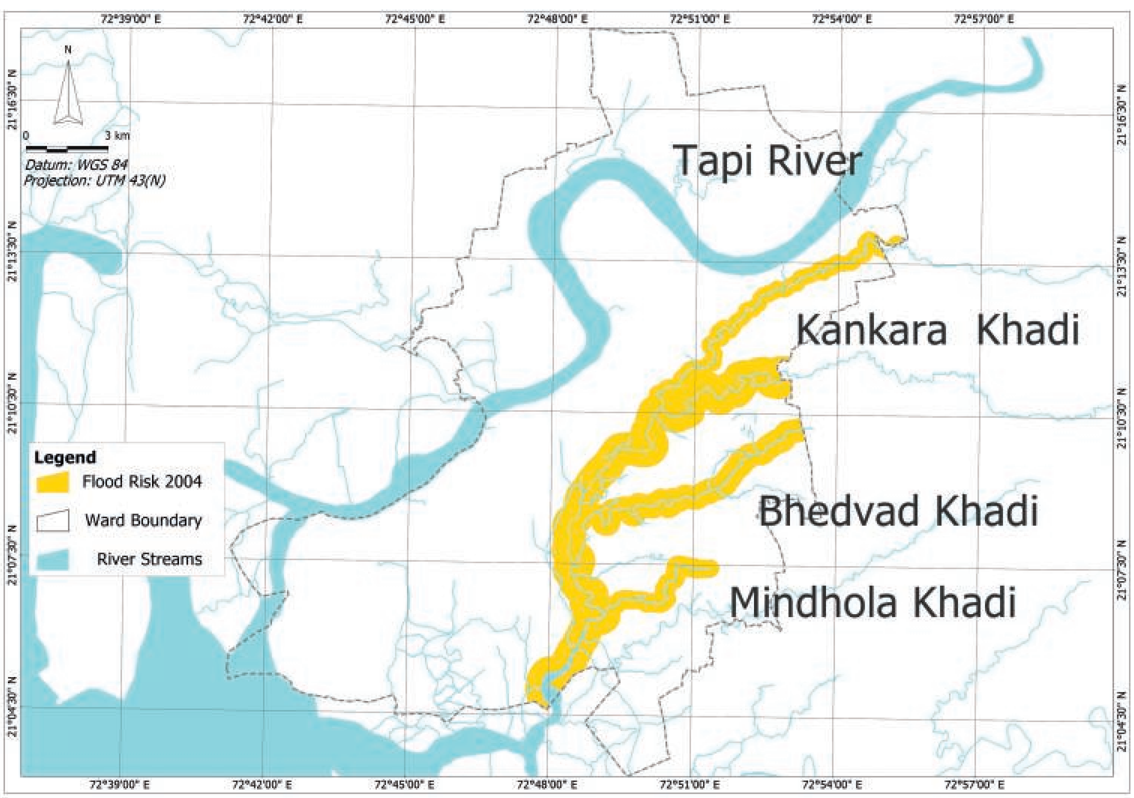
Keywords	Floods, early warning systems, sharing knowledge, disaster and risk
Population (Metropolitan Region)	5,685,000 (Demographia, 2016)
Area (Metropolitan Region)	233 km² (Demographia, 2016)
Income per capita	US$1,680 (World Bank, 2017)
Climate zone	Aw – Tropical savanna (Peel et al., 2007)

Flooding is considered the most common stress in Surat (Arup, 2014). With a population of 4.8 million in 2011, the city has experienced one of the highest growth rates in India over the past decade, almost doubling in size between 2001 and 2011. About 20.9% of the population lives in slum areas (Sawhney, 2013), which tend to be along the city waterways and encroach on about 60% of Surat's public land (Tanner et al., 2009). Surat's main economic activities encompass textile manufacturing and diamond cutting and polishing industries that account for 54% of total employment. Trade and commerce of manufactured goods are the second main source of employment, accounting for a total share of 24% (SMC, 2011). The average annual rainfall in the city is 1,894 millimeters (NDMA, 2010), and climate change scenarios show a projected 200–500 millimeter annual increase in rainfall in the city, thus increasing the risk of flooding (TARU, 2010).

There are two main types of flood events in Surat. The first type, the so-called Khadi floods, takes place along the two streams that go through the city (see Case Study 3.D Figure 1) causing limited levels of damage (SMC, 2011).

The second type, the Ukai Dam floods, tends to cause greater impacts. The dam, which is located about 100 kilometers upstream of the city, is essential for irrigation in the surrounding agricultural area. The increasing demand for water requires maximizing its storage. Therefore, the dam is managed so that it



Case Study 3.D Figure 1 *Flood-prone areas in Surat due to Khadi floods.*

Source: SMC, 2011

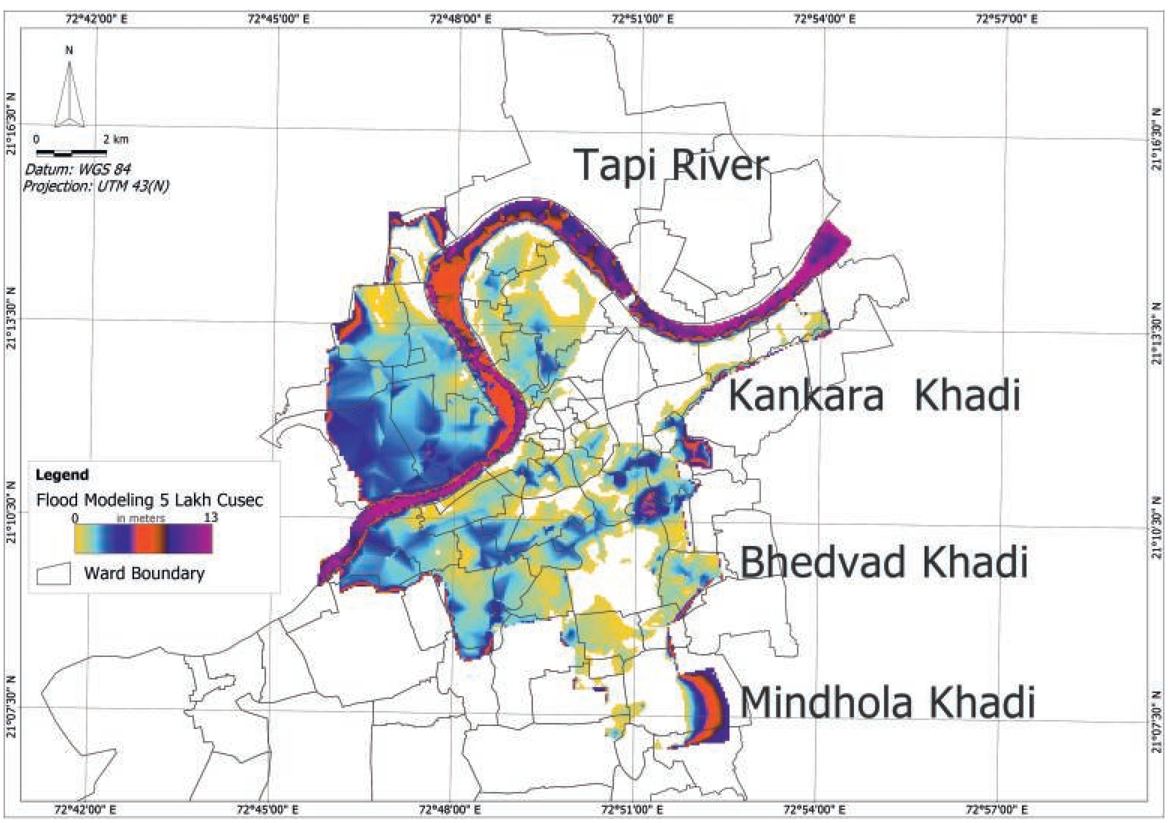
holds the maximum amount of water by the end of the monsoon season (SMC, 2011). The downside of this policy is that extreme rainfall events can trigger the sudden release of high volumes of water in short periods of time, leading to severe flooding in the city (TARU, 2013). Since the construction of the dam in 1972, there have been four major flooding episodes (1994, 1998, 2002, and 2006) following emergency discharges of the Ukai Dam (525, 700, 325, and 909 × 10^3 cubic meters/sec, respectively) (Joshi et al., 2012). The flood episode of 2006 was probably one of the worst experienced by Surat in generations. More than 80% of the city was flooded, affecting 2 million people, of which two-thirds lived in low-income areas. People remained without food and drinking water for 4 days (SAARC, 2010). Damages to public infrastructure added up to US$544 million, and industrial losses amounted to US$3.5 billion (Karanth and Archer, 2014).

Case Study 3.D Figure 2 shows the areas within Surat prone to floods following a discharge of the Ukai Dam of 500 × 10^3 cubic meters/sec (SMC, 2011).

Ukai Dam floods are partly attributed to poor management of the reservoir. City authorities have committed significant infrastructure investments to reduce the risk of floods through its urban drainage systems and flood defenses (da Silva et al., 2012). However, flood control measures rely on Ukai Dam management, which lies beyond Surat's authority. The catchment area spans three states, and further measures require the collaboration between different state administrations (Karanth and Archer, 2014). Earlier, there were limited platforms to share learning between institutions at different administrative levels, but no integrated actions were taken (TARU, 2013). In addition, there was a lack of information exchange between weather forecasters, dam managers, and Surat's authorities. Ukai Dam discharge was a reactive process based solely on water levels in the reservoir (da Silva et al., 2012).

Recognizing the absence of communication between departments at various administrative levels, Surat authorities established in 2009 the City Advisory Committee (CAC), an ad-hoc cross-government body responsible for coordinating disaster risk reduction initiatives and sharing information among multiple stakeholders (SMC, 2011). In 2010, the CAC led a number of state consultations with key stakeholders to gain a better understanding of the nature of floods in Surat and to discuss effective approaches to flood management (Karanth and Archer, 2014).

As a result of these meetings, the importance of information exchange was acknowledged for a better-informed decision-making process to manage the floods. The need became apparent to both share and generate inputs of rainfall forecasts together with hydraulic analyses of the catchment area to inform future emergency discharges (da Silva et al., 2012). Given the trans-boundary nature of these increasing risks, Surat authorities created the Surat Climate Change Trust (SCCT), a collaborative platform to facilitate data collection and foster dialogue, joint deliberation, and action among the parties involved (Karanth and Archer, 2014).



Case Study 3.D Figure 2 *City areas that could be affected by a discharge of the Ukai Dam of 500 × 10^3 cubic meters/sec.*

Source: SMC, 2011

The SCCT played a crucial role in creating an end-to-end early warning system – one of the short-term strategies proposed by Surat Municipal Corporation – which would span the states of Madhya Pradesh, Maharashtra, and Gujarat (SMC, 2011). A number of data transfer mechanisms were generated among the catchment area, the Ukai Dam, and the city. Reservoir inflow and outflow prediction models were also improved through the installation of several weather stations (TARU, 2013).

The early warning system increased the time available for cities to respond from 1 day to nearly 4 days (Bhat, 2011). In addition, the flow of data among multiple institutions helped to minimize peak water discharges of Ukai Dam, thus reducing flood intensity in Surat (TARU, 2013). In 2013, floods carrying a greater volume of water than those of 2006 had a much lesser impact on the city (Arup, 2014).

The present case study on Surat's end-to-end early warning system shows the importance of the participation of multiple stakeholders when designing climate change adaptation strategies. Furthermore, the case exemplifies how ad-hoc cross-government bodies such Surat's CAC or SCCT can be extremely effective in harmonizing collaborations between different administrations while increasing urban resilience.

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Case Study 3.E

Digital Resilience: Innovative Climate Change Responses in Rio de Janeiro

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Keywords	Resilience monitoring system, emergency response, climate change adaptation
Population (Metropolitan Region)	11,835,708 (IBGE, 2015)
Area (Metropolitan Region)	5,328.8 km^2 (IBGE, 2015)
Income per capita	US$42,390 (World Bank, 2017)
Climate zone	Am – Tropical monsoon (Peel et al., 2007)

Over the past 15 years, the city of Rio de Janeiro, Brazil, has gained a reputation for being at the forefront in the development of innovative climate change responses. The city's first greenhouse gas (GHG) emissions inventory dates back to 2000, produced shortly after joining ICLEI's Cities for Climate Protection campaign. By 2011, the city had inscribed voluntary emission reduction targets within local law (Law 5,248), aiming for an ambitious 8%, 16%, and 20% reduction by 2012, 2016, and 2020, respectively–against a 2005 baseline. The initiatives directed at achieving this goal were detailed in the 2011 Action Plan for the Reduction of GHG Emissions, collaboratively developed with civil society organizations, academia, and representatives of local industry (Prefeitura do Rio de Janeiro, 2011a). These ideas were further developed with the support of the World Bank and established the foundations for the 2013 Rio de Janeiro Low Carbon City Development Program (World

Bank, 2013). Consequently, it was not a surprise when, in 2014, the city's mayor, Eduardo Paes, assumed the chairmanship of the C40 Cities Climate Leadership Group. But while progress was steadily being made on climate mitigation, a growing concern for the city's climate-related activity was the gradual increase in the frequency and strength of extreme rain events and the resulting vulnerability of the city to flooding and landslides. This case study briefly reviews how the city, in response to these and other threats, embraced narratives around resilience and coupled strategies for responding to climate change with the use of urban digital technologies of control: the mobilization of ICT systems toward both providing urban services and influencing citizen's behavior and the course of key events in the city. It is an example of how climate change narratives and initiatives transcend environmental issues, potentially playing a significant role in emerging forms of ecological and social control.

In early April 2010, the state of Rio de Janeiro experienced a traumatic rain event that resulted in large areas of the city being flooded and hundreds of landslides (New York Times, 2010). While it is common for Rio de Janeiro to experience a high level of rainfall during the month of April, the 288 millimeters of rain that fell between April 5 and 6 represented more than the total rain average for the entire month and was the highest amount of rain ever recorded for a period of 24 hours (Prefeitura do Rio de Janeiro, 2011b). The emergency left a death toll of more than 210 people, with the media reporting more than 15,000 homeless people and a cost of US$12 billion to the nation's economy. The city of Rio de Janeiro, the state's capital, was significantly impacted. The city's main roads were flooded; power, gas, and water supplies disrupted; and commercial activity paralyzed. Public transport collapsed as hundreds of bus passengers were rescued by fire crews. After 24 hours of continuous rain, the city's Mayor expressed that "The situation is chaos" and ordered all citizens to stay home so that emergency services could focus on helping those in greatest need (BBC, 2010). The death toll affected primarily *favela* inhabitants, low-income residents living in the informal settlements of Rio's hills.

During the event, a major preoccupation of the Mayor was the limited ability of municipal officers to provide and manage emergency response services in a highly disrupted city. As described by a staff member of the municipality, "We didn't have a site from where to manage the city; [a site] with all the required information. Each department functioned in a different locality, and every time we hit a calamity or a crisis it was very difficult to respond" (Interview, 2014).

Once the April 2010 crisis was over, the Mayor enlisted software and ICT companies in the development of an urban operations center capable of increasing the level of integration between different municipal agencies and, in this way, strengthen the city's ability to respond to emergencies. In 2011, the city inaugurated its Center of Operations (also known as COR), a large-scale control room aimed at "interconnecting the information of several municipal systems for visualization, monitoring, analysis and response in real time" (Prefeitura do Rio de Janeiro, 2011b: 14). With more than eighty customizable computer monitors forming a gigantic screen, the room resembles a NASA control room rather than a typical municipal office (Case Study 3.E Figure 1).

Case Study 3.E Figure 1 *Digital resilience: The COR's main control room area.*

Photo: Andrés Luque-Ayala

Its main screens are constantly monitoring the city and its operations through video images captured by more than 800 cameras and maps displaying geo-referenced urban data. These include weather patterns, waste collection functions, public transport movements, and even the location of each of the city's municipal guards. From the COR, city officials make decisions on how to manage the city's everyday infrastructure flows and, when needed, respond to emergencies.

With more than 400 staff members belonging to over forty different organizations, the COR's key abilities are based on its capacity to provide horizontal integration and coordination. In contrast to more traditional control rooms, where a vertical approach emphasizes command and control for a single type of utility or service, the COR operates in a horizontal way by integrating and centralizing dispatch functions and emergency coordination for municipal service providers as well as for other non-municipal agencies. While each agency is still autonomous and maintains its own operative systems and response protocols, the COR provides a digital macro architecture that connects individual systems, as well as a physical location where such integration occurs. It manages to overcome issues of institutional isolation through a digital architecture that facilitates information sharing while maintaining the specialized knowledge and experience that exists within each agency.

As of April 2014, the COR hosted representatives of 32 municipal agencies, 12 private concessions, and a selected number of state level agencies. Among the municipal agencies are the Transport Department, Waste Management Department, Health Department, Social Assistance, the Municipal Guard, Alerta Rio (the city's meteorological monitoring agency), and Civil Defense. The private concessions involved include bus companies as well as Light, the privately owned company in charge of supplying electricity to the city. "We focus on those organizations that are directly linked with citizen's wellbeing on an everyday basis," explains a COR directive (Interview, 2014).

The COR provides a new control capacity to monitor and manage infrastructural flows and ecological conditions on a 24/7 basis with a predictive capacity that enables the mobilization of emergency responses to severe disruption–in particular localized rainfall, flooding, and landslides. It enables infrastructural and ecological disruptions to be more effectively bounded and managed while wherever possible facilitating the maintenance of urban flows and circulations in the rest of the city, from, for example, transport flows and waste collection to trade and other key economic circulations. The city is increasingly managed as a logistical entity in which resilience is the ability to contain disruption and maintain urban circulations even under emergency conditions.

Given its extensive use of urban digital technologies, the COR is globally seen as an exemplar "smart city" initiative (The Guardian, 2014; New York Times, 2012) based on its ability to integrate and rebundle urban infrastructures and services through digital and communication technologies. But within the world of urban responses to climate change, it has also been hailed as an exemplar urban resilience strategy. Rio's COR features extensively in the literature of the Rockefeller Foundation's 100 Resilient Cities program (Rockefeller Foundation, n.d.). The municipality has designated the COR as the primary site from which the city's resilience strategy is to be designed and implemented, with the director of the COR acting also as the city's director of resilience. Transcending the notion of climate adaptation, the municipality embraces the idea of resilience "because this notion includes, but is not limited to, climate change. … [It] also incorporates social challenges, because a resilient city is one where citizens have access to basic services … [and where] economic, social and financial aspects are capable of faster recovery in case of a national or global crisis" (Prefeitura do Rio de Janeiro, 2015: n.p.).

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Case Study 4.A

Climate Change Adaptation and Mitigation for Hyderabad City, India

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Keywords	Heat, drought, water, mitigation and adaptation, population influx
Population (Metropolitan Region)	9,218,000 (United Nations, 2016)
Area (Metropolitan Region)	7,257 km^2 (Hyderabad Metropolitan Development Authority, 2016)
Income per capita	US$1,680 (World Bank, 2017)
Climate zone	BSh – Arid, steppe, hot (Peel et al., 2007)

Hyderabad is located in the north of the Deccan plateau, along the banks of the Musi River in South India. The size of the city is 250 square miles (650 km^2), with a topography of rocky terrain and predominantly gray granite. Hyderabad has many hills of varying altitudes ranging from 542 to 672 meters, and 140 large and small lakes in and around its neighborhood up until the 1970s. Recently, high population influxes have increased pressures on Hyderabad's infrastructure and resources. A population growth of 87.2% in 10 years has made Hyderabad the fourth most populous city in India. Together, these factors have led to serious climate change issues, which have been experienced mostly over the past 5 years. Major issues pertaining to climate change and probable solutions are detailed in this case study.

Population increases within the city, which add pressure to land and water resources, require strong management measures to be implemented by the state government. The growing population requires various types of infrastructure (facilities, transportation, etc.), which in turn increase the city's greenhouse gas (GHG) emissions.

Power Sector

Data from undivided Andhra Pradesh Central Power Distribution Company Limited (APCPDCL), Government of Andhra Pradesh, for 2012 show that the power requirements of Hyderabad city is approximately 2,000 megawatts (MW) in the summer and 1,400 MW in winter. To meet the demand for projected increases in the city's population by the end of the thirteenth Five-Year Plan period (2021–22), Hyderabad certainly needs to have dedicated power plants with a total installed capacity of 8,000–10,000 MW.

At present, APCPDCL data reveal that demand–supply gap for Hyderabad city remains between 2,000 and 2,350 MW. APCPDCL has implemented new rules to shut down its plants for certain fixed days every week. These steps lead to emissions reduction but also to huge loss for businesses and ultimately impact the economy. This adaptation strategy led to a reduction of 3,000 tonnes CO_2 emission per day (EF 0.76 tCO_2/MWh) from the Southern India grid (CEA, 2011).

The state government is spearheading major retrofits and maintenance of power distribution facilities. As an adaptation strategy, APPDCL is modifying 11 kV substations to 33 kV or higher level substations. This adaptation strategy for the power sector will lead to reductions in load loss, resulting in an efficient power supply and energy efficiency. The government is the driver of this adaptation strategy. Cities in other fast developing economies/least-developed countries can follow this strategy to reap the benefits of energy efficiency.

National Mitigation Strategies

Two national mitigation strategies from the central government are under implementation in all states in India:

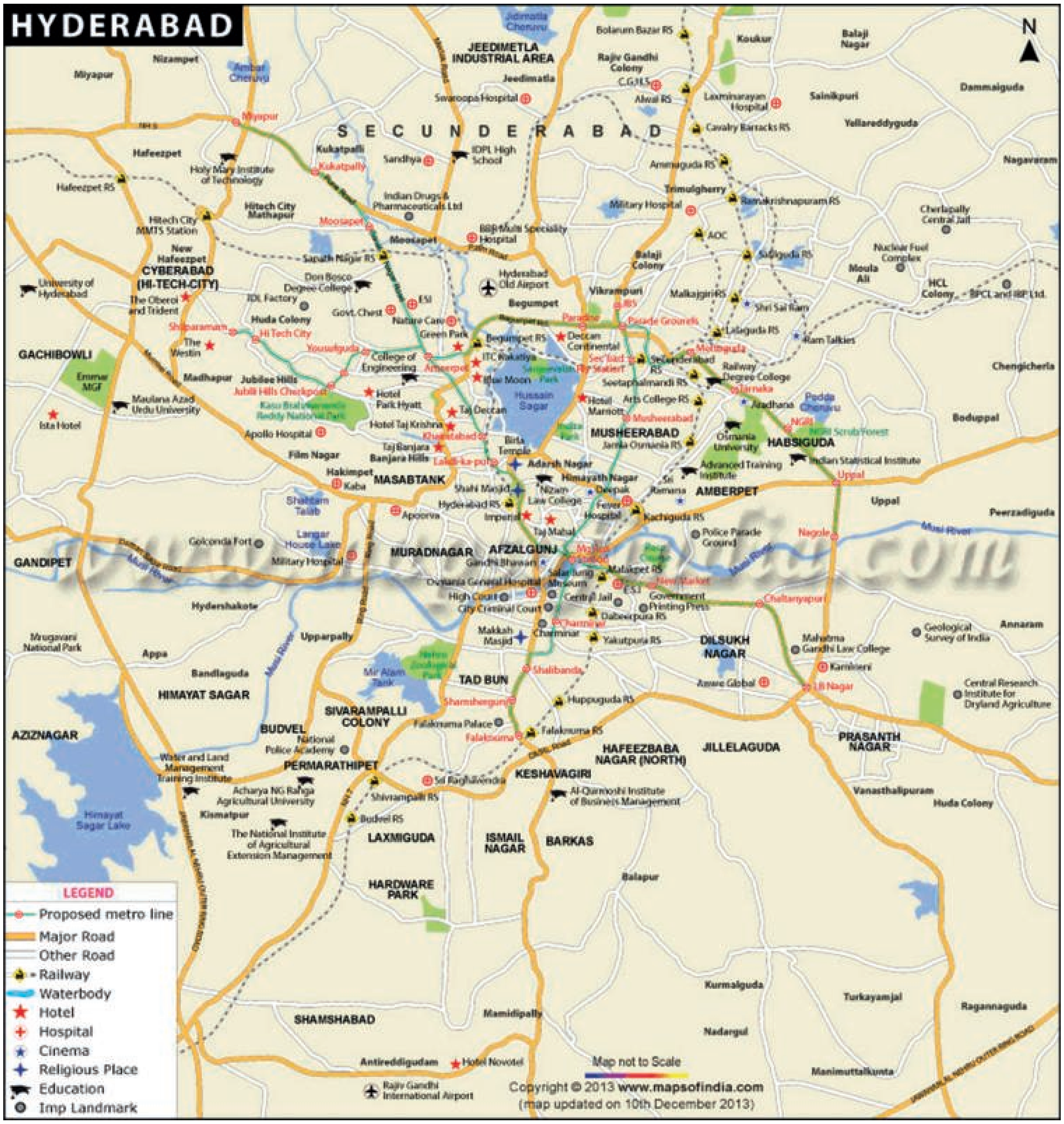
- National Solar Mission and its tradable product Renewable Energy Certificate
- National Mission on Energy Efficiency and its tradable product E-certs

Every power distribution licensee has been directed to meet a minimum 5% of energy demand through renewable energy resources (APERC, 2012); the program is initially planned for 2012–2017. This mitigation strategy can lead to a 5% GHG emission reduction that would otherwise have occurred from thermal power plants.

Roof top solar plants can make every house a power house, thus helping villagers to earn their livelihood/establish community business, help prevent crop loss (through solar water pumps), and improve the education of children because many villagers move to cities for access to electricity, jobs, and education. This adaptation strategy of providing power in villages may be helpful in reducing migration to cities. These strategies, if driven by government and communities together, will be helpful in preventing uncontrolled population influx into Hyderabad.

Strategic Urban Development

The improvement of the Hyderabad drainage system is crucial, especially due to the rocky terrain that prevents rainwater drainage and leads to floods in low-lying areas, traffic congestion, and vector borne diseases.



Case Study 4.A Figure 1 *City of Hyderabad with its infrastructure.*

Source: Maps of India, 2014

Hyderabad is undertaking the following adaptation strategies to combat the urban heat island (UHI) effect (Kleerekoper et al., 2012):

1. Kasu Brahmananda Reddy (KBR) national park in middle of the city, a declared reserved bird sanctuary
2. Fountains at cross-roads (wherever possible) to improve ambiance as well as help reduce the temperature.
3. Adjustment of building density in gated communities
4. Heat-reflective coatings are being promoted for use on home/building exteriors to help maintaining cool temperatures in homes/offices
5. The collection of rainwater (through channels under the footpath) into nearby bodies of water, an effective adaptation strategy for increasing/maintaining groundwater level in urban areas. (This is still to be implemented in Hyderabad.)
6. Sustainable water systems to supply trees with enough water to maximize their cooling ability and shallow canals to absorb and discharge heat are strategies being partially used in Hyderabad
7. Adaptation strategies like rainwater harvesting, installation of solar water heaters, and rooftop solar power to meet 3% of the total energy requirements are made mandatory by the state government for implementation in apartments

Discussion and Outcome

In Hyderabad, communities are driving adaptation measures, and mitigation measures are driven by industries at large. Hyderabad no longer has pure water for drinking or domestic use. Groundwater available at few places around the city is not suitable for drinking or domestic use without purification. Therefore, implementation of reverse osmosis plants for water purification or buying water for drinking purpose are basic necessities in any residential area in Hyderabad. Such crises call for the implementation of community-driven actions like rainwater harvesting in apartments, planting vegetation to the maximum extent possible, channelizing rainwater to enable groundwater recharge, and more, even though the rocky terrain of Hyderabad increases the difficulty of taking water-saving measures. Adaptation measures must drive industries to participate in the implementation of such activities outside their boundaries, maybe as a part of corporate social responsibility (CSR) activities.

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Case Study 4.B

São Paulo's Municipal Climate Action: An Overview from 2005 to 2014

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Keywords	Subnational climate policy, urban transport, mitigation and adaptation
Population (Metropolitan Region)	19,683,975 (IBGE, 2015)
Area (Metropolitan Region)	7,947 km^2 (IBGE, 2015)
Income per capita	US$8,840 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

São Paulo city, located in southeastern Brazil, is São Paulo state's capital and the largest urban conglomeration in South America, with a population of about 11.5 million inhabitants in 590 square miles (IBGE, 2014). In the past decades, the city's economic profile underwent deep transformation, from strongly industrialized to service and technology-oriented. São Paulo has the largest municipal economy in Brazil, with a gross domestic product (GDP) of approximately US$200 billion, 11.5% of the national economy (IBGE, 2011). The scale of these figures compares to those of entire countries such as Bolivia, Portugal, and Denmark.

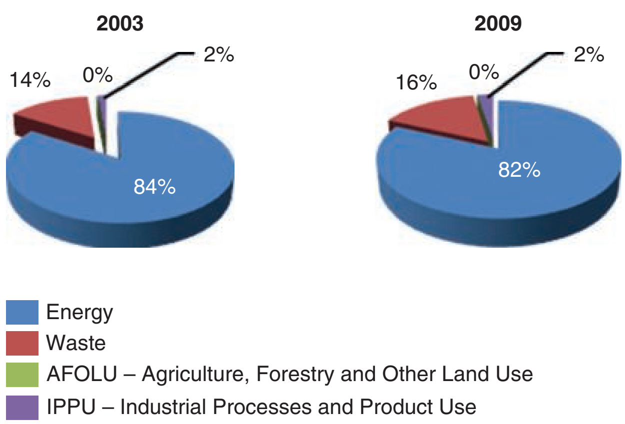
São Paulo pioneered local engagement in transnational climate networks (ICLEI's Cities for Climate Protection Campaign [CCP] and the C40 Cities Climate Leadership Group). The city's first greenhouse gas (GHG) inventory was undertaken within the CCP. It was published in 2005, considering 2003 as the baseline year. Results demonstrated that primary sources were road transport and waste management (UFRJ, 2005).

The second inventory revised the results of the 2005 report for 2003 and expanded the scope until 2011, focusing on energy and waste emissions. There was no significant variation in sources' contribution to the overall emissions of GHG of the city during that period (Instituto Ekos Brasil et al., 2013).

According to the inventory, emissions totalled 12.9 GgTCO_2e, 84% of which was generated by the energy sector and 15% by solid waste management. Road transport accounted for 88.78% of energy emissions, 68.6% of the total municipal CO_2 emissions, mainly from gasoline-powered passenger vehicles.

São Paulo was the first major city in Brazil to address climate change and adopt municipal regulation and implementation of local policies to reduce GHG emissions. The climate agenda was led by the city's Environment Secretariat, and the Municipal Climate Law (in 2009) stands as its most important milestone. It asserts that mitigation of and adaptation to climate change in the city will contribute toward Brazil's compliance with the United Nations Framework Convention on Climate Change (UNFCCC) objectives. It also establishes a mandatory reduction target of 30% of aggregate municipal emissions in CO_2e, by 2012, relative to the 2003 baseline reported in the municipal inventory published in 2005.

This target, however, proved too ambitious. According to the second inventory, GHG emissions increased by 8.7% in 2011 relative to 2003. National subsidies for car ownership and fossil fuel to address the global economic crisis have played an important role in expanding the car fleet in Brazil, especially after 2008 (INCT, 2013). São Paulo's fleet grew by 41%, from 3.35 million to 4.73 million, between 2003 and 2011 (Departamento Nacional de Transito, 2015).

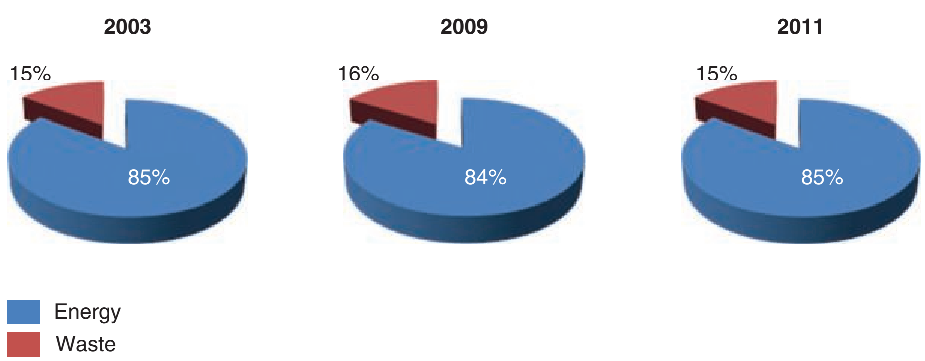


Case Study 4.B Figure 1 *Emissions by sector in the city of* São *Paulo, 2003–2009.*

Nonetheless, São Paulo developed policies to reduce GHG emissions, control local pollution, and generate revenue beyond the climate agenda (Puppim de Oliveira, 2009). The most successful example is methane gas recovery from landfill sites (United Nations, 2014). The city houses two of the world's largest landfill bio-gas power plants. The first methane-to-energy project began operating in 2004 to recover bio-gas from the Bandeirantes landfill and generate electricity at an on-site power plant (ICLEI, 2009). It was the first such project implemented in Brazil to obtain certified emissions reductions under the Clean Development Mechanism (CDM; UN, 2014; World Bank, 2011, 2012). In the first auction, held in September 2007, the transaction totalled about US$16 million. The other two auctions held in September 2008 and in June 2012 resulted in approximately US$17.5 million and US$2.3 million, respectively (BMF-BOVESPA, 2012).

Energy-efficiency projects begun in 2011 are expected to yield economies of more than 1.5 million KWh monthly by replacing incandescent lamps for LEDs in traffic lights and in tunnels, as well as in schools, hospitals, and other municipal buildings (PMSP, 2012b). Transport policies led to further local emissions reductions despite the growth in car ownership. Transport-related measures implemented between 2003 and 2011 resulted in reductions of 6.3% in local air pollutants, as well as 6.7% of CO_2e emissions, avoiding 7,835 tons of CO_2e per month. The *Ecofrotas* program begun in 2005 expanded the bus fleet using cleaner vehicles, with 1,200 new buses using bio-diesel, 60 buses using ethanol, and 319 buses using sugarcane diesel. Furthermore, the city invested in retrofitting and recovering the tram system of 190 vehicles, 92 of which are new, and it reopened an old tram factory in the city. Implementing bus corridors became a top priority for the new administration, which had added 150 kilometers to the system, with 36 kilometers being built by the end of 2014.

Adaptation measures are also required by the Municipal Climate Law as part of the strategy to reduce climate vulnerability in São Paulo (São Paulo, 2011). In 2010, the city began a program to expand waterfront parks through tree planting,



Case Study 4.B Figure 2 *Emissions by sector in the city of* São *Paulo, 2003–2009.*

Source: Instituto Ekos Brasil et al., 2013

Table 1 *Energy emissions (GgCO$_2$e) by subsector. Source: Instituto Ekos Brasil, Geoklock Consultoria e Engenharia Ambiental, 2013*

Sources/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Power	865	889	845	781	739	1,264	650	1,399	830
Industry	3,001	3,059	2,555	2,553	2,566	2,652	2,437	2,426	2,477
Transport	8,989	9,117	9,290	179	9,779	9,822	9,239	9,786	10,589
Fugitive[a]	57	0	0	30	29	122	59	31	94
Total	**12,912**	**13,065**	**12,690**	**3,543**	**13,113**	**13,860**	**12,385**	**13,642**	**13,990**

[a] The United States Department of Energy defines Fugitive Emissions as "the release of Green House Gases from pressurized systems" (USDE, 2015)

Table 2 *Emissions (in GtCO$_2$e) in* São *Paulo city, 2003–2011. Source: Instituto Ekos Brasil, Geoklock Consultoria e Engenharia Ambiental, 2013*

Sector/ Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy	12,911	13,065	12,689	12,544	13,114	13,860	12,384	13,642	13,990
Waste	2,199	2,260	2,335	2,474	2,658	2,307	2,363	2,445	2,440
Total	**15,110**	**15,325**	**15,024**	**15,018**	**15,772**	**16,167**	**14,747**	**16,087**	**16,430**

revitalizing 100 existing parks, and establishing a 1,320,000 hectare park in partnership with the private sector. The municipal housing authority expanded urbanization of shanty towns (*favelas*) and relocation of houses in risk areas (PMSP, 2012a).

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Case Study 4.C

Leuven Climate Neutral 2030 (LKN2030): An Ambitious Plan of a University Town

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Keywords	Baseline emission inventory, climate action plan, housing and transportation, adaptation and mitigation
Population (Metropolitan Region)	99,075 (IBZ, 2016)
Area (Metropolitan Region)	56.6 km² (IBZ, 2016)
Income per capita[a]	US$41,860 (World Bank, 2017)
Climate zone[b]	Temperate, without dry season, warm summer (Cfb) (Peel et al., 2007)

In 2011, the city of Leuven signed a Declaration of Intent to become "climate neutral" by 2030. It established the ambitious climate goal to cut greenhouse gas (GHG) emissions by 80% by 2030 compared to a 2010 baseline.[1] Although the concept of "climate neutrality" might not be scientifically sound,[2] it has been used successfully in several cities and provinces in Belgium to gather public and political support to implement strong climate action (Vandevyvere, 2014). Leuven Climate Neutral 2030 (LKN2030) has since evolved into a multiactor project and process, engaging a broad spectrum of stakeholders in order to collectively design transition paths to climate neutrality. First, a baseline emission inventory of Leuven was carried out, followed by a citywide project to create a roadmap for LKN2030. In 2013, the nonprofit organization Leuven Climate Neutral 2030 was founded, charged with overseeing the envisioned transition of Leuven.

Baseline Emission Inventory of Greater Leuven

The baseline for the emissions inventory was executed for 2010, the year with the most appropriate available data. For LKN2030, only scope 1 (direct emissions) and scope 2 (indirect emissions from imported energy) emissions were quantified and considered. Scope 3 emissions (indirect emissions from imported goods and services) were qualitatively assessed.[3] In 2010, Greater Leuven emitted 808,000 tons of CO_2eq or 8.5 ton CO_2eq per capita (scope 1+2) (Vandevyvere et al., 2013: 41–58).

