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Volume Two

Themes

Climate Change Vulnerability and Impacts in Cities

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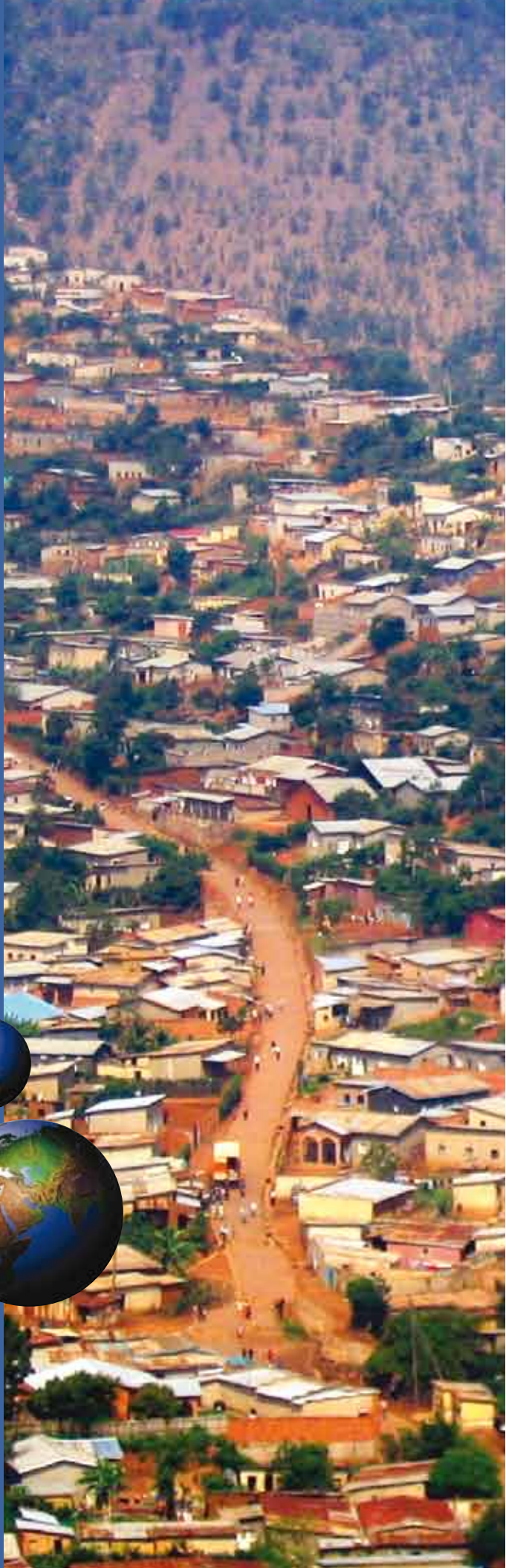

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Chapter I:

Introduction

1. Background

The Methodology for the Preparation of GEO Cities Reports[1], based on that used for the preparation of the Global Environment Outlook (GEO) series, was originally published at the beginning of 2003. This Methodology aimed to support capacity building in the development of city-level integrated environmental assessments, in which the linkages between environmental problems and urban development dynamics are analyzed.

In recent years, as part of the process of improving the GEO Cities Methodology, and responding to important natural events, it was decided to supplement the GEO Cities Methodology with a module addressing vulnerability and adaptation to climate change, to increase the capacity of cities to analyze and prepare for future climate impacts.

This new module analyzes the results of recent research on climate change, its impact on cities and options for responding. Its primary aim is to foster debate and present methodologies for evaluating the level of vulnerability and the adaptation capacity of urban centres.

This module aims to strengthen awareness on possible impacts of climate change, while providing decision makers with a range of instruments to evaluate those impacts. It also provides examples of adaptation policies that could be applied by government institutions and other sectors of society.

2. Objectives of this module

The objectives of this module are to complement the GEO Cities Methodology to assist government and other institutions that are supporting climate change adaptation either from a technical or a policy perspective. It is aimed at broadening technical and institutional capabilities in the context of climate change, as outlined in the Bali Strategic Plan for Technology Support and Capacity Building. The GEO Cities Methodology should be used as a basic reference guide for integrated environmental assessments in cities.[2]

The module focuses on vulnerability and adaptation to climate change and their link to sustainable development. It also includes general aspects related to mitigation of climate change, to the extent they relate to climate change adaptation issues.

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1 UNEP, *Methodology for the Preparation of GEO Cities Reports* (2007).

2 Version 3 of the *GEO Cities Methodology* is available at http://www.pnuma.org/deat1/pdf/Metho_GEOCitiesinddOK.pdf.

It presents a synthesis of the main indicators and existing methodologies on vulnerability and adaptation to climate change that are relevant to the local context. Additionally, it includes a compilation of case studies, exercises and examples on various themes.

This type of project is fundamental for scientific assessment: to bring the findings of science to bear on decision making, in a policy relevant manner, thus meeting the needs of decision makers to strengthen strategies for adaptation to climate change and related processes of sustainable development, with emphasis on capacity development and communication of results from adaptation programmes. This should also support National Communications on Climate Change and National Adaptation Programmes of Action (NAPAs).

In this module, the city is considered as an "urban ecosystem"[3]. In other words, the city is studied from the perspective of natural resources management, which takes in account ecosystem services, and therefore includes surrounding rural areas. Any city, especially one including high-density built-up areas, has a high degree of interdependency with peri-urban and surrounding rural areas, which provide a range of ecosystem services (water, food, flood regulation, garbage disposal services, recreational values, etc.) consumed by the urban area.

The training module aims to be relevant to different urban circumstances, by considering climate change vulnerabilities in the context of other factors like geographical location, level of socio-economic development, and institutional development. For instance, there are major distinctions between cities located at:

- Mega-deltas and other low-lying riparian and coastal areas;
- High altitudes;
- Arid and semi-arid zones;
- Temperate or polar zones (high latitudes).

Additionally, when defining vulnerability levels and capacity for adaptation, the module also considers the economic and social factors that influence the city's environment and the interrelations among different economic and social variables.

Policy makers must address severe climate-related phenomena, such as weather-related disasters, that occur suddenly and unexpectedly. An adaptation policy can diminish vulnerability, especially for the most vulnerable social sectors, and reduce the costs and pressures of responding to extreme events.

[3] Urban ecosystems apply the ecosystem approach to urban areas. Urban ecosystems are dynamic ecosystems that have similar interactions and behaviours as natural ecosystems. Unlike natural ecosystems, however, urban ecosystems are a hybrid of natural and man-made elements whose interactions are affected not only by the natural environment, but also by culture, personal behaviour, politics, economics and social organization (*UNEP-IETC - The Ecosystems Approach to Urban Environmental Management*).

Additionally, it should be kept in mind that it is not always possible to obtain information and precise data to local scale. Therefore, the evaluation of vulnerability and impacts at this level must take into account the uncertainties derived from applying low-resolution data (e.g., at the national or regional level) to the city in question.

The methodology presented in the module offers the possibility to:

- Evaluate climate change impacts on different cities and their implications for human well-being; and
- Consider policy options and response actions in the face of threats from climate change in urban areas.

This module—and the GEO Cities Methodology itself—are based on the approach used for Global Environment Outlook (GEO) reports, and apply the DPSIR (Drivers-Pressures-State-Impacts-Responses) framework to analyze how urbanization influences the environment. It considers factors that put pressure on natural resources and urban ecosystems, resulting in a determined state of the environment and its trend — including in terms of its impact on the quality of life in cities – and puts forward specific responses that could be applied by local government and society.[4]

Upon successful completion of this module, the user will be prepared to analyze climate change and vulnerability as a part of integrated environmental assessments (IEAs) at city level. Specifically, they will be able to:

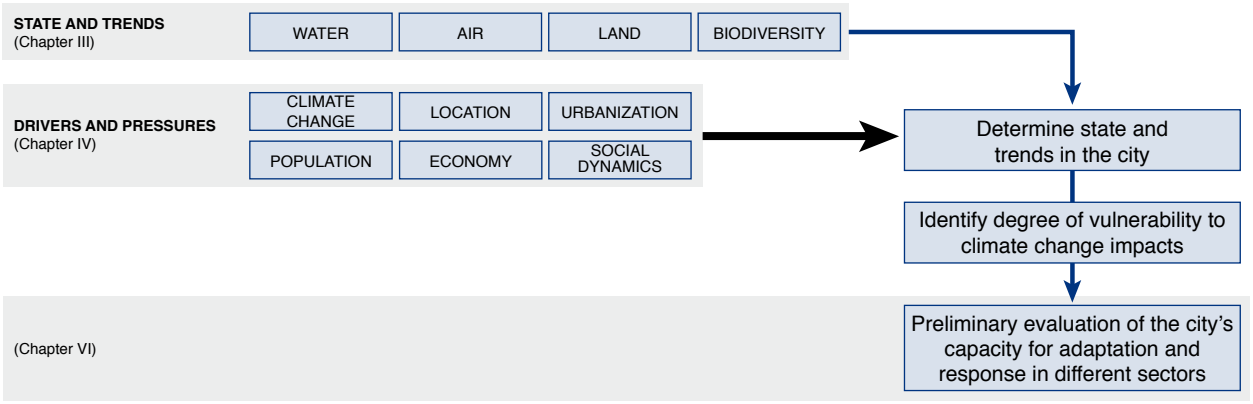
- Conduct and interpret vulnerability assessments by understanding the key components of risk, vulnerability and capacity;
- Identify impacts of future climate change and climate variability on human well-being and the environment;
- Identify key areas in which adaptation to climate change goes hand-in-hand with other development priorities and with building resilience in natural and human systems;
- Identify and develop basic elements of an implementation plan for adaptation options.

Building on the general IEA framework, the following are key questions to be answered through integrated climate change and vulnerability assessments in cities:

- Chapter 3: What is the state of the city's environment, with emphasis on aspects relating to climate change vulnerabilities?
- Chapter 4: How will climate change exert pressures on the city's environment, and what are other drivers and pressures of environmental change with which climate change is likely to interact?
- Chapter 5: What are the likely socio-economic impacts of climate change on cities?
- Chapter 6: What adaptation responses can address the possible impacts of climate change while helping build the resilience of cities?

[4] UNEP, *Methodology for the Preparation of GEO Cities Reports*, Version 3 (2008) available at http://www.pnuma.org/deat1/pdf/Metho_GEOCitiesinddOK.pdf.