Leuven has a strong knowledge-based economy and almost no industry or agriculture. As a result, building-related emissions (household and tertiary sector) amount to nearly 60% of total GHG emissions. Together with transport emissions, they make up 82% of GHG emissions in Leuven. Transition scenarios therefore focus on the renovation of the existing building stock, on greening the energy supply, and on switching to sustainable transport modes (Vandevyvere et al., 2013).

A Scientific Roadmap to Climate Neutrality

Following the Baseline Emission Inventory, a roadmap project was launched, structured along an explicit, combined top-down and bottom-up approach to ensure and maximize public support. The bottom-up process consisted of six thematic groups (energy; built environment; mobility; consumption; agriculture and nature; participation, public support, and transition), each with around fifteen people from civil society, city departments, local businesses, and the university. Simultaneously, there was the local "G20," a transition group with twenty key decision-makers from knowledge institutions, enterprises, local government, and civil society that developed top-down high-level strategies for the city of Leuven. This combined process was supposed to build the necessary local knowledge, create widespread public support for the project, and have a real policy impact (Jones et al., 2012). Both top-down and bottom-up approaches were coordinated by a scientific team of Leuven's University, which simultaneously served as communication link between the two approaches. All the recommendations were combined into a final scientific report (Vandevyvere et al., 2013). In total, some 200 people were active in different sections of the roadmap project. The goal was to shift the process from the city government and the university – the initiators of the process – to a citywide participatory process among civil society, businesses, the university, and the city since participatory processes are vital for building support for the plan and realizing its long-lasting success (Vandevyvere, 2014).

The scientific report made a distinction between immediate and long-term actions and used different scenarios: business-as-usual, Leuven Climate Neutral by 2030, or by 2050. The report focused on five sectors (residential buildings, nonresidential

1 These goals were adjusted to GHG reductions of 67% by 2030 and 81% ("climate safe") by 2050, after the scientific report of LKN2030.
2 The concept of "climate neutrality" generally indicates a GHG emission reduction target of 80% or 90%.
3 Scope 3 emissions are estimated at 2,440,000 tons of CO_2, eq

buildings, mobility, nature and agriculture, and energy) and proposed a list of recommendations, concrete measures, and projects for each sector to reduce GHG emissions. For each measure, the reduction in GHG emissions and economic gain/cost was quantified. Some examples of measures proposed are: five refurbishment "waves" to stepwise retrofit the complete building stock of Leuven, starting with the oldest buildings; a modal shift to 33% bike, 33% public transport, 33% car mobility by drastically improving public transport and bike infrastructure and making the city center completely car-free; and the deployment of renewable energy technologies.

The report concludes that, when all sectors are considered simultaneously, aggregated emission cuts of 55% and 67% are possible by 2030 and 2050, respectively. This would lead to a net profit of €39 (US$46) million per year and €34 (US$40) million per year for 2030 and 2050, respectively. These projections include GHG emissions from local industry, a sector that was not considered for intervention in the report. When GHG emissions of local industry are omitted, the LKN2030 and 2050 scenarios lead to a reduction of 67% and 81%, respectively. This means that a climate neutral scenario can be reached by 2050 starting from the proposed LKN-scenarios of the report.

The final recommendation of the scientific report was to formalize LKN2030 into a long-lasting organization. The nonprofit Leuven Climate Neutral 2030 was established by sixty city stakeholders in 2013. The mission of this organization is to inspire, inform, measure, and facilitate and to involve partners and activate them in regards to Leuven's transition to climate neutrality. In 2013, the organization also launched the public campaign Mission Zero Emission, aimed at increasing the visibility of LKN2030 and putting several initiatives in the spotlight (see Case Study 4.C Figure 1).

In 2015, the Board of Experts – counting ten climate specialists – was charged with translating the scientific report into explicit, yearly operational targets for the nonprofit organization and its partners. At present, some twenty preferential projects have been formulated as transition experiments, and appropriate stakeholders and financing schemes have been identified (Vandevyvere et al., 2015).

Lessons Learned

Several aspects proved vital for establishing a transition project with reasonable chances for success: the scientific support given by the local university, securing engagement from stakeholders and public support by fostering shared ownership in order to gain the required momentum, opening the way for practical implementation through concrete measures and projects, monitoring GHG emissions, and establishing appropriate financing and communication mechanisms. Securing these operational aspects remains a continuous struggle for LKN2030 (Vandevyvere, 2014). Innovation capacity, shared enthusiasm, tangible engagement, and a good balance between bottom-up and top-down actions are promising conditions for the future of LKN2030. Challenges to this optimism are lack of financial input, built-in structural barriers, and the dictates of short-term agendas. Empowerment and leadership now play an important role to secure the success of LKN2030.

Case Study 4.C Figure 1 *Image of public campaign Mission Zero Emission on the Ladeuze square in Leuven (translation: "Insulate with us 500,000 m² of Leuven roofs, 50 times the area of the Ladeuze square, so we save €3 (US$3.5) million each year!").*

Photo: Robbe Maes

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Case Study 4.D

The Challenges of Mitigation and Adaptation to Climate Change in Tehran, Iran

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Keywords	GHGs emission, land-use management, mitigation and adaptation
Population (Metropolitan Region)	8,516,000 (United Nations, 2016)
Area (Metropolitan Region)	1,632 km^2 (Demographia, 2016)
Income per capita	US$6,530 (World Bank, 2017)
Climate zone	BSk – Arid, Steppe, cold (Peel et al., 2007)

Climate change is one of the most important challenges of our time. Climate change is mainly caused by the emission of greenhouse gases (GHG), with a significant contribution from fossil fuel consumption in urban areas. In this case study, we investigate the experience and challenges in reduction of GHGs emissions and adaptation to climate change impacts in Tehran Metropolis. Climate change solutions in a centralized planning system such as Iran need multilevel governance and lifestyle changes. These changes are related to sustainability of local communities and many aspects of urban life.

Due to the fossil fuel base of production, distributions, and consumption patterns in Tehran metropolis, as well as the related lifestyle, GHG emissions per capita are very high, making it the largest source of this kind of emissions in Iran. The results indicate that the building sector (residential, commercial, and administrative buildings) is the most important emitter of carbon dioxide (CO_2) at 21 million tons (Table 1). The consumption of natural gas is the major cause of CO_2 emissions in the building sector.

The second source of CO_2 emissions is urban transportation (14 million tons CO_2). Car-driven land-use planning is the major factor for GHGs emissions, a factor caused by overemphasis on separation of work-residence-leisure activities. This, in turn, has led to 1.5 trips generated for each person and almost 17 million trips a day in Tehran. Bearing in mind the dominance of private

Table 1 *Carbon dioxide emission by sectors in Tehran Metropolis. Source: Tehran Urban Planning and Research Center, 2011*

Sectors	Million tons	Percent	Per capita emission
Residential, commercial and administrative buildings	21	44.3	2.73
Industry	6.9	14.6	0.89
Transportation	14.2	29.9	1.84
Agriculture	0.40	0.9	0.05
Power plants	4.4	9.3	0.57
Other	0.44	1.0	0.06
Total	47.5	100	6.2

cars, the impacts are intensified by the increase in the number of pollutant days and expansion of urban heat island.

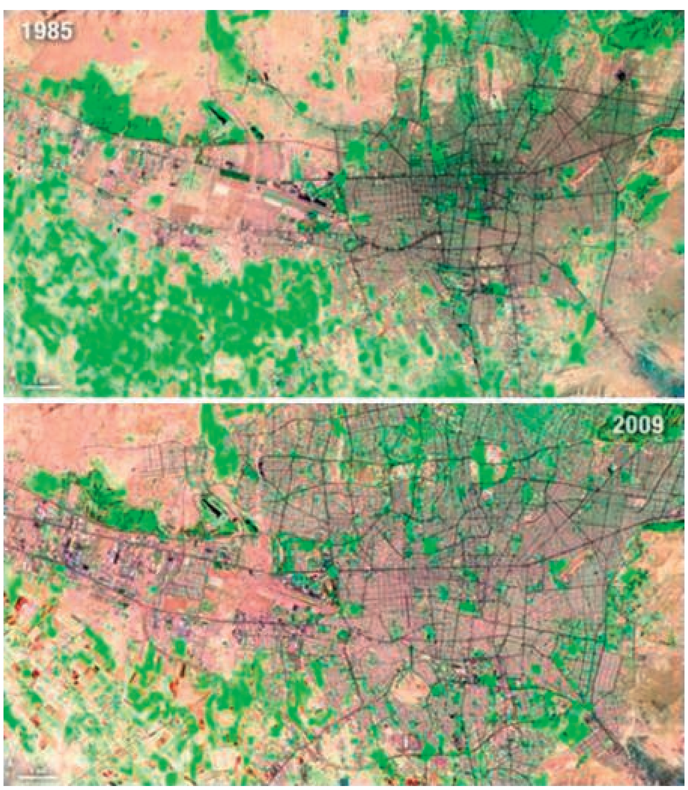
Nevertheless, there are successful actions that have reduced air pollution and GHG emissions in Tehran Metropolis. For example, Tehran urban management has expanded public transportation in recent years. Tehran has 160 kilometers in 5 subway lines with 110 stations. Bus rapid transit (BRT) is another example of sustainable action in the public transportation sector. Tehran has 114 kilometers of BRT in 10 lines with 237 bus stations (Table 2).

Table 2 *Climate change mitigation actions in the transportation sector. Source: Tehran Municipality, 2015*

Transportation sectors	Length (kilometer)	Number of lines	Number of stations
Subway	160	5	110
Bus Rapid Transit (BRT)	114	10	237

Table 3 *Area of built environment changes (hectares). Source: Tehran Urban Planning and Research Center, 2011*

Built area (2010)	Built area (2002)	Built area (1988)	Built area
37,411	30,871	22,790	Hectare



Case Study 4.D Figure 1 *Land use change and green space reduction in Tehran.*

The most important challenge for Tehran urban management in tackling climate change is land-use change and built environment expansion. The area of built environment increased from 22,790 hectares in 1988 to 37,411 hectares in 2010 (Table 3). Rapid urbanization; car-driven land-use planning; and urban management policies such as changes of land-use regulations, expansion of informal settlements, and migration from other parts of the country are the main factors for this change in Tehran Metropolis.

Between 1985 and 2009, the population of Tehran grew from 6 million and to just over 7 million. The city's growth was spurred largely by migration from other parts of the country. In addition to being the hub of government and associated public-sector jobs, Tehran houses more than half of Iran's industry.

Landsat 5 provided false-color images (see Case Study 4.D Figure 1) of Tehran on August 2, 1985 and July 19, 2009. The city is a web of dark purple lines: vegetation is green and bare ground is pink and tan. The images were created using both infrared and visible light to distinguish urban areas from the surrounding desert.

Conclusion

The essential guidelines to reducing GHG and adapting to climate change encompass two categories: (1) The reduction of GHGs by revision of land-use management and zoning by-laws in light of urban sustainability principles and (2) the adaptation to climate change through a reliance on local community assets in the framework of community-based adaptation approach. Tehran urban management strengthens neighborhood management units and subcouncils at the local scale for sustainable community development. The needed radical change in urban lifestyle for coping with climate change impacts cannot be achieved solely by top-down actions. Although considerable efforts have been done by urban management relating to the expansion of public transportation, still extensive measures in all other urban planning dimensions should be taken along with lifestyle changes.

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Case Study 4.E

Managing Greenhouse Gas Emissions in Rio de Janeiro: The Role of Inventories and Mitigation Actions Planning

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Keywords	GHG emissions, local initiatives, mitigation strategies
Population (Metropolitan Region)	11,835,708 (IBGE, 2015)
Area (Metropolitan Region)	5,328.8 km² (IBGE, 2015)
Income per capita	US$8,840 (World Bank, 2017)
Climate zone	Am – Tropical monsoon (Peel et al., 2007)

Rio de Janeiro's Experience

In a pioneer action seen in Brazil and Latin America, Rio prepared in 2000 the first greenhouse gas (GHG) inventory for a city. This study was based on data collected from 1990, 1996, and 1998 (Dubeux and Rovere, 2007). The main methodological challenge was adapting the International Panel on Climate Change (IPCC) Guide to consider emissions resulting exclusively from the socioeconomic activity of the city (Neves and Dopico, 2013; Dubeux, 2007). Another issue was the data collection itself, which was highlighted by the researchers as the most difficult part of the inventory. The problems not only involved being unable to contact a single responsible sector (local, state, or national), but also discrepancies because the data obtained varied at different governmental levels.

In January 2011, Rio enacted Law No. 5248 establishing the Municipal Policy on Climate Change and Sustainable Development (PMMCDS, in Portuguese). Article Number Six states the city's commitment to reduce GHG emissions by 8%, 16%, and 20% in 2012, 2016, and 2020, respectively, compared to the level of emissions from the city in 2005 (Carloni, 2012).

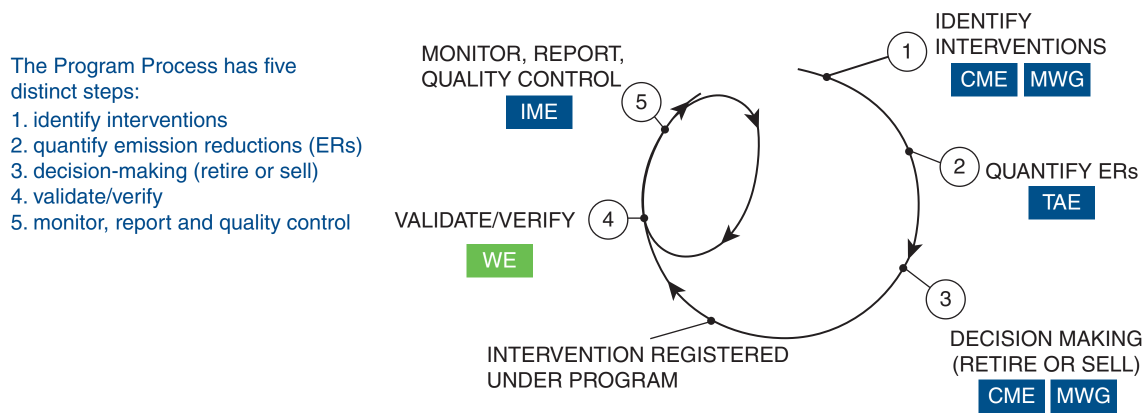
To understand and quantify these goals in terms of volume of GHG emissions, the city conducted a new emission inventory for the year 2005 (Rovere et al., 2012) and updated the previous one. With the purpose of trying to understand how the economic sectors and actions of the city's government could contribute to this reduction, a study of emissions scenarios was also developed for the period 2005–2030 (Rovere et al., 2012). In 2013, the city completed the 2012 inventory and updated the 2005 numbers.

In 2011, Rio, in partnership with the World Bank, developed the Rio de Janeiro Low-Carbon City Development Program with the purpose of tracking the performance of policies and actions with the potential to mitigate emissions (World Bank, 2012). This program allows accomplished reductions to be accounted for in order to monitor, record, and verify achievement of the targets set in PMMCDS and also to certify them for possible commercialization in carbon markets. The International Organization of Standardization (ISO) certifies this program by ISO 14001 and ISO 14064.

The program is structured on two important pillars: (1) Program Roles and (2) Processes for Program Planning and Evaluation. Each new activity that reduces emissions – called an intervention – goes through the same five-step Program Process. This procedure ensures the viability of replicating this initiative in other cities.

Table 1 *The roles of Rio Low Carbon City Development Program. Source: World Bank, 2012*

Fixed Assignments
Coordinating Management Entity (CME): The CME is the central body within the municipality that oversees the coordination and management of the program. Fulfilling this role in Rio is the Mayor's Office (known as "Casa Civil").
Information Management Entity (IME): The IME is the central body that coordinates and manages all information and data related to the Program. The IME must ideally have both coordinating capabilities with all municipal departments and experience in collecting and managing large quantities of data. Fulfilling this role in Rio is the Instituto Pereira Passos (IPP).
Variable, Intervention-linked Assignments
Multisector Municipal Working Group (MWG): The MWG is a working group consisting of members from across the municipality with multiple areas of relevant expertise. It acts as an advisory committee to the CME. The composition and attendance of the MWG may vary from intervention to intervention, but it will always be coordinated by the CME.
Technical Advisory Entity (TAE): The TAE is an entity or consultant with technical expertise in the quantification of emission reductions.
Validation and Verification Entity (VVE): The VVE is an ISO-accredited environmental auditor. It validates and verifies the emission reductions generated by interventions under the Program. For any given intervention, the TAE and VVE must not be the same entity to ensure integrity in the audit process and avoid conflict of interest.



Case Study 4.E Figure 1 *Five steps of the Program process.*

Source: Reproduced with permission from World Bank, 2012

Table 1 explains the roles of groups assigned to carry out the program.

The Program Process advises on the procedures and criteria against which interventions are assessed, as well as on the process of monitoring, reporting, and verifying emission reductions generated by interventions. The Program Process steps are presented in Case Study 4.E Figure 1.

Conclusion

The GHG inventory process is not intended to be an end in itself, but rather a tool for monitoring emissions and a basis for developing strategies to reduce GHG emissions. Quantifying the emission reductions of different mitigation actions can be complex and expensive, but following other cities' examples and using their strategies as base points is a good start.

In this sense, Rio de Janeiro's experience can be helpful. The PMMCDS and Rio's Low Carbon City Development Program may be studied and replicated, and more information will be aggregated if other cities use this pioneering program.

It is important to ensure comparability among different studies from different cities and help promote cooperation among them in mitigation and adaptation to climate change. Therefore, it is necessary to bring all actors together in order to compare experiences and optimize efficiency and tools.

By promoting these associations and the exchange of experiences, cities can be supported by programs and organizations that promote partnership and collaboration. One example is the C40 Cities Climate Leadership Group, a group that connects more than seventy-five of the world's greatest cities, and where the current chair is Rio de Janeiro Mayor. ICLEI—Local Governments for Sustainability is another example of a network connecting cities, towns, and metropolises that are interested in building a more sustainable future. United Cities and Local Governments (UCLG) is another example of how cities are engaged in together and enhancing their experiences.

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Case Study 4.F

Climate Change Adaptation and Mitigation in Sintra, Portugal

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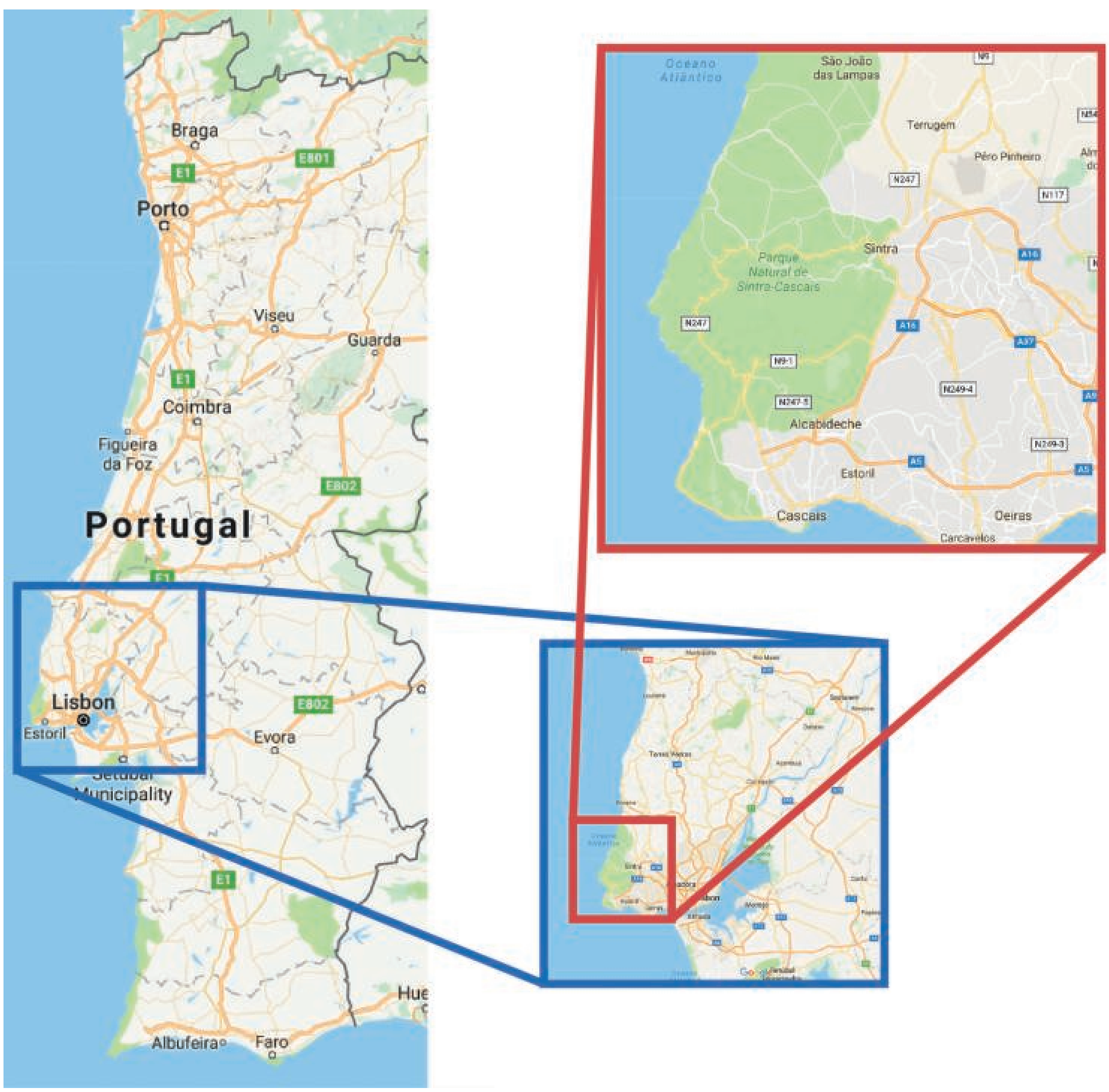
Aalborg University

Keywords	Adaptation, mitigation
Population (Metropolitan Region)	2,812,678 (Statistics Portugal, 2015)
Area (Metropolitan Region)	3,015.24 km² (Statistics Portugal, 2015)
Income per capita	US$19,850 (World Bank, 2017)
Climate zone	Csa – Temperate, dry summer, hot summer (Peel et al., 2007)

The municipality of Sintra is located northwest of the capital city of Portugal (see Case Study 4.F Figure 1) and is known for the fairytale scenery of the Natural Park of Sintra. Due to the close connection between nature and culture, Sintra is classified as World Heritage Cultural Landscape (UNESCO, 2016). This makes Sintra an important tourist area in the metro region of Lisbon. Nevertheless, Sintra also has dense urban areas, with more than 375,000 people living in the municipality.

The local government of Sintra expects that the major impacts of climate change in its territory will result from changes in temperature. It is expected that, by 2100, the average daily temperature in Sintra will be 2–3°C higher in the winter season and 5–10°C higher in the summer season in comparison to the current average daily temperatures (Aguiar and Domingos, 2009).



Case Study 4.F Figure 1 *Sintra Municipality location and territory.*

These values may show a spatial variation, being slightly higher in the urban areas (particularly during summer) than in the coastal area of Sintra. Heat waves (with temperature exceeding 35°C) are also expected to be more frequent and longer-lasting in the future (Aguiar and Domingos, 2009).

A consequence of this rise in daily and extreme temperatures is an increased risk of forest fire. In Portugal, the estimated annual cost associated with forest fires is between €60 (US$70.8) million and €140 (US$165.3) million. Apart from the associated costs, forest fires represent a major problem for the municipality because of the great ecological and cultural value, both regionally and nationally, of the Natural Park of Sintra. Case Study 4.F Figure 2 shows the location of the Park in the territory of Sintra. This is a vulnerable zone in matters of forest fires.

Climatic scenarios suggest that, in 2100, the risk of forest fires in Sintra will be 65–100% higher than the present situation (SIAM, n.d. b). The risk of fire is also related to vegetation. Increasing average temperatures have impacted the type of vegetation found in Serra de Sintra. Higher temperatures encourage the proliferation of shrub vegetation, which is prone to combustion (SIAM, n.d. b). Fires in Serra de Sintra are of major concern for the municipality since fire puts at risks not only local populations but also tourists and historic monuments. More than 1 million people visit Sintra's monuments annually. This number is expected to rise with the increased number of warm days (Fundação da FCUL, 2009).

Concerned with these predictions, and in order to reduce the territory's vulnerability to forest fires, the municipality has engaged in climate change mitigation and adaptation planning in its territory. The local government of Sintra has been the key driver in developing climate change strategies for the municipality. Sintra's government considers that it is beneficial to the municipality to have an adaptation and mitigation strategy focused on a regional and local level because, even though climate change is a global issue, its impacts are felt locally (Santos, 2009).

The municipality is collaborating with several partners. The local government collaborates with the CCIAM research group (from the Faculty of Sciences of University of Lisbon) and other institutes, such as the Authority of Civil Protection and the Portuguese Environment Agency, carrying out studies (at a national and regional level) relevant to Sintra's territory. The CCIAM research group is the major partner. The group elaborated a Strategic Plan for the municipality of Sintra to face climate change (PECSAC) by request of the local government of Sintra (SIAM, n.d. a). The plan, adopted in 2009, focuses on the most relevant sectors of the municipality: water resources, coastal areas, biodiversity, forest, agriculture, tourism and leisure, and human health. To further develop PECSAC, climatic and socioeconomic scenarios were used to elaborate an integrated and multisectoral methodology to evaluate impacts and propose adaptation actions to face climate change, following the methodology of the Intergovernmental Panel on Climate Change

Case Study 4.F Figure 2 *Serra de Sintra.*

(IPCC). The Special Report on Emissions Scenarios (SRES) were, however, not used when planning adaptation actions (Martins, personal communication, February 2015).

After the assessment and identification of vulnerabilities and risks, a list of adaptation measures and processes were set to better prepare the territory and population for the impacts of climate change foreseen in the scenarios. One adaptation measure suggested education of and increased awareness by citizens and tourists in order to prevent behaviors that may increase the risk of fire. The next step in the Sintra adaptation plan is the implementation of the adaptation actions suggested and the involvement of key stakeholders (from the public and private sectors). The final step in Sintra's methodology is the monitoring and evaluation of the actions and adjusting the adaptation strategic plan (Santos, 2009). This is a dynamic process, evolving over time as new data and answers arise.

The mitigation goals of the municipality follow the national goals set by the Kyoto Protocol and the international goals to limit, on a global level, the increase in world temperature to 2°C (Santos F. D., 2009; Aguiar and Ferreira, 2009). Sintra's mitigation strategy focuses on energy efficiency and carbon sequestration actions. The municipality intends to reduce global GHG emissions by implementing local initiatives and by synergies with national policies and measures (SIAM, n.d. c). The mitigation actions proposed by Sintra focus on topics that cross municipal sectorial boundaries, such as buildings, mobility, urban planning, behavior, and renewable energies (biomass and bio-gas) (Santos, 2009).

Sintra's adaptation and mitigation strategic plan is not an isolated project. PECSAC takes into consideration other existing national, regional, and local strategic plans (Santos, 2009), and PECSAC is also integrated into other municipal plans (Martins, personal communication, February 2015).

The municipality is committed to having a strong impact in the adaptation of Portuguese cities to climate change. Sintra collaborates with the ClimAdaPT.Local project (do Vale, 2015), which is a network in which stakeholders share knowledge and experiences with the aim of supporting the development of climate change adaptation strategies at a local level. Sintra, having already adopted a climate change adaptation and mitigation strategic plan, will support other municipalities' work during the project (ClimAdaPT.Local, 2015)

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Case Study 5.A

Urban Regeneration, Sustainable Water Management, and Climate Change Adaptation in East Naples

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Keywords	Water, hydro-geological risk, flash floods, urban regeneration, Sustainable Drainage Systems (SuDS), adaptation plan
Population (Metropolitan Region)	3,114,000 (SVIMEZ, 2016)
Area (Metropolitan Region)	1,023 km^2 (Demographia, 2016)
Income per capita	US$31,590 (World Bank, 2017)
Climate zone	Csa – Temperate, dry summer, hot summer (Peel et al, 2007)

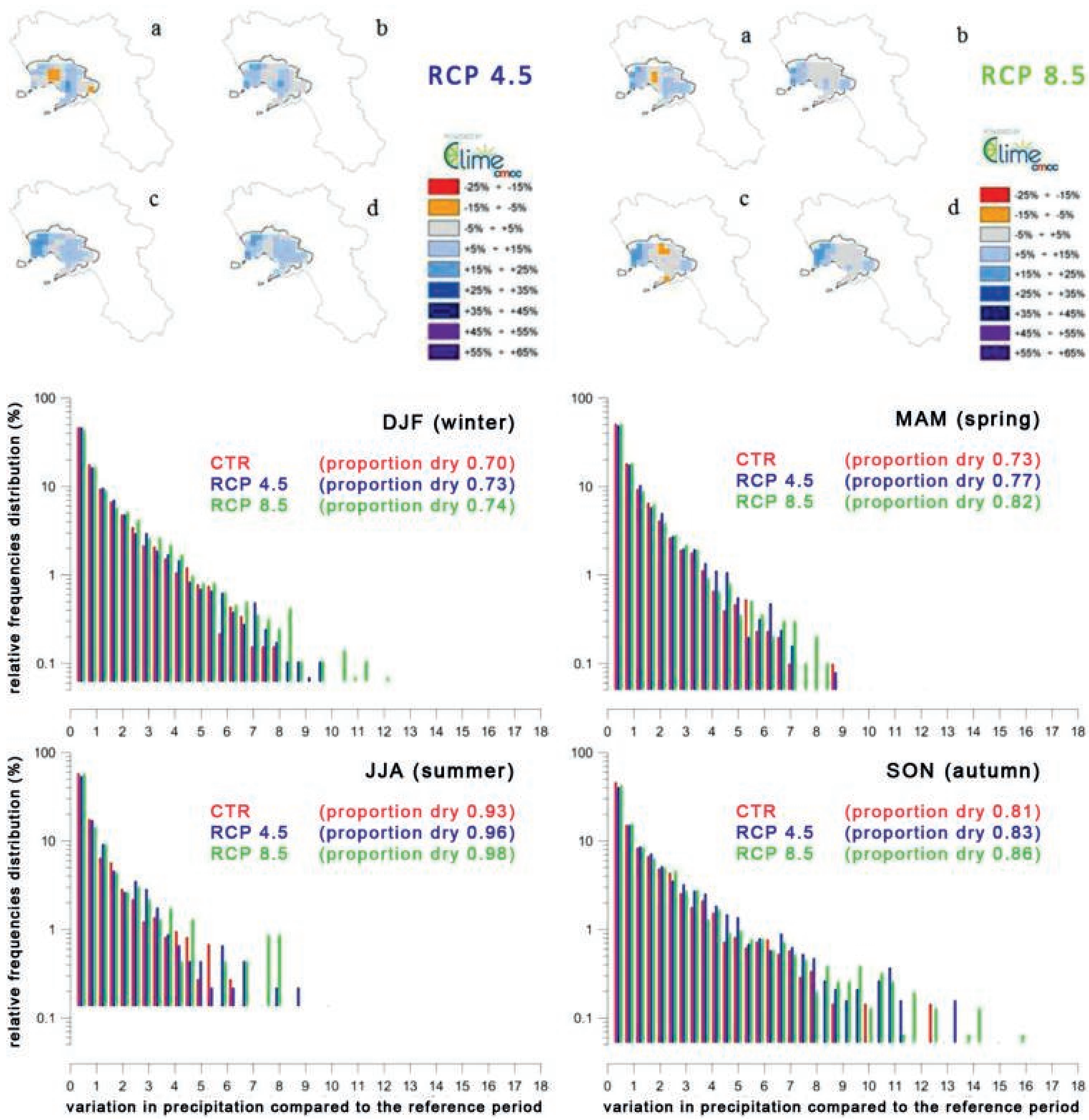
East Naples (Napoli), the main expansion area of the Metropolitan City of Naples (about 5 million people, density 2,172 inhabitants per square kilometer (SVIMEZ, 2014), is situated on the alluvial plane of the old Sebeto River (now flowing underground), from the Volla basin (North East) to the Naples port seafront (South). The area is framed on the northwest by the Capodimonte Hill and on the southeast by the Monte Somma-Vesuvio mountain system. Rainwater coming from the hill systems flows almost entirely in the area of the floodplain due to extensive soil sealing following the expansion of the Naples metropolitan area. The reduced depth of the aquifer, combined with high runoff, exposes the entire area to significant hydro-geological risk conditions amplified by increasing extreme precipitation events, thus requiring a more efficient management of flash flood risk.

The shutting down of industrial sites that in the past drained significant amounts of water from the aquifer is "renaturalizing" a traditionally swampy territory, and underground water is increasingly invading foundations, tunnels, and subway areas. Violent tropical-like storms are growing in number and intensity in recent years, and their effects are strongly amplified by urban sprawl. In 2014, two major events struck the area, in June and October, with severe consequences on the built environment and the economy.

Increasing impacts are connected to damage to transport networks and to frequent business interruptions due to flooding of building ground levels hosting productive activities or warehouses, as well as to the reduction in property values due to the risk-proneness of the area. This is leading to significant weaknesses in the implementation of territorial redevelopment plans. Other important impacts have been experienced in the agriculture sector, with large damages to crops and resulting in significant losses in local gross domestic product (GDP).

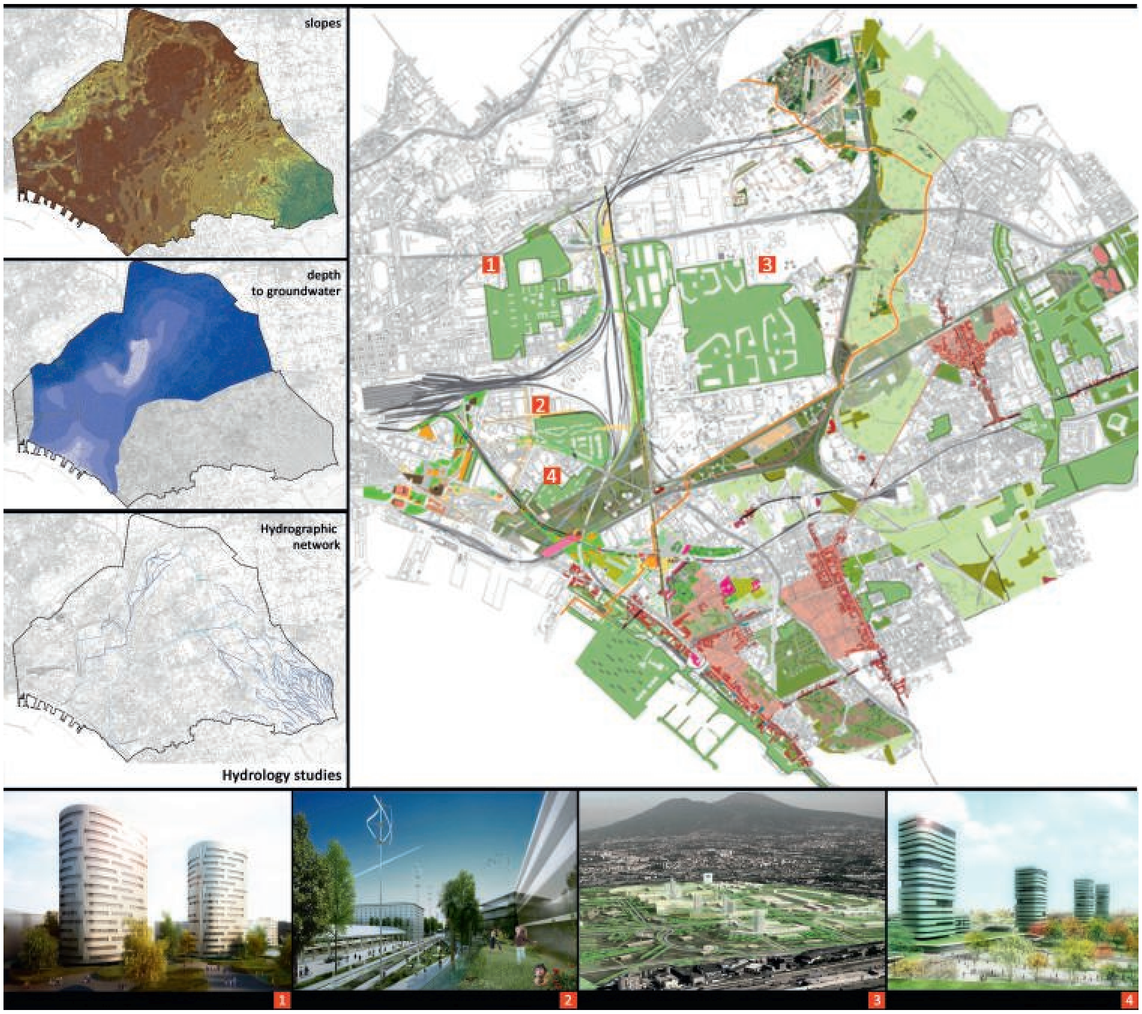
East Naples is experiencing important territorial and urban redevelopment processes. Large public investments are planned in the area (of about €740 (US$873.8) million), and brownfield redevelopment is the object of several projects for new mixed-use districts in former industrial areas through the NAPLEST committee (Comitato NaplEST, 2012).

The many issues connected to hydro-geological risk represent a critical factor for public and private investments, and cost-effective adaptation strategies are required to reduce physical and economic impacts in the mid to long term. The complexity of the design and governance processes require a thorough assessment of alternative technological options and design/planning scenarios at building, urban, and territorial scales, supported by multicriteria and cost-benefit analyses, as a key aspect to address public administration policies and to regulate private initiatives.