Figure 1.1: Context, Goals and Process of the Assessment



Exercise 1.1: Context, Goals and Process of the Assessment

Are you using this training module in the context of a particular assessment your city is conducting? If so, it is useful to start by reviewing the context, goals and process of the particular assessment you are carrying out.[5]

- Have specific goals been established for this assessment?
- Is there a specific reason why the assessment is being carried out at this particular point in time (e.g., political impetus, response to recent disaster events, availability of donor funding)?
- What degree of confidence do the participants have that the assessment will lead to sustained action in the city? (assess on scale of 0-5)
- Are there any specific policies and plans in which the outcomes of this assessment likely to be used:
  - Separate environment or climate change plan (at national, provincial or city level)?
  - General development plans (at national, provincial or city levels)?
  - Sectoral plans (e.g., water management plan, transportation plan)?
  - Regulations or zoning?
  - Other?
- Have any of the following been secured?
  - Funding to complete the assessment process
  - Funding for implementation of the outcomes of the assessment
  - Political commitment to act on the outcomes of the assessment
- Are all the relevant stakeholders involved in the assessment process, or should efforts be made to include any additional stakeholders?[6] Consider:
  - Their stake in the issue or vulnerability to climate change impacts (e.g., the urban poor)
  - Their formal position (e.g., governmental authorities that need to be involved in climate change adaptation)
  - Their control over the relevant resources
  - Their power to promote, hinder or block implementation (e.g., activist groups, lobby groups)

[5] Additional tools and guidance are available in United Nations Centre for Human Settlements (UN-Habitat), *Planning for Climate Change: A Resource Guide for Urban Planners* (draft, 2010), pages 25-40.

[6] Some exercises on stakeholder mapping can be found in UN-Habitat, *Participatory Vulnerability and Adaptation Assessment: A toolkit based on the experience of Sorsogon City, Philippines* (draft, 2010), pages. 13-14.

CHAPTER II:

Urban development trends and vulnerability – concepts and basic definitions

1. Urban development trends

Historically, cities have been recognized for their significant contribution to the socio-economic development of a country. They are important centres of productive activity and economic growth at all levels and play an essential role in social development. Their attractiveness with respect to internal migration is due in part to the wide range of basic services that they can offer such as potable water, sanitation, education, health and housing. Cities are also centres of progress, culture and knowledge.

However, the speed of urban expansion may have negative effects on the quality of the urban environment, undermining the sustainability of the social and economic progress achieved.

Human activity generates a great quantity of biological, solid and chemical waste, which greatly impact the environment at all levels. Urban environmental conditions have deteriorated in a significant way in terms of river and aquifer pollution, atmospheric contamination, inadequate management of urban waste, and the deterioration of green areas, among other things, that generate increasing risks for the population's health.

Cities do not merely affect their own environment. To sustain themselves, they need raw materials and natural resources which they themselves cannot generate: water, wood, energy, food and other inputs. These are all available within the natural environment, whether near the cities or further away. These are products that are transported via a network of roadways, railways, ports and airports, which also link the spaces between cities.

Natural phenomena must be added to this dynamic. Hurricanes, cyclones, earthquakes, volcanic eruptions, floods and droughts have profound implications for the configuration of human settlements.

Socio-economic conditions and inefficient institutional arrangements limit the capacity to prevent or mitigate climate change impacts and extreme events. These factors have transformed vast regions and urban centres into extremely vulnerable zones, both physically and socially.

The confluence of all these elements creates a situation of urban vulnerability that affects low-income communities in particular, since they are forced to occupy areas that are at greater physical and environmental risk.

Table 2.1: Level of urbanization per region and tipping points urban vs. rural

Region	Tipping point before 2010 (year)	2010 urban (%)	Tipping point after 2010 (year)	2050 urban (%)
World		**50.6**		**69.6**
MORE DEVELOPED REGIONS	before 1950	75.0		86.0
Europe	before 1950	72.6		83.8
Eastern Europe	1963	68.4		79.9
Northern Europe	before 1950	84.4		90.7
Southern Europe	1960	67.5		81.2
Western Europe	before 1950	77.0		86.5
Northern America	before 1950	82.1		90.2
Oceania	before 1950	70.6		76.4
LESS DEVELOPED REGIONS		45.3	2020	67.0
Africa		39.9	2030	61.8
Sub-Saharan Africa		37.3	2032	60.5
Eastern Africa		23.7		47.6
Northern Africa	2005	52.0		72.0
Southern Africa	1993	58.8		77.6
Western Africa		44.6	2020	68.0
Asia		42.5	2023	66.2
Eastern Asia		48.5	2013	74.1
South-Central Asia		32.2	2040	57.2
South-Eastern Asia		48.2	2013	73.3
Western Asia	1980	66.3		79.3
Latin America and the Caribbean	1962	79.4		88.7
Central America	1965	71.7		83.3
South America	1960	83.7		91.4
Source: United Nations Department of Economic and Social Affairs (DESA), World Urbanization Prospects—2007 Revision Population Database[7]				

It is true that no matter the path of economic development a country has chosen, urbanization remains an inevitable outcome of this effort across the world.[8] This tendency presents an enormous challenge to efforts to address poverty and climate change.

[7] Table adapted from United Nations Human Settlements Programme (UN-Habitat), *State of the World's Cities 2010/2011: Bridging the Urban Divide* (2008), Table 1.1.1.

[8] UN-Habitat, *State of the World's Cities 2010/2011: Bridging the Urban Divide* (2008).

The urban transition occurs at different times and with diverse growth patterns but the real challenge remains for governments to take actions that allow residents to make the most of living in cities. Already, half the world's population is urban. Currently, the less urbanized regions are Asia and Africa, but they are expected to reach their respective tipping points – that is, when their populations are more urban than rural – in 2023 and 2030, respectively.[9]

From 2025 to 2030, average annual global growth in the proportion of people living in cities is expected at 1.5%, meaning that by the middle of the century (2050) the urban population is due to reach 61.8%.[10]

The biggest challenge for governments is the increase in the most economically vulnerable populations in cities. The immense majority of the poor lives without adequate housing or access to basic services, and trends evidence a worsening of this situation.

Box 2.1: Urbanization trends in Latin America

There are specific factors that affect the state of the environment in Latin America. One of these is urban population concentration.

According to 2005 data, Latin America and the Caribbean had a population of 557 million inhabitants, representing 8.5% of the world's population. The urban population rose that year to 77.3%, and was expected to climb to 80.6%[11] by 2015. The region has been transformed into the most urbanized in the developing world.

The growth in urbanization in Latin America and the Caribbean has been quite impressive. The urban population grew by 3.5% annually during the second half of last century, rising to 47% in 1950 and attaining 75% in 2000. Nearly 32% of the region's population lives in big cities, widely surpassing Asia (15%) and Africa (13%). [12]

During the second half of the Twentieth Century, the urban population increased significantly, moving from 59 million to more than 350 million inhabitants. In 2000, nearly a quarter of the population was concentrated in the four mega-cities[13] (México City, São Paulo, Buenos Aires, Rio de Janeiro), and in the three other largest urban centres (Lima, Bogotá and Santiago de Chile).

Urbanization in the region has been, in most cases, rapid, disorganized and severely detrimental to the environment. The region is the best example in the world of income disparity and the cities most strongly reflect this situation. The greatest number of poor resides in the cities, resulting in increased urbanization of poverty.[14]

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9 Ibid
10 Ibid
11 United Nations Development Programme (UNDP), *Human Development Report 2007-2008—Fighting climate change: Human solidarity in a divided world* (2007, New York).
12 Romero-Lankao, P., *et al.* (eds.), *Can Cities Reduce Global Warming? Urban Development and the Carbon Cycle in Latin America* (2005, Mexico, IAI, UAM-X, IHDP, GCP).
13 Defined as cities with more than 8 million inhabitants.
14 UNEP, *Perspectives on the urban environment in Latin America and the Caribbean: Evaluation and results of GEO Cities* (2004, Mexico).

Approximately two-thirds of the region's poor live in precarious[15] city zones. Although the period from 1990 to 2005 saw decreases in the absolute numbers of slum dwellers in the region and in their percentage of the region's urban population, over 100 million people in Latin America and the Caribbean are still living in unacceptable conditions.[16] This report states that 86% of the urban population currently has access to improved sanitation, though much remains to be done in terms of service quality, the treatment of urban sewage, and the sustainability of services in a scenario of pollution and climate change. Likewise, the region has made significant progress in terms of coverage of drinking water systems, with 97% of the urban population able to access safe drinking water. Nonetheless, the United Nations (2010) highlights that water available to a large proportion of people is not true drinking water and the supply is irregular.

This training module is a supplement to the *Methodology for the Preparation of GEO Cities Reports*.[17] It applies the D-P-S-I-R matrix (Driving Forces, Pressures, State, Impacts, Responses), which can provide a structure for analysis of urban trends and preparation of an integrated environmental assessment.[18]

The main focus of the methodology is the need to ascertain the way in which urbanization impacts the environment, through factors that place pressure on the natural resources and local ecosystems, giving rise to a particular environmental state, which in turn impacts the quality of life in cities, and that calls for governments and local communities to take specific action.

The analysis should bring together elements of the social, economic, political and territorial dynamics of the urban development process and its interaction with the environment.

In this regard, it is essential to have some knowledge of the characteristics of the main activities of municipalities, the structure of social inequality of the city, the main factors that determine space occupation, the local institutional organization, with emphasis on those public institutions set up to protect the environment, and the mechanisms for social participation in the development of public policies, among other things.

2. Vulnerability assessments and the DPSIR framework[19]

The D-P-S-I-R methodology is an analytical tool that can be used to analyze the interactions between urban trends and the environment. It seeks to establish a logical link between its components to guide the evaluation of the state of the environment based on factors that exert pressure on natural resources and which should be considered as the "causes" of the current state of the environment, enabling each city to develop responses to deal with specific environmental problems.

15 Precarious city zones can be defined as areas of the city where living conditions are very poor and insecure, whether as a result of natural factors (e.g., steep slopes and landslides, low-lying areas and flooding), human (high levels of crime) or economic and social factors (poverty, income inequality, lack of sanitary infrastructure and conditions, such as clean water supply, health policies), and where human well-being is affected.

16 United Nations, *Millennium Development Goals: advances in environmentally sustainable development in Latin America and the Caribbean*, (2010, ECLAC, Santiago, Chile).