Case Study 5.A Figure 1 *Extreme precipitation scenarios for the period 2021–2050 in Naples Metropolitan Area developed by Euro Mediterranean Centre for Climate Change (CMCC), downscaled according to the RCM COSMO CLM (www. clmassembly.com) through CLIME software. Results, developed for subdaily (a-6h; b-12h; c-24h) and daily (d) scales, show increased extreme events in the autumn-winter season compared to the reference period 1971–2000, of 20% for the RCP 4.5 emission scenario and 40% for RCP 8.5, respectively.*

Source: AdBCC, 2014



Case Study 5.A Figure 2 *Hydrology studies, adaptation plan, and urban regeneration projects in East Naples area.*

Source: UNINA-NAPLEST

The extent of the challenge has created a unique opportunity for a strong multidisciplinary network of different actors at the local level, where local authorities, researchers, and businesses play an active role as action/policy drivers of climate change adaptation. The main stakeholders of this process – Municipality of Naples, Central Campania River Basin Authority (AdBCC), Department of Architecture (DiARC) and PLINIVS-LUPT Study Centre of the University of Napoli Federico II, the Technological District for Safety and Sustainability in Construction (STRESS Scarl), Fintecna (a major public real estate holding company), and Napoli Builders Association (ACEN) – have been committed to identifying adaptive planning and design solutions for the redevelopment of the area, addressing climate change adaptation objectives within the planned urban regeneration investments.

These activities included both hazard and impact modeling based on climate change scenarios for both urban and building design strategies.

Joint efforts by AdBCC and UNINA resulted in the release of the Plan for Hydrogeological Risk-Prone Areas or PSAI (AdBCC, 2014), a unique tool for safeguarding and mitigating risk in the territory through the definition of local guidelines and standards and by updating a previous (2007) version of the plan. The approach is based on the development of supporting tools compatible with models and tools employed by AdBCC, such as the application of CLIME software (developed by Euro-Mediterranean Center for Climate Change [CMCC]) to define 30 years of extreme precipitation simulations in the area based on alternative RCP scenarios. The integration of these simulations within the urban and building design actions allowed a more comprehensive approach to the mitigation of hydro-geological risk and adaptation to extreme precipitation events, thus strengthening the connections among climate science, governance policies, and planning/design solutions.

A more thorough understanding of climate change processes in the area has determined the need to review planned and ongoing urban regeneration actions, thus highlighting weaknesses in conventional approaches (Moccia and Palestino, 2013; Palestino, 2013; Russo, 2012):

- Lack of coordination between sectoral plans and municipal/regional urban and territorial planning (often limited to regulatory advice and not translated into effective local environmental planning and policy actions)
- Persistence of a conflict between municipal and higher level European Union (EU) and Regional planning (the former often based on prescriptive regulations on land, the latter reflecting key environmental issues)
- Experimentation and implementation of good practices for sustainable and adaptive design, such as the redevelopment of the Manifattura Tabacchi area (design by Mario Cucinella Architects), are likely to be undermined if not included in a network-based planning and governance perspective
- “Green infrastructure thinking” needs to be assumed as a guiding principle in municipal and regional planning, with an awareness of the costs and public investment needed

The following measures have been addressed by the NAPLEST Committee and technical advisors from UNINA, focusing on resilience-based design strategies:

- Nearly zero energy standards for new buildings
- Adaptive retrofitting of the existing building stock (buildings and open spaces) through envelope retrofitting (mechanical strengthening, wastewater reduction, etc.) and sanitation systems retrofitting (rainwater harvesting, recycling and reuse of gray water, etc.)
- Sustainable drainage systems (SuDS) implementation, such as permeable paving, stormwater detention, and infiltration solutions
- Evapo-transpiration increase through vegetative surfaces by building green and blue-green infrastructures (bicycle paths and pedestrian areas, green roofs and facades, etc.)
- Technological options and functional-spatial layouts for ground and underground floors of buildings (e.g., pilotis[1], nonresidential uses, water discharge solutions)
- De-sealing of outdoor surfaces and implementation of SuDS for infiltration and rainwater retention, runoff reduction, etc.
- Improvement of wastewater network
- Protection of transport networks and integration of blue and green infrastructures (e.g., greenways, green buffer zones, technical solutions for roads and highways based on surface draining and runoff control)

Lessons learned from the East Naples Case Study show the effectiveness of a networking approach based on knowledge exchange among decision-makers, academics, and practitioners, where assessment tools and cost-effective technological solutions developed through research and decision-support activities allow the integration of climate change adaptation pathways into brownfield and urban regeneration processes.

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1 A piloti is an architectural term referring to posts that support a building, enabling the ground floor to be open for other uses (Grieve, 2007).

Case Study 5.B

Realizing a Green Scenario: Sustainable Urban Design Under a Changing Climate in Manchester, UK

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Keywords	Heat island effect, green space, surface temperature modelling, planning and design
Population (Metropolitan Region)	2,732,854 (Office of National Statistics 2015)
Area (Metropolitan Region)	1,276 km² (Office of National Statistics, 2015)
Income per capita	US$42,390 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Executive Summary

Climate change impacts are exacerbated in urban areas by the urban heat island (UHI) effect, which intensifies risks associated with high temperatures to urban populations and infrastructure. Increasing green space, especially in densely built-up areas, is a valuable adaptation response to climate change and addressing the UHI effect. Vegetation influences the microclimate of an urban area, acting to reduce local temperatures through direct shading, evapotranspiration, and storing and reradiating less heat than built surfaces. Urban greening also contributes to creating attractive urban centers essential for economic growth. In urban areas undergoing redevelopment, a collaborative approach with planners, builders, and landowners is required to deliver local action. This case study reports on the modeled impact of redevelopment scenarios based around different amounts of green space on surface temperatures for a knowledge quarter near Manchester City Centre, UK.

Introduction and Case Study Location

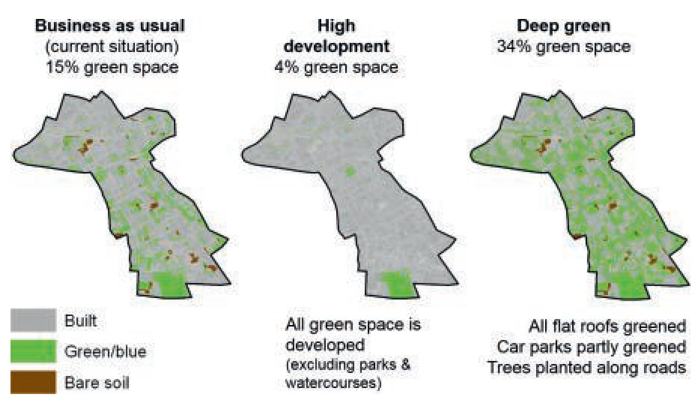
Manchester has a pronounced UHI, with temperatures in the core urban areas around 3°C (5°C) warmer on summer days (nights) (Smith et al., 2011). Furthermore, the particular socioeconomic and demographic characteristics of Manchester's communities, in addition to physical environment characteristics, suggests that there are pockets of high social vulnerability to climate change impacts including heat waves and flooding (Kazmierczak and Cavan, 2011). This case study focuses specifically on urban greening as a strategy to cool the urban thermal environment.

This study was conducted in the Oxford Road Corridor area in Manchester, UK. This is a strategically important economic development area and a major transport link, extending south from Manchester City Centre and covering an area of 2.7 square kilometers. The area presents a particular challenge for greening since it is highly built-up, having only two small parks, a few street trees and small areas of green space among buildings, and is largely privately owned.

Methods

A scenario-driven approach was used to investigate the cumulative impact of climate change and land surface cover scenarios on localized maximum surface temperatures (experienced approximately 2 days per summer). Three development scenarios were proposed: Business As Usual (assumes the same 15% green space as the current situation); Deep Green (34% green space); and High Development (4% green space) (Case Study 5.B Figure 1). Future surface temperatures were then modeled under each of the development scenarios using an energy exchange model for the 2050s A1FI emissions scenario – now a freely available online tool – STAR (The Mersey Forest and the University of Manchester, 2011; Cavan et al., 2015). A series of structured interviews were then carried out with a partnership of local stakeholders to (1) transfer the knowledge gained through the scenario modeling exercise, (2) ascertain stakeholder perceptions of the research results, and (3) consider barriers and opportunities associated with implementing the deep green scenario in practice.

Results and Discussion



Case Study 5.B Figure 1 *Simulated development scenarios from aerial photograph interpretation.*

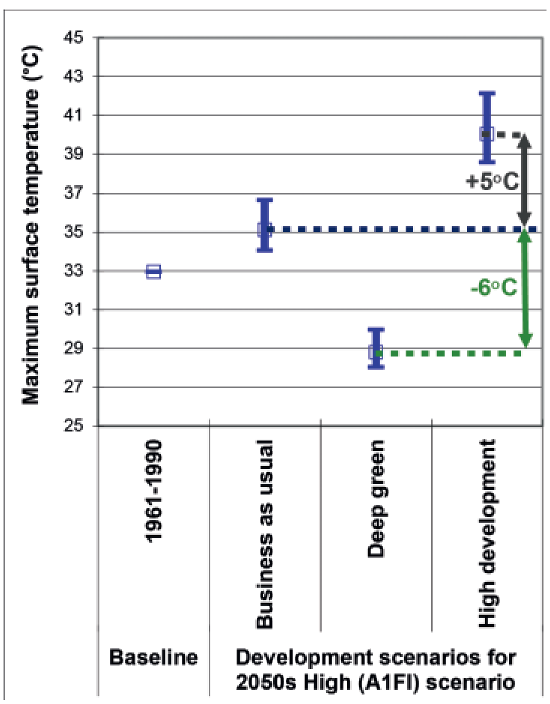
Source: Revised from Carter et al. (2015). Base map Crown Copyright and Database Right 2015, Ordnance Survey (Digimap Licence)

Impact of Changing Land Surface Cover on Maximum Surface Temperatures

An increase in green space could help to address rising temperatures associated with climate change (Case Study 5.B Figure 2). If land surface cover ratios remain the same (Business As Usual), climate change will increase maximum surface temperatures by 1.1–3.7°C (2050s A1FI) (UKCP 2009). Under the High Development scenario, projected maximum surface temperatures increase by at least 5°C. In contrast, provision of additional green space under the Deep Green scenario results in around 6°C reduction in projected maximum surface temperatures in relation to the Business As Usual scenario. Around 21% of green space will maintain baseline 1961–1990 temperatures.

Opportunities for Realizing a Green Scenario

Interviews with the local stakeholders revealed that there is a good chance for implementation of elements of the Deep Green scenario. Climate change is perceived to be a significant issue; there are some foundations already in place in the existing local development strategy, and an array of examples of ongoing and planned initiatives of enhancement of green space exist and can stimulate shared learning. Furthermore, positive perceptions of the co-benefits of greening, including an increase in human thermal comfort and quality of life and a reduction in artificial cooling usage (lowering energy bills), could be significant incentives for landowners and developers to invest in green spaces.



Case Study 5.B Figure 2 *Impact of development scenarios on maximum surface temperatures for the 98th percentile summer day. Bars show the variability of the 100 weather generator runs.*

Source: Revised from Carter et al., 2015. Weather generator data copyright UK Climate Projections 2009.

Financial issues were considered the main challenges to achieving the Deep Green scenario. The stakeholders highlighted that uncertainty about the economic benefits of green space, perceptions that it is not a necessary measure, and long payback times of green space, particularly for green roofs, were all obstacles in justifying investments. Furthermore, maintenance issues, such as the negative impact of trees on utilities, technical difficulties hindering retrofitting green roofs, and uncertainty about maintaining the functionality of green space under changing climate conditions, were highlighted as key threats in realizing the Deep Green scenario.

Transferable Lessons

The high density of cities and restricted opportunities for urban greening present a key barrier affecting local capacity to adapt urban areas. Furthermore, the high private land ownership in cities and low amount of publicly owned land awaiting redevelopment means that planners have limited scope to deliver adaptation actions. A collaborative approach to adaptation, with planners working together with building and land owners, is essential at the local scale. A further key lesson from this case study is the usefulness of quantitative information to clearly illustrate the extent of UHI and climate change to stakeholders, thus helping to build their knowledge of the impact on their specific assets and thus stimulate willingness to take appropriate actions.

This research was conducted as part of the EcoCities project, a joint initiative between the University of Manchester and Bruntwood; further details are available at www.adaptingmanchester.co.uk. This contributes to the Greater Manchester Evidence Base for Sustainable Urban Development and Manchester: A Certain Future – the city's shared plan to tackle climate change.

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Case Study 5.C

New Songdo City: A Bridge to the Future?

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Keywords	Eco-city, smart city, ubiquitous city, mitigation, planning and design
Population (Metropolitan Region)	45,000 (Gale International, 2016)
Area (Metropolitan Region)	6 km^2 (Songdo IBD, 2015)
Income per capita	US$27,600 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

The Republic of South Korea's New Songdo City is an urban are occupying 1,500 acres of "reclaimed" land from the Yellow Sea. It is governed by the Incheon Metropolitan City's Free Economic Zone, which is part of the national commitment to develop a green economy. Planners designed New Songdo City to be an international business center that takes advantage of South Korea's geographic location within Northeast Asia. In 2001, the City of Incheon contracted U.S.-based Gale International, a property development firm, to develop the city in a joint partnership with POSCO, the South Korean construction conglomerate(Southerton, 2009). Gale International contracted the architectural firm, Kohn, Pedersen, Fox Associates to design the city. At a cost of US$35 billion, news media sources frequently label it the largest private development project in history. Construction began in 2004 with the landfill, and, by 2014, an estimated 70% of the city was complete. Developers project the city to have a residential population of 65,000 and a workforce of 300,000. While still under development, New Songdo City is a fully functional urban space.

New Songdo City brings together multiple design concepts that potentially make it a bridge to the future of sustainable urbanism. It has the highest concentration of LEED certified buildings in the world and several, such as the Sheraton Hotel, have won international awards for their sustainable design (Arbes and Bethea, 2014). Green spaces constitute 40% of the landscape (KPF, 2014), and planners designed them for enhancing air circulation, assisting with rain runoff, and promoting pedestrian and bicycle traffic. It has extensive bike trails, and wide, safe sidewalks intended to reduce car dependence. New Songdo City has a cutting-edge waste collection system, one that uses a pneumatic system that takes garbage from offices or residencies to the waste disposal facility. The system does not require garbage trucks (Shwayri, 2013), which reduces carbon emissions and traffic congestion. The city has a network of buses that circulate people within the city but also provides links to Incheon's urban center, the International Airport, and to Seoul. An underground metro line runs around the city's circumference and also links to Incheon and Seoul. New Songdo City also aims to generate efficient energy use through "ubiquitous" Internet technologies designed by Cisco System's "Smart + Connected Cities" program. Ubiquitous technology uses the Internet to link hardware and software to monitoring systems to generate efficient resource consumption (Yingitcanlar and Lee, 2014). Consequently, Songdo consumes 40% less energy per capita than other cities of similar scale.

Gale International, Incheon Metropolitan City, and the Republic of South Korea clearly made strides toward creating a more sustainable urban form in Songdo City. Building from the ground up offers significant advantages for sustainable design because planning does not run into the obstacles of a built environment as well as the customary practices of citizens living in an already existing city. Especially considering that several built-from-scratch eco-cities, such as China's Dongtan eco-city, a zero-carbon project, have failed, New Songdo City appears to be among early success stories, along with Abu Dhabi's Masdar City. Marking its development as a global business hub, the United Nations selected New Songdo City to host the offices of the Green Climate Fund in October 2012.

There are, however, several climate adaptation limitations with the New Songdo City project. First, its creators have not yet established the explicit goal of creating a carbon-neutral city, which was the stated objective for both Dongtan and Masdar City. Second, New Songdo City remains an urban form designed to accommodate the car. City streets are wide boulevards, capable of handling high volumes of car traffic. Intersections are regulated by traffic lights, with timing best suited for the automobile instead of the pedestrian. Planners built a massive underground parking lot, one that encompasses the entire city core and that has the goal of allowing car users quick and easy access to their destination, a convenience that encourages driving over public transit. Third, New Songdo City still has an urban metabolism defined by late capitalism's cradle-to-grave production and consumption system. Despite attempts to close the loop in garbage handling, the city remains an open-loop system (Kuecker, 2013b). Because of its dependence on material supplies from outside the city, New Songdo City contributes to increasing levels of carbon emissions. Fourth, while the city design resulted in an admirable commitment to LEED standards, the jury itself is still out about the carbon footprint of these certified buildings (Ko et al., 2011). Building materials expend carbon in their extraction, production, transportation, and construction. A building may well be climate friendly in its design, but much depends on the habits of its clients, such as their use of air conditioning, lighting, the density of people in work spaces, or the placement and design of furnishing and decorations. Sixth, the city has high electrical demands, especially for running the city's ubiquitous platforms, as well as cooling systems that have a significant energy demand in the South Korean summer. Seventh, the city has eco-unfriendly features, such as the Jack Nicklaus-designed golf course, which is proudly featured in city marketing (Southerton, 2009). Finally, the goal of creating a regional hub locks city users into a jet-set lifestyle, one that burns carbon on each flight to Tokyo, Shanghai, or Hong Kong while fostering a culture of consumption. From this view, New Songdo City lacks the cradle-to-cradle, closed-loop design required for a truly sustainable design needed for successful climate adaptation and mitigation.

Some critics also raise questions about New Songdo City's reputation for sustainability. One of the top concerns is the branding efforts of New Songdo City's developers, who engage in an impressive marketing campaign designed to get tenants for the office towers and residents for the apartments. Gale International, for example, explicitly states that their main goal is to create a city with the highest "quality of life" (Kim, 2010). While their goal may translate into high Human Development Index statistics, close analysis reveals an urban form that replicates features of a gated community built for a transnational class of business elites and wealthy refugees from the inconveniences of a megalopolis like Seoul. In this urban model, the sustainable city becomes a marketable commodity available to the highest bidder, set against the minimal standard of life for billions of urban dwellers. Matched with agendas like the United Nation's Sustainable Development Goals, New Songdo City appears an inappropriate response to the challenges of climate change.

In New Songdo City's short history, it has undergone several re-brandings: business hub, smart city, global university, biotech and hospital hub, and eco-city. The instability reveals uncertainty about how this new urban form fits within 21st-century urbanism. Some see it as a "bridge to the future," a "test-bed" (Kim, 2014) of new technologies and innovative design that serves as a necessary step in climate mitigation and adaptation. Others debunk the bridge metaphor, preferring to view New Songdo City as representing the maladaptive propensities of capitalist markets (Kuecker, 2013a). As investments at unprecedentedly high scales of social and financial capital are made into the building of eco-cities in China, South Asia, and Africa, it is important that this new urban form is critically examined to determine if it is indeed the bridge to the future. These doubts extend beyond New Songdo City and call into question the depth and substance of South Korea's highly publicized green economy agenda.

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Case Study 5.D

Adaptation in Rotterdam's Stadshavens: Mainstreaming Housing and Education

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Keywords	Urban flooding, sea level rise, adaptation policy
Population (Metropolitan Region)	1,173,561 (Rotterdam The Hague Metropolitan Area, 2016)
Area (Metropolitan Region)	990 km^2 (Rotterdam The Hague Metropolitan Area, 2016)
Income per capita	US$51,210 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

In Rotterdam, the Netherlands, a 16 square kilometer area called Stadshavens or "City Ports" (Case Study 5.D Figure 1) sits between the city center and Europe's leading seaport, the Europoort. The Stadshavens area has become the focal point of the Rotterdam Climate Initiative (RCI). Launched in May 2007 by former Rotterdam Mayor Opstelten during a global summit[1] hosted by former U.S. President Bill Clinton and Mayor Michael Bloomberg in New York, the RCI set forth ambitions to spur projects that aimed to promote the development of a sustainable city that would be at the forefront of research and innovation in climate change adaptation.

National Policy, Local Agenda

The Stadshavens project was initiated in 2002 by the City of Rotterdam as what was then perceived by planning officials as a conventional post-industrial waterfront redevelopment assignment. Port facilities were expected to migrate to other areas in the Port of Rotterdam less encumbered by physical and regulatory

Case Study 5.D Figure 1 *Stadshavens Port Area, Rotterdam, in 2014.*

Source: Stadhavens Rotterdam Programme Office

1 C40 Large Cities Climate Summit, May 14–17, 2007, New York.

restrictions. This process was expected to create opportunities to redevelop parts of the Stadshavens area into urban residential waterfront neighborhoods (Daamen, 2010). However, these expectations soon had to be revised because the Rotterdam Port Authority (RPA) – the area's principle landlord – favored an economic development perspective that focused on continued port-industrial uses and combined port-related service functions. The RPA had a strong case because few of the companies in the Stadshavens area were inclined to move their business further downstream to the more modern Europoort and Maasvlakte areas.

While discussions in Rotterdam developed around a revised development trajectory for the Stadshavens area, climate change emerged more emphatically within the Dutch national policy agenda. The National Spatial Strategy established in 2004 led to a period of policy reframing efforts that favored a "working with the water" over the prevailing "fighting against the water" rhetoric common in the economic development discourse. Several national planning programs and decisions followed that focused on broadly preparing the country for the consequences of climate change, such as the Delta Commission Report of 2008. Water-sensitive development and flood risks were dominant topics in these policy briefs, and Rotterdam was soon identified as one of the cities in the country most vulnerable to flood risks within the context of urban development (Lu and Stead, 2013).

Mainstreaming

The Dutch national climate change policies have, in part, been translated by local governments through a process of "mainstreaming," wherein a larger set of social, economic, public health, water management, and other public policy domains are amended to operationalize the broader intent of the national policy to address climate change. By 2008, the Stadshavens area was designated as a potential testing ground for climate change adaptation measures and pilot projects. The area is largely situated outside of the city's protective dike structure, and studies showed that the village of Heijplaat – located in the center of the area – was particularly vulnerable to floods. Likewise, the village housed a particularly sensitive low-income community that was struggling to survive. Given its unique positioning, Heijplaat was selected as an initial testing ground for mainstreaming[2] a climate policy within existing housing and education policy domains. With a clear site and a broad set of objectives, the city and the RPA sought to negotiate a new agreement. In addition, two local educational institutions and a housing association – owner of most of the social housing – soon became major partners in revitalizing the village of Heijplaat and redeveloping the adjacent facilities of the Rotterdam Dry Dock Company (RDM).

Flood protection measures were included into a more specific agreement for the village in 2012, presenting a larger framework of economic, social, and environmental values and objectives under the overall framework of sustainability. Flood protection measures in the Heijplaat/RDM area are based on the idea of "multilevel security." This concept dictates that protective measures like dams and dikes are complemented by flood risk reduction measures at the district and building scales. For Heijplaat, this has been translated into the development of a small dike (3.6 m above sea level) between the water's edge and the new west side of the village, elevating vulnerable new development locations and designing vital infrastructure, public spaces, and new homes in such a way that flood risks are reduced (Richter, 2014). In addition, new housing prototypes were developed that include passive and autonomous systems that not only reduce risk from flooding but also serve climate mitigation ends through a lower "clean energy" carbon footprint. Although the recent downturn in the Dutch economy has impacted the pace of implementation, partners at Heijplaat seem determined to advance their integrative efforts and turn the village into a showcase of sustainability and resilience.

Aside from housing, economic development was advanced with the RDM shipyard being repositioned as a Research, Design, and Manufacturing campus (Vries, 2014). Together with local educational institutions, the RDM facilities were thus redeveloped to accommodate technical education and research. In addition, space was developed to house start-up companies ranging from an emergency housing material supplier to a manufacturer of electric motorcycles. The organizational and spatial configuration of RDM is designed in such a way that, as students develop their technical competencies, they can laterally transition into providing a well-trained workforce for the emerging companies housed on-site. Likewise, with a capacity to accommodate scientific and engineering research, students at all levels are reciprocally engaged in developing applications, techniques, materials, and designs tested and evaluated on-site. This vertical alignment of education and commerce has served as a model for similar post-industrial facilities around the world.

Advancing Capacities

The next phase under way at RDM/Heijplaat includes a focused expansion of the facilities and corresponding programs to advance capacity for designing and constructing floating structures and water-dependent infrastructure. By building a political coalition around a diverse set of goals including housing and education, Rotterdam has advanced an adaptive capacity that goes beyond physical interventions to the inclusion of social systems that are perhaps the first line of defense in the face of climate change.

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Case Study 5.E

Climate Change Mitigation in a Tropical City: Santo Domingo, Dominican Republic

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Keywords	Natural disasters, urban transportation, forestry conservation, urban planning and design
Population (Metropolitan Region)	3,020,000 (United Nations, 2016)
Area (Metropolitan Region)	427 km^2 (Demographia, 2016)
Income per capita	US$6,390 (World Bank, 2017)
Climate zone	Am – Tropical monsoonal (Peel et al., 2007)

Introduction

The Dominican Republic needs to justify the environmental impacts of climate change to ensure the country's future growth. As an island nation, threats will be experienced on the three coastal sides of the country as well as on its interior. It will experience increased population shifts as migration gravitates from rural communities to urban environments. Such influx will contribute to urban carbon emissions, and the city's infrastructure can be strained in regard to building operation, transportation, and energy provision. Urban projects will need to address such impacts and seek to reduce greenhouse gas (GHG) emissions.

Santo Domingo: The Oldest City in the New World

The impacts of climate change will affect cities in various ways and disturb current economic, cultural, and social balances. The city of Santo Domingo has been a model for other similar metropolitan areas in the Caribbean context. With its rapid growth and investment in economic sectors, the city has emerged rapidly as an economic center that attracts investment and development opportunities. This model has been considered by other countries (including Haiti) as an example of how smart investment can foster job growth and infrastructure investment within a short time span.

Santo Domingo is in a position to be a leader in the reduction of GHG emissions because internal investment and support is readily available to foster such initiatives. A framework and the necessary tools, such as those used by New York's PlaNYC 2030, can lead sustainability initiatives (New York City Office of Long-Term Planning and Sustainability, 2007).

Island in Context

The Dominican Republic shares the island with the neighboring country of Haiti, occupying two-thirds of the island territory. It has 49,000 square kilometers with 1,288 kilometers of coast lines. Forty percent of the land cover is forested. The Dominican Republic is strategically located between neighboring countries in the Caribbean, Central, South and North America.

Learning from History

The Dominican Republic was the first settlement in the new world, founded by Christopher Columbus during his first travels across the Atlantic Ocean. The City of Santo Domingo was founded in 1496; it is 519 years old and is the oldest functioning city in the Western Hemisphere.

Preserving and Ensuring the Island Economy

With a US$61.6 billion gross domestic product (GDP; World Bank, 2013), the Dominican Republic maintains its economic growth primarily through its service industries that include business and finance investments. Its manufacturing industry includes mining of nickel, gold, and silver; and it hosts a textile industry. Its agricultural sector is a strong exporter of organic fruits and vegetables, tobacco, and sugar. The island maintains a strong tourism industry, with nearly 3 million foreign visitors on a yearly basis.

Population Growth and Forecast

Approximately 10.4 million people live in the Dominican Republic, and currently 70.8% of the population lives in urban areas (United Nations Statistics Division, 2013); 3 million people reside in Santo Domingo alone. It is estimated that the population will increase to 12.1 million by 2030 (Euromonitor International, 2013).

Sustainable Networks of Connectivity through Infrastructure

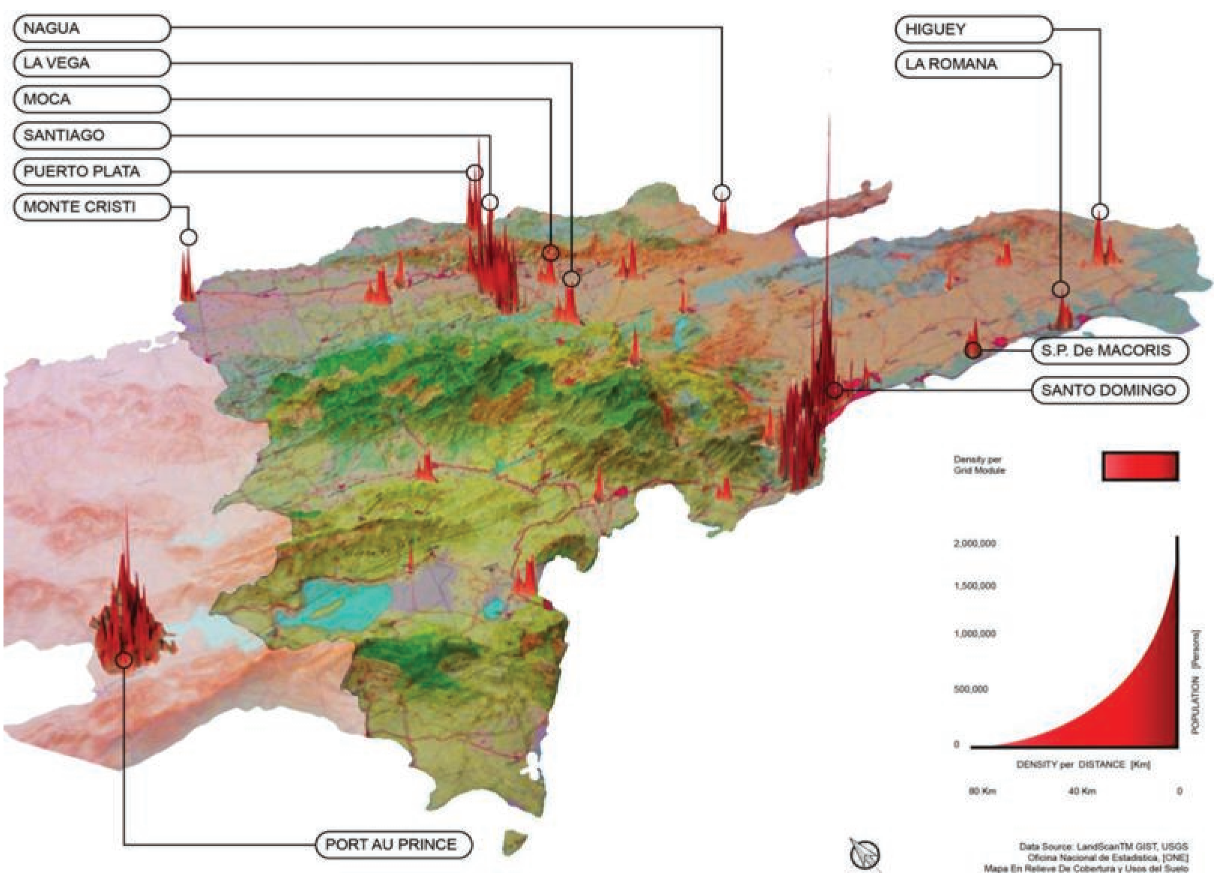
Since 1986, the country has sustained a resilient construction industry. Capital investment from both public and private sectors has focused on the transportation industry, primarily through road construction. The country has ten international airports with fourteen shipping ports along its costal edges.

Natural Disasters: A Methodology for Resilience Planning

The Dominican Republic is a hot spot for natural disasters. The island has a history of floods, storms, earthquakes, landslides, and tsunamis (the last recorded tsunami occurred in the north province in 1946), tracked since record keeping began in the 1500s. The World Bank indicates the island is at risk to hurricanes, landslides, and earthquakes, in order of priority. About 33.75% of the land area is estimated to be affected, with 66% of the total population projected to be high risk (Dilley, 2005) in the aftermath of a disaster.

Urban Sprawl

Santo Domingo is a dense urban environment. Santo Domingo's growth is directed toward the north and west of the city. These districts are bounded by waterfronts, fault lines, and steep terrain. The majority of commercial and higher end residential building construction is conducted under the rules and regulations required by local building codes, but there are also residential communities expanding through "automated construction," a method whereby individuals utilize construction methods not coherent with local codes or building ordinances



Population density concentration spike mapping on the island of Hispaniola- Dominican Republic.

Image Credit: Richard Gonzalez, AIA

and subjective to individual knowledge. The control and oversight of these building structures remain of concern because many may vulnerable to impacts on life and safety.

Mitigation Strategies: The Shifting of GHG

The Dominican Republic aims to reduce GHG emissions by 25% with a targeted date of 2030 (International Partnership on Mitigation and MRV, 2014). This was announced at a UN Climate Change conference (COP18) hosted in Doha, Qatar. This incentive includes financial support, with the government of Germany as a partner. The three task areas include economic development, reduction of poverty, and securing social inclusion (National Council on Climate Change, 2012). The Dominican Republic has also identified four sectors for the reduction of GHG: transportation, energy, forestry conservation, and water management.

The country is investing largely in its transportation infrastructure. Santo Domingo is expanding its mass transportation system with an underground metro subway. In its second phase of completion, the system will expand to service the east-west districts of the City, with future plans to expand toward the North.

Although the demand for energy outweighs the supply, the Dominican Republic is investing in several alternatives for energy production, including a focus on hydro plants near rivers and solar and wind farms in certain sectors of the country.

Forestry conservation plays a major role in the reduction of carbon. The Dominican Republic plans to conserve existing undisturbed parks and ecological habitats in a nationwide effort. There is also a tree planting initiative for the city of Santo Domingo (Office of the National District, 2010) and a GreenBelt project highlighting eight park areas linked via a series of pathways and water channels (Grupo Tierra Dominicana, 2008).

Water management plays a key issue in regards to catchment, processing, and distribution. The city of Santo Domingo has experienced water overflows and flooding in the aftermath of strong tropical storms. The public works department is planning on expanding the city's sewer lines, which currently services 40% of the city. The system will implement new street catchments, distribution lines, and treatment plants. This system will also address waste mitigation because small items constantly congest the distribution of water in the underground piping.

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Case Study 6.A

The Community-Driven Adaptation Planning: Examining the Ways of Kampungs in North Coastal Jakarta

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Keywords	Flood, community-based adaptation, planning, environmental justice
Population (Metropolitan Region)	10,483,000 (United Nations, 2016)
Area (Metropolitan Region)	3,225 km² (Demographia, 2016)
Income per capita	US$3,400 (World Bank, 2017)
Climate zone	Am – Tropical, monsoon (Peel et al., 2007)

Jakarta, the biggest mega-coastal city in the Southeast Asia region inhabited by more than 10 million people, has experienced climate-related disasters – especially flood events – for decades. Located on land that is sinking at a rate of about 2 centimeters per year over the past three decades, the north coast of Jakarta is potentially at risk of flood from sea level rise, high tides, and extreme rainfall (DKI Jakarta, 2012a). In addition to major infrastructures (e.g., power plants, national harbor, and logistic centers), the northern coastal area is also shaped by dozens of poor informal settlements called named *kampung*. More than 60% of Jakarta's population live in *kampungs* and manage to survive, although their living places are vulnerable to flooding. How they prepare their settlements and deal with flood risks is a major resource that should be incorporated into urban adaptation planning. This form of knowledge needs to be studied in order to increase the effectiveness of urban adaptation.

The Indonesian Association of Urban and Regional Planners (IAP) and the government of DKI Jakarta Province, supported by START (Global Change System for Analysis, Research, and Training), have initiated community-driven adaptation planning in the *kampungs* of Kamal Muara and Kebon Bawang. The initiative aims to know how *kampung* residents plan to adapt their settlements to current and increasing flood risk, how they would provide design guidelines for existing and new developments, and how they control the uses of the land and buildings in their own areas (IAP, 2012). The government can benefit from these types of knowledge in developing effective adaptation strategies, thus complementing the spatial and development planning process. In addition, the collaborative process among *kampung* residents, planners, and government officers has also bridged different perceptions of the meaning of flood-related vulnerability and adaptation itself.

Both *kampungs* are extremely high-density settlements. For example, Kamal Muara is inhabited by 4,200 people on only 7 hectares. Nearly 90% of the *kampung* area is occupied by buildings, with only a few open spaces left. The residences, small shops, and public facilities, such as mosques and communal bathrooms, are the dominant land uses. Narrow alleys structure the settlement area. The *kampung* residents are mostly low-income groups that work as casual workers, street vendors, and fishermen. They consciously perceive that their living place is a flood-prone area due to extreme rainfall, tidal flood, or overflowing rivers. They know that when a flood occurs, the physical environment not only becomes water-inundated, but also highly polluted with garbage-laden water. By shifting our focus in vulnerability and adaptation assessment from technical experts to a people-centered approach, we can reveal the adaptive practical knowledge of the urban poor.

Kampung residents have locally embedded knowledge of adapting their settlements to floods (Simarmata, 2015). They can intuitively map the inundated area, sense the frequency of flooding, and work together to overcome the impact of floods. They use local resources, such as wood, plywood, bamboo, and sand sacks to raise alley pathways. They have a locally embedded adaptation plan (LEAP) to manage the functionality of houses and follow evacuation strategies when floods come. They can adapt to the flooding but fail to deal with pollution and seawater intrusion. Therefore, the *kampung* residents recognize that they need an adaptation plan, with an aim of not just stopping or avoiding flood events, but of minimizing the pollution and building water protection infrastructure. Case Study 6.A Figure 1 shows how *kampung* resident identified the root causes of their problems through a series of group discussions. They shared the problems that are caused by the floods and prioritized them for development of adaptation strategies.

Public facility improvement was a top priority for private space adaptation. In the group discussion, they agreed to put water infrastructure improvements as top priorities, such as drainage (no. 1) and clean water supply (no. 3). *Kampung* residents also understood the importance of design guidelines for their settlement. They discussed the design principles that were initially introduced by the planners participating in the discussions. They argued that the water infrastructure was ultimately the best way to create adaptive *kampungs*, which should be achieved by applying amphibious building concepts, increasing houses' permeability to water, and accelerating water flow to the estuary. Therefore, they recommended that the stilt house be a preferred building type, that drainage levels should always be

Case Study 6.A Figure 1 *Root causes analysis in Kamal Muara.*

Source: PICAS report, 2012; Photo: Paramitha Yanindaputri

below the road, and that public facilities should be built above the projected flood level and serve as a multipurpose space. Last, alleys should be designed as social spaces as well.

The dynamic conversation also covered how *kampung* residents control land use and building development in their areas. They do not have rules for managing density and did not know that the government has special zoning regulations for floodplain zones. Having had the discussion, they suggested three categories to characterize flood areas in their areas: low-level flood (20 cm), middle-level (20–60 cm), and high-level (60 cm) (DKI Jakarta 2012b). These categorizations resulted from the reflective process on the series of flood events experienced in their areas. They also actively contributed to the discussion on what type of regulations would properly apply for their areas.

The three main parts of the community-driven planning have opened the eyes of government and planners on how local people have the capacity to manage their own settlements to withstand flood impacts. Even though the existing practices did not show aspects of quality and sustainability, government and planners can start the planning process from what they have learned. Knowing how people have adapted for decades is very important because the knowledge has been embedded and institutionalized within the community. Based on this knowledge, the city can develop an inclusive adaptation strategy.

The adaptation knowledge that is embedded in the everyday life of the urban poor has not yet been properly combined with development planning. The tacit form of this knowledge has created a missing link in establishing a connection to adaptation planning at the city level. We found that by shifting methods from technical experts to a people-centered approach, we can reveal the adaptive practical knowledge of the urban poor. This is a useful and essential data source in assessing vulnerability and providing adaptation options. We suggest that local community adaptation should be incorporated into adaptation planning processes at the city level.

Summary

Flooding is the most typical urban problem, especially for low-lying coastal cities such as Jakarta. The urban poor who have lived in various *kampung*s for many decades have experienced and adapted to floods on their own. However, the adaptation knowledge that is embedded in the everyday life of the urban poor has not yet been properly combined with development planning. The tacit form of this knowledge has created a missing link in establishing a connection to adaptation planning at the city level. By applying a people-centered approach in three *kampung*s in Jakarta, we revealed the adaptive practical knowledge of the urban poor. This is a useful data source in assessing vulnerability and providing adaptation options. We suggest that local community adaptation should be incorporated into adaptation planning process at the city level.

Acknowledgments

Author wishes to thank Dani Muttaqin, Adriadi Dimastanto, Agung Mahesa, and Raka Suryandaru for contributing data and information during and after the Planning for Integrated Coastal

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Case Study 6.B

Participatory Integrated Assessment of Flood Protection Measures for Climate Adaptation in Dhaka

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Keywords	Climate adaptation, flood protection, multi-criteria analysis, prioritization, participatory approach, environmental justice
Population (Metropolitan Region)	18,237,000 (United Nations, 2016)
Area (Metropolitan Region)	368 km² (Demographia, 2016)
Income per capita	US$1,330 (World Bank, 2017)
Climate zone	Aw – Tropical Savannah (Peel et al., 2007)

Dhaka, the capital of Bangladesh, is one of the largest megacities in the world, and its population is growing rapidly. Due to its location on a deltaic plain, the city is extremely prone to detrimental flooding. Moreover, being located in the active river tidal zone, the low-lying areas are often engulfed by high tides. Risks associated with these are expected to increase further in the coming years due to global climate change impacts as well as the high rate of urbanization the city is facing (Haque et al., 2012). Although the government is planning several adaptive measures to protect the area from floods, it lacks a systematic framework to analyze and assess them.

Case Study 6.B Figure 1 *Flood map of Dhaka city during 1998 flood showing inundated study area.*

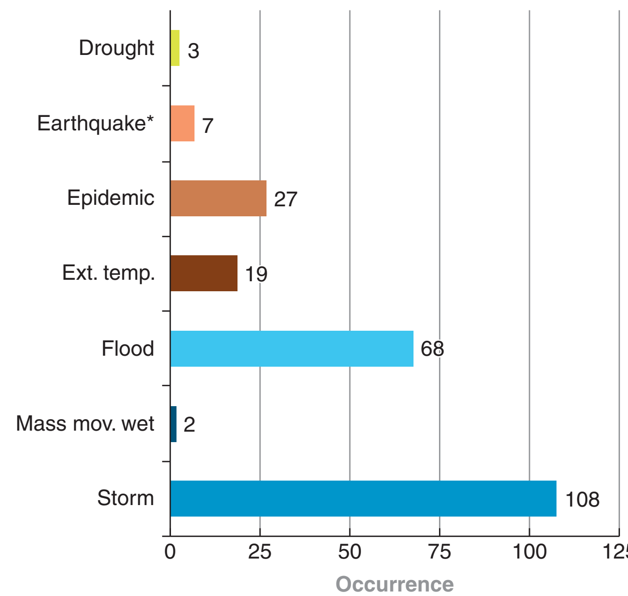
Source: Nishat et al., 1999

Case Study 6.B Figure 2 *Waterlogging in secondary road of Dhaka; waterlogging in main arterial road of Dhaka.*

Source: Hossain, 2015

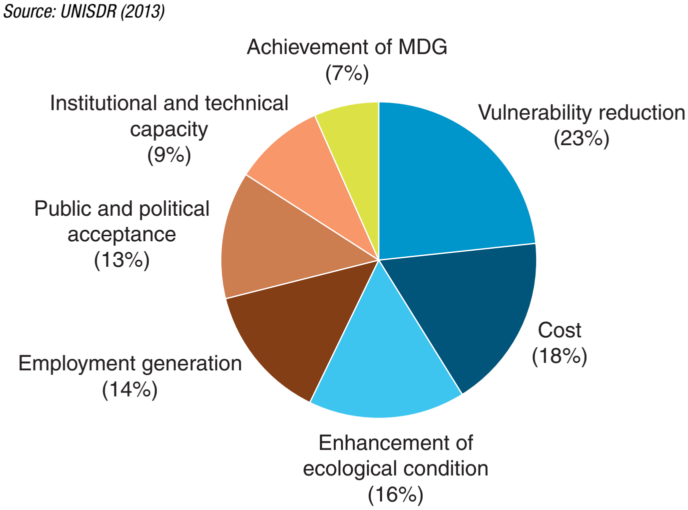
Case Study 6.B Figure 3 *Disruption of communication due to flood.*

Source: Habitat International Coalition, 2009



Case Study 6.B Figure 4 *Natural disaster occurrence in Bangladesh from 1980 to 2010.*

Source: UNISDR (2013)



Case Study 6.B Figure 5 *Stakeholders' preferences on evaluation criteria.*

Traditionally, the water-retention areas in Dhaka have efficiently stored the excess water caused by high-intensity rainfall and the canals, which are connected to the rivers, gradually drain the water. The situation is changing. The population of Dhaka is increasing and land scarcity is resulting in the encroachment of these water-retention areas, which mostly lie in Dhaka East. The city drainage system has not improved with the pace of rapid urbanization; consequently, these low-lying areas suffer from inundation. Dhaka East was almost completely inundated in the floods that occurred in 1988, 1998, and 2004, and it was inundated for longer than the other parts of the city. It is not only affected by the river flood, but also by the urban flood caused by excessive runoff due to rainfall. Prolonged inundation caused severe damage to urban agriculture and also to infrastructure (i.e., roads, housing, and piped services). Disruption of communications had severe impact on trade and education, whereas contaminated water led to health hazards.

The study identifies, analyzes, and prioritizes adaptation measures to address flood risks in Dhaka East while applying a multicriteria analysis (MCA) framework. The study emphasizes the importance of the participatory process to an informed decision-making in formulating policy in the context of a least developed country (LDC) at a city level. Furthermore, it provides decision support to both local and national policy-makers regarding the selection of adaptation measures that meet multiple local objectives considering budget, institutional, and technical capacity constraints. The assessment framework involved both stakeholders by eliciting their views and values (normative judgments) and experts (technical expertise). Moreover, the exchange of information from a multitude of stakeholder perspectives makes the outcome of decision-making more legitimate and defensible. Adaptation assessment in Bangladesh is crucial because the level of vulnerability to climate change is very high and resources are very limited. It explores the development of a platform for knowledge generation and sharing that can be used during the MCA process as an important element for enhancing institutional capacity during the decision-making process.

Data have been collected from both primary sources (in-depth interviews, focus group discussion, questionnaire survey, direct observation) and secondary sources (archival records, policy papers, official reports, relevant case studies, relevant literatures in peer-reviewed journals).

The assessment involved the following steps:

Selection of adaptation options: The adaptation options for the study area proposed by the government (flood embankment, pumping stations, regulators, retention basins, construction and upgrading of the road network, flood walls, and canal improvement) were included in the assessment. Additional adaptation options (emergency response mechanism and early warning system) were selected for assessment based on case studies.

Stakeholder criteria selection: In order to assess the adaptation measures, evaluation criteria were identified and selected in a participatory manner (focus group discussions) involving relevant stakeholders (i.e., ward commissioners, community representatives, government and private-sector officials). Thus, the criteria reflect the main objectives and views of different stakeholders, Stakeholders were confronted with the views of other stakeholder group representatives, hence avoiding manipulation of the responses.

Experts' impact judgments: The scoring of each adaptation option against the selected evaluation criteria was conducted by experts on flood protection based on their areas of specialization and experience.

Stakeholders' criteria weighting: Weighting (relative importance) of selected criteria was conducted based on a second round of focus group discussion with the stakeholder group (see Case Study 6.B Figure 5).

Prioritization of options: This step aimed to prioritize the adaptation measures under investigation for the study area based on their weighted scores.

Sensitivity analysis: A sensitivity analysis was conducted to investigate how sensitive the result of the final ranking was to the input variable of criteria weights and to incorporate the uncertainty and range of stakeholders' preferences.

The final outcome of the study is the ranking of adaptation measures (**Case Study 6.B** Table 1), which shows that protection of water-retention areas, enhanced early warning systems, and canal improvements are the highest ranked flood protection measures based on the selected evaluation criteria and stakeholders' preferences. This is an interesting outcome, since the "construction and upgrade of drainage system" is being discussed and considered as a main flood management measure in Dhaka. However, in this study, it has been proved to be a far less prioritized measure. Apparently, if the drainage system is improved, it is expected to reduce flooding, but there are other issues that should also be considered. Construction and upgrading of the drainage system requires a large budget as well as enhanced technical capacity, which are not readily available in a low-income country context. Protection

Case Study 6.B Table 1 *Final ranking and scoring results of adaptation measures.*

Measures	Score	Rank
Protection of water retention areas	0.74	1
Enhancing early warning systems	0.72	2
Canal improvements	0.69	3
Embankments	0.56	4
Construction and upgrading of storm sewer/ drainage systems	0.52	5
Raised roads	0.47	6
Enhancing emergency response mechanisms	0.44	7
Flood walls	0.40	8

of water-retention areas has proved to be the most effective option for reducing the vulnerability of the study area to flooding while simultaneously meeting other important criteria such as cost, enhancement of ecological condition, employment generation, and the like. The sensitivity analysis showed that the results are robust with regard to changes in criteria weights. It is evident from the final ranking results that the highest ranked alternatives performed very well at the most important criteria.

The adaptation assessment undertaken provides significant support for policy design and decision-making for a LDC like Bangladesh, where resources are limited and vulnerability to climate change impacts is high. Although the provision of a structured prioritization of adaptation measures for flood management is a challenging goal, the exchange of information from a large group of stakeholders made the outcome of the decision-making more legitimate and defensible. Moreover, by including both experts and stakeholders, the MCA process contributed to knowledge generation and sharing, which is an important element for enhancing institutional capacity for decision-making.

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Case Study 8.A

Parque del Lago, Quito: Reclaiming and Adapting a City Center

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Keywords	Urban ecology, reclamation, design, ecosystem services, water supply, adaptation, mitigation
Population (Metropolitan Region)	1,754,000 (United Nations, 2016)
Area (Metropolitan Region)	536km² (Demographia, 2016)
Income per capita	US$5,820 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Quito, Ecuador, is the highest official capital in the world, a UNESCO Cultural World Heritage site, and home to over 1.75 million inhabitants (United Nations, 2016.). The city is nestled in the Andes Mountains in the Guayllabamba River basin, on the eastern slopes of the Pichincha volcano. Quito is a central hub of economic and political activity in South America as the headquarters of the Union of South American Nations and a major cultural site with one of the largest and best-preserved historic centers in the Americas.

Quito is already vulnerable to current climate conditions and these risks are expected to intensify with climate change (Magrin et al., 2014; Revi et al., 2014). Nearly 100% of Quito's water supply comes from freshwater streams flowing from the surrounding mountains, glaciers, and protected areas. Climate change in the region is expected to accelerate losses of glacier extent and further increase temperatures, which each could imperil the sustainability of the water supply (Magrin et al., 2014; Rabatel et al., 2013). Anticipated changes in precipitation are more uncertain due to complex feedbacks with the mountainous terrain and regional processes, such as El Niño. However, extreme events such as droughts and storms are expected to become more common (Magrin et al., 2014). These climate risks are exacerbated by other regional pressures such as increasing urbanization, extensification of agriculture and cattle ranching, and demands from hydropower (Revi et al., 2014).

Redevelopment as an Opportunity for Renewal: Climate Adaptation and Mitigation

Within this context, the Metropolitan Municipality of Quito, the Corporation for Environmental Health, and the Architects Association of Pichincha-Ecuador are planning the redevelopment of Quito's former international airport (Mariscal Sucre International Airport) into an ecological urban park, referred to as Parque del Lago, to enhance the sustainability and livability of the urban environs (Case Study 8.A Figure 1; Metropolitan Municipality of Quito, 2008). This redevelopment, similar to projects in other cities globally, offers an opportunity for re-visioning the urban core into a platform that provides a diverse set of social, environmental, and economic benefits while simultaneously addressing the challenges from a changing climate. The efforts to repurpose this urban infrastructure into a vibrant public and ecological site began in 2008, during which time the construction of the city's new international airport outside of central Quito was under way. The new Mariscal Sucre International Airport, located in the Tababela parish about 18 kilometers east of Quito, commenced operations on February 20, 2013. The old Mariscal Sucre International Airport ceased all operations the night before, opening the door for urban revitalization. Currently, the repurposing efforts of the old airport are being assessed within the city's long-term development plan and political agenda. The creation of what would become Quito's largest urban park is envisioned as becoming a vital asset for all demographic groups living in and around Quito's metro area, as well as a guide for regional and international urban planners on promoting urban sustainability in the context of climate change (Metropolitan Municipality of Quito, 2008).

One of the proposed plans for Parque del Lago (Flynn et al., 2012; Figure 2) envisions designing the park's features along three overarching goals: hydrologic sustainability, biodiversity preservation, and ecosystem services. The proposal includes altering the terrain and hydrological networks of the park into an array of interconnected channels and streams. A large water collection and aquifer recharge lake receives the water flows of the site while providing a range of recreational activities for the park's visitors. The former runway is repurposed as a central recreational and commercial promenade, connecting and orienting the park along its dominant north-south axis. A series of paths and trails explore the park's terrain and anchor its thick wooded areas, meadows, grasslands, lagoons, streams, pools, gardens, and fields. The mosaic of wooded areas and clearings provide public space for commercial activities and outdoor concerts, as well as habitat for Quito's rich surrounding biodiversity.

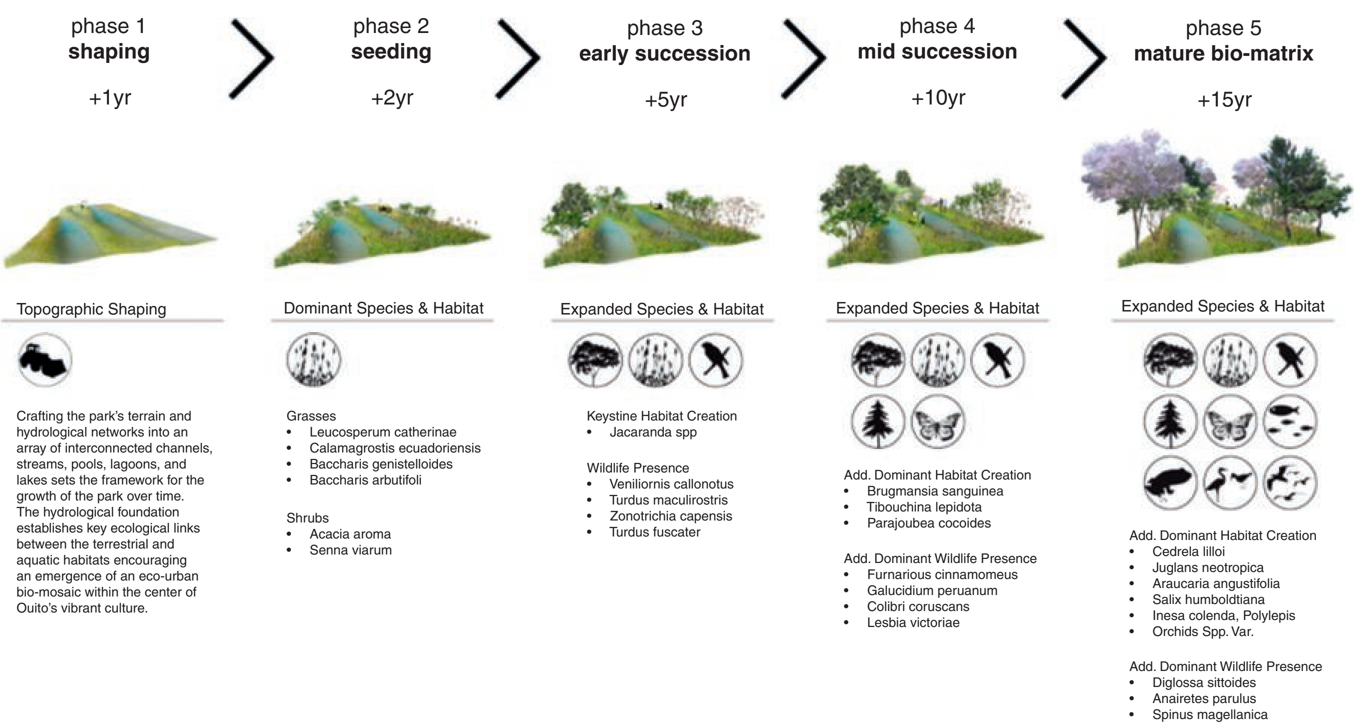
Each of these design features provides a variety of benefits to the urban core with respect to climate change. The hydrologic network functions as a buffer against potential increases in storm severity, absorbing runoff from the surrounding mountains and urban environment while simultaneously increasing groundwater recharge rates below to the city's strained aquifer. A mixture of fast- and slow-growing tree species is selected to provide carbon offsets early in the park's life span and that are sustained over

Case Study 8.A Figure 1 *Context map of metropolitan Quito, Ecuador, illustrating the location of the Mariscal Sucre International Airport within the surrounding urbanized landscape.*

Image credits: M3PROJECT, Flynn et al., www.m3project.com

Case Study 8.A Figure 2 *Illustrative plan to reclaim and adapt Quitos' Mariscal Sucre International Airport into a thriving ecological-urban landscape system designed to increase Quito's preparedness for and resiliency to climate change. The southern lake is fed by channels of grass-lined streams, interspersed with wooded groves to enhance stormwater mitigation, habitat, air quality, and carbon sequestration.*

Image credits: M3PROJECT, Flynn et al., www.m3project.com



Case Study 8.A Figure 3 *Conceptual diagram illustrating the successional development and diversification of the former Mariscal Sucre International Airport site over the first 15 years. The strategy highlights accelerated species diversity and accumulation of biota over the trajectory of site transformation.*

Image credits: M3PROJECT, Flynn et al., www.m3project.com

time as a climate mitigation measure (Case Study 8.A Figure 3). Evapotranspiration and shade from the plant canopy, as well as evaporation from the large lake, will cool local temperatures and help mitigate the urban heat island effect.

Quito is situated in a global biodiversity hot spot, the Tropical Andes (Meyers et al., 2000), and the proposal selects plant species to represent the rich diversity endemic to the region. The proposal includes the concept of ecological succession intrinsically into the design, where early successional grasses, sedges, and pioneer trees will provide habitat for several endemic bird species long absent in the urban core, including the Pacific horneo and the scarlet-backed woodpecker. Pioneer species such as the leguminous shrub *Aromita* help improve soil quality through nitrogen fixation and will be planted throughout the park early on to remediate the legacy of urban soil degradation. As the park matures, long-lived native species such as the jacaranda, South American cedar, and Ecuadorian walnut will start to dominate the park's landscape. These slow-growing long-lived trees include several species listed as endangered on the International Union for the Conservation of Nature Red List, a global authoritative source for the conservation status of species. Growth of these tree species will promote local biodiversity, provide mixed woodland area for recreational use, and serve as iconic species of the park, embodying habitat resembling that of pre-urban Quito. Finally, the mixture of habitats (e.g., woodland, grassland, wetland) emblematic of the Tropical Andes will provide refuge for many species of bird, butterfly, and others threatened by climate change, while the growth and succession within the park will ensure that many of the ecosystem services are maintained over time.

The park will become a foundational unit in the local urban community and regional ecosystem, benefiting both people and wildlife. Educational placards explaining the identity and function of various species and features of the park will help connect the local population with their regional ecology and the various services these species provide. The FONAG program, a Heritage Trust created by the local Metropolitan Water and Sanitation Department (EPMAPS) with support from the U.S. Agency for International Development and the Nature Conservancy, promotes water conservation and stewardship in Quito. FONAG and EPMAPS can become key allies to the park, supporting its water and biological conservation goals and providing input from their network of local supporters. Financial considerations are also included in design implementation, where a portion of the revenue from FONAG could support park development early on, while, over the longer term, revenue from commercial activities within the park (e.g., paddle boat rental, pavilion rental space, concert ticket sales) could pay back the heritage fund to benefit future generations. Additionally, carbon offsets from the growth of these long-lived tree species can be leveraged in a regional carbon market and tracked to account for the local carbon footprint.

Conclusions from Quito and Lessons for Other Cities

The Parque Del Lago proposal for the city of Quito is an example of the kind of integrative design that can help transform urban areas, which currently cover only 3% of the global land area but appropriate 60% or more of the earth's resources (Grimm et al., 2008), into sustainable systems for human and ecological betterment. The challenges to this city from climate change are great, but the lessons from stakeholder engagement and education, local adaptation planning, and successional design can help propel Quito forward and provide guidance for other cities as they address climate change adaptation and mitigation in the urban context.

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Case Study 8.B

São Paulo 100 Parks Program

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Keywords	Parks, adaptation, mitigation, ecosystems, landslides, floods, biodiversity
Population (Metropolitan Region)	19,683,975 (IBGE, 2015)
Area (Metropolitan Region)	7,947 km² (IBGE, 2015)
Income per capita	US$8,840 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Urban parks (particularly those alongside riverbeds and on steep slopes) are important climate adaptation measures because they prevent risks from landslides and floods, restore microclimates, and improve biodiversity. The recovered vegetation is also an important mitigation measure because plants and soils store carbon. Between 1992 and 2004, only one park was created in São Paulo, a megacity with almost 12 million inhabitants living in 1,522 square kilometers (IBGE, 2014). In 2005, there were 33 parks, totaling 15 million square meters of municipal protected green areas. Still, there were neighborhoods in the city with 700,000 inhabitants without a single local park. From 2005 to August 2008, 17 new parks were established, expanding and distributing more evenly such areas within the macro-regions of the city. The goal for 2010 was to achieve 100 parks and 50 million square meters protected. In 2010, 60 parks (totaling 24 million m²) were implemented, expanded to 133 parks (of which 21 are linear [alongside riverbeds]), totaling 35.66 million square meters or 2.4% of territory by the year 2012, when the project was discontinued after a municipal election (PMSP, 2007).

The 100 Parks Program to São Paulo aimed to identify the highest number of available areas and turn them into parks, thus expanding areas of leisure and contact with nature and, at the same time, more evenly distributing these sites. Among the Program's many objectives can be cited preventing flood hazards and erosions, mitigating heat island effects, providing local leisure options and avoiding trips to distant parks, ensuring soil permeability, sequestering carbon through planting 1.5 million new native trees of the Atlantic Forest, and improving conditions for biodiversity. Beyond urbanism, leisure, and contemplation, parks were considered as a whole system within the city. Several parks at the margins of the Guarapiranga Reservoir were part of a water defense strategy aiming to prevent illegal occupations on areas prone to floods and to prevent supply contamination. In the north, on the edge of the Cantareira Mountains, the implementation of linear parks was proved crucial to establish a barrier to irregular occupation (mostly by slums). Similarly, in the lowland region of the Tietê River, marshes were protected, implementing recreational areas and allowing for better river sanitation and clean-up works.

Linear parks were devised to protect preservation areas, avoid occupation in high-risk areas, help to combat flash floods, create cultural and leisure options for the surrounding population, and recover local stream margins. Natural Parks aim at the preservation of biodiversity in the city according to the commitment that the municipality assumed in Nagoya, Japan – the Aichi Biodiversity Targets at the Tenth Conference to the Parties of the UN Convention on Biodiversity. A Strategic Master Plan introduced the Environmental Riparian Areas Recovery Program as a structural element of urbanization. Linear parks (i.e., recovery of valley riverbeds) were the main line of action for this program, defining utility strips along water courses in order to implement green infrastructure, environmental restoration, and recreation (PMSP, 2010).

The first stage was to identify available areas, their characteristics, and potential uses. More than 200 areas were registered as having potential for parks. If the area was private and there was confirmation of the interest in turning it into park, the municipality started a process of expropriation through Public Utility Decrees. A total of sixty-nine areas were expropriated. The acquisition was often by the Environmental Compensation fund for public and private works, which had carried out tree removals in other places of the city (Ceneviva, 2014). In some cases, parks were created by demand of the population living nearby. The parks were located on compensated lands mainly along the southern branch of the São Paulo Ring Road, allowing for the creation of four natural parks in the region. Where the areas were already publicly owned, the process was faster. In the case of private areas turned into public parks (through expropriation or donations), fencing and surveillance were provided, plus studies of fauna and flora and architectural projects. Before being opened, each park is appointed an administrator with a background in environmental areas. This professional supervises surveillance and management contracts (building services, toilet maintenance, landscaping and gardening). The administrator is also responsible for daily activities, representing the municipality and coordinating – together with Management Centers – the implementation of environmental education programs within the park and in the surrounding community. Once opened, a Steering Council is elected that monitors the life of the park and suggests and proposes uses (PMSP, 2012).

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Case Study 8.C

St. Peters, Missouri, Invests in Nature to Manage Stormwater

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Keywords	Stormwater management, natural capital, urban climate change adaptation system, ecosystem-based adaptation
Population (Metropolitan Region)	56,971 (U.S. Census, 2016)
Area (Metropolitan Region)	57.93 km² (U.S. Census, 2016)
Income per capita	US$56,180 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

The majority of North American engineered infrastructure faces a backlog of overdue maintenance, pressing needs for modernization and growth-driven expansion, and cost constraints. The 2013 American Society of Civil Engineer report card rates U.S. infrastructure only a D+ overall (American Society of Civil Engineers, 2015). The situation is similar in Canada, where the Federation of Canadian Municipalities has pointed to a chronic infrastructure "funding crunch" (FCM, 2006). This raises vital questions about the extent to which municipalities can meet additional infrastructural and financial burdens imposed by climate change impacts such as increased frequency and intensity in rainfall, increased flood risks, and earlier snowpack melt.

Investment in local nature preservation, restoration, and enhancement can provide a cost-effective approach to increase community resilience to these and other climate impacts. Municipal services such as stormwater management and clean water supply are typically provided through engineered assets such as stormwater systems and water purification facilities or through "green infrastructure" such as engineered bioswales and raingardens.

However, some pioneering municipalities are investing in natural systems such as their local streams, rivers, wetlands, and aquifers to provide these services, in part or whole, and integrating management of these "natural assets" into an overall stormwater management strategy.

The City of St. Peters, in St. Charles County, Missouri, is one municipality that is using this approach. Their initiative is at an early stage but already merits attention as a cost-effective model for municipal infrastructure. Although designed to meet U.S. Environmental Protection Agency (EPA) stormwater quality guidelines, St. Peters' approach is readily transferable to and relevant for urban climate change adaptation strategies. The EPA notes that precipitation in the U.S. Midwest is likely to become more intense (UCS, 2009), which could increase flood risks and reduce summer water availability (EPA, 2015). St. Peters' staff report changes in rainfall patterns, including an increased frequency and intensity of rainfall, and anomalies such the city receiving 50% of its average annual rainfall in May and June of 2015 alone.

St. Peters has a population of nearly 55,000 people and an enviable quality of life, with 25 parks, more than 30 kilometers of hiking trails and 9 out of every 10 residents living within 1.5 kilometers of a park. However, St. Peters has faced challenges in maintaining its built infrastructure. Since the economic downturn in 2007, for example, the city has lost US$2 million in property tax revenue. Meanwhile, acute flooding resulted in stormwater quality that fell short of state and federal standards. This left the city with the daunting challenge of paying for an estimated US$119 million in stormwater upgrades with an annual budget for this purpose of only US$600,000.

St. Peters explored options for a comprehensive stormwater management system to improve water quality and alleviate flooding. The potential to improve and maintain existing natural systems as a key component of this approach emerged for four reasons:

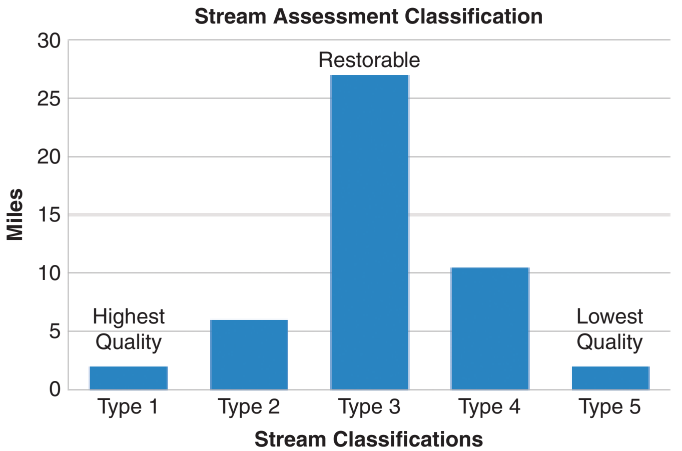
1. St. Peters has a municipal separate storm sewer system (MS4), a system which discharges untreated stormwater runoff into local water bodies. This required a permit from the EPA. The EPA encourages approaches that emulate natural systems by reintegrating rainwater into the natural water cycle (EPA, 2009)– although there is no specific state or federal requirement to protect existing natural systems.
2. St. Peters recognized the capital and operating savings involved in preserving, enhancing, or restoring existing natural systems rather than building new engineered or "green" infrastructure.
3. Many of the natural systems in the St. Peters drainage basins are on private land. Preserving these requires only that the city secure maintenance easements from landowners, a more cost-effective approach than securing easements for capital projects on private lands or purchasing the land. Public maintenance easements also removed a burden from landowners and community associations, if they were previously maintaining these areas.
4. St. Peters places a high value on its natural spaces and recreational areas. This gave the city a logical starting point for preserving existing natural assets and an approach that was consistent with community values related to parks and nature.

The St. Peters' asset management plan conducted a condition assessment of the city's approximately 75 kilometers of stream corridors, including the streams themselves and engineered detention and retention basins (Smith, 2015). The assessment gave the city its first comprehensive understanding of the role of natural systems in the city's stormwater management and of the interaction between natural systems and the city's engineered assets in the management of stormwater.

The assessment demonstrated that about 1% of the natural systems were in intact condition, about 14% could be easily restored to a similar state, and about 85% were severely degraded and would require major interventions to remove invasive plants, replant native species, change the tree canopy, and stabilize banks. This understanding allowed St. Peters to establish

Case Study 8.C Figure 1 *Spencer Creek in St. Peters. A condition assessment of approximately 75 km of stream corridors gave the city its first comprehensive understanding of the role of natural systems in the city's stormwater management and of the interaction between natural systems and the city's engineered assets in the management of stormwater.*

Source: City of St. Peters



Case Study 8.C Figure 2 *Results of the St. Peters' stream assessment classification. Types 1 and 2 were designated as preservation projects. Types 3 and 4 were designated as restoration projects.*

Source: City of St. Peters

management priorities. For example, the city was able to emphasize the monitoring of intact natural systems to prevent degradation and therefore future costs; intervene quickly in the natural systems that could be easily restored to avoid further deterioration and associated costs; and address any health, safety, and property issues in the most degraded areas. The assessment also gave St. Peters baseline data against which to monitor ecosystem changes and the effectiveness of its efforts.

The assessment also created a foundation for outreach and awareness efforts that resulted in a 72% public approval vote in August 2012 in favor of the "Proposition P" sales tax increase (City of St Peters, 2015). Proposition P funding has enabled St. Peters to undertake capital and maintenance projects worth US$9.4 million to prevent stormwater pollution and erosion of creek banks, maintain detention basins, and improve other natural areas. The goal of the stream stabilization and basin retrofit projects is to mimic nature and use native plantings to filter stormwater and remove pollutants (City of St Peters, 2013) The projects thus far blur the distinction between "engineered" and "natural" systems because many of the latter have been altered or engineered to varying degrees. Nevertheless, they suggest that there are measurable benefits to the City of St. Peters in understanding, managing, and/or restoring *existing* natural systems and allowing them to function, to the greatest extent, as nature intended rather than focusing strictly or primarily on either engineered "gray" assets such as stormwater channels or engineered "green" assets such as bioswales and raingardens.

A comparable example is from the Town of Gibsons, just north of Vancouver, British Columbia. Gibsons has committed to manage and maintain its natural assets (such as green space, forests, topsoil, aquifers and creeks) in the same manner as its storm sewers, roads, and other traditional engineered assets. Their strategy focuses on *identifying* existing natural assets that provide municipal services, including services related to climate change adaptation; *measuring* the value of the municipal services provided by these assets; and making this information operational by *integrating* it into municipal asset management through governance system changes (Brooke, 2015). The assets under consideration include forested headwaters that convey stormwater, an aquifer, and the ocean foreshore. As with St. Peters, the town of Gibsons faces climate change impacts. These include sea level rise, increased precipitation, and earlier snowpack melt (Vadeboncoeur and Matthews, 2014). Evidence from Gibsons shows that preserving natural assets provides the town with equivalent municipal services to engineered assets at a substantially lower cost and suggests that protecting existing natural systems can increase the town's resilience to climate change impacts (Town of Gibsons, 2014).

In conclusion, while the evidence base is currently limited, it suggests that the assessment and management of existing natural systems as part of an overall asset management strategy can save capital and operating costs and increase municipal resilience to current funding and infrastructural pressures as well as additional ones anticipated as a result of climate change.

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Case Study 9.A

Climate Adaptation in Helsinki, Finland

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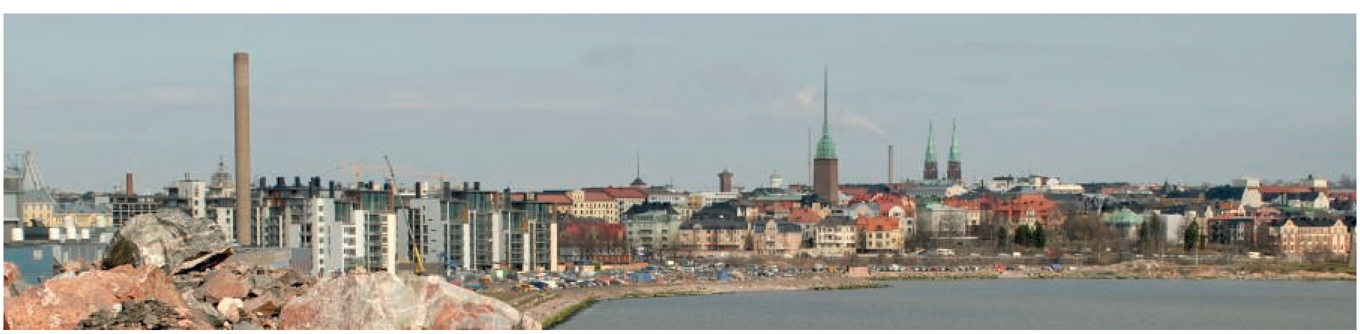
Keywords	Coastal flooding, sea level rise, built environment adaptation
Population	620,715 (City of Helsinki, 2015)
Area	719 km² (City of Helsinki, 2015)
Income per capita	US$44,730 (World Bank, 2017)
Climate zone	Dfb – Cold, without dry season, warm summer (Peel et al., 2007)

The metropolitan region of Helsinki has faced flood events during recent years that have raised flood risk management higher on the city's agenda. Most notable was the record-high coastal flood of January 2005 that in the city of Helsinki saw the establishment of a working group on flood management and subsequent work toward a strategy on flood management (Valkeapää et al., 2010). According to the strategy, the main risks arising from climate change in Helsinki related to flood management are seen to be sea level rise, storm surges, and increased precipitation, with riverine floods causing local challenges.

In Helsinki, exposed bedrock, clay, and moraine and sandy soils are present in about equal shares. In the center of the city, the coastline has been largely modified by landfills over decades (see Case Study 9.A Figure 1). The properties of the soil and the coastline itself have an impact on both construction and adaptation options. Although isostatic rebound (currently at around 4 mm per year) compensates for some of the sea level rise, which is some 20% weaker than the global average, the Helsinki region is facing up to +90 centimeters higher sea level by the year 2100 compared to the year 2000, +33 centimeters being one central estimate and −8 centimeters being the lowest estimate (Kahma et al., 2014). These values do not depict the future flood levels, however, because the projected impact of storm surges have to be added. Currently (in 2011), the mean annual high water level in Helsinki is at +1.21 meters and the estimated 1/250 flood level is +2.08 meters (in N_{2000}, the Finnish national height system) (Kahma et al., 2014). For a comparison, during the flood of January 2005, sea level in Helsinki rose to +1.70 meters (N_{2000}) (Parjanne and Huokuna, 2014).

In 2100, the 1/250 flood level is predicted to rise to +2.73 meters (N_{2000}) (Kahma et al., 2014). Based on this value, the lowest recommended construction level for Helsinki was set at +2.80 meters (N_{2000}), not including the impact of waves, which must be calculated separately for individual coastal stretches.