17 UNEP, *Methodology for the Preparation of GEO Cities Reports, Version 3* (2008).

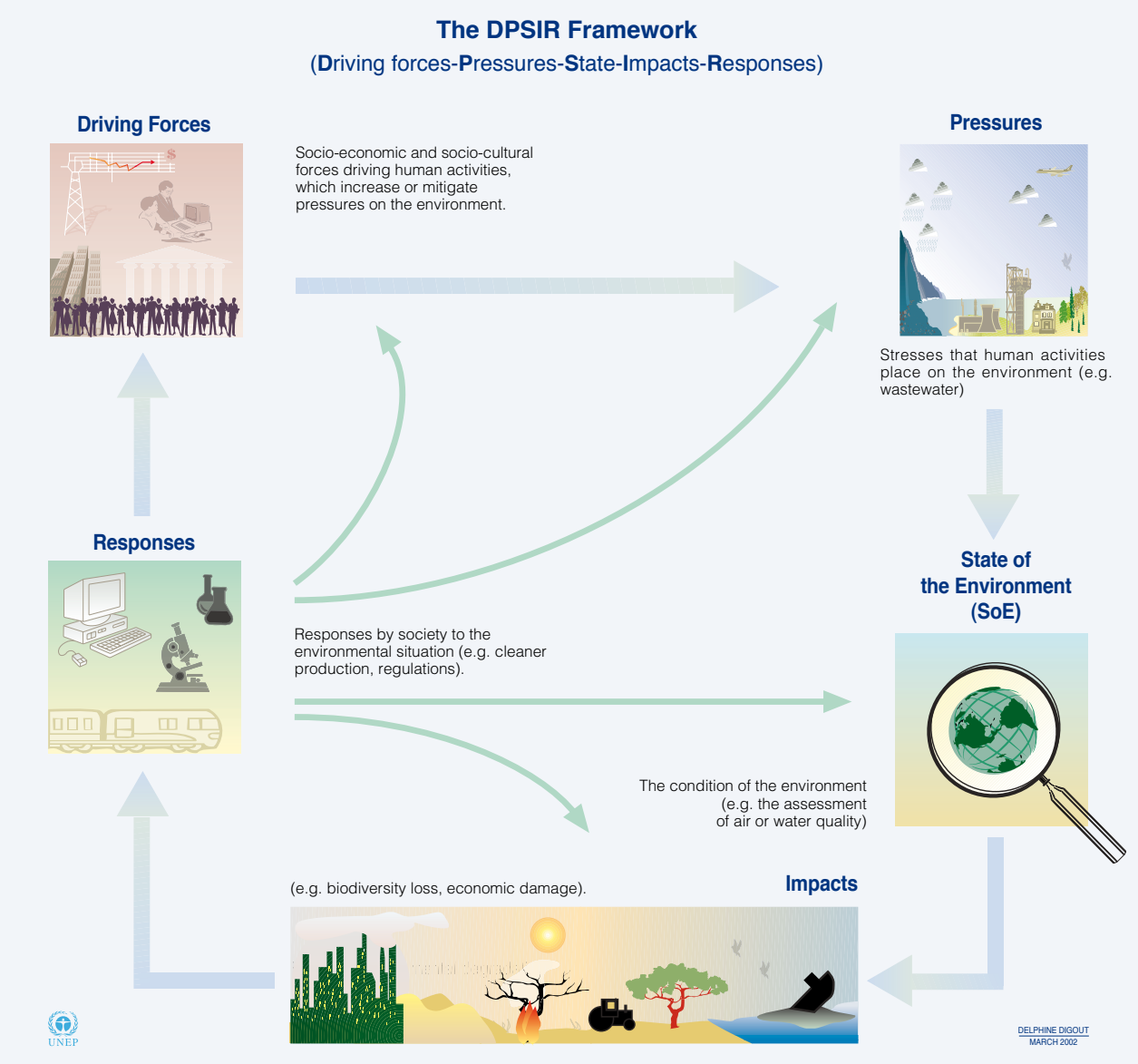
18 UNEP, *GEO Resource Book—Module 5: Integrated Analysis of Environmental Trends and Policies* (2007).

19 UNEP, *Methodology for the Preparation of GEO Cities Reports, Version 3* (2008).

The basic elements for the **DPSIR framework** (Figure 2.1) respond to the following basic questions, regardless of the size of the area under consideration:

1. What is happening to the environment? (state)
2. Why is this happening? (driving forces and pressure)
3. What is the impact? (impact)
4. What are we doing? (response)
5. What will happen if we do not act now? (future outlook)
6. What can we do to reverse the current situation?

Figure 2.1: Road Map to Climate Change Vulnerability and Impact Assessment using the DPSIR Framework



Source: Global International Water Assessment (GIWA), 2001; European Environment Agency (EEA), Copenhagen.

The elements that make up the D-P-S-I-R matrix and which correspond to the earlier questions are:

Driving forces. Driving forces are at times referred to as indirect or underlying forces. They are related to fundamental societal processes that promote activities that have a direct impact on the environment. Key forces include: population trends; consumer behaviour and production; scientific and technological innovation; economic demand; markets and trade; resource distribution patterns; institutional and socio-political frameworks and value systems.

The characteristics and importance of each driving force varies substantially from one region to another, as well as between regions and nations. For example, with regard to population dynamics, many developing countries are still experiencing population growth while many developed countries have a stable or aging population. Additionally, resources and opportunities are distributed unequally within and among the regions.

Pressures. Pressures affect state of the environment variables individually and collectively. Key pressures include emissions of pollutants or waste, land use changes, and resource extraction. Human interventions may be directed towards causing a desired environmental change such as land use, or they may be by-products of other human activities (e.g., pollution). Often, a combination of pressures leads to environmental change. For example, climate change is a result of emissions of different greenhouse gases, deforestation and land use practices.[20]

By knowing the factors that are causing pressure, one seeks to answer the following question: *Why is this happening?*

For the purposes of this module on vulnerability of cities to climate change, this global challenge (i.e., climate change itself) is considered to be a powerful factor in terms of pressure on the various elements of the environment as well as on socio-economic activities.

State. This refers to the condition of the environment as a result of pressures, for example, the level of atmospheric pollution, soil erosion or forest cover. The information on the state of the environment answers the following question: *What is happening to the environment?*

Impact. This is the effect produced by the state of the environment in terms of quality of life and human health, the environment itself, the built environment or the local urban economy. For example, an increase in soil erosion may cause a drop in food production, an increase in food imports as well as an increase in the use of fertilizers and malnutrition. Impacts, be they on human well-being, the social and economic sectors or environmental services, are highly dependent on the characteristics of the drivers.[21]

[20] UNEP, *Global Environment Outlook (GEO-4): Environment for Development* (2007, Nairobi); UNEP, *Integrated Environmental Assessment Training Manual* (2007, Nairobi).
[21] UNEP, *Global Environment Outlook (GEO-4): Environment for Development* (2007, Nairobi).

Responses. These correspond to the collective or individual actions that mitigate or prevent negative environmental impacts, that correct the damage caused to the environment, that protect natural resources or contribute to a better quality of life for the local population. Responses may include regulatory activities, budget allocations for environmental protection or research and consumer preference, changes in administrative strategies and the handling of information related to the environment. Societal responses can be: a) directed at *reducing exposure* to environmental impacts; b) responses to assist *adaptation* to the impacts that occur, including to build the capacity to adapt to environmental changes.[22]

In order to measure the society's response, more analysis and interpretation is required by the assessment team.[23] The instruments included in this category of the matrix are aimed at answering the question: *What are we doing?*

Responses to the question: *What will happen if we do not act now?* are intended to use the current state to inform an analysis of the future outlook for the environment. The underlying logic of the D-P-S-I-R matrix allows links to be established to project the future of current environmental conditions, which in turn encourage analysis of the possible effects of current action. This raises the possibility of strategic action being taken to change the direction of environmental trends in each locality.

The D-P-S-I-R matrix seeks to define, as accurately as possible, the patterns of relationship between the various anthropogenic actions and the environment, in the case of this module, those that apply to the relationship between the urban space and the environment.

The D-P-S-I-R matrix is a conceptual framework for organizing and grouping together, in a logical manner, factors that affect the environment, the effects of human activities on ecosystems and natural resources as well as the impact on health and the environment itself. The matrix is equally useful for analysing the involvement of society and local government to tackle the problems caused by human actions.

When the process of evaluating the environment is carried out as a "photograph" of the environmental conditions at a given time (synchronic outlook), it is easier to ascertain the relationship between certain components in terms of specific human activities and environmental factors. This allows the analyst to determine more precisely the extent to which a given instrument should be considered a response or a pressure on the environment.

Since it is also necessary to follow the movement or the dynamic of the urban-environmental interaction over a period of time (diachronic interaction), some policies – which from a "snapshot" or synchronic perspective would be located in the category of responses – may be interpreted as factors exerting pressure on the environment over time.

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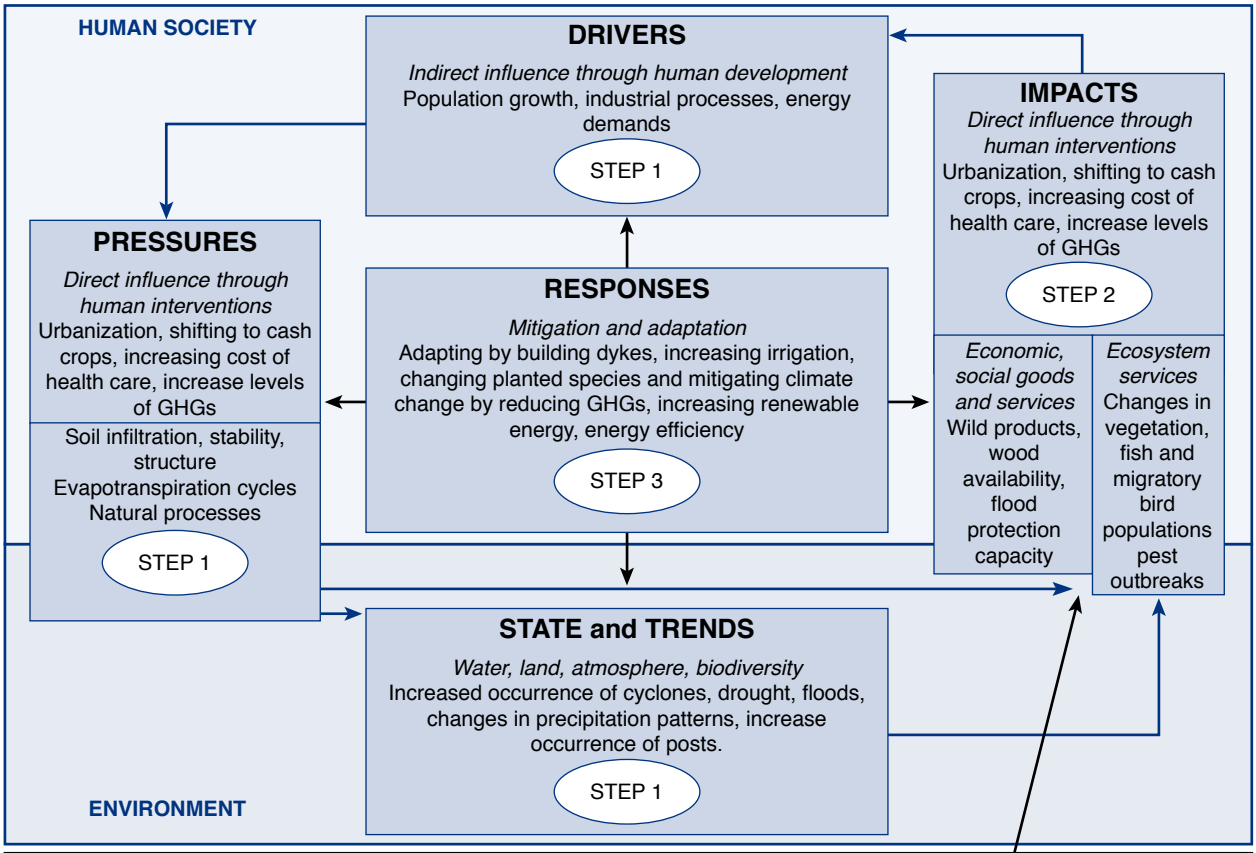
22 UNEP, *Integrated Environmental Assessment Training Manual* (2007, Nairobi).