For new coastal construction sites, following recommended lowest construction heights in detailed planning is a key means of adaptation (Valkeapää et al., 2010). The city of Helsinki has also invested in flood walls and pumping stations at several vulnerable spots that have existing infrastructure. Most of these



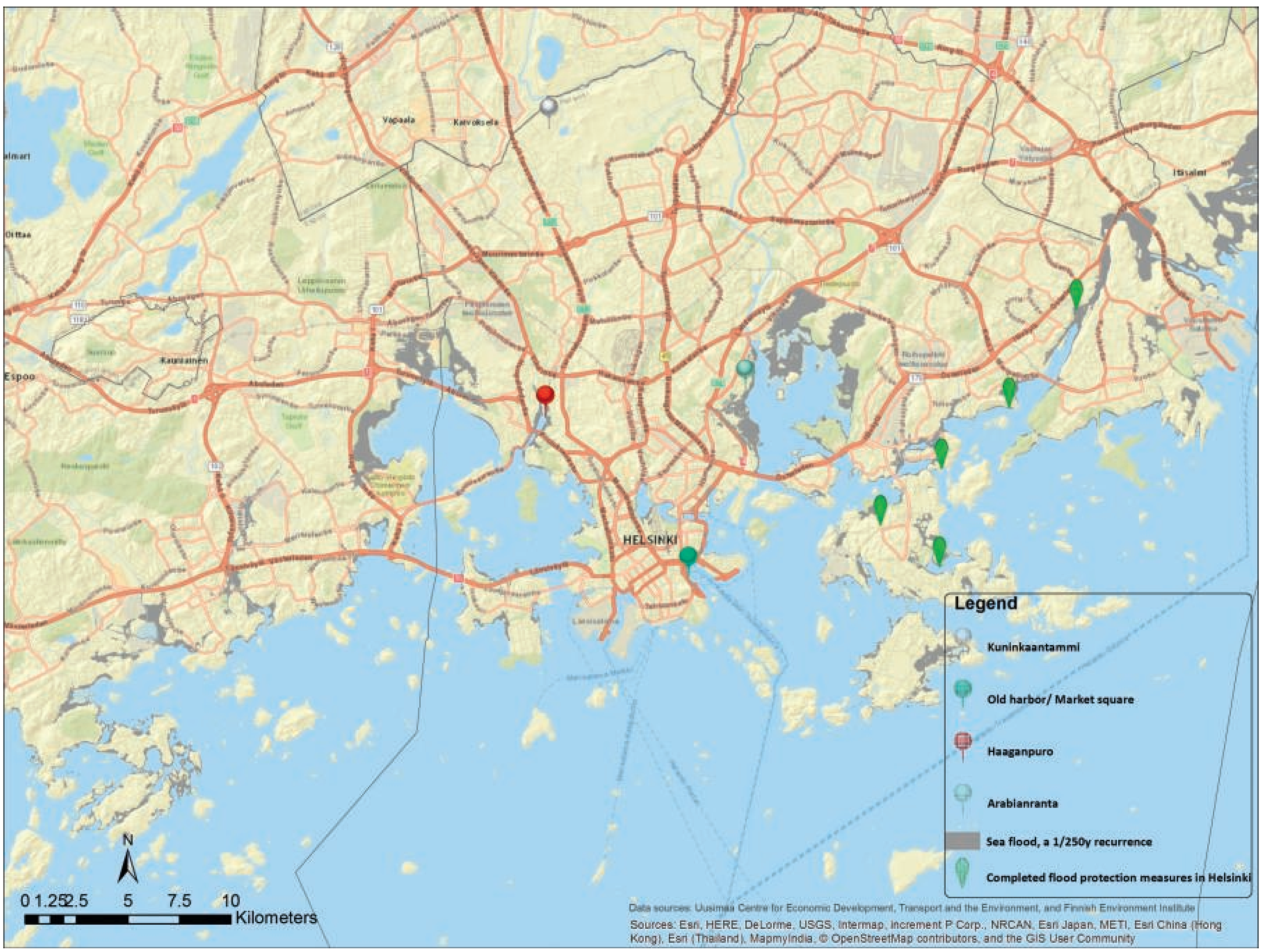
Case Study 9.A Figure 1 *Coastline of southern Helsinki.*

Photo: Jari Väätäinen

areas are old bay areas with clay soils reclaimed from the sea due to isostatic lift. The flood walls are typically embankments made of stabilized clay and soil and vary between 30 and 1,300 meters in length (FCG, 2007). In some coastal areas, such as in Arabianranta, a brownfield development located close to the mouth of river Vantaa about 2 km north of the city center, the immediate coastline has also been left undeveloped to serve as floodplains, both because of recreational needs and due to poor soils leaving the sites unsuitable for development (see Case Study 9.A Figure 2). Many largely unprotected flood-prone areas remain, however, most notably in the historic city center around the old harbor and market square, with considerable economic assets invested in the building stock.

Extreme precipitation events can cause increased flooding in the whole metropolitan region, but these events are hard to predict both temporally and spatially (Venäläinen et al., 2009). In order to adapt to both current and foreseen extreme precipitation events, the city of Helsinki has created a strategy for handling stormwater that prioritizes treating rainwater locally by delaying the flow (Nurmi et al., 2008). Examples of this approach are the Kuninkaantammi residential area currently under construction about 10 km north of the city center, where localized rainwater treatment through rain gardens and green roofs will be applied; and Haaganpuro stream, a 12 km long urban stream flowing through the North-Eastern suburbs of Helsinki, where natural flows have been restored to slow the flow to protect areas downstream from flooding. The city has also upgraded sections of the sewage network in the city center to accommodate floodwaters.

Milder and wetter winters as projected for the Helsinki region are also a problem for the long-term durability of man-made



Case Study 9.A Figure 2 *The residential area of Arabianranta with a floodplain in the foreground, shown during a swell of +70 cm in December 2006.*

structures and public infrastructure. These impacts may be mitigated through improving guidance and permit procedures for building and construction and by taking these risks more thoroughly into account in detailed planning (Yrjölä and Viinanen, 2012).

While many of the decisions regarding adaptation can be made at the municipal (city) level, water and flood risk management are also guided by national and European legislation and partly fall to the regional authorities.

Finland was the first European country to develop a National Adaptation Strategy for climate change in 2005 (Swart et al., 2009), further revised in 2015. The strategy identified national causes for concern and helped different sectors to get started on evaluating their own vulnerability to the impacts of climate change. It also served as an impetus for the municipalities to study their vulnerabilities and adaptation needs.

On the municipal and regional level, two organizations have taken a leading role in adaptation: the Helsinki Region Environmental Services Authority (HSY) and the City of Helsinki Environment Center. HSY coordinated the preparation of the Helsinki Metropolitan Area Climate Change Adaptation Strategy (HSY, 2012) and also monitors the progress on adaptation in the metropolitan area. The Metropolitan Area Adaptation Strategy focuses on topics that cross municipal, sectoral, and administrative boundaries, such as land-use planning, traffic management, storm water management, rescue services, and health care. The strategy process was a communication and negotiation exercise that was based on voluntary commitment. Rather than aiming at legal enforcement, it aimed at a broad consensus among the forty-five organizations that contributed actively or provided comments on the strategy. Although the strategy is not legally binding, it has been taken up in the environmental policies and adaptation activities of the municipalities of the metropolitan area.

On the municipal level, the city of Helsinki Environment Center compiled and prioritized all relevant adaptation measures for the city, with a strong focus on the effects of sea level rise and the potential increase in precipitation (Yrjölä and Viinanen, 2012; Haapala and Järvelä, 2014). Furthermore, the Environment Center is active in a network of Finnish municipalities and research institutes that collects best practices and tools for adaptation under a shared webpage (www.ilmastotyokalut.fi). Monitoring and evaluating the implementation of these measures are going to be important activities in coming years. In the long term, risk assessments and understanding the economic implications of the impacts of climate change and adaptation are likely to gain importance.

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Case Study 9.B

Urban Wetlands for Flood Control and Climate Change Adaptation in Colombo, Sri Lanka

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Keywords	Wetlands, flood control, flooding, resilience, adaptation, ecosystem-based adaptation, coastal
Population (Metropolitan Region)	2,251,274 (Sri Lanka Red Cross, 2016)
Area (Metropolitan Region)	676 km² (Sri Lanka Red Cross, 2016)
Income per capita	US$3,780 (World Bank, 2017)
Climate zone	Af – Tropical, rainforest (Peel et al., 2007)

Introduction

The Colombo metropolitan region is situated along the coast, with the Indian Ocean as its western boundary. As a coastal city situated on a floodplain, Colombo is expected to be vulnerable to the effects of climate change, impacting settlements, infrastructure, and other sectors. Vulnerable populations are found in settlements near the beach, in the floodplains of the Kelani River, and along canals and wetland areas. The Colombo Metropolitan region includes Sri Lanka's administrative and financial capitals and adjacent suburban areas. The city of Colombo has a resident population of more than 600,000, while in the larger metropolitan region, the population totals more than 5.8 million people (DCSSL, 2012; SLRCS, 2015).

Climate Change Impacts, Trends, and Projections

An analysis of the historical changes to Colombo's climate is not publicly available and a detailed analysis currently does not exist in literature. Discernible trends in sea level rise have not been identified for Colombo because tide gauge data in the harbor have shown fluctuation over time (Weerakkody, 1997) and changes in sea level rise for Sri Lanka are generally not known (Eriyagama et al., 2010). Furthermore, future projections for temperature, precipitation, and sea level rise are also not available for Colombo or its metropolitan region. The lack of localized climate risk information poses a challenge for effective climate change adaptation planning at the metropolitan region scale.

The main extreme weather events and disasters that occur in Sri Lanka include floods, droughts, landslides, and cyclones, and these are expected to increase in frequency due to climate change (Eriyagama and Smakhtin, 2010). Increases in the frequency and intensity of floods and droughts and in the variability and unpredictability of rainfall patterns are likely to occur in the future in Colombo (MESL and ADB, 2010). Sri Lanka has long had issues with coastal erosion, and this will be exacerbated by storm surges and sea level rise in the future (MESL, 2011). Flooding is identified as a constraint to the city's economic growth. Saline intrusion due to sea level rise is expected to affect aquifers in the coastal area, which could potentially impact the city's drinking water supply. Mosquito-related diseases such as dengue fever are likely to rise if rainfall increases because it influences the spread of the disease (MESL, 2010).

Role of Colombo's Urban Wetlands in Flood Control

Colombo has some existing ecological features that can help build resilience toward climate change impacts and disasters. The Colombo metropolitan region encompasses an interconnected system of natural wetlands that provides flood control. A core area of these urban wetlands has been conserved and designated as the Colombo Flood Detention Area for the primary purpose of mitigating floods (CEA, 1994).

The growth of the city, coupled with ad-hoc expansion, has posed multiple threats to these ecosystems. Recent research (Hettiarachchi et al., 2014) has demonstrated that the wetland system is undergoing transition from a habitat dominated by native grass to one that is comprised of small trees and shrubs (44%), while the peaty soil has changed to a semi-mineral soil. The transition has compromised the water-holding capacity of this wetland system, undermining its flood control function. In-depth research of the largest wetland, the Kolonnawa Marsh in the Flood Detention Area and surrounding rice paddy land, has identified that 13.5% and 60% of these areas, respectively, have been converted to non-wetland uses between 1980 and 2014. While the rate of change is alarming, the protected wetland regions of the Flood Detention Area by Sri Lanka Land Reclamation and Development Corporation (SLLRDC) have remained largely intact from 1999 onward. Conversion of land use together with nutrient pollution have resulted in the wetlands undergoing a major ecological transformation. The removal of certain uses of the broader wetland ecosystem (e.g., rice paddy cultivation) due to urbanization is one of the main drivers of ecosystem transformation, while climate change could impact the current transformation. According to the study, both legal and illegal conversion of wetlands (into non-wetland uses) is continuing, exacerbating the current destruction. At the same time, major or moderate floods in the area are increasing, based on a newspaper content analysis done by researchers. It was reported that a major or moderate flood has been reported every year after between 2005 and 2011 in the Flood Detention Area watershed. The floods of 2011 were recorded as the most severe in the history of Colombo, displacing nearly 15,000 people.

Climate change poses additional risks to these wetlands systems. Changes in rainfall regimes (e.g., intense rainfall events), increase in temperature, intrusion of saline water due to sea level rise, and storm surges are further challenges to Colombo's wetlands. These challenges will be twofold: climate change itself will impact the ecosystems and ecological function. Additionally, extreme rainfall, storms, and floods will require further flood control, highlighting the need for ecosystem-based adaptation. It is of utmost importance that these elements are thoroughly researched to identify and implement appropriate management practices.

Overcoming Challenges and Increasing Resilience

The case study demonstrates that urban wetlands can play an important role in controlling floods in the Colombo metropolitan area, but changes in its ecological regime are compromising its potential of providing ecosystem services. To maximize the potential of ecosystem-based adaptation mechanisms, it is vital to identify climate risks by using downscaled climate projections. This would also allow the identification of direct climate change impacts to ecosystems, while impacts to humans and their coping mechanisms will also have further knock-on effects on ecosystems. These factors could undermine the effectiveness of wetland ecosystems to build resilience. Identifying such risks at the outset will enable appropriate conservation and management mechanisms and will provide the best opportunity to build resilience.

In the broader context, the lack of climate risk information poses a major challenge to identifying impacts and building resilience in the Colombo metropolitan region. Coastal storms, floods, and heat waves in other cities demonstrate that a city's inhabitants, ecosystems, and infrastructure, such as railroads, roads, power stations, water systems, and wastewater treatment plants can be severely affected if resilience measures are not in place. Localized climate risk information, projections, and research are prerequisites for a comprehensive climate risk assessment for the Colombo metropolitan region. Such an assessment is essential to ensure that the correct type of solutions and resilience efforts are implemented. If future climate change projections are not considered, some actions could be maladaptive, worsening the impacts of climate change. Once impacts, projections., and vulnerabilities are identified, developing integrated, locally co-generated solutions will be vital to ensure the resilience of dense human settlements, critical infrastructure, and ecosystems. Ideally, these should begin with small-scale pilot projects that will enable lessons to be learned for scaling up.

Case Study 9.B Figure 1 *Settlements adjacent to Colombo's wetlands.*

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Case Study 9.C

Storm Surge in Costa da Caparica, Almada, in January 2014

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Keywords	Storm surge, adaptation, mitigation
Population (Metropolitan Region)	2,812,678 (Statistics Portugal, 2015)
Area (Metropolitan Region)	3,015.24 km² (Statistics Portugal, 2015)
Income per capita	US$19,850 (World Bank, 2017)
Climate zone	Csa – Temperate, dry summer, hot summer (Peel et al., 2007)

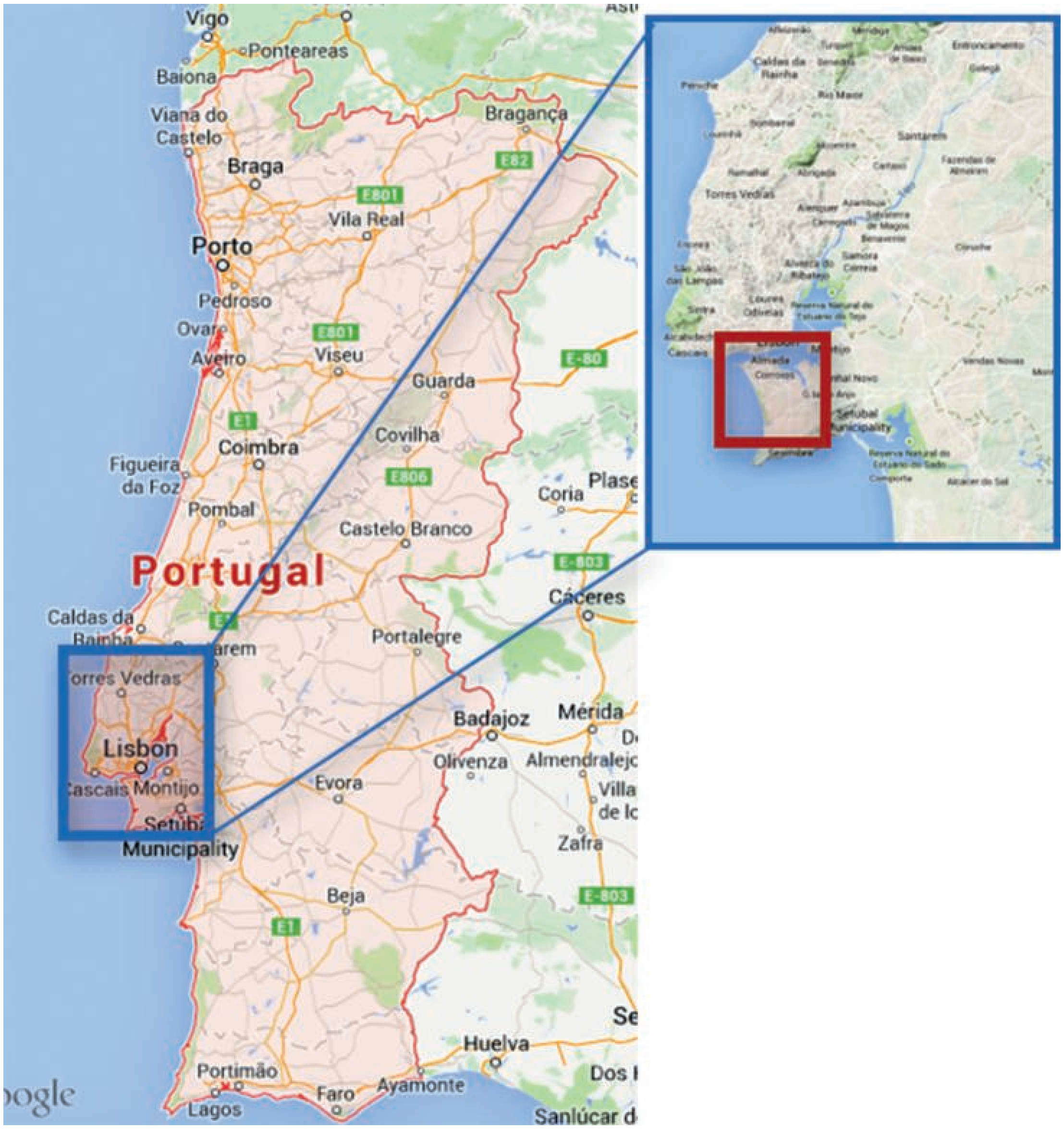
Almada municipality is part of Lisbon Metro Region and it is located on the southern margin of the Tagus River (see Case Study 9.C Figure 1). The municipality is densely populated. It has around 174,000 citizens (more than 2,000 inhabitants/km^2). With an area of 70 square kilometers, Almada has 35 kilometers of waterfront: 22 kilometers of riverside and 13 kilometers oceanfront. A wide beach line characterizes the Atlantic coast of Almada (see Case Study 9.C Figure 2).

Almada's oceanfront is extremely popular in the summer season, particularly the beaches of Costa da Caparica, a parish of Almada municipality with 13,400 inhabitants (Câmara Municipal de Almada, Divisão de Estudos e Planeamento, 2014). The beaches of Costa da Caparica are highly visited by tourists and citizens from the nearby municipalities. In 2014, Almada hosted around 130,000 holidaymakers who contributed an estimated €13 (US$15.3) million to the municipality (Cardeira, personal communication, 20 October 2015). Tourism is an important economic sector for the municipality (ICLEI and CEPS, 2013). The maintenance of the beaches is, therefore, of great importance for the municipality.

Unfortunately, Almada's Atlantic coast is also the most vulnerable zone of the municipality. Case Study 9.C Figure 2 shows the location of this zone. The main vulnerabilities to climate change that the territory of Almada faces are related to coastal erosion, storm surges, and coastal flooding (Freitas et al., 2010).

A study carried out nationally has revealed that the coastline of Almada has a medium to very high risk to the impacts of climate change on the Portuguese coast (e.g., rise of sea level, change of maritime agitation patterns, and storm surges) (Santos e Miranda, 2006). In fact, the adaptation strategy of Almada was initiated as a precaution due to its coastal vulnerability. The local government of Almada has decided to carry out studies on a local scale to evaluate potential future scenarios, following the methodology of the Intergovernmental Panel on Climate Change (IPCC) in order to take informed decisions and wisely select measures to effectively adapt Almada's territory to climate change (Freitas, 2015).

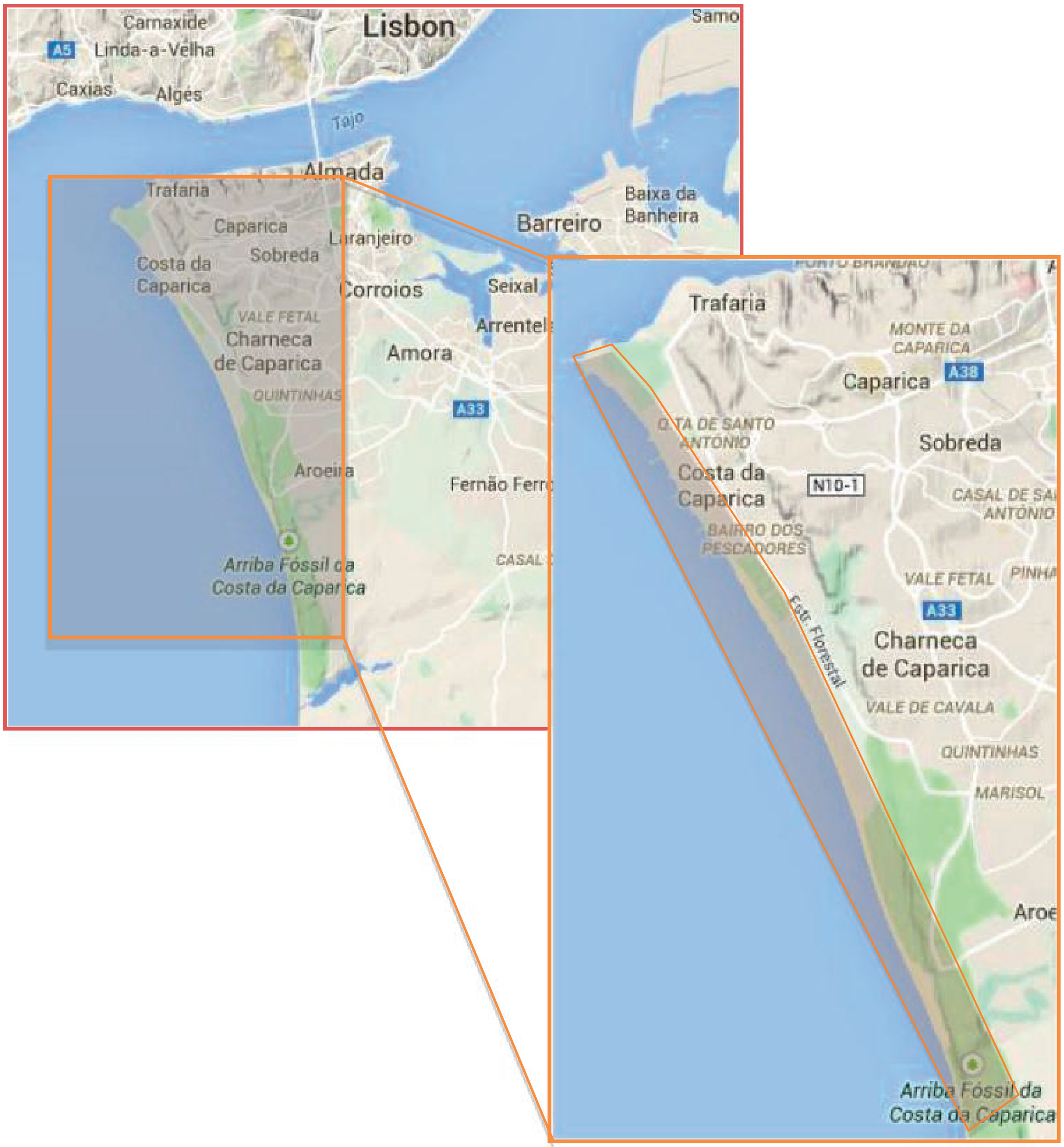
In the past century, the sandy beaches of Costa da Caparica have seen, at various periods, a significant volume of their sand



Case Study 9.C Figure 1 *Almada municipality location in Lisbon Metro Region.*

disappear (Veloso-Gomes et al., 2009). Between 1950 and 1972, groins and a seawall were constructed to minimize losses and stabilize the shoreline; these hard measures successfully contributed to the stability of Almada's sandy beaches in the following years. However, since 2000, these beaches have again been showing signs of instability resulting in considerable sand loss (Veloso-Gomes et al., 2009). To oppose this phenomenon, the municipality has implemented soft measure. It artificially nourished Costa da Caparica beaches with more than 2.5 million cubic meters of sand (Veloso-Gomes et al., 2007, 2009). The nourishment of Almada's beaches took place in 2007, 2008, 2009, and more recently, after the winter storm of 2014. According to the Portuguese Environment Agency (APA), the last sand nourishment cost €4 (US$4.7) million.

Costa da Caparica beaches have also experienced storm surges events. The most recent happened in January 2014. That event was, reports say, a result of a storm–tide interaction (Portuguese Environment Agency, 2014). The combination of high tide level and the occurrence of a storm surge led to an abnormal elevation of the water level in the Atlantic Ocean, which affected the Costa da Caparica beachfront (see Case Study 9.C Figure 3). Storm surge results from a tsunami-like phenomenon of rising water that, in many cases, leads to coastal floods (NOAA, n.d.; Santos e Miranda, 2006). This is of major concern for population and infrastructures located near the coastal frontline. Case Study 9.C Figure 4 shows how close bars, restaurants, camping parks, and the urban area are to the ocean, putting the citizenry and tourists at risk. In 2014, this phenomenon resulted in considerable sand loss from Costa da Caparica beaches and coastal flooding with damage to Almada's oceanfront infrastructure (Portuguese Environment Agency, 2014). According to the APA, the rehabilitation of beach structures, such breakwaters, cost more than €500,000 (US$590,400).



Case Study 9.C Figure 2 *Almada's oceanfront and identification of vulnerable zone.*

In Portugal, adaptive measures have, in most of the cases, been reactive responses to climate change events that have occurred rather than a pro-active response to predicted scenarios (Santos e Miranda, 2006). Apart from the hard measures described, Almada trying to adapt to climate change. In 2007, Almada introduced a strategic mitigation plan to face climate change – ELAC. The strategic adaptation plan is currently being developed.

Even though the adaptation strategic plan is only now being developed, adaptation is included in Almada's local climate change strategy. Adaptation measures have been already introduced in the municipality, such as the increment of flooding quotas in order to prevent the construction of infrastructure in vulnerable zones. Climate change studies are also being integrated into other existing local plans. This integration has the goal of creating synergies between municipal plans (Freitas e Lopes, 2013). Recommendations for climate change adaptation have, for example, been integrated into the recently reviewed local plan of Fonte da Telha that defines the urban development strategy to that area. With this approach, the local government expects to be better prepared for climate change, implementing adaptive measures to minimize its impact on infrastructure and population.

Not only the local government of Almada is apprehensive about coastal erosion. The Portuguese government is concerned with the vulnerability of the Portuguese coast and the potential climate change impacts on the coast. The ministry of Environment and Spatial Planning has requested a vulnerability assessment of the Portuguese coast, and the study revealed that 25% of the coast is exposed to processes of erosion and 66% is at risk (Ministry of Environment, Spatial Planning and Energy, 2015). The Ministry plans to make an investment of

€750 (US$885.6) million until 2050 in adaptation actions such planning and protection measures, elaboration of risk maps, artificial nourishment of beaches, and monitoring the Portuguese coast. These measures are in line with the strategic adaptation actions of the local government of Almada.

Case Study 9.C Figure 3 *Costa da Caparica beachfront and storm surge 2014 detail.*

Apart from the Portuguese government, other stakeholders have been actively collaborating to the climate change adaptation of Almada, including the Department of Environmental Sciences and Engineering (DCEA) and the Center for Environmental and Sustainability Research (CENSE) of the Faculty of Sciences and Technology of University Nova of Lisbon (FCT-UNL), the National Laboratory of Civil Engineering (LNEC), and the Portuguese Environmental Agency (APA).

CENSE and DCEA are collaborating with Almada by using the municipality as a case study on research projects about coastal communities' adaptation and resilience to climate change. They are also supporting Almada in the ClimAdaPT.Local network, of which Almada is a member. DCEA and CENSE are also collaborating on the research group Grupo de Trabalho do Litoral created by the Portuguese government with the goal of introducing solutions to storm surges and coastal erosion on vulnerable coastlines, such as the Atlantic front of Almada (Ferreira, 2015).

LNEC is developing an alarm system to coastal flooding risk. The project (HIDRALERTA) uses the Atlantic coast of Almada as one of its case studies, thus making an important contribution to the municipality's work regarding civil protection (Fortes, 2015). The maps of risks and vulnerability developed by the APA on a national level are very useful for the work being developed in Almada municipality. The findings of the national studies are used to support the local government's own studies.

In relation to the efforts of climate change mitigation, the strategy of Almada is to reduce its greenhouse gas (GHG) emissions by 20% by 2020, as agreed in the Covenant of Mayors (Câmara Municipal de Almada, 2010). The mitigation actions proposed by the local government focus mainly

Case Study 9.C Figure 4 *Costa da Caparica land occupation.*

on the sectors of buildings, public illumination, and industry and transportation, and on the promotion of energy efficiency and the use of renewable sources of energy. By combining its adaptation and mitigation actions with national measures and policies, the local government of Almada expects to achieve the goal set for the municipality and to prevent the occurrence of contradictory impacts (EGENEA, 2007; Câmara Municipal de Almada, 2010).

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Case Study 10.A

Economic Cost and Mental Health Impact of Climate Change in Calgary, Canada

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Keywords	Health, extreme events, rainfall, adaptation, flooding
Population (Metropolitan Region)	1,214,839 (Government of Canada, 2015)
Area (Metropolitan Region)	704 km^2 (Demographia, 2016)
Income per capita	US$43,660 (World Bank, 2017)
Climate zone	Dfb – Snow, fully humid, warm summer (Peel et al., 2007)

The economic costs of climate change to a developed nation city can be illustrated by Calgary, the fourth largest municipality in Canada that sits on the Bow River basin. With a population of 1.2 million, many Calgary residents are either near or on the Bow River and Elbow River floodplains (with some residents living on designated flood ways or in the flood fringe). In June 2013, days of heavy rains in Calgary caused an increase in both rivers. Heavy floodwaters poured into the streets of the downtown core, washing away roadways and bridges. (Munich RE, 2014) With the city under meters of water, 50,000 people had to be evacuated from twenty-six communities.

Historically, both the Bow and Elbow River have flooded (e.g., 1932, 2005); dams were built following these disasters, effectively protecting residence from high-precipitation weather events. In the 1970s, the population in Alberta grew by 30% (Alberta Municipal Affairs, 2015) from the oil boom (Humphries, 2009), with many residents settling in Calgary. This increased the city's density and put pressure on urban infrastructure. Moreover, increasing temperatures in a changing climate have led to increased glacial melt in the Rocky Mountains, increasing the likelihood of high-intensity precipitation events and flooding. The June 19, 2013, flood was the costliest natural catastrophe in Canada's history. More than 30,000 residents were without power and 4,000 businesses were unable to function. In total, the extreme event caused CAD6 billion in total damage with CAD1.7 billion in insured losses. The disaster was also associated with an estimated CAD2 billion future loss to the Canadian economy (and Gross Domestic Product [GDP]) (Menon, 2013).

The flood event triggered the need for change. Calgary promptly moved forward with plans to develop an Expert Management Panel on River Flood Mitigation with six areas of action: managing flood risk; watershed management; event forecasting; storage, diversion, and protection; infrastructure and property resiliency; and changing climate. Their report, *Calgary's Flood Resilient Future*, was released in June 2014. The sixty-two-page paper outlines the panel's major findings under the identified themes with immediate (e.g., urge the Province to regularly review and update official flood hazard maps), mid-term (completed within 2015–2018, e.g., create graduated flood protection level requirements for City infrastructure, long term (initiated within 2015–2018, e.g., develop a time-phased plan to remove buildings from areas with high flood risk, while minimizing the disruption to affected communities), and ongoing actions (e.g., publish up-to-date, graduated flood maps for public information) (Calgary, 2014). Separately, a pilot program, Depave Paradise, was initiated. Increases in impermeable services in dense urban centers vastly contribute to increased flooding. Depave Paradise envisions these spaces being transformed into permeable green spaces. The initiative also creates interim holding tanks for rainfall during extreme events.

Following the flood event, Alberta Health Services recognized the mental health impact of the extreme event. Both Alberta Health Services (AHS) and the Red Cross went door to door to ensure that residents received the emotional help they needed to recover from the flood. AHS immediately provided $25 million in mental health support related to the floods, pledging a total of $50 million in funding to support immediate and future mental health needs. Specifically, the funding provided fifteen experts in mental health to the High River community, with on-site visits from clinical staff to evacuees housed in hotels. Additionally, they hired child and youth mental health experts and provided training and education for disaster responders and flood victims, including suicide prevention training, loss workshops, and psychological first aid. The province also appointed a Chief Mental Health Officer and distributed information (translated into several local languages) to 85,000 residents on where and how to access counseling services and how to manage stress. The flood highlights the cascading effects of disasters in densely populated urban cities and way the impact of these events extends beyond their initial damages, causing future losses to the economy and unexpected health impacts.

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Case Study 10.B

New York's Million Trees NYC Project

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Keywords	Trees, green infrastructure, public–private partnership, urban forest, health, mitigation
Population (Metropolitan Region)	20,153,634 (U.S. Census, 2016)
Area (Metropolitan Region)	17,319 km^2 (U.S. Census, 2015)
Income per capita	US$56,180 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

Introduction

MillionTreesNYC is a public–private initiative launched in 2007 in New York with the goal of planting and caring for 1 million new trees across the city's five boroughs by 2017. Involved organizations include NYC's Department of Parks and Recreation, the New York Restoration Project, the Office of the Mayor, and several universities and research institutes. MillionTreesNYC is part of PlaNYC 2030, a comprehensive plan comprising more than 100 initiatives citywide that seek to support the long-term sustainability of New York and to prepare for the challenges of climate change.

A main goal of the MillionTreesNYC program is the reduction of atmospheric CO_2. Trees accomplish this in two ways: first, by carbon sequestration, and second, via avoided CO_2 emissions that result from reductions in heating/cooling energy use. Trees help reduce energy needs via a combination of shading, transpiration-led air cooling, and wind-speed reduction that reduces the movement of outdoor air into interior spaces that results in heat loss. A 2007 study estimated that the shading and climate effects of existing NYC trees resulted in a cost savings for electricity and natural gas of US$27.8 million annually or US$47.63 per tree. The associated net annual CO_2 reduction was 113,016 tons, valued at US$754,947 or US$1.29 per tree (Peper et al., 2007). The cost-effectiveness of trees' ability to reduce carbon, however, differs both by tree species and by planting location. A 2013 study demonstrated that, in the New York region, the London plane tree is the most cost-effective species due to its long life span and large canopy. The most cost-effective tree-planting locations, meanwhile, are those in areas with a higher proportion of low-rise and residential buildings, where the energy savings from shading will be the greatest (Kovacs et al., 2013).

Expected adaptation benefits of the MillionTreesNYC program include summertime ambient temperature reduction, improvements in air quality, and improved stormwater management. New York like many urbanized areas, is subject to the heat island effect whereby summertime ambient temperatures in the city center are warmer than temperatures in the surrounding suburbs and rural areas. This effect is largely driven by the lack of vegetated surfaces (e.g., grass and trees) in the city center. On average, the daily minimum temperature in New York is 7.2ºF (4ºC) warmer than the surrounding suburban and rural regions, a discrepancy that becomes more pronounced during heat waves. A 2006 modeling study that focused on the New York area found street trees to be one of the most effective urban heat island reduction strategies, yielding the most cooling per unit area of the heat island mitigation strategies studied (Rosenzweig et al., 2006). Trees' ability to reduce local ambient air temperatures is the result of a combination of shading effects and transpiration.

Reduction in ambient temperatures also results in improvement in air quality, due both to reduced ozone levels and to reduced emissions from power generation. Additional ways that trees improve air quality are via interception and absorption of airborne pollutants. Net annual air pollutants removed, released, and avoided average 1.73 lb per tree and were valued at US$5.27 million (or US$9.02 per tree) in 2007 (Peper et al., 2007).

Finally, the Million Trees program is expected to improve New York's ability to cope with storms and flooding. Plants are able to store water in their tissues and thus can absorb excess rainwater much better than hard surfaces such as asphalt, and they can mitigate the burden placed on stormwater and sewer systems during periods of heavy rainfall. As of 2007, New York's street trees were estimated to reduce stormwater runoff by 890.6 million gallons annually, with an estimated value of US$35.6 million (Peper et al., 2007).

Altogether, the benefits of urban trees are calculated to far exceed the cost of their care. Analyses conducted in conjunction with the project estimate that New York's street trees provide US$5.60 in benefits for every dollar spent on tree planting and care.

Human health and well-being is one of the key areas that MillionTreesNYC aims to improve. Tree-related health benefits include averted heat-related morbidity and mortality from ambient temperature reduction, reduced respiratory illness due

Case Study 10.B Figure 1 *New York street trees.*

Photo: Daniel Avila

to improvements in air quality, and a general increase in physical activity associated with green space. A possible health dis-benefit of tree planting programs, however, is increased allergic disease owing to tree pollen. Research is currently under way to determine the relationship between tree pollen prevalence and the incidence and prevalence of allergic diseases in New York as in the case of the benefits of urban trees, initial studies have determined that both the density of tree canopy and the specific species of tree are important factors to consider in assessing the allergenic potential of urban tree pollen (Lovasi et al., 2013; Kinney et al., 2014).

As of August 2014, MillionTreesNYC was nearing its goal of planting 1 million trees. More than 900,000 trees had been planted, placing the project on a trajectory to completion nearly 2 years ahead of schedule (Case Study 10.B Figure 1).