23 UNEP, IISD & Ecologistics International, *Capacity Building for Integrated Environmental Assessment and Reporting: Training Manual*, Second edition (2000), p 5.

Processes such as those found in the urban-environmental relation always presuppose a flow of interactions overtime. This implies that the factors that belong to or influence the response category may be considered, at a later date, as part of the pressure mechanisms on the environment. This happens both in the "positive" sense, for instance, when they function as factors limiting the degree of pressure exerted by the population or industry on natural resources or ecosystems, and as "negative" when they are not capable of reversing the trend of the pressure detected earlier, or when, even unintentionally, they end up stimulating or increasing pressure on the environment.

Finally, there is the importance of integrated and sequential assessment of the environment, as shown in the D-P-S-I-R matrix (Figure 2.2).

Figure 2.2: Climate Change Vulnerability and Impact Assessments for Adaptation[24]



Source: Bass *et al.* (2008), modified

[24] Adapted from Baas, S., Ramasamy, S., DePryck, J.D and Battista, F., *Disaster Risk Management Systems Analysis: A Guide Book* (2008, Rome: Food and Agriculture Organization of the United Nations (FAO)).

This knowledge will allow responses to be taken addressing the environmental problems detected, as well as corrections to existing policies and programmes based on the current environmental situation and that projected for the future. Adoption of this outlook will help identify difficulties in the implementation of response actions developed at the local level, defining the various levels of responsibility of each relevant actor (federal governments, states or localities, businesses, civil society organizations, the local population, etc.).

2. Vulnerability assessments: Key issues

Recognizing, or assessing, a city's risk and vulnerability to climate change is the first step towards adaptation actions. Methods of vulnerability assessment have been developed in the fields of natural hazards, food security, and to determine how people cope with climate hazards.[25]

Vulnerability is a concept broader than just impacts to climate change, and its relation to risk and hazards is analyzed hereafter.

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability expresses the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including climatic variability and extreme events. Vulnerability is a function of the character, magnitude and rate of climate change, as well as of the variation to which a system is exposed, its sensitivity and its capacity for adaptation.[26]

According to the United Nations Development Programme (UNDP), vulnerability differs from risk. The etymology of this word is the Latin verb *vulnerare* ("to injure"). Whereas risk includes exposure to external hazards over which persons have little control, vulnerability is a measure of the capacity to manage these dangers without any loss of well-being that might be potentially irreversible in the long run. Therefore, for example, persons who live in the Ganges Delta and those who live in Lower Manhattan are exposed to the hazard of flooding caused by sea-level rise. However, the degree of vulnerability differs in each case, with a high degree of vulnerability for those living in the Ganges Delta due to the level of poverty and the poor infrastructure for protection that exists in this zone.[27]

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25 H.-M. Füssel and R.J.T. Klein, *Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking in Climatic Change*, 75 (2006): 301–329.

26 IPCC, *Climate Change 2007—Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. (2007, Cambridge University Press, Cambridge, United Kingdom).

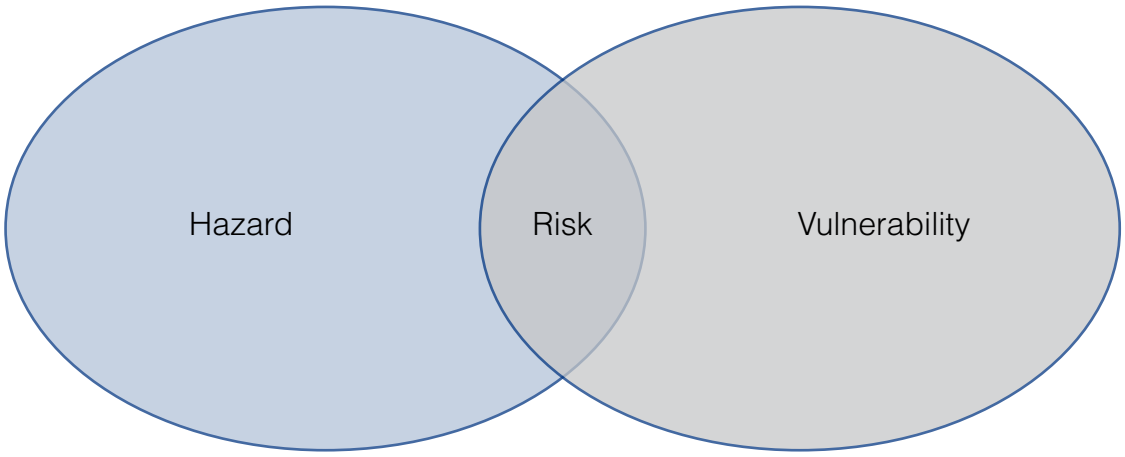
27 UNDP, *Human Development Report 2007-2008—Fighting climate change: Human solidarity in a divided world,* (2007, New York).

Although there are differences in the use of terminology, most analytical frameworks for measuring vulnerability distinguish three components:

a) exposure (the nature and degree to which a system is exposed to significant climatic variations),
b) sensitivity (the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli), and
c) adaptive capacity for response, or resilience, that is the ability of a system to adjust to climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

These three components may vary considerably from one individual to another, as well as from one social group or community to another. Additionally, vulnerability is multidimensional (effect of different stress factors at the same time) and depends on spatial and temporal scales (potential for change in the stress factors over time).[28] In other words, risk can be seen as the overlay between vulnerability and hazard (Figure 2.3)' both hazard and vulnerability being dynamic over time.

Figure 2.3: The relationship between hazard, vulnerability and risk



[28] UNEP and Netherlands Environmental Assessment Agency, *Vulnerability of People and the Environment—Challenges and Opportunities, Background Report on Chapter 7 of the Fourth UNEP Global Environment Outlook (GEO-4)*, (2009, Nairobi, Kenya).

Vulnerability depends on context, and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question. Certain factors are likely to influence vulnerability to a wide variety of hazards in different geographic and socio-political contexts. For instance, a household´s access to water, land and other resources is an important determinant of its vulnerability to climate change. Multiple factors converge to make populations inhabiting coastal zones and small islands highly vulnerable.

Understanding of vulnerability includes identifying to what extent the system is sensitive to identified impacts based on available adaptive capacities. The following questions could be used to investigate the available capacities and strategies:

1. How often do the identified impacts, including disasters, hit the community? Is the incidence increasing?
2. What capacities are lacking to address the identified impacts?
3. Which organizations/institutions, if any, support existing coping strategies or promote new strategies?

In this context it is important to assess what are the major impacts on physical and social systems from climate variability and change, as will be discussed in the next chapter.

Vulnerability assessments

Vulnerability assessments are essential in responding to future climate risks and the assessment process itself can help to improve management of current climate risks. Although assessments are scale-specific (e.g., local, national, regional scale), cross-scale interactions occur given the interdependency of social and ecological systems and the relationship to national and sectoral policies and decisions.

CHAPTER III:

State of the urban environment and its vulnerability to climate change

What is of the state of the city's environment, with emphasis on aspects relating to climate change vulnerabilities? This is a question that this chapter attempts to answer.

Sectors or systems generally adapt to variability in environmental conditions and, to a certain degree, are more resilient when these changes are included in their natural (normal) variability. However, when the environmental changes are more extreme or persistent than those to which the systems or sectors normally adapt, this can lead to vulnerability.

Some authors have expressed concern over the occurrence of possible abrupt climate changes. An accumulation of gradual changes in a complex system can reach a tipping point which causes a sudden change, above which the natural or human system resilience becomes overburdened and cannot adapt to change. In fact, the IPCC, in its 2007 Fourth Assessment Report, recognizes that the vulnerability associated with climate change on industry, settlements and societies[29] is more linked to extreme events rather than to gradual variations in climate.

The IPCC report also considers that climate change may be interacting with, and possibly exacerbating, other environmental changes that are occurring as well as the current environmental pressures on human settlements. In a nutshell, climate change is not the only stress that impacts human settlements (cities) but it certainly interacts with other existing pressures.[30]

It is expected that changes will occur in the temperature, rainfall regime, vegetation, sea level and intensity of extreme weather events. Some areas will become drier while some will become more humid. Under these conditions, the effects of climate change on biodiversity and ecosystem services will increase. Ecosystem services will be directly altered by climate change via changes in productivity, changes in the areas with plant cover, as well as through changes in the frequency of extreme weather events. Moreover, it is expected that climate change will affect ecosystems, for example, a rise in sea level will affect coastal vegetation.

A number of services that are important for development will be affected by climate change. These are, among others, the supply of clean water, energy and food services, maintenance of healthy surroundings and protection of the environment, its biodiversity and the ecological goods and services associated with it.

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29 T.J. Wilbanks, P. Romero Lankao, M. Bao, F. Berkhout, S. Cairncross, J.-P. Ceron, M. Kapshe, R. Muir-Wood and R. Zapata-Marti, *Industry, settlement and society. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.), (2007, Cambridge University Press, Cambridge, United Kingdom), pages 357-390.

30 Wilbanks *et al.* (2007), pages 360-361.

A useful starting point for climate change vulnerability and impact assessment, therefore, is to review the current state of the city's environment—including its air, water, biodiversity and land resources—as well as recent or ongoing visible changes. The exercise in this chapter is a brief summarized assessment of the state of a city's environment. A more detailed assessment can be carried out using the GEO Cities Methodology.[31] The exercise in this chapter focuses on aspects of a city's environment that relate most strongly to expected climate change impacts.

Exercise 3.1: Questionnaire to guide the analysis of the state of the city's environment in relation to climate change

***Water**:*

Questions	Indicators
• What are the sources of water supply? • Which water basins supply the city? Is underground water used? • What has been the average flow in recent years? • Is this flow constant?	• Hydrographic basins that supply the city, average annual flow
• What is the water used for? What is the order of importance between domestic, industrial, energy, agricultural and other uses?	• Water demand according to type of use; water balance • Coverage of water supply and sanitation
• What access does the public have to drinking water? Those who do not have access, how do they obtain water?	• Percentage (%) of the population supplied with drinking water
• Where are the supply centres located within the city? What is the price per cubic metre? Has this been increasing?	• Price of domestic potable water
• What is the degree of contamination of the water?	• Volume of wastewater per type of use • Type and level of contaminants within wastewater • Volume of water treated

Air:

Questions	Indicators
• What are the sources of atmospheric pollution: mobile or fixed? • Does industry use energy derived from fossil fuels? • Is there a fleet of older vehicles? • Are there areas in the city that are particularly polluted by traffic congestion? • With respect to industrial pollution, what type of pollution is there? Does this affect any particular area of the city?	• Atmospheric pollution in recent years compared with standards (e.g., international, national, municipal) • No. of vehicles (private or public); age of vehicles • Indicators of the type of pollution by type of industry

[31] UNEP, *Methodology for the Preparation of GEO Cities Reports, Version 3* (2008), available at http://www.pnuma.org/deat1/pdf/Metho_GEOCitiesinddOK.pdf.

Biodiversity:

Questions	Indicators
• What is the surface area of plant cover within the city zone? What is the number and size of gardens within the city? How much green space is there per inhabitant? • What type of fauna lives in different parts of the city? Are any endangered fauna present in the city? • What are the terrestrial or marine ecosystems that impact the city's development? • What is the number and size of public parks? • What type of services do they offer? What is their degree of preservation?	• % of urban areas devoted to green spaces: woods, mangroves, etc. • No. and size of public parks • No. and size of public gardens; density per locality (districts) within the city (m^2/inhabitant)

Land:

Questions:	Indicators:
• What are the main land uses in the city? • What are the most frequent risks for urban land? Are there landslides caused by rain, earthquakes, flooding, drought, etc? • In what period of the year do these occur? • Are they recurrent and more intense each time?	• Changes in land use in hectares • Map of risk zones • No. of dwellings and inhabitants in these risk areas • List of earthquakes or floods in recent years and their intensity • Quantification of damage and losses from previous disasters • No. of informal or poor settlements. No. of inhabitants

Exercise 3.2: Which of the following disasters/hazards currently affect the city (yes or no)?

1. Earthquakes (Y or N)	
2. Hurricanes/cyclones/typhoons, storms or extreme rainfall (Y or N)	
3. Floods (Y or N)	
4. Tsunamis or storm surges (Y or N)	
5. Droughts (Y or N)	
6. Volcanic eruptions (Y or N)	
7. Avalanches or landslides (Y or N)	
8. Extreme temperatures (Y or N)	
9. Others (specify) (Y or N)	

There are also other examples for possible systems of questions and indicators that examine and measure a range of city services and quality of life factors. The Global City Indicators Program[32] provides an established set of city indicators with a globally standardized methodology that allows for global comparability of city performance and knowledge sharing.

[32] http://www.cityindicators.org/

City performance relative to each of these themes is measured by a suite of several indicators, which collectively tell a "story". Overall, 94 indicators have been proposed (see Annex II).

This set of global city indicators was selected based on significant input from the partner cities, ensuring that these indicators reflect city information needs and interests, and a rigorous screening process.

CHAPTER IV:

Climate change in the context of other drivers and pressures of environmental change in cities

By knowing drivers and factors that are causing pressure, one seeks to answer the following question: *Why is this happening*?

Once the factors that explain the state of the environment have been identified, we can analyze elements of vulnerability to the impacts of climate change (as a powerful pressure factor), to determine if the existing responses to these problems are adequate, and what other type of action should be taken to reduce pressure on the natural resources, and to develop the capacity for adaptation, thereby improving the state of the environment and the population's well-being.

The impact of climate change on cities is directly related to the specific location of each urban centre. It is therefore important to establish a classification of settlements according to their size, as well as factors such as their relationship with other cities, geography, topography, ecosystems and climate. This analysis should take into account elements that characterize the economic and social development of cities. For instance, climate change impacts will be different, say, in settlements that are dependent on the exploitation of natural resources in arid zones, as compared with cities located in coastal areas with economic activities related to tourism.

1. Geographical location

It is worth bearing in mind that many aspects of a city's environment may not be accidental, but can be significant reasons for the city's existence. For instance, a high proportion of cities are located in coastal zones or low-lying deltas that are at high risk of disasters like cyclones, flooding and tsunamis, as well as sea level rise, but which are also located in the most fertile land with the best access to trade routes. Urban residents may sometimes select to live in a higher risk location in exchange for the better economic opportunities that it offers.

The degree of vulnerability reflects how susceptible a system is to certain risks. In this case, the impacts depend not only on risks, but also on a city's capacity to adapt to new climatic conditions. Both the magnitude and the rate of climate change are important in determining the sensitivity, adaptability and vulnerability of a system.

Additionally, the impacts of climate change on an urban centre are likely to be more serious if the relevant institutions and social systems are less developed. Although it can be difficult to measure vulnerability empirically, it is possible to develop vulnerability indexes that can provide a tool for decision makers. In many cases, policy makers will have to pursue adaptation policies based on previous experiences, observation and projections, rather than wait for impacts to affect the people.

Figure 4.1

Risks currently have different impacts on different cities, and different impacts on different localities within the same cities or regions. The same is true of climate change. The impacts will always depend both on the geographical location and the social and economic conditions that make the city, locality or region more or less vulnerable. Hence, there is a need to analyze specific aspects of climate change, taking into account the physical and/or geographical location of the city and the specific socio-economic factors that affect its development.

For the purposes of this module, it is suggested that a classification be used that initially defines the physical and geographical elements and analyzes the economic, social and political variables which, when inter-related, bring about higher or lower levels of vulnerability to climate change.

The classification can take into account physical-geographical elements:

- Cities located at high altitudes or in mountainous zones;
- Cities located in mega-deltas, riparian or low-lying coastal areas;
- Cities located in arid or semi-arid zones;
- Cities located in temperate or polar zones (high latitudes).

Box 4.1: Cities and deserts

Given the restrictions that are inherent in dryness, deserts are among the least populated areas on the planet. Around 6% of the world's population resides in arid and very arid zones which account for 20% of the world's land area. Approximately 94% of desert dwellers live in developing countries, with extremely high rates of population growth.

During the Twentieth Century, the number of persons living in desert areas located in developing countries multiplied by eight times, with most of this population growth occuring in cities. Some desert countries with relatively-strong industrial and service sectors have large urban populations, including Qatar (92.3%), Bahrain (90.2%), Saudi Arabia (88.5%), Libya (86.9%), and United Arab Emirates (85.5%).

Most major population centres of the contemporary world are located outside deserts. At their beginning, many of these centres were established as small agricultural communities for which access to fresh water was essential (Portnov and Erell 1998). In contrast, urban development in deserts often generates sufficient economic outcomes to justify the considerable costs of importing fresh water (Portnov and Safriel 2004).

Historically, desert settlements have been scattered and sparse, and served as commercial and administrative centres, which sprang up around mines, transportation routes, and other local amenities (Saini 1980; Golany 1979; Issar 1999). Some were established as strategic outposts in response to various geopolitical and security considerations (Portnov and Erell 1998). Today, desert towns and cities function as irrigation centres, garrisons, communications nodes and political, administrative and regional centres; they may also be focused on tourism, recreation, mining or other industries (Kates *et al.* 1977).

There are four major factors contributing to a recent increase in the pace of desert urbanization:

- Relocation of territory-consuming enterprises, military and research installations from overpopulated core regions to peripheral desert areas;
- Mining and power engineering facilities, as resources are depleted in traditional mining centres and other less remote non-desert locations;
- Development of transport infrastructure which extends the commuting frontier of existing population centres into more remote desert hinterlands;
- Development of means of pumping fresh water over considerable distances from natural sources, and desalination technologies which have become more available and affordable (Portnov and Erell 1998).

Predicted global warming will also draw the desert frontier closer to many existing population centres, thus bringing more cities currently located at desert fringes closer to the desert; some may even become desert cities eventually. Thus, as a result of climate change, more non-desert people of today are likely to become desert inhabitants of tomorrow.

Concurrently, two major factors reduce the attractiveness of desert regions for newcomers — limited and undiversified employment opportunities and remoteness from major cities, which are major foci of employment, services and cultural life. However, if these drawbacks are mitigated, desert cities may exhibit impressive growth (such as in, for example, Tucson and Phoenix, Arizona), outranking even long-established non-desert communities.

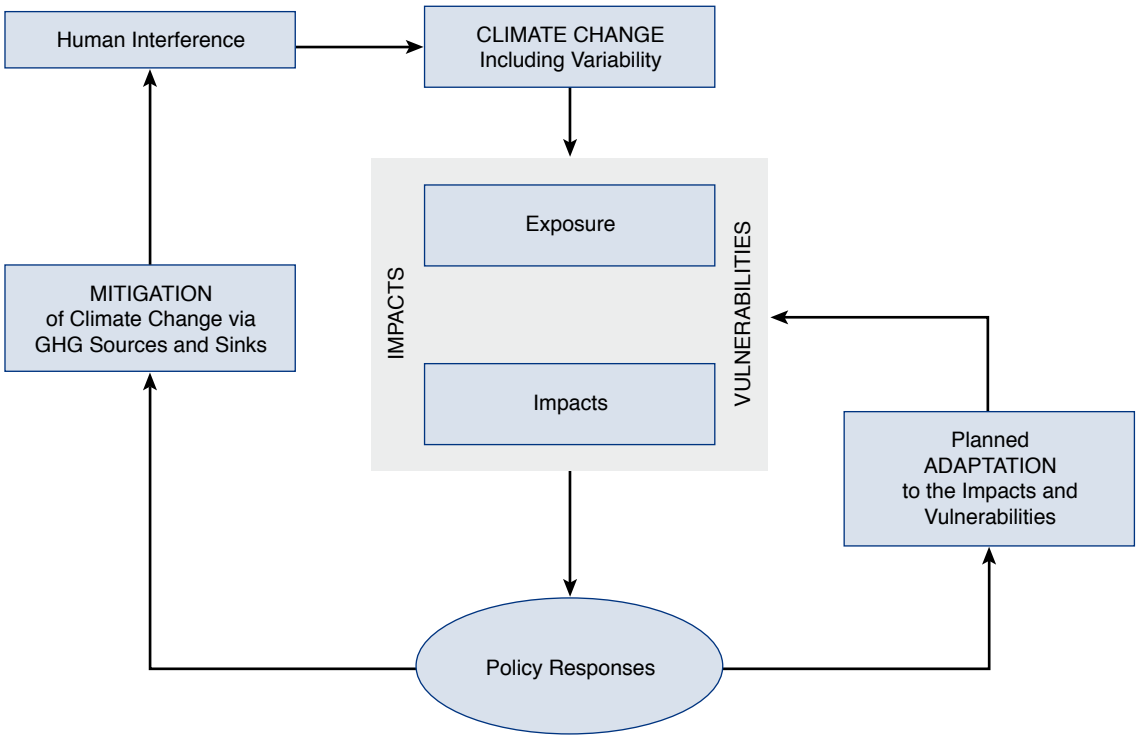
Source: UNEP, *Global Deserts Outlook*, Exequiel Ezcurra (ed.), (2006, Nairobi, Kenya).

2. Environmental and socio-economic factors

Environmental and socio-economic factors (drivers and pressures) determine the degree of vulnerability of the city to climate change. The increase in greenhouse gases of anthropogenic origin in the atmosphere brings about change in a number of climatic and non-climatic variables (see Figure 4.2), with marked impact on cities. Such climatic variables include, amongst others:

- Sea-level rise
- Average increase in global temperature
- Changes in rainfall distribution and quantity
- Increase in the frequency and/or intensity of extreme events

Figure 4.2



Vulnerability to climate change can be exacerbated by other non-climatic stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, and incidence of diseases. Therefore, climate change vulnerability assessments need to examine the underlying socio-economic, institutional, and, to a lesser extent, political and cultural factors that influence vulnerability alongside processes that shape the consequence of climate variations and change to identify the conditions that amplify or dampen vulnerability to adverse outcomes, as shown in Figure 4.2.