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Case Study 10.C

City of Toronto Flood: A Tale of Flooding and Preparedness

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Keywords	Flood, extreme events, heavy downpour, adaptation
Population (Metropolitan Region)	5,583,064 (Government of Canada, 2015)
Area (Metropolitan Region)	5,906 km² (Government of Canada, 2015)
Income per capita	US$43,660 (World Bank, 2017)
Climate zone	Dfb – Cold, without dry season, warm summer (Peel et al., 2007)

On July 8, 2013, an extreme rain event, only surpassed by Hurricane Hazel (285 mm) in 1954, devastated Canada's largest city with 126 millimeters of rain. Within a few short hours, precipitation changed roads to waterways, causing rivers to rise 3 meters, leading to flooding and erosion in all corners of the urban municipality. The average rainfall in Toronto (the fourth largest city in North America) for the entire month of July is normally is 74 millimeters. That one day saw more than 50 millimeters above the monthly average. The economic costs of the storm were as vast as the devastation: more than CAD1.6 billion in total losses, with CAD920 million in insured losses and property damage in Toronto and surrounding areas and CAD65,325,842 in operating expenses to the City's public sector for the clean-up (City of Toronto, 2013).

In the past decade, Toronto has been impacted by two other extreme rain events. Late in August 2005, 122 millimeters of rain fell causing CAD671 million in damages and triggering the City of Toronto to reflect on its preparedness. Two years after the storm, they developed the Climate Change Action Plan with the objective of exceeding the Kyoto greenhouse gas reduction target (of 80% reduction by 2050) and greening the city's operations. Shortly after, in 2007, the report *Ahead of the Storm* (with multiple images of the 2005 extreme event) outlined a number of short-term actions to start in 2008 that would "improve [Toronto's] ability to cope with climate change, and [included] 29 longer-term actions that [would] result in a comprehensive adaptation strategy." Two years after its publication a 5-day rain event (July 24–28, 2009) left Toronto with a further CAD228 million in losses. In October 2009, the city released the Power to Live Green: Sustainable Energy Strategy that further defined Toronto's mitigation measures.

Despite these strategies and plans, momentum on preparedness and resilience was weakening due to a change in political power. The 2013 event highlighted the city's vulnerability to climate change and the economic damage that a one-day rain event could cause. The July 8, 2013, flood overwhelmed the city's combined sewers, flowed sewage into Lake Ontario, and ushered in a chain of cascading impacts: Toronto beaches, that on average were safe to swim in 90% of the time (Toronto Foundation, 2014), were deemed unsafe for a week during peak tourist season following the storm, and single-family homes and private businesses were inundated with both floodwaters and hazardous sewage, impacting livelihoods and economic activity in the City's core. Those same flooded buildings, if not properly treated, produced mold that had the potential to cause significant chronic respiratory health impacts. The power outage in some communities led to improper refrigeration and citizens being exposed to foodborne illnesses (*Campylobacter enteritis* and salmonellosis). All of these cascading impacts put greater stress on Toronto's health system, increased future economic loss, and created ongoing mental and emotional stress for the city's residents.

The storm underscored the need for a compressive flood prevention strategy and increased investment to the city's aging infrastructure. As a result, Toronto increased investment to reduce the impact of future flood events.

Following the extreme event, the following measures were implemented:

- Investment in Toronto Water Infrastructure, with CAD3.1 billion over 10 years on wastewater and stormwater collection systems
- Basement Flooding Protection Subsidy Program, with CAD962 million provided for the program (an increase from CAD500,000 in 2010 to CAD11 million in 2014)
- "Cause and effect" studies of the water damage to properties, particularly in the west end, to determine the conditions of the sewer system and stormwater storage capabilities
- Financial assistance for damage caused by the storm
- Combined sewer overflows control in Humber River and Black Creek
- Sewersheds and investigation of basement flooding in Study Areas 4 and 5
- Increased public education through partnership with the Toronto and Region Conservation Authority in the form of public meetings, fact sheet distribution to households, and advertisements in local news to help property owners learn how to protect their homes from flooding

The July 8 storm also renewed interest in mitigation as well as adaptation. At the start of 2015, the City Council tabled a motion to establish a Climate Change Mitigation and Adaptation Subcommittee that "makes recommendations to, and reports through, the Parks and Environment Committee" and will "determine and report back on its terms of reference, which are to include a review of City policies, expert advice, and international best practices to mitigate and adapt to climate change." There is optimism that this committee will set in motion policies and measures that will better prepare the city for the next extreme event. The subcommittee is set to meet in March 2015 with a report expected by April 15, 2015 (City of Toronto, 2015).

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Case Study 11.A

Peri-Urban Vulnerability, Decentralization, and Local-Level Actors: The Case of Flooding in Pikine/Dakar

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Keywords	Flood, community-based adaptation, peri-urban vulnerability, municipal capacity, housing
Population (Metropolitan Region)	3,653,000 (United Nations, 2016)
Area (Metropolitan Region)	194 km² (Demographia, 2016)
Income per capita	US$950 (World Bank, 2017)
Climate zone	BSh – Arid, steppe, hot (Peel et al., 2007)

In Senegal, the effects of climate variability and change are manifested through coastal erosion, the degradation of mangroves, and a decline in overall rainfall coupled with an increase in frequency and intensity of precipitation and sea level rise. In 2012, floods affected 287,400 people in the country and caused the contamination of drinking water sources, nineteen deaths, and the displacement of 5,000 families (OCHA, 2015). In urban areas, the exposure to risk is distributed unevenly because 38.1% of the urban population in Senegal lives in slums (UN Habitat, 2008b). Because of the inadequacy of basic services and infrastructure, poverty, social inequality, and inadequate social security systems, the urban poor are the most vulnerable to adverse weather conditions (Bicknell et al., 2009). In Senegal, a large share of this population lives in Pikine, a densely populated peri-urban area with a population of 915,300, situated on the periphery of Dakar. The area developed from the early 1950s with uncontrolled urban growth resulting from rural-urban migration and state-ordered evictions from Dakar city center (Fall et al., 2005). Short and more intense outbursts of rain together with a rapid and anarchic urbanization process, nonexistent storm drainage and waste disposal systems, and the rising groundwater table of the Thiaroye aquifer create increased local runoff rates in the area (Faye, 2011). The result is a higher frequency, intensity, and duration of floods reported over the past 13 years (CRED, 2009). In Pikine, floods have had wide-ranging impacts on the food security, health, infrastructure, and housing conditions of the affected communities. Here, the impacts of flooding bring to light the environmental and social inequalities that characterize these areas and aggravate already precarious living conditions by playing the role of multipliers of existing vulnerabilities. Homes and livelihoods are at risk because these people mainly depend on activities that are disrupted by floods, such as small-scale commerce and artisanal trade. In the long term, climate change is likely to exacerbate these conditions due to more extreme weather events and because Senegal is among those countries with the highest proportion of its urban population living in low-elevation coastal zones. In Dakar alone, 61.6% of the population is considered to be at risk from sea level rise and has already been experiencing rising sea levels of 1.5 centimeter per decade over the past 11 years (UN Habitat, 2008b).

The municipalities of Pikine are characterized by high-density shelters, insecure tenure, and primitive shacks built alongside with more modern housing. These hazardous environments

Case Study 11.A Figure 1 *Guinaw Rail Nord/Dalifort (municipalities of Pikine). Photo: Caroline Schaer*

Case Study 11.A Figure 2 *Guinaw Rail Nord/Dalifort (municipalities of Pikine).*

are considered a necessary compromise for affordable housing close to work opportunities, despite lack of essential services. Critical infrastructure and state services such as waste management, sanitation, and water are at best unsatisfactory and at worst nonexistent. The government intervenes during floods through the formal national risk prevention and disaster management system, namely the "Plan ORSEC," (Direction de la Protection Civile, 2013) which is under-resourced. Given the lack of government prioritization of disaster response and the decentralization process initiated in 1996, local municipalities have an essential role to play in disaster risk management and climate change adaptation. However, the decentralization of responsibilities has not been followed by fiscal decentralization, which means that local municipalities in Pikine are characterized by a lack of financial and human capacity. They are therefore often powerless in responding to the impacts of recurrent flooding and cannot plan for climate adaptation within their jurisdiction. The main part of local municipalities' work is therefore to allocate the negligible municipal budget for reducing flood impacts. As a result, it has been largely left to local actors alone to deal with the short- and long term effects of living in a flood-prone area.

The limited room for maneuvering of the urban poor does not mean that they are powerless. Based on semi-structured interviews, observations, and focus group discussions conducted in these municipalities, it was found that they apply a wide and diverse range of strategies that allow them – in a context of weak state capacity – to react to recurrent flooding with varying degrees of success and sustainability. In Guinaw Rail Nord (GRN) and Dalifort (see Case Study 11.A Figure 1), two municipalities of Pikine, there is an abundance of community-based support networks and associations that seek to provide support to residents. Residents facing flood risks also apply individual disaster risk reduction and adaptation strategies, including improving their houses (i.e., new roof, sanitation), selling off assets, investing in water pumps, and the widespread elevation of the outside and inside floors with garbage, gravel, and sand. The latter strategy may be considered as an urban alternative to raising houses on stilts. This means that many houses are filled up, to the point where some windows are at ground level and the ground floor becomes uninhabitable. Houses are then heightened to compensate for the lost space. Partly as a result of this modus operandi, 40% of all houses in GRN are abandoned. "If we continue like this we will soon reach the sky" expressed a resident to explain the futility of this strategy. The most vulnerable households often do not have any other options than to continue to live in their flooded homes, by elevating their beds on bricks, sanitizing the flood water to avoid diseases, and keeping children in sight on the beds.

The absence of effective disaster risk management and adaptation planning forces the urban poor in Pikine to cope with disproportionate levels of risk. By acting alone, communities are often forced to cope with recurrent flooding through the application of strategies that are very limited in time and scope, which often has undesirable effects for the most vulnerable. They are left with few possibilities for adaptation, which makes them increasingly vulnerable to future floods. The example from GRN and Dalifort shows that there is a strong need for building the financial and human capacity of local municipalities for disaster risk management and climate change adaptation. A strong support from local government to locally initiated actions by community groups and networks of individuals is a precondition for local action to become a catalyst for adaptation and thereby enable them to tackle the challenges posed by climate change in poor urban areas.

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Case Study 11.B

Climate Change Adaptation and Resilience Building in Manila: Focus on Informal Settlements

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Manila Observatory

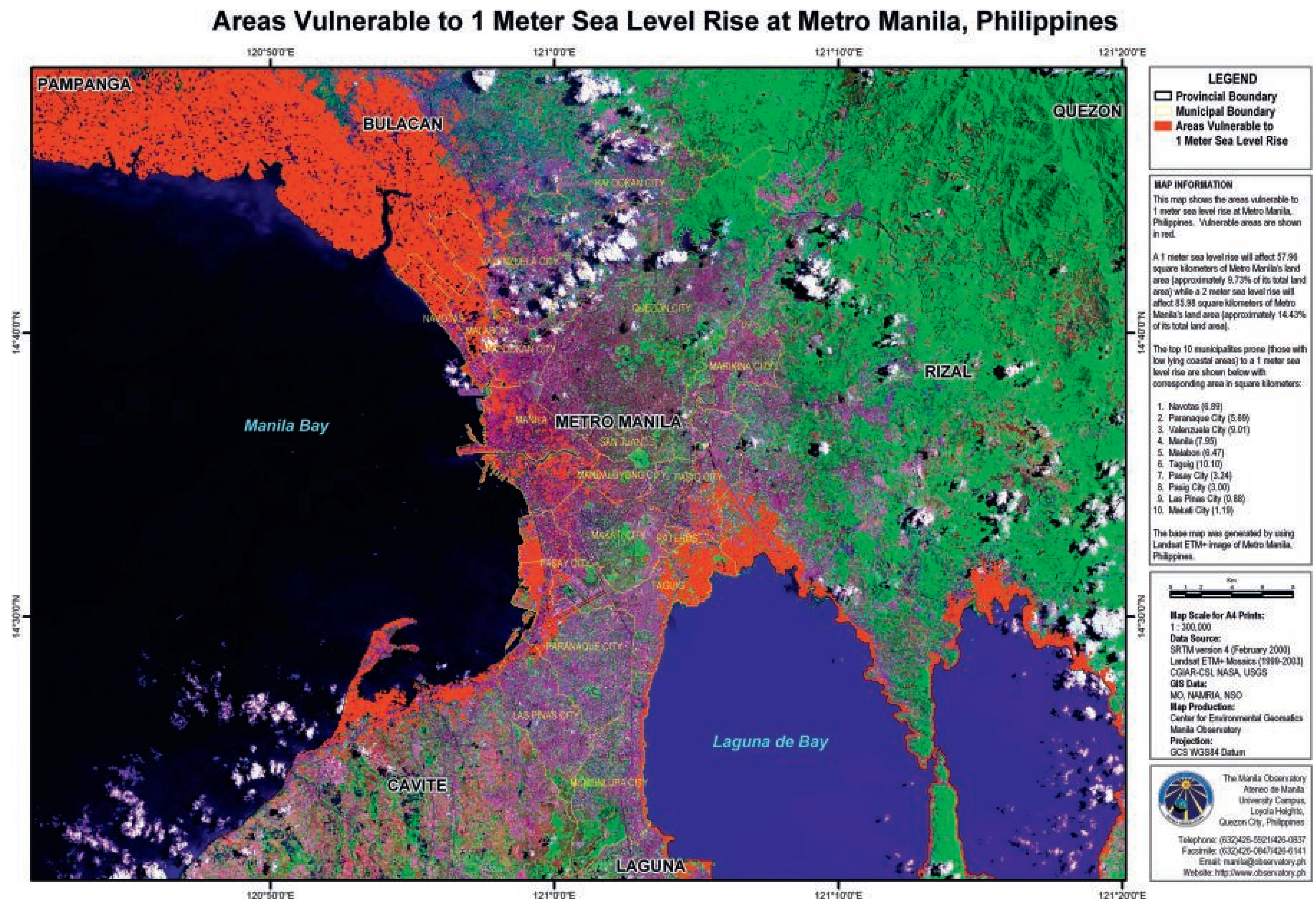
Keywords	Adaptation, resilience building, informal settlements, sea level rise, land tenure, housing
Population (Metropolitan Region)	11,855,975 (Philippine Statistics Authority, 2015)
Area (Metropolitan Region)	620 km² (Philippine Statistics Authority, 2015)
Income per capita	US$3,580 (World Bank, 2017)
Climate zone	Aw – Tropical savannah (Peel et al., 2007)

The Philippines is one of the most vulnerable and risk-prone countries in the world (World Risk Report, 2014) to both climate change and disasters. Its capital, Manila, is considered highly vulnerable and has experienced devastating floods in recent years. Manila sits on a semi-alluvial floodplain with a land area of approximately 636 square kilometers (Bankoff, 2003, Yulo-Loyzaga et al., 2014).

Bounded on the east by the Sierra Madre Mountains and the Marikina Watershed, in the southwest by Laguna de Bay, and in the west by Manila Bay (Case Study 11.B Figure 1), the Pasig and Marikina Rivers are Manila's main drainage-ways to Laguna Lake and Manila Bay. The capital's existing drainage system of *esteros*, a network of natural channels constructed during the colonial period, have proved inadequate today (Bankoff, 2003). More than 20% of the historical drainage capacities have been lost to urban developments (Zoleta-Nantes, 2003). Compounding this, eighty-seven chokepoints constrict the flow of many rivers that cross Manila. Thus, the megacity's drainage capacity is significantly compromised not only by elevation, topography, and the morphology of its rivers, but also by industrial, residential, and institutional developments and informal settlements (Siringan, 2013).

Manila has a population of 13.9 million (UN Habitat, 2015) but hosts a daytime population of 16–18 million people. Composed of seventeen political-administrative units (sixteen cities, one municipality), Manila contributes more than a third (37%) of the national gross domestic product (GDP). Drawn by the prospect of income opportunities, its population continues to increase rapidly as a result of high population growth and in-migration (Porio, 2011). Currently, the metropolis has a density of 18,648 persons per square kilometer but is projected to reach about 29,146 in the year 2025 (Porio, 2014). Approximately 4 million persons as of 2010 are living in informal settlements (Ballesteros, 2010.

While Manila's historical rainy season is from June to August, recent years have witnessed an increase in flash floods due to enhanced southwest monsoon events, thunderstorms, and tropical cyclones. A regional climate model (RegCM3) estimates an increase of rainfall associated with the peak of the southwest monsoon season of up to approximately 20% (Narisma et al., 2014). While the typhoon season normally occurs from June to November, the past few years have seen tropical cyclones and extreme rainfall events occurring throughout the year (Porio, 2012).



Case Study 11.B Figure 1 *Manila topography and low elevation coastal zones.*

Source: Narisma et al., 2014. Manila Observatory

The challenge of climate change adaptation and resilience in Manila lies in balancing the demands for shelter and basic services for the poor and the restoration and enhancement of drainage capacity through spatial planning and the implementation of risk-sensitive zoning laws.

Informality and Vulnerability

Slum growth is projected to be up to 3.14% per year (Table 1). The highest estimated annual growth in slum population growth is identified at the port area of Manila (Case Study 11.B Figure 2). With an estimated growth of 10% per year, these coastal communities along Manila Bay are natural catchment zones for rural migrants from other Philippine regions and provinces (Yulo-Loyzaga et al., 2014).

Migrants and poor communities often settle in slums or informal settlements in high-risk or hazard-prone areas. Informal settlements typically have little or no infrastructure that helps provide protection from storm events and other natural hazards (Feiden, 2011; Porio, 2012).

Moreover, the 2008 Philippine Asset Reform Card states that a large portion of the population living in Manila does not have security of tenure in their housing, jobs, and livelihood sources. Only 61% of households in Manila have sufficient access to basic services (Porio, 2011). However, being poor is not the only reason why certain sectors are more vulnerable to floods or other environmental hazards – spatial isolation and lack of participation in decision-making intensify their present and future vulnerability (Zoleta-Nantes, 2003). These patterns of settlement may be connected to the lack of ability of government agencies to impose building and infrastructure standards, which results in unregulated growth and expansion of informal settlements (Porio, 2011).

Adaptive Risk Governance, Equity, and Resilience

Manila was historically governed as one planning unit as recently as 40 years ago. Today, sixteen cities and one municipality independently exercise political and administrative control of the city. These administrative areas are not ecosystem-based and physical plans are not integrated.

Tropical storm Ketsana in 2009 caused severe losses and damages in Manila and in provinces in Luzon. In response, a PhP50 Billion campaign intends to provide resilient housing,

Table 1 *Slum population, urban Philippines. Sources: Family Income and Expenditure Survey; Metro Manila Urban Services for the Poor (MMUSP) Project, HUDCC, 2008; Philippine Institute of Development Studies, 2011*

	Slum Population 2006	% Slum	Slum Annual Growth Rate (%) (2000–2006)	Projected Slum Population		
				2010	2020	2050
Urban Philippines	2,936,011	7.10	3.40	3,819,766	6,572,683	12,967,806
Large towns/cities	978,422	5.57	3.49	1,122,335	1,736,317	10,108,036
Manila	1,351,960	12.17	8.55	1,877,003	4,689,943	6,668,187
Manila[a]	4,035,283	36.33	3.14	4,565,951	6,294,181	8,949,102

[a] *Data for Manila based on broader definition of slums, which include squatter or illegal settlements and settlements under informal arrangements (i.e., no formal or legal documentation of arrangement) and blighted area.*

Notes: Large towns and cities refer to administrative towns/cities with population as of 2007 above 100,000 to 2,000,000. Slum population growth rate is estimated using exponential growth; r = ln{Pt/Po)/t; for large towns/cities, period covers 2003–06.

Slum population projected is based on estimated slum population growth rate.

Slums are defined as households in illegal settlements (i.e., without consent of owner) or living in makeshift housing.

Case Study 11.B Figure 2 *Samar settlement along Manila Bay, Philippines.*

Photo: Neal Oshima, from Lungsod Iskwater: The Evolution of Informality as a Dominant Pattern in Philippine Cities, *Alcazaren et al., editors, co-published by the Luis A. Yulo Foundation for Sustainable Development, Inc., and Anvil Publishing. Inc.*

relocation, and income opportunities for Manila's urban poor (Yulo-Loyzaga, et al., 2014). Portions of a new metro-wide flood control masterplan is currently in various stages of implementation.

This effort, however massive, has not yet proved adequate in coping with persistent poverty, income inequality, and population growth as the drivers of vulnerability and exposure in Manila's informal settlements. This plan has also failed to provide coordinated solutions to the removal of river and coastal easements by officially permitted industrial, commercial, and residential developments. It is these developments and the income opportunities that they provide that have drawn informal settlers to hazardous interstices of the city.

The Philippine Supreme Court recently declared the government procedures used to fund the master plan unconstitutional, rendering its future implementation uncertain (Philippine Daily Inquirer, July 20, 2014).

Despite these setbacks, there are initial steps to provide in situ resettlement through construction upgrading and capacity-building in disaster preparedness for informal communities. The institutionalization of green building codes and solid waste management and recycling programs by several local governments in the metropolis is now under way. These plans integrate solid waste management with income opportunities and flood management for the informal settlement communities in the flood-prone areas of the city. Ultimately, local government coordination and scaling up human settlements and ecosystem-based physical planning for Manila is required for developing climate resilience. Efforts to integrate the informal economy by recognizing its value contributions to formal supply and service chains need to be accelerated. The economic integration of informal settlers must be accompanied by the extension of basic social services, including access to health care and housing support options, such as relocation and in situ upgrading. The combination of economic integration and access to basic social services is just the first step in adaptation to the impacts of both rapid and slow-onset extreme weather events. Both Pasig City and Marikina City have relocated informal settlements within the city as well as upgraded the basic services to and drainage systems of marginal communities along the riverlines. Ultimately, a combination of evidence-based government programs and non-governmental organizations in support of livelihood diversification and training in emergency management are essential to community-based climate and disaster resilience.

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1 A large part of this presentation is based on the initial findings of the “Coastal Cities at Risk” (2011–2016), a 5-year research project supported by the International Development Research Center (IDRC) and implemented by Manila Observatory (MO) in partnership with Ateneo de Manila University and other universities in Canada, Thailand, and Nigeria. The overall findings of the project Characterizing Vulnerability in Metro Manila: Coastal City at Risk) was by Yulo-Loyzaga et al., in the Coastal Cities at Risk Mid-Term Conference in Vancouver, Canada, March 16–21, 2014.

Case Study 12.A

Consolidated Edison after Hurricane Sandy: Planning for Energy Resilience

Michael Gerrard

Columbia Law School, New York

Keywords	Heat wave, storm, electricity, utilities, policy regulations
Population (Metropolitan Region)	20,182,305 (U.S. Census, 2015)
Area (Metropolitan Region)	17,319 km^2 (U.S. Census, 2015)
Income per capita	US$56,180 (World Bank, 2017)
Climate zone	Dfa – Cold, without dry season, hot summer (Peel et al., 2007)

Superstorm Sandy in October 2012 caused a large-scale disruption of electric service in the New York region. Consolidated Edison Company (Con Edison), the principal provider of electricity in New York and Westchester County, suffered major damage to substations, transformers, cables, and other equipment. More than 1,150,000 customers lost electrical service – five times the number of outages caused by the second-largest service disruption, Hurricane Irene of 2011. Some customers were out of service for as long as 2 weeks.

Shortly after the storm, the Sabin Center for Climate Change Law at Columbia Law School prepared a petition (ultimately co-signed by six non-governmental organizations [NGOs], including the Natural Resources Defense Council and Earthjustice) with the New York Public Service Commission (PSC) to require all the utilities it regulates (electricity, natural gas, cable, telephone, and private water) to develop climate change adaptation plans. Shortly thereafter, on January 25, 2013, Con Edison filed with the PSC for its next rate increase for its electric, gas, and steam systems. The request included US$1 billion in storm hardening (i.e., physical improvements to make the system more resilient to extreme weather events). The investments involved four kinds of actions: protecting infrastructure, hardening components, reducing impact, and facilitating restoration.

The Sabin Center, upon examining the filing, determined that it involved efforts to prepare for the next Sandy-like event, such as placement of sea walls around or elevation of sensitive equipment. However, it did not address increasing risks of other climate events that could result from climate change and disrupt service, such as heat waves. The Sabin Center formally intervened in the rate proceeding. It supported the planned expenditures but argued that a broader array of climate-related threats should also be considered.

To inform Con Edison about increasing risks due to climate change, the Sabin Center also brought a scientist from Columbia's Center for Climate Systems Research to a meeting with top Con Edison officials. The scientist, Dr. Radley Horton, gave a presentation about the latest climate projections for the New York region based on the New York City Panel on Climate Change (NPCC, 2013). This presentation helped to persuade Con Edison that climate change does indeed pose a real threat to the company's operations.

The PSC staff convened a collaborative effort involving itself, Con Edison, various representatives of New York State, New York, Westchester County, labor unions, electricity consumers, academic centers (including the Sabin Center), and environmental NGOs. The collaborative met intensively in the summer and fall of 2013 in an effort to resolve a number of issues in the rate proceeding, including climate change preparedness. In December 2013, the parties reached an agreement. One of the elements of that agreement was that Con Edison would retain the services of climate scientists to prepare more fine-grained projections of future climate conditions in the service area than had previously been available, and that, based on these projections, the company would determine whether changes were needed to its capital plans or its operation and maintenance procedures.

Since the ratepayers would pay for this work, the agreement required the approval of the PSC. In February 2014, the PSC issued a decision that not only approved the Con Edison agreement, but also indicated that it expected the other regulated utilities in the state to adopt similar measures.

The study mandated by the agreement is now under way, leading to the preparation of a Climate Change Vulnerability Study. It will examine, among other things, the vulnerability of the electrical utility system to floods, wind, and heat waves, and it will evaluate Con Edison's current design standards for each condition and advise on whether they should be modified. The Sabin Center and the Center for Climate Systems Research are participating in the study.

Con Edison is also proceeding with the physical work that was part of its initial rate proposal, including such activities as hardening the overhead electric distribution system, the gas system, and the steam tunnels; hardening generating stations and substations; and protecting the telecommunications system. Con Edison is also undertaking a quantitative risk assessment in order to identify cost-effective resilience actions.

To ensure that the other utilities in the state follow the PSC's requirements, the Sabin Center has intervened in the next two major rate proceedings to be filed – Central Hudson Gas &

Electric and Orange & Rockland Utilities. After negotiations, both companies agreed to review the results of the Con Edison study once it is completed, together with any other climate information submitted by the Sabin Center or others, and then to consider whether further adaptation measures are needed.

The Sabin Center has given a number of presentations around the United States and one in Europe advocating use of this approach outside New York. Environmental advocates in a number of states are now considering this option. Efforts are also now under way to persuade the North American Electric Reliability Corporation (a Congressionally authorized entity that sets reliability standards for the nation's electric grid) to take climate change into account.

This effort was led by one academic center and strongly supported by climate scientists in the same university. Several, NGOs, another university (Pace Law School), and the Law Departments of New York State and New York joined in the action. The scientific evidence persuaded the electric utility company and its state regulators of the wisdom of enhancing the resilience of the system.

This effort can be replicated throughout the United States and potentially in other countries. Each of the fifty states has a public utility regulatory agency charged with the responsibility to ensure the reliability of utility service. Most of these agencies have administrative procedures that would allow citizens to intervene or otherwise participate in their rate cases and other proceedings. Thus, advocates in the other states can utilize the strategy that was successfully utilized with Con Edison.

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Case Study 14.A

How Can Research Assist Water Sector Adaptation in Makassar City, Indonesia?

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Keywords	Drought, water pollution, infrastructure, community-based adaptation, planning
Population (Metropolitan Region)	1,520,000 (Demographia, 2016)
Area (Metropolitan Region)	179 km² (Demographia, 2016)
Income per capita	US$3,400 (World Bank, 2017)
Climate zone	Am – Tropical, monsoon (Peel et al., 2007)

Makassar, the largest and most urbanized city in eastern Indonesia, is home to 1.4 million inhabitants with a population density of around 8,011 persons per square kilometer (BPS, 2014). Like many cities in Indonesia, Makassar is struggling to provide a clean water supply for its people. Currently, only 62% of the population has access to clean water – the rest rely on groundwater or carted water. The city's Millennium Development Goal target is clean water access for 78% of the population by 2015; however, this might not be achieved because of many existing challenges such as decaying infrastructure, financial and capacity constraints, and the need for sharing surface water resources with other municipalities within the MAMMINASATA metropolitan region (Case Study 14.A Figure 1).

Furthermore, the water resources are highly seasonal and prone to droughts and high sedimentation due to soil erosion and landslides in the upper catchment. The population is projected to increase by 20% by 2020, whereas water demand is expected to increase by more than 120% as people become more affluent and more connected to the water infrastructure. The MAMMINASATA water supply master plan for 2025 recommends the construction of a new dam, infrastructure upgrades of the water treatment plants, and changes to distribution system coverage in the next 30 years. This plan has not considered the risks of climate change on water resources because an assessment of these impacts had not been conducted for this region at a scale useful for the city's decision-makers.

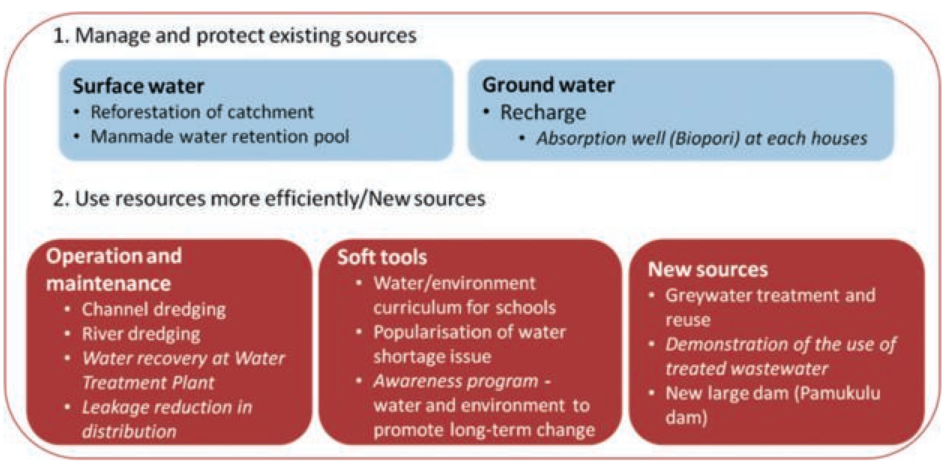
Case Study 14.A Figure 1 *Makassar city as part of the MAMMINASATA metropolitan region, which also encompasses three other municipalities (Maros, Gowa, and Takalar) in South Sulawesi Province, Indonesia. The Jeneberang and Maros rivers feed several water treatment plants in the region. The rivers are also major source for agricultural irrigations.*

Research to Understand Problem and Develop Solutions

The first climate adaptation–related initiative in the city was a collaborative effort among Australian and local researchers, local postgraduate students, the Australian aid agency, local governments, and water utilities. It aimed to inform policy to improve access to clean water and sanitation and to manage the impacts of development and climate change (Kirono et al., 2014). First, it developed a better understanding of current and future water services challenges in the region. This included new information on projections of climate and water resources over the coming few decades, as well as the ability of meeting urban clean water demand under a range of plausible scenarios.

The analyses suggested that problems related with water availability and high sedimentation will still occur in the future. Without additional infrastructure upgrades, as outlined in the MAMMINASATA master plan, water shortages will be common from around 2020. Even more, infrastructure upgrades may only provide short-term water security and need further adaptation from around the 2040s. Thus, there is an immediate need to shift reliance on large infrastructure alone to solutions that combine infrastructure and preventive measures, such as demand management and behavioral changes.

Stakeholders then gathered to understand implications, discuss urban water cycle and integrated water management concepts, and identify adaptation strategies to improve the sustainability of water supply. The strategies fall into two categories: (1) managing and protecting existing resources and (2) resource efficiency and exploration of new sources



Case Study 14.A Figure 2 *Identified adaptation strategies and options. Italicized options are those on their way for implementation.*

(Case Study 14.A Figure 2). Adaptation options for the former include reforestation of upper catchment and groundwater recharge, for example, through *Biopori* – a locally developed tool designed to aid water infiltration and treatment using organic matter in man-made small-diameter pits. Meanwhile, those for the latter include leakage reduction in the distribution system and an awareness program to promote long-term mindset change.

Some of these options are now finding implementation in the city. For example, a legislative framework for *Biopori* has been discussed with funding provided by the Ecoregion Management Centre for Sulawesi and Maluku (PPE SUMA). However, the performance of the *Biopori* for the soil conditions in Makassar and its long-term infiltration capacity, in view of maintenance and operation practices by the public, still need to be verified, so monitored trials are recommended. Likewise, investment will be required to educate and incentivize residents to maintain the *Biopori* in the long-term.

The feasibility of *water recovery* – that is, reusing the water that was discarded during the treatment process – at the City's water treatment plants (WTPs) was studied by the company operating the WTPs. Early results suggest that it will add a 7% increase to current production at each WTP.

Several awareness programs have been implemented by the PPE SUMA office and the Makassar Public Work Agency (PU). The former promotes water use efficiency and discourages solid waste disposal to waterways for a range of audiences (government, communities, and students) using a variety of tools (e.g., education park, books, and videos). Meanwhile, the PU conducts community education on wastewater management in low-income areas of the city. The PPE office also has implemented a pilot test and demonstration for rainwater harvesting and graywater reuse for an office building.

At the city scale, the PU recently funded an effort to revise its clean water supply master plan to incorporate new information developed by this research initiative.

Lessons Learned

This study was undertaken to address the need for improving the adaptation capability of Makassar's urban water system to multiple drivers including climate change. In doing so, it brought global and regional climate change issues into focus by demonstrating local impacts that people care about (e.g., water supply) and relating them to the local government agenda (e.g., the MAMMINASATA master plan). The approach allows stakeholders to examine when and in what conditions the water supply may or may not meet demand. It also allows them to develop multiple adaptation strategies that are targeted to the local context and to identify when risk management measures will be needed.

The high level of stakeholder involvement within this research played a critical role in fostering multiple modes of communication, participation, and social learning between researchers and stakeholders. It also ensured a match between the knowledge needed and the knowledge produced (Larson et al., 2012). Furthermore, the deliberate stakeholder engagement process is proved to increase the likelihood of research uptake into the city policy formulation domains – as demonstrated by the city's recent effort in revising its water supply master plan to mainstream results from the research.

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Case Study 14.B

Rotterdam's Infrastructure Experiments for Achieving Urban Resilience

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Keywords	Ecosystem-based adaptation (EbA) and disaster risk reduction (DRR), flood water, wetlands, stormwater management
Population (Metropolitan Region)	1,173,561 (Rotterdam The Hague Metropolitan Area, 2016)
Area (Metropolitan Region)	990 km^2 (Rotterdam The Hague Metropolitan Area, 2016)
Income per capita	US$46,310 (World Bank, 2017)
Climate zone	Temperate, without dry season, warm summer (Cfb) (Peel et al., 2007)

Over the past 150 years, the port city of Rotterdam has experienced a number of changes – both climatic and non-climatic in nature. The population, the economic value of infrastructure, the city's physical features, and its relationship with surrounding peri-urban and rural areas have all increased significantly. The frequency and intensity of extreme weather events and their impact on the conditions of the city's protection dykes are also increasing and are expected to be much greater in the future.

Climate Change Issues

The city is highly vulnerable to coastal flooding. It has had several near-miss types of catastrophic floods, such as the North Sea storm surge flood of 1953 that caused heavy loss of life and property in the Netherlands. The city also was spared severe flooding during the river Meuse floods of 1993, which caused heavy damage in upstream regions. A new precipitation record was set in August 2006 that caused widespread flooding and damage in the city (C40 and CDC, 2015).

Adaptation Strategy

The Municipality of Rotterdam has an adaptive urban planning process that targets citywide interventions at a topical level (district/neighborhood) when considering the national policy on water (Delta Program). Specifically, the City Council took the lead in establishing the Rotterdam Climate Initiative in 2007, which focused on the management of "too much and too little" water as well as increasing the use of green technological solutions. The Regional Program Committee, responsible for implementation of the national water policy at the regional level, cooperates actively with the city office on urban planning. As a result of this collaboration, various multifunctional infrastructures for making the city climate proof were piloted, including submerged parking in the city center (dc. Museum park), water squares that fill with rainwater and act as water storage, and replacing impermeable paved surfaces in the waterfront area with green lawns to increase water infiltration while also improving Boomjes promenade, an amenity of public urban space.

Water Squares

The first water square was built by combining a playground and water Fun Park with water storage during heavy rainfall. Next to the underground Museum parking facility, a 10,000 cubic meter overflow facility was built to hold peak rainfall. The submerged parking lot is inundated in cases of emergency. In addition to the 5,000 square meter vegetation wall at West Blaak parking facility, 50,000 square meters of green roofs have been installed throughout the city, with the ambition to increase this to 160,000 square meters by 2014. Enterprises and citizens are invited to join through awareness projects, showcases, and incentives such as green roof subsidies of €30/m^2 (US$35.4/m^2). During the Green Year of 2008, the City of Rotterdam constructed eight vegetation roofs, the largest of which was on the Sophia Children's hospital. The goal was to show not only the beauty but also the usefulness of green roofs for water storage, insulation, ameliorating air quality, and biodiversity.

Introduction: Floating Urbanization

Rijn-Maashaven showcases delta technology, beginning with the realization of the Floating Pavilion in 2011. Water recreation and events on a floating stage are organized regularly. The floating pavilion is a 12 meter high construction of three half-round transparent hemispheric constellations. It was built in 2010 and is located in the Maashaven on the City Ports area. It serves as a venue for events, hosts an exposition about the area's development and living "on" water concept, is envisaged as location for a National Water Centre (Stadshavens Rotterdam, 2010, and is a new icon in the area, frequently visited by delegations from all over the world. Plans are to transfer it to another part of City Ports in 2015. It is also the first step in constructing 13,000 apartments, 1,200 of which will be on water, a goal outlined in the "Creating on the Edge" vision (Frantzeskaki et al., 2014) and thus freeing land for urban greenery (see Case Study 14.B Figures 1 and 2).

Case Study 14.B Figure 1 *Floating pavilion.*

Green Adaptation Strategy: Boompjes Promenade: Greening the Waterfront

Boompjeskade is a riverbank location where impermeable pavement has been replaced with grass, creating space for water to infiltrate and to be retained as well as space for people to use. It is a pilot site for greening the riverbanks and promoting biodiversity. Attempts to create soft edges between quays and the river failed in past years due to the use of the river as a main artery for shipping with stringent safety regulations that did not allow "greening" to be part of the design. Efforts in this direction for unused harbor inlets remain limited. In strategies where water bodies (including the rivers) and green areas are understood and dealt with as interdependent ecosystems, synergies can point to more robust urban designs and interventions. However, because the greening of riverbanks is also seen as a promising alternative in view of higher risks for flooding (Delta Program, 2012), limiting or restricting "soft edges" or greening is often considered controversial. In places where this is not the case, there is still a lack of soft water-edges. This is also evinced by the number of references to supportive ecosystem services in the visions, plans, and strategies of the city. This approach may be partially the result of limited collaboration between departments of spatial planning and sustainability with the city's ecology office (Frantzeskaki et al., 2014).

Impacts and Lessons Learned

To maintain the city's historical growth and resilience, mainstreaming climate change risk management into urban development planning has been adopted by Rotterdam. Given the uncertain nature of climate change, the city is largely focusing

Case Study 14.B Figure 2 *Well-adapted city parks.*

on no-regret adaptation measures such as strengthening of dykes, water management, and flood disaster risk reduction. The city government is dealing with climate uncertainties by anticipating changes and dealing with them in a flexible manner by making climate resilient urban developments. The City, ranked fourth among European Green Cities in 2014 aims to reduce CO_2 emissions by 50% by 2025 and to be 100% carbon neutral by 2025 (C40 and CDC, 2015). The key lessons for the resilient city are forward planning, good leadership, and scientific management.

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Case Study 14.C

Environmental Impacts in São Paulo City, Brazil

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Flood, landslide risks, drainage system, hydric crisis	Flood, landslide risks, drainage system, hydric crisis
Population (Metropolitan Region)	19,683,975 (IBGE, 2014)
Area (Metropolitan Region)	7,947 km² (IBGE, 2014)
Income per capita	US$8,840 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

Climate change is expected to increase the risks of flooding and landslides in the São Paulo Metropolitan Area (SPMA) because these are associated with extreme events like storms and heavy rainfall, as well as with the urbanization process, which causes soil compaction and impermeability. Heat waves that have occurred in recent years are also factors that make the city vulnerable. Currently, a major water supply crisis has demonstrated the most important risk factor for the city (http://www2.sabesp.com.br/mananciais/divulgacaopcj.aspx).

The SPMA is set in the sedimentary basin of the Tiete River centered near 23° 32' S, 46° 38' W, a low-lying region inside the Atlantic Mountain Chain. It occupies approximately 8,000 square kilometers and is surrounded by hills that vary from 650 to 1,200 meters in height above sea level. Its proximity to the ocean influences the atmospheric circulation patterns. The region is encroaching on the remaining portions of the Atlantic forest biome, which, in Brazil, despite the high levels of devastation, is still home to a significant amount of biological diversity. The vegetation of the region is therefore made up of fragments of secondary Atlantic forest (known as the Mata Atlântica). São Paulo is the largest metropolitan area in Brazil with almost 20 million inhabitants. It is located in São Paulo State in southeastern Brazil, approximately 600 kilometers southwest of Rio de Janeiro and 80 kilometers inland from the Atlantic Ocean; it has a population density of about 2,500 inhabitants per square kilometer. The population grew by 0.98% from 2000 to 2010, due mainly to the difference between births and deaths, in spite of an outflow due to migration to other states (Migration rates are –1.62 per thousand inhabitants; amounting to 30,300 people per year) (IBGE, 2010).

According to SEADE (Production Center for the processing, analysis, and dissemination of socioeconomic information about the state of São Paulo) (2010), the SPMA is also home to the largest employment base in the country (9.7 million workers). The gross domestic product (GDP) is about US$347 billion, and it has a GDP per capita of around US$17,666 with a per capita income of about US$470. São Paulo's largest industries are slightly more diverse than those in other metropolitan areas in Brazil. Its largest sector, services, makes up 50% of the economy, and, since 1990, São Paulo has seen the largest growth in its information services (251%) and business services (105%).

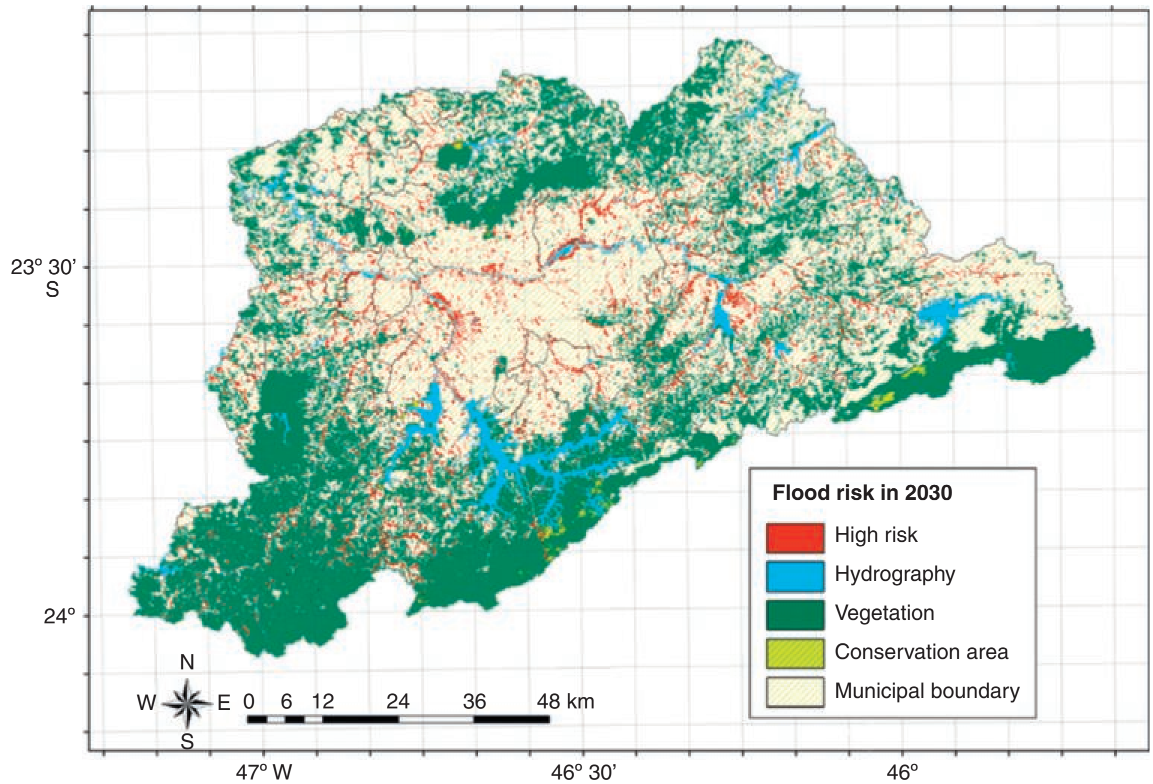
With the urban growth scenario developed by Young (2013), it is possible to analyze the projected changes in 2030 in regard to environmental risks. The principal environmental risk factors and threats are droughts, flooding, and landslides

The current situation remains high risk, considering the analysis since 2001. By 2030, the urban area will have spread by approximately 38.7% and will cover 3,254 square kilometers. With this growth, the region will have 807 square kilometers of areas subject to the risk of floods, a 46% increase during the period.

In terms of flooding risks, the areas susceptible to flooding accounted for 23.5% of urban area in 2008, and 22.3% in 2030 (Young, 2013). The areas at risk increased by approximately 254 square kilometers due to urban sprawl of a total area of 1,141 kilometers. Case Study 14.C Figure 1 shows the possible change in flood risks in 2030 (Young, 2013).

In terms of landslide risks, the vulnerable areas in 2030 may be approximately 4.27% of the expansion areas (these usually occur on high slopes and in vulnerable areas). This seemingly small percentage represents a relative increase of upward of 200% in the area, or, in other words, the area currently prone to landslides (0.9%) could almost triple, from 21.21 square kilometers in 2008 to 69.88 square kilometers in 2030 due to projected city expansion.

There are very strong indications that climate change is in progress, demonstrated by the analysis of a time series of climatological and hydrological data (de Carvalho et al., 2014). These have important consequences for water resource management. These climate changes may bring



Case Study 14.C Figure 1 *Areas in* São *Paulo Metropolitan Area vulnerable to floods in 2030 considering urban expansion.*

Source: Young, 2013

continuous stress to the long-term water security of people in the São Paulo Metropolitan Area, with implications for the water supply.

Existing information shows that São Paulo's systems do not have sufficient capacity to ensure the flow needed to supply service to the population in the medium and long term, considering that the constant demand for water for SMPA and Campinas region is 20.65 m^3/s (average demand in the first half of October 2014).

The prospect of recurring extreme events – such as prolonged droughts alternating with floods – requires a far-reaching vision for planning in São Paulo. To address these conditions, it is urgent to build long-distance channels to transport water, drill wells in the Guarani Aquifer and the transposition basins, or find water in the basins near the Cantareira System.

The preservation of ecosystem services and the protection, conservation, and restoration of biodiversity in the Tiete River Basin is fundamental in the case of São Paulo. The Cantareira Water System that supplies São Paulo is composed of twelve municipalities. A study of Assad et al. (2015) shows the deficit of vegetation in each municipality, especially along rivers that supply the system. Table 1 quantifies the area that must be revegetated to ensure both adequate water supply and biodiversity protection.

General Conclusions

The water crisis in the São Paulo Metropolitan Area, along with the direct influence of climate and hydrological changes, is aggravated by changes in land use, deforestation in the areas containing water sources, and a lack of basic sanitation and sewage treatment. Excess pollution prevents the use of water, even though the causes are relatively well known by managers and organizations that control and monitor the quality of water, air, and soil. On an emergency basis, some actions are suggested to deal with the current drought crisis:

- Immediate changes to the governance system of water resources
- Modernization and streamlining of the management systems. Changes must be implemented in sectorial management response and locally integrated into the ecosystem level (watershed), taking into account ecological, economical, and social impacts
- Implementation of contingency plans
- Reduction of losses in water distribution systems
- A drastic reduction in water consumption
- Major campaigns for rational use for water, reducing waste, and expanding the reuse of water

Table 1 *Revegetation needed the in medium (5 years) and long term (10 years) in Tiete River Basin for the Cantareira Water System.*

Municipality	State	Area (ha)	Natural vegetation (ha)	Natural vegetation (%)	Drainage network length (km)	Area to be revegetated (ha)
Bragança Paulista	SP	51,253.44	5,640.12	11.00	828.52	**5,429.30**
Caieiras	SP	9,620.59	4,797.09	49.86	213.27	**652.14**
Camanducaia	MG	52,821.32	26,410.74	50.00	1,389.92	**2,985.75**
Extrema	MG	24,448.53	7,417.43	30.34	569.75	**2,264.67**
Franco da rocha	SP	13,415.17	4,108.59	30.63	349.91	**1,391.37**
Itapeva	MG	17,727.30	5,295.83	29.87	500.58	**1,518.61**
Joanópolis	SP	37,412.07	17,743.50	47.43	861.00	**3,530.50**
Mairiporã	SP	32,063.92	17,046.96	53.17	848.81	**2,662.75**
Nazaré paulista	SP	32,618.48	15,475.46	47.44	751.07	**4,006.75**
Piracaia	SP	38,539.42	12,832.66	33.30	902.14	**6,322.72**
Sapucaí-mirim	MG	28,490.09	17,201.58	60.38	684.89	**1,464.46**
Vargem	SP	14,257.02	3,231.56	22.67	271.41	**2,313.78**
Total		**352,667.35**	**137,201.52**		**8.171.24**	**34,542.80**

- Immediate investment in long-term measures, such as building long-distance channels for transporting water, drilling wells in the Guarani Aquifer, and transporting water between basins
- Protection, conservation, and restoration of biodiversity along rivers
- Promotion of revegetation actions over the more than 8,000 kilometers of rivers that are part of the Cantareira System, to protect the source and prevent soil erosion

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Case Study 15.A

Closing the Loop in Waste Management in Southern Sri Lanka

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Keywords	Solid waste management, disasters, mitigation
Population (Metropolitan Region)	761,370 (Sri Lanka Red Cross Society, 2015)
Area (Metropolitan Region)	1,270 km^2 (Sri Lanka Red Cross Society, 2015)
Income per capita	US$3,780 (World Bank, 2017)
Climate zone	Af – Tropical, rainforest (Peel et al., 2007)

Solid Waste Management Activities through the Green Recovery Program

Solid waste management is a pressing issue in many urban, peri-urban, and rural areas of Sri Lanka due to the lack of proper collection and disposal systems. Municipal solid waste is a major contributor to climate change, and improper waste management can lead to greenhouse gas emissions such as carbon dioxide and methane, as well as place impacts on health and the environment. Solid waste management is especially a challenge in smaller cities, towns, and peri-urban areas where the waste management infrastructure is not as extensive as in larger cities and town. This case study demonstrates an effective process to manage solid waste with the participation of a range of stakeholders, including local authorities, private businesses, and local communities. The Green Recovery Program, a partnership between American Red Cross and World Wildlife Fund (WWF-US) was launched in 2006 as a post-disaster recovery and resilience project to assist countries devastated by the Indian Ocean tsunami of 2004 (Environmental Foundation and WWF-US, 2010). The Indian Ocean tsunami remains one of the most devastating disasters of recent times with regard to the loss of human lives, economic cost, and post-disaster recovery efforts. The Green Recovery Program is one of the first examples of a humanitarian–environmental group partnership that aimed to build post-disaster resilience.

In Sri Lanka, the partnership joined forces with the Environmental Foundation to address many post-disaster recovery and resilience issues. Solid waste management was one major challenge, and the Program carried out several activities to address this. Composting, recycling, and landfilling were approaches undertaken by local authorities and stakeholders to minimize and manage waste. However, one of the main challenges has been the disintegration of such approaches. Under the Program, several interventions were initiated to close the loop in waste management through an integrated approach.

Composting and Home Gardening as a "Backdoor" Approach to Waste Minimization

The partnership supported disaster-affected families to adopt environmentally friendly waste management practices at the household level. The first step focused on reducing household waste that required disposal. Composting and home gardening were introduced at the community level in coastal urban areas in the Devinuwara, Matara, and Weligama Divisional Secretariat Divisions in the Matara District of Sri Lanka (Environmental Foundation and WWF-US, 2010). This was considered a "backdoor" approach to composting because waste separation was introduced through the promotion of home gardening within these communities. Training on organic home gardening techniques and composting were provided, along with material inputs of compost, seeds, and plants. As a result households were able to enjoy the benefits of composting through pesticide-free vegetables in their home gardens. This in turn helped improve nutrition and increase food security and household savings. While making compost, households were encouraged to separate recyclables, and recycling business networks were developed to collect the recyclables from these peri-urban villages. Additionally, community campaigns and awareness programs were carried out to discourage use of non-biodegradable bags and packaging ("refuse"), and the standard "three-R" approach – reduce, reuse, and recycle – was emphasized to minimize waste generation at the household level. The Environmental Foundation worked with American Red Cross Water and Sanitation Program and the local Sri Lanka Red Cross Society (SLRCS) staff to train volunteers and community leaders as social mobilizers to reach a wide range of beneficiary families at the village level. More than 1,950 beneficiary families received support from the Program for composting, home gardening, and hygiene promotion.

Local-Level Collection Networks and Recycling

Often the missing link between separation and recycling is the collection network for recyclables, especially polythene and plastic. This is less of an issue in large cities where citywide collection systems are in place; however, it is a challenge in urban areas away from large cities. to close the loop in waste management, the Environmental Foundation obtained the support of a local youth group, Sumithuro Api, who were already engaged in recycling from paper-based waste (Environmental Foundation and WWF-US, 2010). The group, after receiving training, engaged in collecting polythene and plastics from villages, which were then sent to local recycling centers.

The program also supported a recycling facility operated by a local business owner (Environmental Foundation and WWF-US, 2010). The program supported the facility by purchasing machinery and by providing funding to construct a small-scale recycling facility. This facility was supported by local recycling networks and helped revive and establish new polythene collection networks to absorb material to fulfill the capacity of the factory by developing a market-based recyclable collection system.

In larger towns in the region, due to the lack of space, people depend on local authority services for waste management. To complete the waste management loop at the larger urban level, the partnership supported the Weligama Urban Council, a pioneer in the country in composting municipal solid waste, to expand its composting yard and recyclable storage facility (Environmental Foundation and WWF-US, 2010).

Lessons Learned

This case study demonstrates how solid waste management in small towns, cities, and peri-urban areas can be effectively managed to mitigate greenhouse gases. It highlights the importance of addressing every component of the waste management cycle. The disintegration of just one component can result in the breakdown of the management process. It highlights that including the private sector, especially for recycling, is vital to ensure demand for recyclables and to make the process sustainable. Another key to the success of this model was the use of social mobilization approaches and community participation in the process. Awareness creation, sensitization, motivation, and voluntary community actions were key in binding the technical components when closing the loop in waste management.

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Case Study 15.B

Accra, Ghana: The Challenge of a Developing City

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Keywords	Municipal solid waste, landfill, sustainable waste management, informal recycling sector
Population (Metropolitan Region)	2,316,000 (United Nations, 2016)
Area (Metropolitan Region)	971 km² (Demographia, 2016)
Income per capita	US$1,380 (World Bank, 2017)
Climate zone	BSh – Arid, steppe, hot arid (Peel et al., 2007)

In 2013, the citizens of Accra generated conservatively 2,200 tons per day of municipal solid waste (MSW) (Oteng-Ababio, 2014). The National Environmental Sanitation Policy (NESP) mandates each district assembly to be responsible for solid waste management (SWM), which normally covers collection and sanitary disposal with little or no incentive for waste minimization, thus compromising the ability of city authorities to provide efficient SWM services (MLGRD, 2010). Source separation, for example, remains alien in most cities, while the lack of an exact inventory of the waste stores in the face of illegal dumpsites and disinterested public officials has exacerbated the situation, creating a MSW industry that is vague, disjointed, and dysfunctional (Oteng-Ababio et al., 2013). Typically, waste collection (about 75% of the city's generated waste) and transport to poorly managed dumpsites consume a disproportionate and unsustainable share of municipal budgets (estimated at US$3.45 million or GHS 6.7 million per year), leaving many communities without basic collection and disposal services and driving them to burn their waste – with deleterious health impacts (Oteng-Ababio, 2015).

Solid waste collection in Accra is mostly privatized. The city contracts with about nine waste collection firms that are responsible for all residential, commercial, and industrial waste generated in their respective collection districts. The firms recover their costs by collecting city-regulated fees from waste generators (Alhassan et al., 2014). Waste is collected using different types of vehicles ranging from tricycles to small trucks equipped with compactors, to large trucks with or without compactors. The major reasons for partial waste collection coverage on the part of the private service providers are inadequate or late payment of operational funds and lack of a system for monitoring the performance of private contractors. Among other attempts to increase collection coverage, there is a current attempt by the local authority, in collaboration with Zoomlion, a private company, to mount a project that will provide free plastic waste containers to individual households (Thompson, 2010; AMA, 2015).

Over the past 10 years, AMA has used at least seven temporary (poorly managed) dumping grounds within the city perimeter to dispose of the city's solid waste, thus impacting public health and the environment. This has led to public outrage and resulted in AMA and Ghana's Environmental Protection Agency (EPA) to work toward the closing of open dumps in the city of Accra. The city is served by the new Tema sanitary landfill, located at Kpone, 30 kilometers from the city center (Ranjith and Themelis, 2013). This facility was constructed and is operated by Zoomlion Ghana, a private Ghanaian company. The landfill was constructed to accept 700 tons per day but currently receives more than double that amount (more than two-thirds comes from Accra). The city recently entered into a contract for the construction of a new landfill, but a site has not been determined and financing is not certain. It is unknown whether the new landfill will include leachate and LFG collection systems. The non-collected waste is openly burned or dumped in stormwater and sewage water drains. Open burning of waste is common even in high-income communities.

Case Study 15.B Figure 1 *Dumping ground in Accra, to dispose of the city's solid waste.*

Currently, nearly all recycling activities in the city in particular and the country as a whole are carried out by the informal recycling sector, with participants typically coming from impoverished and marginalized groups working in hazardous conditions to help address this growing burden (Oteng-Ababio, 2015). These waste pickers collect recyclables by sorting through mixed waste on the streets or at the dumpsites. Some informal recyclers also collect waste by going home to home and by offering incentives to households. Recently, there appears to be a semblance of some collaboration between the informal waste sector and some private companies. For example, the new Tema landfill built and being operated by Zoomlion provides a special shed for informal waste recyclers to sort out recyclables.

The fact that Accra generates a large amount of organic waste (about 65%) that is high in moisture content but without a proper recycling plant makes a sad commentary. There is no official dedicated organics collection service provided by the city, but there are two innovative models currently in place in Accra: a community-based, small-scale composting project and a large-scale, open-window facility with a materials recovery unit. The small-scale composting project involves collecting approximately 2 tons of organic waste per day from sixty companies, mainly hotels and restaurants in the tourist area of Osu. These companies receive a 5–10% collection discount depending on volume. The diverted organic waste is sent to neighborhood composting centers where it is converted to compost. The large-scale Accra Composting and Recycling Plant (ACARP) receives approximately 500 tons of MSW per day (organic and nonorganic). The plant is owned and operated by a private company through a public–private partnership with the city. Since its commissioning in 2012, the facility has processed a total of 16,000 tons (CCAC, n.d.)

Case Study 15.B Figure 2 *E-waste scavengers in Accra burning wires to harvest copper.*

Ghana reached the middle-income level in 2010 and, more than half (51.9%) of its population lives in cities (GeoHive, 2014). Recognizing that urbanization is growing and that rising incomes also increase waste generation, addressing the downstream consequences of waste collection and disposal practices is clearly a priority because waste is not only an important climate challenge, but one that affects every aspect of life for people in the city and beyond. The city, through its development partners, has shifted focus from its old management practices to attempts at reducing short–lived climate pollutants (SLCPs) through well-managed waste systems to help mitigate climate change and produce significant local and national health, environmental, and economic co-benefits, including improved quality of life and, importantly, dignity for local communities. Consequently, the city of Accra has made much progress toward sustainable solid waste management. It closed the last waste dump within the city, constructed a new sanitary landfill, started operations at the new material recovery and composting facility, and is encouraging the informal waste recycling sector (Ranjith and Themelis 2013; Oteng-Ababio, 2015). The city is now striving, with much financial difficulty, for 100% collection of MSW, increased public awareness and participation in reducing littering, and stopping the open burning of waste that constitutes a major threat to public health through dioxin and particulate emissions.

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Case Study 15.C

The Successful Actions of London Municipality

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Keywords	Municipal waste management, efficient source separation, landfill tax
Population (Metropolitan Region)	8,673,713 (Office of National Statistics, 2015)
Area (Metropolitan Region)	1,572 km^2 (Office of National Statistics, 2015)
Income per capita	US$42,390 (World Bank, 2017)
Climate zone	Cfb – Temperate, without dry season, warm summer (Peel et al., 2007)

The city of London, like most cities in the developed world, has generally adopted the philosophy of waste prevention and minimization, recovery, incineration, and landfill as the menu for developing their municipal solid waste management (MSWM) systems. In 2013, Londoners produced 3.6 million tons of municipal solid waste (MSW), a 20% decrease since 2000 (Defra, 2015). The treatment of MSW is dominated by waste-to-energy (WTE), 44.1% of the total, followed by recycling/composting (30.4%) and landfilling (25.5%). The landfill disposal exhibited a decrease of 72% since 2000, whereas WTE increased by 65% and recycling/composting increased by 216% (Defra, 2015). Additionally, the CO_2-eq saved from the use of recycling and reusing was calculated by UK authorities to be 5.9 million tons, from composting 1 million tons and from energy recovery 0.18 million tons. Landfilling emitted 2.8 million tons, thus making a total saving of CO_2-eq from the waste disposal methods applied in London 4.3 million tons (Defra, 2015)

The main driver for the rapid growth of sustainable waste management technologies in London was the increase in the landfill tax, from US$90 (or £58) per tonne in 2011 to US$130 (or £80) per tonne in 2014, which actually raised London's annual bill for sending municipal waste to landfills from about US$430 (or £265) million to roughly US$485 (or £300) million (Greater London Authority, 2011). In addition, the cost of recycling was rapidly decreased by –US$40 (−£26) on average in 2014, thus promoting such methods of waste disposal. The landfill tax has also made the cost of generating energy from waste more comparable to landfill and in some cases more commercially attractive, depending on contractual arrangements (Greater London Authority, 2011)

In addition to the increase in the landfill tax, the Department of Environment Food and Rural Affairs (Defra) has revised its definition of municipal waste to include more commercial waste. This brings it into line with other European Union (EU) countries and ensures that the UK is meeting landfill diversion targets under the European Landfill Directive. Implementing this new measure will put considerable pressure on local authorities, communities, and businesses to better manage more of their waste (Greater London Authority, 2011)

The key characteristics of London's waste management is promoting waste management activities to achieve the greatest possible climate change mitigation and energy saving benefits while managing as much of London's waste within London as possible, aiming toward managing 100% of London's waste within London by 2031 (Greater London Authority, 2011).

There are many local and regional education programs and initiatives ("less in your bins, more in your pocket") "nice save" campaign; community composting and reuse; WM facilities producing electricity and heat for local use; volunteer clean-up campaign and others) organized and sponsored by the municipality that provide producers and consumers with the knowledge, infrastructure, and incentives to change the way they manage municipal waste. The main target of these programs is to reduce the amount of waste generated, encourage the reuse of items that are currently thrown away, and to recycle or compost as much material as possible (Greater London Authority, 2011).

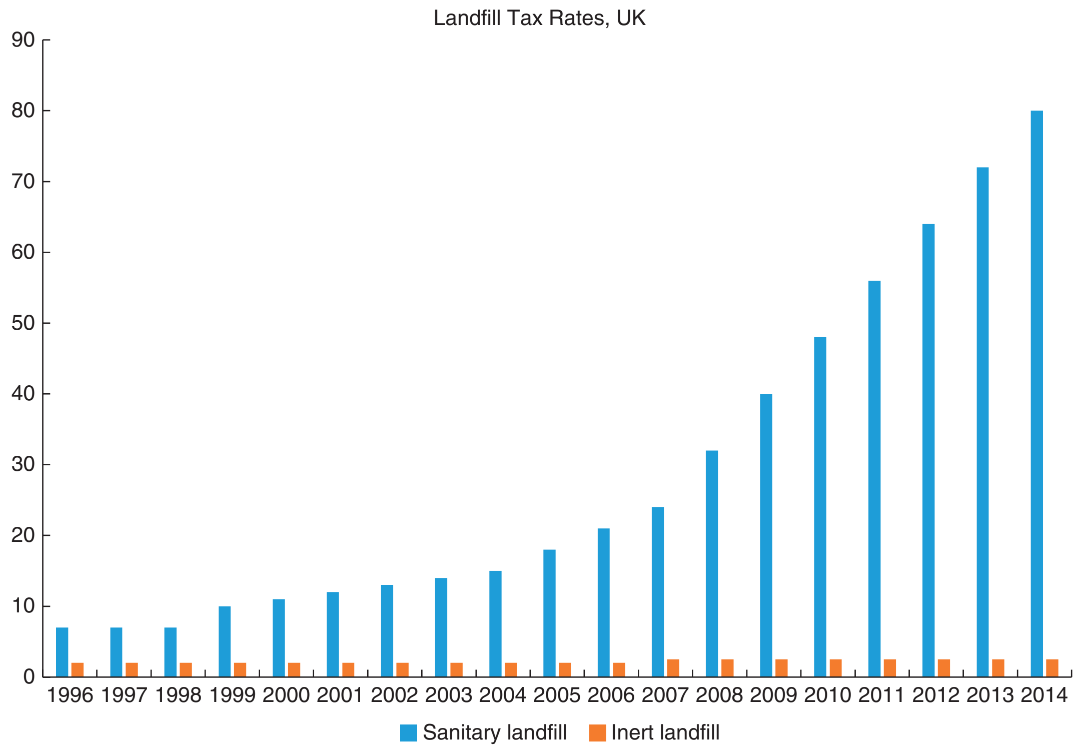
London's household recycling and composting services are active in all boroughs and provide curbside collection services for paper, mixed cans, and plastic bottles. All except two boroughs collect glass at the curbside and all except one collect cardboard. Thirteen boroughs collect mixed plastics from curbside services, and nine boroughs collect food and green garden waste together. Some boroughs provide food and green garden waste collections for flats and estates. (Greater London Authority, 2011). There are forty-one reuse and recycling centers (RRCs) in London, providing drop-off facilities for a range of household waste materials for reuse, recycling, and disposal. They serve a wide community, from the inner city to the semi-rural fringes of London.

In addition, the CO_2eq emissions performance standard (EPS) was implemented for London's municipal waste management activities to work toward achieving rather than prescribing particular waste management activities or treatment technologies. This approach supports waste activities and services that reduce the amount of municipal waste produced and captures the greatest number and highest quality of materials for reuse, recycling, or composting and low-carbon energy generation. A key characteristic of this approach is that it allows flexibility. Waste authorities can look across the whole waste system to find the greatest CO_2eq savings to make an important contribution to achieving the EPS depending on their specific circumstances. In addition to the EPS, the Mayor has set a minimum CO_2eq emissions performance standard that requires all energy generated from London's municipal waste to be no more polluting in carbon terms than the energy it replaces. With this approach, the municipality advocates the development of low-carbon municipal waste management technologies. This is estimated to be possible for about 40% of London's municipal waste after recycling or composting targets are achieved by 2031 (Greater London Authority, 2011).

The municipality has also produced a non-statutory Business Waste Strategy for London's commercial and industrial waste and for construction demolition and excavation waste – waste that is collected and disposed of by waste operators under private contracts rather than by local waste authorities. Waste produced by businesses, be it from shops, restaurants, and offices; industrial processes; or construction and demolition sites – makes up 80% of London's waste: 16 million tonnes a year (Greater London Authority, 2011)

A recent study funded by the municipality concluded that a "do nothing new" approach would lead to an increase in London's annual municipal waste management bill to about US$1,100 (or £680) million by 2031. The results from the study showed that by changing the way Londoners manage their municipal waste, London could save between US$920 (or £573) million and US$1,350 (or £838) million and save between 20 million and 33 million tonnes of CO_2eq emissions by 2031. (Greater London Authority, 2011) These savings can be achieved predominantly by reducing the amount of household waste produced per household each year by approximately 1%, by a gradual decline in municipal waste sent to landfill, by achieving 45–67% recycling and composting rates (including reuse), and by increasing the amount of non-recycled and organic waste used for energy generation.

In addition to making carbon savings, optimizing the treatment of waste can also contribute significantly to a reduction in London's energy bill. Based on the wholesale cost of electricity and gas, London's municipal waste after maximizing recycling could contribute US$150 (or £92) million of savings to London's US$7.1 (or £4.4) billion electricity bill and take US$38 (or £24) million off London's US$4 (or £2.5) billion gas bill (Greater London Authority, 2011)



Case Study 15.C Figure 1 *The increase in the UK's landfill tax rates over time. This landfill tax increase helped to incentivize recycling.*

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Case Study 16.A

Low-Carbon Transition in Shenzhen, China

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Keywords	Low-carbon transition, emissions trading system (ETS), China's low-carbon pilots, local carbon policy action, typhoons, extreme rainfalls
Population (Metropolitan Region)	10,828,000 (United Nations, 2016)
Area (Metropolitan Region)	1,748 km² (Demographia, 2016)
Income per capita	US$8,260 (World Bank, 2017)
Climate zone	Cfa – Temperate, without dry season, hot summer (Peel et al., 2007)

China is the world's largest carbon emitter and, at the same time, increasingly determined to address climate change. Because the top leadership announced capping carbon emissions by 2030 (The White House, 2014), this goal will influence Chinese cities in the coming years. Given that 40% of carbon emissions are from dozens of China's largest cities (Dhakal, 2009) and are primarily from their industrial sectors (Wang et al., 2012), these cities are key sites for addressing climate change and are influential in shaping the future direction of China's actions on climate change.

Case Study 16.A Figure 1 *The electronic taxi in Shenzhen. As of November 2014, there were 9,392 new electric vehicles (Shenzhen Municipal Government, 2015); the program is just one of the city's low-carbon successes.*

More than 80% of Chinese cities (at the prefecture level and above) have stated goals to become eco-cities, and more than 40% have set targets to become "low-carbon cities" (Zhou et al., 2012). Shenzhen is one such city, but it is also unique among its peers because it was the first to set targets for peak carbon emissions from 2017 to 2020 (National Development and Reform Commission [NDRC], 2014), and it achieved the lowest energy consumption per gross domestic product (GDP) among major Chinese cities in 2010 (Liu et al., 2012). By continuously expanding green areas to increase carbon sinks and introducing market mechanisms and legislation in the Shenzhen Emission Trading Scheme (Shenzhen ETS), this city enhances its low-carbon transition through reducing carbon emission and is a leader in China's local low-carbon practices.

Shenzhen, the core city of the Pearl River Delta urban cluster, has a population of more than 10 million and is roughly 1,991 square kilometers in size. As one of the first Chinese coastal cities to open up in 1980s, it has achieved rapid economic growth but suffered from a deteriorating environment in the process. In 2005, the Mayor of Shenzhen called for a policy solution to the "four challenges" that threatened Shenzhen's development: limited land and space resources, energy and water resource shortages, a burgeoning population, and weak environmental carrying capacity. Subsequently, the municipal government issued regulations to strengthen urban environmental protection, which laid the foundation for Shenzhen's leading role in local low-carbon policy actions in China.

As the impact and severity of climate change in Shenzhen become increasingly clear, the city's actions to address climate change take on an even greater significance. Shenzhen has encountered climate hazards such as extreme rainfall, typhoons, and more, which as a whole result in the direct economic loss of RMB200 million in 2014. In March 2014, the daily amount of extreme rainfall was more than 150 millimeters, which resulted in flooding occurring in more than 100 municipal places, more than 200 flights delayed, and one person dead (Meteorological Bureau of Shenzhen Municipality, 2014:). To curb these hazards' disastrous impact at the local level, Shenzhen has developed several precautionary measures such as the local hazard monitoring system and the code of practice in times of typhoon and extreme rainfall (Meteorological Bureau of Shenzhen Municipality, 2013). As the first city to issue a code of practice related to extreme weather in mainland China, Shenzhen is increasing its capacity to adapt to climate challenges through educating its public about the extreme weather situation and protecting them from exposure to potential risks under the influence of extreme rainfall and typhoons (Meteorological Bureau of Shenzhen Municipality, 2013). In addition to adapting to climate challenges, the municipality also strengthens the local environmental standards for carbon mitigation in land use and transportation.

Strengthening Local Regulation on Ecological Protection and the Promotion of a Low-Carbon Transition

To address the challenges posed by limited local resources, the local government strengthened environmental regulations to protect land from overexploitation and invested in urban greenway development. In line with Shenzhen's policy on environmental protection, almost half of the land in Shenzhen's jurisdiction has been protected from resource exploitation since 2005. At the same time, the Shenzhen Municipal Government has also invested more than RMB 1 billion in greenway construction. The greenway, which extends over 2,000 kilometers, not only beautifies its urban environment, but also acts as a significant carbon sink to offset the urban heat island effect. Urban projects like the greenway comprehensively strengthen Shenzhen's urban ecological capacity to absorb carbon emissions.

Shenzhen is among the initial leaders of China's local low-carbon transition. The local government prioritizes the development of low-carbon industries, such as the electrical vehicle industry. Since 2010, it has offered the highest level of local subsidies to each electric vehicle consumer, varying from RMB 30,000 to RMB 60,000 depending on the type of electric vehicle – plug-in or purely electric (Qu, 2014). By November 2014, these subsidies, at least partially, had helped to put more than 9,000 new energy-efficient vehicles on Shenzhen's streets. The resulting accumulated carbon emissions reduction reached more than 200 tons. 3.8 billion RMB of the municipal finance, an increase in RMB by 1.4 billion RMB from funds invested in the previous year, will be allocated to the promotion of new-energy vehicles in 2016 (Tang, 2016). In 2012, the local government decoupled energy consumption and economic growth for the first time; this indicates that local economic growth is not wholly dependent on extensive energy consumption and is a milestone for local low-carbon transition practices.

Local Leadership in the Shenzhen Emission Trading System Pilot

Shenzhen's pioneering role in the development of local low-carbon practices was also demonstrated in its legislation on the Shenzhen Emission Trading System (Shenzhen ETS), which guarantees the operation of market mechanisms to reduce carbon emissions. Local leadership, especially that of top local officials, played a major role in putting low-carbon issues on the local policy agenda. As a result of local leadership's seizure of the "window of opportunity" and its organization of research on Shenzhen's feasibility as an ETS pilot, Shenzhen was selected as one of the initial ETS Pilots by the National Reform and Development Commission. The Shenzhen ETS was launched in June 2013. The corresponding legislation enabled the successful establishment of the Shenzhen ETS because it required participation from relevant industrial sectors. Each industrial participant was tasked with carefully checking its level of carbon emissions and participating in the ETS or otherwise face punishment and penalties for violations. Such legislation on market mechanisms and accountability encouraged the industrial sectors to fully participate in the local low-carbon transition.