The methodology to assess the driving forces and pressures of a city's vulnerability to climate change as proposed in this module contemplates two main steps:

a) Assessing climatic variables and their potential impact on the city
b) Assessing non-climatic stresses to identify the city´s human and built environment characteristics

Integrated analysis of these factors will enable identification of potential impacts of climate change, including the main vulnerable areas in a city and its surroundings. This knowledge is critical for defining priority actions and adaptation plans.[33]

3. Drivers and pressures related to climatic variables

3.1. Rise in average global temperature

There is agreement in the literature of an average global *rise in temperature*. This constitutes a major sources of vulnerability affecting cities. It is *very likely* that over the past 50 years that cold days and cold nights have become less frequent over most land areas (including cities), and hot days and hot nights have become more frequent.[34] The constant increase in the average global temperature constitutes for cities, now and in the future, a *thermal vulnerability associated with temperatures* that they must deal with.

In the period 1996-2005, the average global temperature rose by 0.74˚C (0.56- 0.92)˚C.[35] The IPCC projected, by 2099, an increase of 1.8 (1.1-2.9)˚C for the lowest scenario and of 4 (2.4-6.4)˚C for the highest scenario.[36]

Science is currently able to predict with greater accuracy the future trends and expected results of the impact of climate change on temperature and sea-level rise, in contrast to other variables such as precipitation, wind, and extreme events such as hurricanes, for which, even though projections have been made, they are not as detailed and precise as for the first two variables. Since 1970, there have been more occurrences of heat waves that are closely linked to average temperature rise.

a) Urban heat islands

Heat islands occur in urban areas where temperatures are higher than in the surrounding rural areas, as a result of the daily cycle of absorption and subsequent re-radiation of solar energy received as well as the thermal properties of the buildings, streets, sidewalks, etc., which abound in cities, and which are quite different from the thermal properties of the vegetation that grows in rural areas, among other causes.

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33 World Bank, *Climate Resilient Cities—A Primer on Reducing Vulnerabilities to Disasters* (2009, Washington, DC, U.S.A.)

34 IPCC, *Climate Change 2007: Synthesis Report, Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007, IPCC, Geneva, Switzerland), pages 30 and 104.

35 Figures in italics represent a range of likely scenarios. See box on "Treatment of Uncertainty in IPCC, *Climate Change 2007; Synthesis Report* (2007), page 27.

36 IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30 and 45 (table 3.1).

The reasons that condition heat islands are complex and are linked to the interactions between atmospheric processes at different levels. Not all urban zones are identical; among other things, they differ in the density of construction, and area of tree-lined areas and gardens.[37]

In cities located in temperate or polar zones, and in some settlements in mountain zones during the cold period of the year, the presence of urban heat islands moderates the temperature. In some northern (arctic) regions, the significant increase in soil temperature during the summer may threaten settlements and infrastructure due to the thawing of permafrost soils.[38]

Indicators linked to urban heat islands:

- Records of temperature – average, maximum, minimum. Frequency of thermal events.
- Climatic zoning (largely temperature-related) of the city.
- Percentage of green areas (with trees and gardens) in the city. Distribution of these areas.
- Regulations regarding the distribution of green areas, frontage materials, etc.

b) Retreat of mountain glaciers

The increase in average air temperature is already causing the retreat of high mountain glaciers at temperate and tropical latitudes,[39] and many tropical glaciers are projected to disappear over the next decades.[40]

Indicators linked to the retreat of mountain glaciers:

- Identification of mountain glaciers that are of relevance to the city.
- Changes in the glaciers identified over the previous two decades.

c) Forest fires

A rise in temperature, especially during certain periods of the year, added to a shortage of water, whether seasonal or as a result of drought, increases the risk of forest and vegetation fires inside and close to the city.

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37 Wilbanks *et al.* (2007), pages 372 and 381.

38 Wilbanks *et al.* (2007), page 375.

39 IPCC, *Climate Change 2007; Synthesis Report* (2007), page 30.

40 C. Rosenzweig, G. Casassa, D.J. Karoly, A. Imeson, C. Liu, A. Menzel, S. Rawlins, T.L. Root, B. Seguin, P. Tryjanowski, *Assessment of observed changes and responses in natural and managed systems*, Box 1.1 and Section 1.3.1.1; *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.) (2007, Cambridge University Press, Cambridge, United Kingdom), pages 79-131; Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, *Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (eds.) (2007, Cambridge University Press, Cambridge United Kingdom), page 449; Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007, Europe. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.) (2007, Cambridge University Press, Cambridge, United Kingdom), pages 551, 583-589 and table 13.3.

Although fire risk may be present in any of the zones where cities are located, it is normally highest in arid and semi-arid zones.

Indicators linked to forest fires:
- Areas in the city or its environs (hectares) with forests or other types of vegetation that are at risk from fire.
- Reports of fires that have occurred in the city or surrounding areas over the past five years. Intensity of these fires.

d) Urban atmospheric pollution caused by climate change
With respect to air quality, it is not yet clear what role climate change plays in air pollution; however, it is thought that temperature rise aggravates pollution by increasing the presence of tropospheric ozone (O_3) in many cities.[41]

Increased pollution caused by this gas will occur in cities that are already impacted by ozone pollution from traffic, the presence of polluting industries in the city (or its environs), or specific geographical conditions that cause the gas to form and settle above the city.

Indicator related to urban atmospheric pollution caused by climate change:
- Air quality in the city under study (tropospheric ozone content).

3.2. Average sea-level rise

In the literature reviewed on climate change, it is recognized that one of the major sources of vulnerability of many human settlements (cities) is *sea level rise.* Global average sea level rose between 1961 and 2003 at an average rate of 1.8 mm per year and from 1993 to 2003 at 3.1 mm per year.[42] Global projections by the IPCC, excluding the rapid dynamic of ice flows, project an average sea-level rise of 0.18 to 0.59 meters between 1980-1999 and the years 2090-2099.[43] This elevation constitutes a permanent source of *vulnerability associated with sea-level rise for coastal cities.*

Sea level rise caused by climate change may impact natural coastal systems such as wetlands, mangroves, coral reefs, sea grasses and beaches, causing loss of biological diversity and deterioration in ecosystem services such as the supply of food (fish, crustaceans, molluscs, etc.), spawning areas of many aquatic species and services such as coastal protection against extreme events, carbon storage and water purification.[44]

41 Wilbanks *et al.*, (2007), page 372.
42 IPCC, *Climate Change 2007; Synthesis Report* (2007), page 30.
43 IPCC, *Climate Change 2007; Synthesis Report* (2007), page 45.
44 R.J. Nicholls, P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden and C.D. Woodroffe, *Coastal systems and low-lying areas, Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.) (2007, Cambridge University Press, Cambridge, United Kingdom), pages 315-356 and 372; Wilbanks *et al.*, (2007).

Sea-level rise may also affect land uses, causing damage to the infrastructure of cities in low-lying coastal areas and mega-deltas.[45]

Examples of indicators associated with sea-level rise:
- Elevation of the city above sea level.
- Percentage of land located below or at current sea level, or sea levels projected for the next few decades.
- Record of sea-level rise. Frequency of occurrence of seawater penetration into the city. Amount of land affected.
- Length of city coast.
- Loss of coastal ecosystem area, loss of species, value of lost or degraded environmental services.

3.3. Changes in the quantity and distribution of rainfall

Changes in the distribution and quantity of rainfall constitute another of the main sources observed and projected that create vulnerabilities in cities.

The IPCC highlights that between 1900 and 2005 rainfall increased significantly in the eastern regions of North and South America, Northern Europe as well as North and Central Asia. However, there was decreased rainfall in the Sahel, the Mediterranean, Southern Africa and regions in the South of Asia. Moreover, it is recognized that since 1970, there has been an increase globally in the areas affected by drought.[46]

Examples of indicators of vulnerability associated with changes in the distribution and quantity of rainfall:
- Record of maximum and minimum rainfall, spatial distribution of rainfall, annual pattern.
- Location of the city in drought-susceptible areas.
- Location of the city in areas susceptible to heavy rainfall.

a) Increase in rainfall

In certain regions there has been a *marked increase in rainfall* associated with climate change and this trend is expected to continue as climate change worsens. Rainfall will increase particularly at higher latitudes and in several humid tropical zones. In many cases, this may have beneficial effects for cities located in those regions.[47]

Many cities, especially those situated in mountainous regions, may be subject to risks from landslides or rupture of dykes caused by increases in rainfall. Increases in rainfall can also cause flooding, particularly in cities located on river banks, in mega-deltas or in other low-lying areas. Urban flooding can be an especially serious problem in cities that lack, or have insufficient infrastructure for drainage of wastewater and rainwater.[48]

[45] Nicholls *et al.* (2007), pages 317 and Wilbanks *et al.* (2007), pages 365, 371 and 375.
[46] IPCC, *Climate Change 2007; Synthesis Report* (2007), page 30.
[47] IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30 and 49; Wilbanks *et al.* (2007), page 375, table 7.3.
[48] Wilbanks *et al.* (2007), pages 361, 365, 370-373.

Examples of indicators associated with vulnerability to increased rainfall:

- Low-lying areas of the city at risk from floods, flash floods or landslides (% of total city area).
- Coverage of drainage infrastructure in the city.
- Frequency of floods.
- City areas permeable to surface water (non built-up areas, unpaved areas, green areas).
- Record of level of water in rivers inside and near to the city.
- Rainfall record in the hydrographic basin.

b) Reduction in rainfall

There is scientific agreement that climate change is reducing the rainfall in most arid and semi-arid zones and this decrease will continue and may even lead to a crisis in several cities located in these zones. It is very likely that periods of drought could be more frequent and prolonged.[49]

Examples of state indicators associated with vulnerability as a result of reduced rainfall:

- Water scarcity (frequency, extent and duration).
- Drought duration and frequency.

3.4. Increase in the frequency and/or intensity of extreme events

An increase in the frequency and/or intensity of extreme events can significantly increase cities' vulnerability to climate change.

Generally speaking, these extreme events result in violent increases in the variables previously mentioned (temperature, rainfall, sea-level rise), which may occur alone or together, sometimes in connection with other climatic variables, but always in a harsh and intense manner over a relatively short interval of time. This is the case, for instance, with tropical cyclones (accompanied by heavy rainfall, strong winds and storm surges), severe storms, heat waves, sudden flooding, and forest fires.