With this local legislation on the Shenzhen ETS in place, the system was able to incorporate a large number of entities, including 635 enterprises and 197 public buildings. Participating sectors ranged from electric, industrial, and manufacturing companies to the building sector. As a result of this significant involvement, 3.75 million tons of industrial carbon emissions were mitigated from 2010 to 2013; similarly, carbon intensity – the amount of carbon emitted by a country per unit of GDP – decreased by 33.2% in terms of industrial added value (GDP by industry) from participating entities as compared to the 2010 level (Shenzhen Research Center for Urban Development and China Emission Exchange, 2015). The practices of the Shenzhen ETS demonstrate progress on the low-carbon transition by strengthening low-carbon institutions through legislation, incentivized stakeholder participation, and market mechanisms.

Lessons Learned from Shenzhen's Low-Carbon Transition

Local leadership has played a prominent role in initiating Shenzhen's low-carbon transition. This leadership, and specifically key local leaders, initially raised local awareness of the challenges posed by limited local natural resources and emphasized the importance of balancing economic growth and ecological protection. By fostering the development of less energy-dependent industries and investing in the greening of its urban environment, Shenzhen has steadily transformed its economic growth to include local-carbon features and enhanced its urban capacity to mitigate carbon emissions. After becoming an ETS Pilot region, local leaders strengthened ETS legislation and low-carbon transportation.

Although there has been considerable progress in Shenzhen, there are still many ongoing challenges. There is a need for more and broader public participation in decision-making and implementation. Similarly, more cooperation from enterprises is needed to transform the local economic growth model to become less carbon-dependent. Greater media coverage of the importance of a transition to a low-carbon economy will be important for raising awareness of the big challenges still ahead in Shenzhen. Interviews with officials and expert observers in the city suggest that there needs to be more attention given to the socioeconomic components of Shenzhen's low-carbon energy transition.

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Case Study 16.B

Fort Lauderdale: Pioneering the Way toward a Sustainable Future

Susanne Torriente

City of Miami Beach

Keywords	Sea level rise, community engagement, adaptation, Regional Climate Change Compact
Population (Metropolitan Region)	6,012,331 (U.S. Census, 2015)
Area (Metropolitan Region)	13,150 km² (U.S. Census, 2015)
Income per capita	$56,180 (World Bank, 2017)
Climate zone	Af – Tropical Rainforest (Peel et al., 2007)

The City of Fort Lauderdale is the heart of South Florida on the Atlantic coast of the United States, between Miami and Palm Beach, with a diverse population of more than 170,000. With 7 miles of white sandy beaches, 33 square miles (City of Fort Lauderdale Code of Ordinances, 2015) of an urban metropolis and 300 miles of winding canal coastline it was coined the "Venice of America" many years ago. It is beautiful yet vulnerable to the effects of climate change and sea level rise due to its flat topography, location on a peninsula, dense coastal development, and shallow, porous aquifer.

That vulnerability has become more apparent in recent years. Hurricanes, storms, flooding, and an eroding coastline have affected property, roads, and regional transportation networks and disrupted power and water supplies. Impacts of climate change adversely affect residents and the region's more than 5 million people and 12 million annual visitors. Fortunately, the city and the region have been formally planning and collaborating since 2009 through the leadership of local elected officials and the dedication of staff supporting the Southeast Florida Regional Climate Change Compact, one of the first and largest voluntary, collaborative, and bi-partisan efforts in the country to address climate issues and policy (Southeast Florida Regional Climate Change Compact, 2014).

A seminal moment came in November 2013. Following direct erosional impacts from Hurricane Sandy, additional winds and tides collapsed a portion of Scenic Highway A1A and washed away 2,500 feet of sidewalk, beach showers, a traffic signal, and parking meters along four city blocks. The impact of the storm was a wake-up call that helped the community realize that its future prosperity was in jeopardy and that action was essential to protect its long-term sustainability. The destruction bolstered public support to implement adaptation strategies to reduce the effects of climate change.

The city seized this post-disaster opportunity to rebuild the area for future conditions by creating more sustainable infrastructure with wider sidewalks, protective sand dunes, elevated roadways, and better drainage. This is a model for bouncing forward, not bouncing back – by using the best available data and the public process to build the city of tomorrow.

Fortunately, there was overwhelming political and public support to develop a comprehensive strategy to address growing climate challenges. The City Commission unanimously adopted a community-wide Vision Plan, Fast Forward Fort Lauderdale, and a 5-year strategic plan, Press Play Fort Lauderdale, both of which identify sustainability, climate adaptation, and climate mitigation as the city's top long-term priorities (City of Fort Lauderdale, 2013).

Fort Lauderdale successfully realigned its organizational structure to better integrate and implement these regional and local goals and initiatives. All operations departments have a role in delivering local government services through the lens of climate resilience. Specifically, a new Sustainability Division was created in 2012 and works with subject matter experts in science, environment, planning, fleet management, and waste management across all departments to support this transition and promote the "Greening Our Routine" culture (City of Fort Lauderdale, n.d).

As the sustainability experts shared their knowledge and raised awareness about climate change, employees yearned for additional resources to support ongoing efforts. More than thirty staff, coined "Climate Ambassadors," participated in a 3-day National Oceanic and Atmospheric Administration workshop. They continue to meet quarterly to share experiences regarding planning and implementing sustainable initiatives. This small training program became the catalyst to launch citywide training to educate all 2,600 employees about climate change and their role in mitigation and adaptation efforts. As new employees join the city, their orientation includes a sustainability component (Morejon, 2015). This may be one of the first of few local governments in the nation to institute dedicated climate training organization-wide.

As employees become more mindful of climate change, they are developing new strategies to plan for a sustainable future. A comprehensive Stormwater Master Plan is driving infrastructure investments in drainage, bio-swales, and retention parks to minimize the effects of climate change (Morejon, 2015). Adaptation Action Areas have been incorporated into the comprehensive plan to prioritize funding for infrastructure projects that minimize impacts in vulnerable areas. The city adopted new flood zone maps and instituted tougher regulatory standards to protect future development and minimize the flood risk in low-lying areas.

As momentum builds within the municipal organization, Fort Lauderdale is engaging its community to further adaptation measures. Volunteers serve on the City's Sustainability Advisory Board and participate in events to plant trees and sea oats, collect hazardous waste and recycled materials, and promote walking and biking. A strong network of neighborhood associations serve as sounding boards for proposed initiatives and policy language through workshops, crowdsourcing forums, and Telephone Town Hall Meetings. The annual neighbors survey gauges residents' perception regarding flooding and climate change to identify priorities and allocate future funding (Morejon, 2015).

Fort Lauderdale actively pursues partnerships to explore new ideas, tools, and research. Assistant City Manager Susanne Torriente is a founding member of the Southeast Florida Regional Climate Change Compact. City staff co-authored the Regional Climate Action Plan, a source of strategic climate mitigation and adaptation recommendations. Torriente and staff also serve on several local, state, and national boards dedicated to climate resiliency. The City of Fort Lauderdale was the first municipality on the Compact's Staff Steering Committee. The Compact and Fort Lauderdale model for integration and implementation have opened the door for informational peer-to-peer exchanges with Australia, South Africa, the Philippines, the Canadian consulate, Caribbean Islands, Great Britain, and the Netherlands. Through the ICMA CityLinks program, Fort Lauderdale was chosen by Durban, South Africa, to participate in a peer-to-peer exchange to learn more about the Southeast Florida Regional Climate Compact governance model. This successful relationship led to the creation of several regional compacts in Africa, as well as Broward County and Fort Lauderdale signing the Durban Adaptation Charter. These are the first two U.S. local governments to sign this Charter that promotes local government action to advance climate adaptation (ICMA, n.d.).

Fort Lauderdale partnered with NOAA, the Florida Department of Economic Opportunity, Broward County, and the South Florida Regional Planning Council to serve as a statewide model to develop an Adaptation Action Area Program (City of Fort Lauderdale, 2015). The Urban Land Institute served as a partner on two Technical Assistance Panels to discuss protection of vulnerable destinations and encouraging growth in more resilient areas. Fort Lauderdale works with partners on tools to understand vulnerability, stormwater modeling, climate adaptation cost-benefit analysis, and sea level rise projections. Through these efforts, Fort Lauderdale is piloting emerging technologies such as tidal valves to reduce flooding at high tides.The City is eager and willing to collaborate, learn, and pilot new ideas and emerging technologies in this ever-changing world of tomorrow.

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Case Study 16.C

Democratizing Urban Resilience in Antofagasta, Chile

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Keywords	Participatory urbanism, governance, innovation, community resilience, co-design
Population (Metropolitan Region)	385,000 (Demographia, 2016)
Area (Metropolitan Region)	28 km^2 (Demographia, 2016)
Income per capita	US$13,530 (World Bank, 2017)
Climate zone	BWk – Arid, desert, cold (Peel et al., 2007)

The ability to collaboratively plan for resilience is integral to the mandate of empowering the governance of cities. As urban centers continue to grapple with an ever-growing array of social and environmental challenges, the success of their climate strategies is no longer solely determined by how solutions are implemented on the ground but also by who is involved in their design.

Adapting to climate change is necessary to strengthen the resilience of a city's social and economic systems, and public participation is an important goal in formulating adaptive responses (Larsen et al., 2011). Integrating climate adaptation into planning policies can therefore provide new opportunities for decision-makers to work toward greater livability and inclusion at the urban level.

Calls for the inclusion of a broad range of stakeholders are frequently made in major policy documents and are increasingly made by cities in their own adaptation plans. Already in 1992, Article 6 of the United Nations Framework Convention on Climate Change invoked the promotion of "public participation in addressing climate change and its effects and developing adequate responses" (UNFCCC, 1992: 17).

Despite the resurgent interest in inclusive planning, however, climate adaptation responses are typically place-based and therefore context-specific (Adger, 2001), requiring mutual trust between parties and the fair distribution of power and action outcomes in order to be meaningful. Planning for resilience therefore presents an opportunity for cities to move beyond the limitations of consultation (Arnstein, 1969) toward a broader co-design shift (Bason, 2010).

When applied to urban resilience, the practice of co-design no longer restricts adaptation to the domain of "experts" and scientists, but instead provides an opportunity for communities to have a sense of control and ownership over the changes that affect them. Reclaiming and redesigning public space is often the first step toward establishing promising approaches to collaborative adaptation.

The city of Antofagasta, Chile, is an example of just such an approach. A major mining hub in the country's north, during the past decade the city has seen a steady rise in both economic activity as well as in population growth. As a port city, however, Antofagasta is vulnerable to flooding and is equally exposed to Chile's other primary risks: earthquakes and landslides. While Antofagasta boasts the country's highest gross domestic product (GDP) per capita, it also is considered one of the most expensive to live in, and its population is expected to reach 500,000 in the next 10 years (El Mercurio de Antofagasta, 2010) – factors that challenge the city's ecological limits as much as its need for sustainable urban development.

To respond to these growing pressures, Antofagasta works alongside local service providers, schools, businesses, and neighborhood associations to explore solutions to the challenges of socioeconomic resilience. In 2013, the city enlisted Ciudad Emergente – a Chilean urban planning collective – to facilitate a series of participatory initiatives designed to promote an approach to adaptation that takes into account not only ecological concerns but also social equity and livability.

In the spring of 2013, Antofagasta hosted four *Malones Urbanos* – streetwide, open-air neighborhood meals that double as laboratories for collaborative problem-solving (Case Study 16.C Figure 1). The events were the result of the ongoing partnerships developed by the City and Ciudad Emergente with the Universidad Católica del Norte and the Universidad de Antofagasta, as well as with neighborhood associations. As Chile's second largest city, Antofagasta hosted the *malones* to stimulate creative thinking around issues ranging from placemaking to land reclamation, from climate adaptation to waste management – always in a fun, inclusive way that creates accessible entry points for capacity-building and long-term policy change.

Another participatory intervention is the *Okuplaza*, a daylong event format conceived to gather the input of diverse actors while creating an engaging, temporary public space in an otherwise underused area (Case Study 16.C Figure 2). In 2014, Ciudad Emergente and the City of Antofagasta held two *Okuplazas* to develop participatory indicators to be used as diagnostic tools to assess the health of the community. More than 150 participants gathered during the course of the event to develop tools such as socioenvironmental maps and idea trees for tracking the needs of the local population over the short and long term. Citizens also participated in conservation roundtables, public performances,

Case Study 16.C Figure 1 *The Malon Urbano in Antofagasta.*

Source: Ciudad Emergente, 2013

Case Study 16.C Figure 2 *Okuplaza in Plaza de los Colectivos, Antofagasta.*

Source: Ciudad Emergente, 2014

Case Study 16.C Figure 3 *Limpiezas Participativas in Villa Las Condes/La Corvallis, Antofagasta.*

Source: Ciudad Emergente, 2014

and a photographic exhibition to break down barriers to complex information.

Encouraged by the success of these experiences, in March 2014, the municipality launched *Limpiezas Participativas* (in English, Participatory Cleanings), a project developed by Ciudad Emergente in collaboration with several high schools, the local police department, and the neighborhood association for the city's La Corvallis area (Case Study 16.C Figure 3). Together, 300 volunteers joined forces to clear out unauthorized landfills and put an end to illegal waste dumping. Volunteers split into six "eco-teams" to clear these previously degraded areas and turn them into permanent public spaces. A similar initiative was then repeated in the area of La Cantera in May of that same year to create an intergenerational, multipurpose space that could host free neighborhood fairs, workshops on waste reduction and recycling, and programming focused on strengthening both social exchanges and sustainable living skills.

Mayors Adapt (2015), the European Union's Covenant of Mayors Initiative on Adaptation to Climate Change, believes that "strengthening stakeholder participation sets the foundation for fruitful cooperation among citizens and public administration, which may affect further policy areas as well." Meaningful community engagement strategies can contribute to improving policy outcomes by correcting the imbalance of knowledge that often exists between local government and communities, strengthening local ownership of policy decisions, and enhancing understanding of climate change impacts.

In Chile, rapid urban development has created widespread inequality and continues to put a strain on equitable access to services, infrastructure, and education. In Antofagasta, a political commitment to disaster risk reduction goes hand in hand with a commitment to a better quality of life, increased social cohesion, and support for local responses to climate change. While those presented here are only a handful of examples of the city's approach to co-design, their many positive ripple effects are driving the city's commitment to experimenting with and supporting collaborative adaptation practices that double as best practices for other cities.

Learning from community interventions not only ensures greater relevance on the ground, but also presents an opportunity for policy and action drivers to potentially multiply, going from narrow – often opposing – categories such as "civil society" or "local government" to new and hybrid ones that emerge as more opportunities for input open up in the policy-planning process. Formalizing opportunities for co-design in the adaptation plans of cities like Antofagasta thus encourages social innovation and skill-sharing, building trust and greater social resilience (Christiansen and Bunt, 2012).

For municipalities looking to learn from Antofagasta's experience, the recognition of cities as co-creators of enabling' frameworks will be an important step in the democratization of urban resilience (Camponeschi, 2013). To do so, cities will need to explore new avenues for decision-making, supporting opportunities to embed participation and transparency into the everyday norms that will inform their future responses to climate change and, most importantly, embracing their role as champions of this powerful governance shift.

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Case Study 16.D

Building a Participatory Risks Management Framework in Bobo-Dioulasso, Burkina Faso

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Keywords	Heat waves, droughts, risk management, participatory process, adaptation, floods
Population (Metropolitan Region)	735,000 (Demographia, 2016)
Area (Metropolitan Region)	101 km^2 (Demographia, 2016)
Income per capita	US$640 (World Bank, 2017)
Climate zone	Tropical, savannah (Aw) (Peel et al., 2007)

Bobo-Dioulasso, the second biggest city in Burkina Faso, is situated in the Hauts-Bassins region. Climate change will exacerbate vulnerabilities associated with the combined effects of population growth, land degradation, and reduced rainfall, leading to decreases in agriculture production, proliferation of disease vectors, affecting agro-sylvo-pastoral industries, and undermining local and national development.

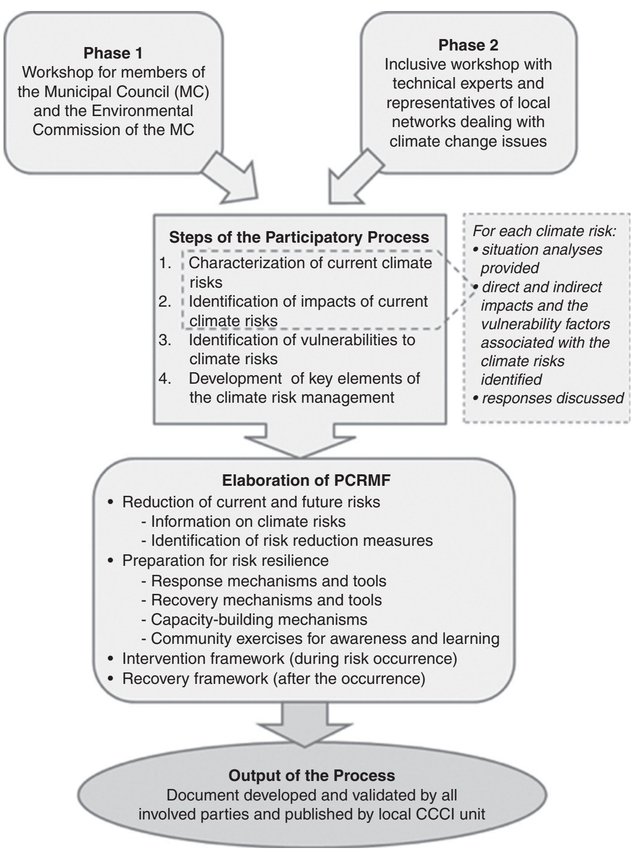
Relevance to Climate Change Adaptation and Mitigation in Terms of Action and Strategy

To address the challenges of climate change, the municipality decided to set up a project to strengthen its capabilities. In July 2010, it became a formal partner of the UN Habitat Cities and Climate Change Initiatives (CCCI). CCCI focuses on small- and medium-sized cities in developing countries and aims to increase efforts toward adaptation through four main objectives: (1) promote active climate change collaboration between local governments and their associations, (2) enhance dialogue so that climate change is firmly established on the political agenda, (3) support local governments in making climate sensitive changes, and (4) foster awareness, education, and capacity-building strategies that support the implementation of climate change strategies (UN Habitat, 2011a).

During the first step of the CCCI program (2011–2012), the municipality carried out an initiative called "The City of Bobo-Dioulasso against the Effects of Climate Change: Framework to Improve Dialogue between Local and National Actors." During this initial phase, residents, community actors, territorial officials, and local policy-makers were involved in a study of the challenges and preparatory measures necessary with regard to climate change; an action plan for the management of climate risks and disaster was also developed and approved by local representatives (Ricci et al., 2015) (Case Study 16.D Figure 1).

Actions and Policy Drivers

The implementation of CCCI was promoted and supported by UN Habitat, and the municipality of Bobo-Dioulasso is the key actor for the implementation of the program. However, the multilevel process takes into account existing experiences, knowledge, know-how, and expertise to develop local requirements that are consistent with mitigation and adaptation to climate change (Case Study 16.D Figure 2). The approach then sought to create opportunities to:



Case Study 16.D Figure 1 *Architecture of the action plan for climate risk and disaster management.*

Source: Ricci et al., 2015

- Bring together all inhabitants (men, women, youth), municipal managers, local and national partners, and technical and financial partners
- Encourage an open and constructive discussion to enhance knowledge and awareness of climate change–related issues and build consensus among all stakeholders about the essentials that must underpin the work of the project
- Solicit and obtain the commitment of everyone to get involved in achieving mutually agreed objectives

Subsequent climate interventions formulated by the local population and local authorities focus on the implementation of regulations, decision-making on the control of carbon emissions, construction of energy-efficient buildings, and conservation of urban forests and natural resources. However, further action, such as dissemination of warning systems, emergency services, and support systems for the most vulnerable people and the construction of emergency shelters, still need to be taken by the local authorities (UN Habitat, 2011b, 2013).

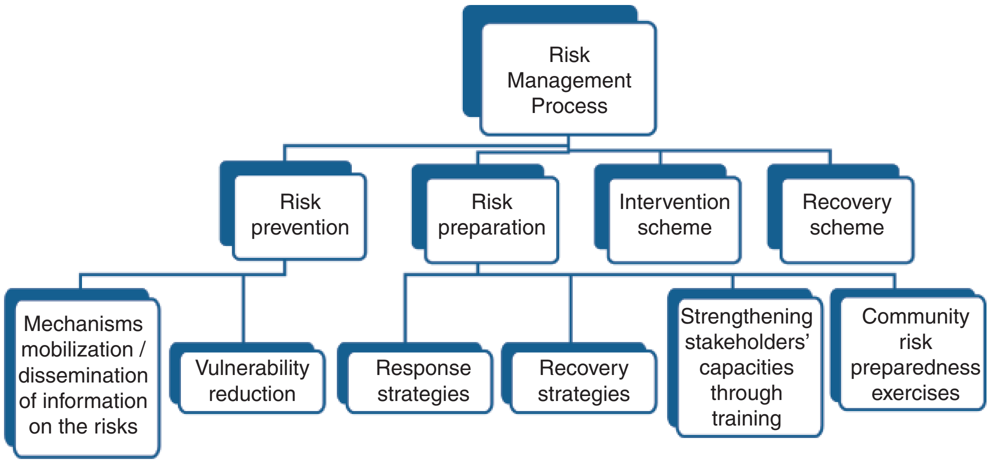
Impact and Scale

One of the key outcomes of the initial phase of the CCCI in Bobo-Dioulasso has been the creation of the municipal charter of collaboration and permanent dialogue for a climate-resilient Bobo-Dioulasso ("Charte municipale de collaboration et de dialogue parmanent pour une ville de Bobo-Dioulasso resiliente au climat"). Apart from the efforts of individual stakeholders and groups of stakeholders, the role of administrative districts in participatory risk management is particularly relevant.

Local actors, including municipal and territorial officials, local networks, and experts, were involved in a multistep participatory process (Case Study 16.D Figure 3) for the formulation of a Participatory Climate Risk Management Framework (PCRMF). Under the framework, which was discussed and adopted by

Case Study 16.D Figure 2 *Participants in the fifth consultation workshop with municipal and territorial officials.*

Source: CCCI Team Bobo Dioulass



Case Study 16.D Figure 3 *Process for the formulation of the Participatory Climate Risk Management Framework.*

Source: Ricci et al., 2015

municipal representatives and an expert from local climate change network (Institut d'Applications et de Vulgarisation en Sciences [IAVS] – Pôle Bobo-Dioulasso), the local actors agreed that the management of present and future climate risks requires, first, the prevention and reduction of climate change impacts (UN Habitat, 2011b, 2014, Ricci et al., 2015).

Lessons Learned

The PCRMF, formulated in a participatory manner by local actors, is ready for implementation under the institutional leadership of the municipality of Bobo-Dioulasso. A first lesson that can be derived from this participatory work is the detailed collection of observed climate trends and impacts by the population and local actors. As a result, the Municipal Council is ready to lead or support proactively preventive actions for adaptation and mitigation of the negative impacts of climate change. Financing and implementing the set of actions recommended in the framework could mobilize a variety of financial partners as well as stakeholders at different levels: community or local level, national level, and bilateral and multilateral international levels.

Additionally, this case study shows that small- and medium-sized cities have a crucial role in addressing climate change challenges and that adaptation needs to be mainstreamed and implemented at the local level. Risk management is a useful approach to limit vulnerability to current and future hazards. However, different types of constraints need to be considered in the implementation of climate change initiatives. The regulatory capacity of public authorities and the balance of power and resources play major roles in the implementation of adaptation at the local level. Capacity and resources are directly linked to legitimization and information. Therefore, financial resources and decentralization reforms can be major challenges for climate change adaptation and risk reduction.

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Case Study 16.E

Warsaw and City Sustainability Reporting

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Keywords	Data measurement, reporting, governance, transparency, sustainability, indicators
Population (Metropolitan Region)	1,735,442 (Statistical Office in Warsaw, 2015)
Area (Metropolitan Region)	517.2 km² (Statistical Office in Warsaw, 2015)
Income per capita	US$12,680 (World Bank, 2017)
Climate zone	Dfb - Cold, without dry season, warm summer (Peel et al, 2007)

Sustainability Reporting

Sustainability reporting – publishing data on an entity's environmental, economic, and societal performance and governance – is an essential step in climate change mitigation and adaptation (Sulkowski and Waddock, 2013). As a management tool, it can help city managers evaluate plans, investments, regulations, and incentives to optimize quality of life and climate mitigation and adaptation (Ballantine, 2014). Among other motivations, organizations also engage in sustainability reporting as a way to better communicate with stakeholders, encourage innovation, boost confidence of investors, and attract, retain, and inspire talented people (Hughey and Sulkowski, 2012; KPMG, 2013; Walsh and Sulkowski, 2010; Wu et al., 2011).

Sustainability reporting among cities is at a much earlier phase of adoption than among companies. While a sustainability reporting framework for corporations, the Global Reporting Initiative (GRI), was founded in 1997 (Brown et al., 2009), a similar framework for cities did not appear until late 2012 in North America: the Sustainability Tools for Assessing and Rating Communities (STAR Communities, 2015). The first set of indicators designed for global adoption by cities was not published until 2014 (the International Organization for Standardization's ISO 37120:2014). In 2013, when more than 4,000 companies published sustainability data, including 93% of the largest 250 corporations in the world (KPMG, 2013), it was still considered innovative for a city to release such data (Ballantine, 2014).

Data Related to Climate Change

All standards suggest that reporting entities publish specific facts related to their organizational profile and governance, plus statistics about environmental, societal, and economic impacts. We present here examples of major metrics that most directly gauge an entity's impacts upon and vulnerability to climate change, plus goals, investments, and progress toward eliminating its negative impacts and adapting to a changed climate:

- Energy consumption within the organization
- Reduction in energy used as a result of efficiency initiatives
- Habitats protected or restored
- Direct greenhouse gas (GHG) emissions
- Indirect GHG emissions
- Reduction of GHG emissions
- Investment in environmental protection expenditures

City of Warsaw Implements Sustainability Reporting

Warsaw, capital of Poland, has an official population of 1.7 million with a total of almost 3 million people in its metropolitan area. It was systematically razed near the end of World War II by occupiers as punishment for resisting and has been rebuilt since 1945. The reconstruction included the largest rebuilding of a Medieval Old Town. At the same time, city planners of the foreign-imposed Communist regime laid out a sprawling new grid of avenues between four- to six-car lanes in width. This context, coupled with the explosive growth of Poland's economy since the country's return to full independence in 1989, has resulted in a mix of opportunities and challenges that, as in other cities, are directly related to climate change.

The 2013 Warsaw Integrated Sustainability Report was the first in the world to use the latest standard (called G4) of the Global Reporting Initiative partly to draw attention to the concept of city sustainability reporting (Cohen, 2013; City of Warsaw, 2013), a distinction that earned it a spot on a list of the top 10 sustainability reports of 2013 (Cohen, 2014). In 2014–15 the city took additional steps of referencing the new ISO standard and engaging local university students under the oversight of professors to complete the reporting exercise (Ballantine, 2014).

Box 1 Highlights of Warsaw's Climate Mitigation and Adaptation

- 25% of Warsaw is green space
- Co-generated heat distribution system from electricity production is third largest (1,700 km) in the world
- Fuel use, because of co-generated power and heat, is 33% more efficient than many power plants elsewhere in the world
- Recently modernized water treatment plant was the largest environmental protection investment in Europe (totaling €769 (US$908.4) million) and is 33% powered by processed solids from wastewater
- Ranked 16th out of 30 in the European Green City Index
- Biomass-based energy generation to grow from 2% to 10% and waste-to-energy from 1% to 8% from 2010 levels to 2020, with a goal of cutting emissions 20% below 2007 levels by 2020
- Adjacent UNESCO World Biosphere Reservation is home to thousands of plant and animal species

In Warsaw, as elsewhere, sustainability reporting can play a key role in furthering climate change mitigation and adaptation by:

- Optimizing outcomes by helping leaders see positive relationships between climate policy and economic, societal, and local environmental benefits

Encouraging residents (and other stakeholders) with positive-but-underappreciated facts about the city, and inspiring further climate-friendly behavior choices (e.g., related to recycling, lifestyle, and commuting)

Lessons Learned and a Checklist for Implementing Sustainability Reporting

Cities can readily adopt the practice of sustainability reporting. Based on implementing sustainability reporting for Warsaw and municipalities in the United States, sometimes with university student teams, the author offers the following generalized steps to consider:

1. Study the conceptual background of sustainability reporting, standards, and examples.
2. Find a champion of reporting within city government.
3. Explore partnerships with local education institutions and engage university student teams under the guidance of professors, staff, or consultants. This creates many side benefits such as spreading awareness of climate change mitigation and adaptation and other community sustainability issues, inspiring and informing research, and training students in environmental policy, communications, statistical analysis, and public and private sector management.
4. Identify what matters to stakeholders.
5. Choose whether to use or reference a standard.
6. Research and prepare the report, starting with available goals and statistics.
7. Consider a summary of key indicators plus a longer full report.
8. Seek internal or external verification. Corporations often have their sustainability reports audited to make them more credible to investors and other stakeholders.
9. Search for – and incorporate – feedback. Ideally, reporting is a channel for not just sharing data, but also for hearing ideas on improving goals, actions, and outcomes.
10. Before publication, prepare a roll-out and communications strategy. Be aware that, in a politicized climate, even a pragmatic exercise in transparency may be criticized.
11. Consider alternative communication media. Availability of open, real-time city data on mobile devices could help steer behaviors to be more climate neutral (Batty et al., 2012). An example of this is the public transportation navigation application from CityNav in Poland, which updates actual positions of buses, trains, and trams in real time, making mass transit even more predictable and appealing to users.
12. Encourage ambition in goal-setting and the active use of sustainability reporting as a tool for planning and evaluating progress toward, ideally, a net zero emissions future.

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Case Study 16.F

City of Paris: 10 Years of Climate Comprehensive Strategy

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Keywords	Mitigation, adaptation, policy, heat wave, multisectoral comprehensive strategy
Population (Metropolitan Region)	11,959, 807 (INSEE, 2016)
Area (Metropolitan Region)	12,012 km² (IAU Ile-de-France, 2016)
Income per capita[a]	US$38,950 (World Bank, 201)
Climate zone	Cfb – Temperate, Without dry season, warm summer (Peel et al., 2007)

PARIS Climate Action Plan

In 2007, the City of Paris adopted its First Climate Action Plan. (City of Paris, Urban Ecology Agency, 2012). It was elaborated in an innovative collaborative approach involving all Parisian community: authorities, economic stakeholders, citizens, non-governmental organizations (NGOs), and more. The Plan sets five commitments:

1. Decrease greenhouse gas (GHG) emissions by 75% in 2050 compared with 2004
2. Reduce GHG emissions by 25% in 2020 compared with 2004
3. Reduce energy consumption by 25% in 2020 compared with 2004
4. Get 25% of renewable energy sources (RES) into the energy mix
5. Adapt Paris to climate change

After 5 years and some important successes in mobility, housing retrofitting, and community involvement, the city council decided to update the First Plan in 2012.

The Second Plan reaffirms the objectives of the initial plan. It is a comprehensive strategy trying to mainstream climate change mitigation and adaptation in all sectors. The plan itself is divided into six chapters:

- Urban planning for energy efficiency
- Low-energy and affordable housing
- The service industry in Paris, a new challenge
- Toward transport that improves the climate and air quality
- Toward sustainable food and consumption that generates less waste
- An adaptation strategy

To achieve these goals in all targeted sectors, the City of Paris has undertaken extensive outreach and mobilization action. This includes the Paris Action Climat partnership agreement (City of

Paris, 2013) with community stakeholders who become involved in the momentum of the Paris Climate Action Plan. Other communication tools include the game Clim'Way Paris, available online and free to every person having Internet access: www.climway.paris.fr. Players of the game have a choice of different actions to implement in order to reach the objectives of the Paris Climate Action Plan. The game shows the evolution of Paris from 2004 to 2050. Another information tool the city developed is the solar potential register, available online, which allows each Parisian to check the feasibility of installing solar panels on his or her building in terms of energy production: www.cadastresolaire.paris.fr. Mobilization of citizens is an important action for the Mayor (at that time Bertrand Delanoë, now Anne Hidalgo) and was why he decided to create the Paris climate agency in March 2011.

Paris Climate Agency (APC)

The Paris Climate Agency was set up on the initiative of the City of Paris to help achieve the goals of the Climate Action Plan and to inform Parisians about energy efficiency. The Paris Climate Agency has eighty-five members and partners. It is a key driving force for regional energy transition, seeking to involve the future Metropolis of Greater Paris and assisting with operational projects, particularly the energy retrofit of buildings. By promoting dialogue and debate around these major issues, the APC also helps create a common knowledge basis and initiatives to support urban transformation. It brings stakeholders together in an alliance that aims to achieve a sustainable energy transition in the city and to combat climate change (APC, 2015).

Energy-Efficient Refurbishment of Social and Private Housing and Commercial Stock

Paris, one of the densest cities, occupies more than 130 million square meters of housing and commercial real estate. Most of these buildings were built before the first thermal regulation law in 1975. With the Paris Climate Action Plan, all new buildings must be designed with energy performance better than national standards.

The challenge is to refurbish the stock. To show that it is possible, the City of Paris invested more than €200 (US$236) million in 5 years to retrofit 30,000 housing units. This program improved energy efficiency, decreased GHG emissions, created more than 1,500 local jobs, improved quality of life for tenants, and reduced their energy bills by at least 30%.

The other challenge is to mobilize the private sector to do same. To carry out the strategy in this sector, the City of Paris combines strong financial intervention in selected urban districts together with measures conducted by the APC on the whole territory. For example, a web platform CoachCopro© (www.coachcopro.com) helps Parisians conduct their retrofitting projects. This platform will be extended to the professional sector and will facilitate the process of rehabilitation by helping building owners and enterprises find relevant financial tools.

A New Mobility: A Challenge for Paris and Its Metropolis

The City of Paris has one of the densest public transportation networks of both metro and buses, but traffic jams and bad air quality are important issues. In 2001, Mayor Delanoë decided to establish a new mobility policy that would reduce dependence on cars, develop active mobility modes (cycling, walking), and improve public transportation inside and outside Paris. Almost 15 years later, results are 32% less traffic, 25% less air pollution emissions, and 15% less GHG emissions., and now new shared services like Vélib' (24,000 bikes) or Autolib' (2,000 electric cars) are part of the way of life for Parisians.

For the next 20 years, the challenge is to adapt this success model to the wider Metropolis (7 million inhabitants). Greater Paris will see major projects in transportation and urban development to improve quality of life, regional solidarity, and attractiveness with a program worth €32 (US$37.8) billion over 15 years. Significant urban projects will emerge along the Greater Paris Express transport route, such as new neighborhoods with an array of features including housing, economic activities, and university and cultural facilities – especially around the strategic, structural points provided by the stations. The idea is to enable business clusters to take root while rebalancing the Paris region, opening it up to its more remote, isolated areas.

The urban system exemplifies how Paris's economic potential is being harnessed to tackle the new challenge of energy transition, accelerating the move toward a green economy and creating a unique attractiveness factor. The APC motivates stakeholders by means of an alliance for metropolitan energy transition and the fight against climate change

Supported by a complete system of closely networked stakeholders plus highly effective, progressive networks and infrastructure, Paris stands out as a platform for innovation and experimentation driven by a shared, socially responsible political will.

An Innovation Laboratory for the Green Economy

Paris is a skills incubator not only for education but also for research and development, and global economic leaders are investing in the development of clean technologies in Paris. Paris welcomes and actively supports innovative start-ups and arranges local testing in what has become an urban laboratory. For example, Paris Région Lab and the APC have launched two calls for experimentation in energy efficiency (Paris Région Lab, n.d.).

Paris and its metropolis are already moving toward an energy transition through:

- Efficient infrastructure with a focus on new functionalities and practices in the water, energy, and mobility sectors
- Innovative energy systems that are managing workflows as close to producers and consumers as possible; this includes European flagships such as the Paris district cooling network
- Information and communication technologies geared toward the "smart city"

These elements are presented in a dedicated platform (APC, n.d.)

Resilience and Adaptation

Paris not only is taking action on climate change mitigation, it has also assessed its vulnerabilities and opportunities with regard to climate change and resources depletion (water, energy, food, biodiversity) in a comprehensive study in 2012–2013. More than a hundred persons participated in the study (scientific committee, stakeholders, and city representatives) through interviews and workshops that are now summarized into twenty-five sectoral and impact sheets. This initial diagnosis concludes that the main threats the City of Paris will face with climate change are urban heat islands and heat waves, floods and intense rainfall, drought spells and water depletion, and storms and land subsidence. These will affect the energy distribution network and the built environment (especially regarding summer thermal comfort) as well as public health (air quality, heat waves, floods) and the overall economy of the country (Seine flooding).

This diagnosis is now a baseline to co-elaborate the adaptation strategy of Paris as it faces climate change and resource depletion, with Parisian stakeholders involved. The adaptation strategy is completely integrated into the Paris Climate Action Plan. In 2015, the ongoing adaptation actions and presents goals toward the adaptation of Paris will be affirmed. This strategy will be an answer to decrease risk but especially an opportunity to create a new positive urban ecosystem in Greater Paris for improving the quality of life of its citizens in the decades to come.

The main actions implemented in Paris for its resilience and adaptation concern the greening of Paris (new parks, green infrastructures, green roofs and facades, urban agriculture), flood prevention and action plans, a biodiversity preservation plan, an intense rainfall plan, a heat wave warning and assistance plan, and a water savings plan. Sectoral studies and experiments have been instituted to better understand the efficiency of potential adaptation solutions (e.g., quantifying the cooling effects of different green and humid spaces in Paris).

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