These extreme events are occurring with greater frequency and/or intensity and in many cases the scientific community is attributing this trend largely to climate change.[50]

Increased intensity and/or frequency of extreme events already comprises, and is expected to continue comprising, the main cause of vulnerability of cities to climate change. It is also a source of vulnerability for urban systems that may not have been subjected to the effects of extreme events in the past. [51]

Cyclones are an example of extreme events that have increased their activity in the North Atlantic since 1970 and are expected to increase in intensity (heavier precipitation and larger peak

[49] IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30, 46, 47-49; Wilbanks *et al.* (2007), pages 370, 375, 382.
[50] IPCC, *Climate Change 2007; Synthesis Report* (2007), page 30; Wilbanks *et al.* (2007), pages 371-375.
[51] IPCC, *Climate Change 2007; Synthesis Report* (2007); Wilbanks *et al.* (2007).

windspeeds) in the future, although there is less confidence in projections of a global decrease in the *number* of tropical cyclones (IPCC, 2007).[52] Cyclones can affect cities that are in their trajectory with intense rainfall and strong winds, with stronger effects on cities located in coastal areas, near rivers or in delta regions as a result of intense waves and storm surges.

Other extreme events exacerbated by climate change include severe storms, intense heat waves, heavy rainfall, massive fires, intense flooding and landslides caused by a very high water content in the soil as a result of heavy rainfall or flooding.[53]

The extreme events associated with climate change present particular challenges for cities both in developed and developing countries, bearing in mind that many of them are experiencing rapid urbanization in areas located in coastal zones, close to slopes, in gullies and in other areas that areas risk from flooding or landslides.

Examples of indicators associated with vulnerability to extreme events:

- Historical record of extreme events. Type, magnitude, size of city area affected.
- Location in the city of zones with a propensity for extreme events.

Exercise 4.1: Create a small team to identify the current and projected vulnerabilities of your city to climate change. Prepare a list.

The identified vulnerabilities could come from any of the sources studied in this chapter (higher temperatures, sea level rise, rainfall and extreme events)?

Are you aware of any other sources of vulnerability not studied in this chapter?

Assess on a scale of 0 to 5, the importance of each of the identified vulnerabilities of the city to climate change.

Do all areas of the city share the same degree and sources of vulnerability? Use a map to indicate the vulnerable zones in each case.

[52] IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30, 46, 53.
[53] Wilbanks *et al.* (2007), pages 362, 366, 382.

Box 4.2: Summary of consequences, observed and expected, of climate change on the state of the environment of cities

- Thermal vulnerability or vulnerability associated with high temperatures:
  - Urban heat islands
  - Retreat of mountain glaciers
  - Forest fires
  - Urban pollution as a result of climate change
- Vulnerability associated with sea level rise
- Vulnerabilities associated with rainfall:
  - Increase in rainfall
  - Reduction in rainfall
- Vulnerability associated with extreme events

4. Non-climatic drivers and pressures

The vulnerability brought about by physical and geographical conditions may be increased by the prevailing socio-economic and political factors within cities. These factors can become drivers and pressures that affect the city´s vulnerability to climate change. A list of drivers and pressures related to the socio-economic context of cities is presented hereafter.

4.1. Examples of drivers of change within the socio-economic context of cities:

a) Demographic dynamics

- Population growth
- Migration
- Population structure by sex and age

b) Socio-economic dynamics

- Gross Domestic Product (GDP)
- Employment
- Main economic activities (agriculture, industry, trade, services, transport, energy, tourism)
- Transport networks and hubs
- Motorization index
- Income distribution (e.g., Gini Coefficient)
- Level of poverty
- Access to basic services (drinking water and sanitation, electricity, health, education, nutrition, housing, transportation, etc.)
- Values and customs

c) Other drivers

- Local administrative structure
- Dynamics of urbanization and land use, e.g., surface area and population in authorized and unauthorized human settlements, or change from non-urban to urban

4.2. Examples of socio-economic pressures resulting from the drivers mentioned above

a) Consumption of resources

- Water consumption
- Fuel consumption
- Electricity consumption

b) Generation of emissions, residue and waste

- Liquid waste
- Solid waste
- Emission of polluting gases, including greenhouse gases

Exercise 4.2: Questionnaire guide to define geophysical, environmental and socio-economic elements (driving forces and pressures) that influence cities' vulnerability to climate change

Physical and geographical context of the city

Questions	Indicators
• Where is the city located? • What are the general features of the city? • Does it include urban and rural areas? • What are the geographical features, topography, and climate? • What is the relationship between the ecosystems in the city and the geographical characteristics? • Brief overview of the history of the city	• Ranges of altitude in the city • Type of climate during the year (range in temperature and humidity) • Rainy season, intensity of rainfall during each period, and average rainfall (mm) • Main natural ecosystems in the city

Urbanization

Questions	Indicators
• How has land use changed? • What are the main forces related to economic and social developments that have changed the land use? • Main activities carried out in the area of the city represented in percentage of occupied space (industrial production, general services, tourism, housing)	• % of urban area and % of rural area in two selected years • Map of land occupation in selected years (for example, 1970 and 2008) • Change in land use • Extent of the urban area and its growth rate

Population dynamics

Questions	Indicators
• What is the population size? • What is the composition of the population according to age?	• Rate of population growth between censuses • % of population according to age ranges, for example, less than 15 years of age, between 15 and 60 years of age, above 60 years of age
• What is the urban/rural population distribution?	• % of urban population, % of rural population; examine two selected years and note differences
• What is the population concentration according to municipalities?	• % of the population in each municipality
• What is the population density?	• Trend in population density; average for the city • Population density in the main townships or sections of the city
• What is the relative size of the migrant population arriving in the city? • What are the main areas that they arrive from?	• Rate of growth in the migrant population

Economic dynamics

Questions	Indicators
• What are the GDP dynamics and how do the main economic activities carried out in the city contribute to this?	• GDP growth rate • Growth rate in the major productive activities over a given period; analyze the trend
• What is the total working population and what percentage of the economically active population (EAP) is involved in the major socio-economic activities?	• % of EAP involved in the major activities identified
• What is the profile, according to size, of enterprises: large, medium and small • What is the productive scale of the city and how are productive activities changing over time?	• Number of enterprises according to size: large, medium or small; the scale can be defined by the value of annual sales or number of workers • Growth rate in the volume and value of production per year (for example, for the period 1990-2008)
• What is the impact of each type of economic activity in terms of use of natural resources and resultant economic impact?	• Inventory of socio-economic activities that have caused environmental deterioration (e.g., oil spills) • In the case of exploitation of wood resources, indicate the trend in deforested area
• What is the main destination of production (internal market and/or external market)?	• % of the production from each activity that is channeled to internal and external markets, respectively
• What resources are available to the municipal government?	• Total municipal budget • % from local taxes and levies • % from national resources • % from local markets—shares and loans • % from international markets • % from international and multilateral lending agencies

Social dynamics

Questions	Indicators
• What is the level of the population living in poverty? Differentiate between poverty and extreme poverty. Location of the most vulnerable population in the city. • What are the main causes of poverty in the city?	• Life expectancy at birth • % of the population living in poverty • % of the population living in extreme poverty • Gini Coefficient
• Coverage of basic services such as drinking water, electricity and sanitation • Is there a difference in the coverage of these services within the city? For example, sections with more than 90% coverage and other areas with less than 50% of the families or homes covered?	• % of the population or homes served with drinking water, according to the city's main areas; if possible, compare two selected years to observe improvement, worsening or unchanged situation • % of the population or homes with sanitation, according to the city's main areas; if possible, compare two selected years • % of the population with electricity services, according to main areas
• What is the provision for health services?	• % of GDP allocated to the health sector • Number of inhabitants per doctor • Number of inhabitants per hospital bed • Number of health facilities by type over time
• What are the main illnesses affecting the population of the city? Are some of them associated with the quality of the environment?	• Rate of occurrence in the number of cases of acute respiratory illnesses, water-borne diseases and other diseases related to environmental quality
• What educational services are provided? • What is the progress in the literacy rate? • Are there contrasts? What is the degree of school drop-out?	• % of GDP allocated to the education sector • Literacy rate and trend • Number of students per teacher • Growth rate in number of children of school age • Rate of school drop-out
• What are the characteristics of the transport system?	• Rate of increase in the number of motor vehicles, according to type of vehicle — for public or private use • Average age of public transport vehicles • Rate of increase in emissions generated, according to type (CO_2, total suspended particles)
• Political structure of the city	• Is the city a national or provincial capital where a large number of decision makers live? • Would a disaster in the city influence provincial, national or international political activity or policies beyond the city's boundaries?

Risk management (yes or no)[26]	
1. Authority (institution) designated by the national government (Y or N)	
a. Term of assignment? (years)	
2. Elected head of the institution (Y or N)	
a. Term of elected official (years)	
3. Does the city have:	
a. A department for risk management (Y or N)	
b. A department dealing with the environment, sustainability, or climate change (Y or N)	
c. Are (a) and (b) in the same department? (Y or N)	
4. Other government office structures (at the state or national level), do they include:	
a. A department responsible for risk management (Y or N)	
b. A department dealing with the environment, sustainability or climate change (Y or N)	
c. Are (a) and (b) in the same department (Y or N)	

Vulnerability and response capacity in built environments	
1. Does the city have Master Plans for its development? (Y or N)	
2. Does the city have urban development and land use plans? (Y or N)	
a. Population in authorized urban settlements (% of total)	
b. Population in non-authorized areas (% of total)	
c. Population density in non-authorized areas (H,M,L)	
population in informal areas >20% of total (H)	
population in informal areas < 20% and >10% of total (M)	
population in informal areas <10% of total (L)	
d. Population in old buildings and areas of historical interest (% of total or H, M, or L using ratings in 2c)	
3. Does the city have building codes? (Y or N)	
a. Level of buildings that do not fully meet codes (% of buildings affected)	
4. Vulnerability observed in buildings during the most serious previous natural disasters:	
More than 15% of buildings were damaged (H)	
Between 5% and 15% of buildings were damaged (M)	
Less than 5% of the buildings were damaged (L)	

[54] The following exercises are based on World Bank, *Climate Resilient Cities—A Primer on Reducing Vulnerabilities to Disasters* (2009, Washington, DC, U.S.A.).

Disaster Response System	
1. Does the city have a disaster response system? (Y or N)	
2. Is the disaster response system adequate and prepared to deal with any type of natural disaster affecting the city? (Y or N)	
3. Is the disaster response system regularly practiced? (Y or N)	

CHAPTER V:

Socio-economic impacts of climate change on cities

Climate change is already occurring; that is a fact. This was one of the conclusions of the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report published in 2007. In this report, the Panel evaluates globally, and in some cases regionally, the peer-reviewed scientific literature on climate change impacts and vulnerabilities in a number of sectors. The IPCC utilizes several socio-economic scenarios to project, 100 years from today, the likely behavior of a naumber of environmental variables linked to climate change.[55]

In the previous chapter the most important vulnerabilities of cities *associated with temperature increase, sea-level rise, rainfall variation and changes in the intensity and/or frequency of extreme events* were discussed. This chapter studies the related socio-economic impacts on cities.

These four types of impacts, though not exhaustive, are mentioned in the literature as those which have the greatest effect on cities.[56] They can also affect a system or sector in specific city acting on their own, or in association with one or more of the other variables.

1. Temperature increases

Although urban agricultural production is not normally an important economic sector for cities, it does carry some weight since it is closely linked to food security and because it can generate employment for a large number of persons in urban and peri-urban zones. In areas surrounding cities at mid to high latitudes, it is projected that an increase in the average temperature will favour some crops, which have better yields up to certain temperature threshold. At lower latitudes, especially in seasonally dry and tropical regions, these same increases in temperature are projected to decrease crop productivity.[57]

An increase in the average temperature in the city causes an increase in energy consumption through air conditioning of homes and food refrigeration, especially in tropical and subtropical regions and during the summer (warm season).[58]

The consumption of drinking water also increases, sometimes even affecting its supply. In arid and semi-arid tropical regions, this increase in water consumption can result in severe complications.[59]

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55 IPCC, *Climate Change 2007; Synthesis Repor*t (2007), section 3.2.
56 Wilbanks *et al.*, (2007), page 375, table 7.3.
57 IPCC, *Climate Change 2007; Synthesis Report* (2007), page 48.
58 Wilbanks *et al.*, (2007), page 365; table 7.3.
59 Wilbanks *et al.*, (2007), page 362 and page 365.

Intense heat can cause health problems and even death in old persons and those with low incomes who cannot afford the cost of air conditioning.[60]

With respect to cities located in temperate or polar zones, and in some mountainous regions, during the cold period of the year temperatures may become milder, thereby reducing cost of heating.[61]

During the summer, in polar cities with areas of permafrost, thawing can occur, which in turn can cause buildings and other infrastructure to collapse, resulting in additional costs for their repair or for new construction.[62]

The receding and the disappearance of glaciers due to increases in temperature in temperate and tropical regions, as well as in high mountain areas, can affect water supply from thawing.[63]

Several cities situated in mountainous regions are supplied with water from glacier melt, or from hydrographic basins that are themselves supplied from the glaciers. The disappearance of these glaciers means that hydraulic infrastructure will have to be built, which, in many cases, will be difficult with the resources available.[64]

High temperatures, in cities that have tropospheric ozone pollution, can cause a rise in ozone levels, leading to health problems in the human population and damage to plants and animals.[65] The tourist industry in some cities situated in temperate, polar and high-mountain regions may benefit from warmer conditions during summer months whereas, during the winter months, the skiing industry in some areas may suffer due to a reduction in snowfall.[66]

Increased temperatures in some regions may contribute to an increase in the incidence of certain illnesses, such as dengue fever, yellow fever and malaria, transmitted by vectors that are sensitive to temperature (such as mosquitos), with resulting impacts on public health expenditures.[67]

60 Wilbanks *et al.*, (2007), page 362, box 7.1.
61 Wilbanks *et al.*, (2007), page 361.
62 Wilbanks *et al.*, (2007), table 7.3.
63 IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30 and 50; Rosenzweig *et al.* (2007), pages 83, 86-87; Magrin *et al.* (2007), page 589, table 13.3; and Schneider *et al.* (2007), page 788.
64 Parry *et al.* (2007), pages 36 and 61; Rosenzweig *et al.* (2007), page 87; Magrin *et al.* (2007), page 589, table 13.3; and Cáceres Silva (ed.) (2001).
65 Wilbanks *et al.*, (2007), page 362.
66 Wilbanks *et al.*, (2007), page 368.
67 Parry *et al.* (2007), pages 47 and 66, table TS 3; Wilbanks *et al.*, (2007), page 372; Rosenzweig *et al.* (2007), pages 107-108; and McMichael *et al.* (2001), pages 464-466.

Examples of impact indicators related to thermal vulnerabilities in cities

- Increase in cases of illnesses transmitted by temperature-sensitive vectors.
- Increased mortality from hyperthermia.
- Increase in consumption of drinking water and water for cooling.
- Increase in the sale of fans, air-conditioners, refrigerators. Impact of these sales on energy consumption.
- Crop yield in urban or peri-urban agricultural zones.
- % of the population dependent on sources of water supply that are linked to mountain glaciers. Reduction in the supply of water from these sources.
- Changes in numbers of tourists (especially in temperate or mountain areas).
- Increase in levels of tropospheric ozone in cities.

Box 5.1: Case study: Shrinking of tropical glaciers and its impact on water supply in Quito, Ecuador

Quito is the capital of the Republic of Ecuador, and is located at an altitude of 2,850 meters above sea level. Its population depends largely on water supply from the Andean mountains.

The glaciers of the tropical Andes, from Bolivia to Venezuela, represent 10% of the Andean glaciers. Their high altitude makes them useful tools for studying variability and climate change.

Measurements carried out on glacier 15-alpha of the snow-covered Antisana indicate that there was a gradual decrease in the length of the glacier between 1956 and 1998. In 1999, as a result of the change of phase of the El Niño phenomenon, there was an increase in length of 16 metres.

The sensitivity of the glaciers in the snow-covered Antisana to the warm phases (El Niño) and cold phases (La Niña) of the El Niño Southern Oscillation (ENSO) is quite remarkable. The balance in mass tends to diminish in the face of high-intensity El Niño events, while it tends to level off during La Niña events, even becoming positive in some instances.

Studies carried out in other countries point to a shrinking of their glaciers as a process that has intensified since the decade of the eighties. At an altitude of up to 4,555 m, glacier coverage of the Antisana decreased from 70% to 54% during the period between 1956 and 1998.

The importance of the glaciers is seen by their contribution to the supply of water for irrigation (the central valleys of the country) and potable water for Quito.

Source: Cáceres Silva, Luis (editor), *National Communication of the Republic of Ecuador to the UN Framework Convention on Climate Change* (2001, National Climate Committee, Ministry of the Environment, Gráficas Iberia, Quito).

2. Sea-level rise

Even in the absence of climate change, coastal cities, especially those located in low-lying coastal zones and mega-deltas, are vulnerable to the forces of coastal dynamics. In many of these zones, various anthropogenic factors are present that reinforce their vulnerability, such as changes in land use, and construction of infrastructure in places that compete with the natural equilibrium of the ecosystems.

Much of the infrastructure in low-lying coastal regions cannot withstand the pounding of the sea (waves and tides). Water erodes the cement of buildings near the sea, and seawater can penetrate the lowest areas of cities, causing permanent flooding.

Coastal cities located in regions with low precipitation, without rivers or with populations exceeding the natural capacity for water supply, are generally served by underground reservoirs. Under certain conditions, salination of the aquifers can take place, resulting in a decrease in the supply of potable water to the city. In these cases, health services may have to deal with an increase in illnesses associated with a reduction in water supply and an increase in salination of aquifers. Evacuation may also be necessary in some cases.

Urban and peri-urban agriculture located near coasts can be affected by sea-level rise and salination of aquifers. Industries located near the coasts can also experience serious impacts such as destruction and flooding of their facilities. Tourism can register losses due to deterioration of beaches or ecosystems, and destruction or deterioration of buildings and facilities like ports and monuments. Systems for discharging liquid waste and rainwater into the sea can also be seriously damaged.

Examples of indicators related to impact on cities of sea-level rise resulting from climate change:

- Quality of water from supply sources. Degree of salination.
- Number of persons affected by water salination.
- Effects of impact on species, coastal ecosystems, ecosystem goods and ecosystem services.
- Impacts on infrastructure and cost of these impacts.
- Cost of the territory lost or affected.
- Impacts on historic buildings or monuments.
- Industries affected or re-located.
- Number of abandoned dwellings and persons affected.
- Number of persons re-located.

3. Changes in rainfall patterns

3.1. Increase in rainfall

Trends from 1900 to 2005 have been observed in annual rainfall in many regions. During this period, the annual rainfall had increased in some regions and decreased in others. The projection for the future may continue observed patterns in recent years. Globally the area affected by drought has increased since the 1970s.[68]

A permanent and sustainable increase in rainfall in a city and its hydrographic basin benefits agriculture due to the increase in the quantity of water available. Abundant rainfall in summer also cools down the urban environment, balancing the effect of otherwise increased temperatures, and promoting the growth of more luxuriant urban vegetation thereby reducing irrigation costs and saving water. Abundant rainfall also reduces the consumption of electricity for cooling and air-conditioning, removes pollutants and dust from the atmosphere and helps in purifying the air.

However, when rainfall increases and the drainage system in a city is non-existent or inadequate, or when the city's natural drainage (non-built-up land that can absorb water) is too small, urban flooding occurs, damaging homes, streets, service networks (for water, electricity and telephones), flooding tunnels and underground areas and, in some cases, the lower floors of buildings and houses. This situation is accentuated when the city is situated in a low-lying area (either coastal or inland), or on the bank of a river or lake.

Floods have a negative impact on urban or peri-urban agriculture, affect some industrial, commercial or financial activity of the city and result in costs from damage to infrastructure, including health facilities and historic monuments. Potable water can become contaminated and require treatment, water-borne illnesses can increase.

An increase in rainfall can also cause nearby rivers and lakes to overflow their banks, even when rainfall occurs outside the city itself. Continuous rainfall can cause landslides in vulnerable areas of the city, resulting in injuries, collapsed structures and high costs.

[68] IPCC, *Climate Change 2007; Synthesis Report* (2007), pages 30 and 46.

Box 5.2: Case study: Impact of flooding in Jakarta, Indonesia

In its First National Communication under the United Nations Framework Convention on Climate Change (1999) the Government of Indonesia stated that it needed to improve its capacity to predict the effects of climate change. To this end, the need for coordinating national efforts to deal with phenomena associated with climate change, such as flooding and droughts, was emphasized.

Jakarta, the political and economic capital of Indonesia, has a surface area of 650 km², with a population of 8,489,910 persons (up to 18.6 million in its metropolitan area), according to 2008 data.

The city is located on the northwest coast of the island of Java, next to the River Ciliwung in the Bay of Jakarta, which is at the entrance to the Sea of Java. The northern part of the city lies on a plain, some eight metres above sea level, creating many areas that are vulnerable to floods that are quite frequent in the rainy season.

These floods are worsened by problems with urban infrastructure, such as a poor drainage system, obstruction of the conduits for wastewater, and deforestation of the rapidly urbanized Bogor and Depok regions.

In 1996, the city suffered severe flooding, and some 5,000 hectares were inundated. Years later, during the floods of February 2007, more than 60% of the total area of the city was completely inundated and the water level reached four metres in some areas.

Material losses in 2007 amounted to some 572 million dollars, about 80 persons perished and, according to conservative figures, about 350,000 persons were forced to leave their homes.

Sources:

- Sugandhy, Aca et. al., *First National Communication of Indonesia under the United Nations Framework Convention on Climate Change*, (1999, State Ministry of Environment, Jakarta).
- *Indonesia: Floods - Feb 2007, Indonesia: Floods in DKI Jakarta Province, updated 19 Feb 2007*, Emergency Situation Report No. 6, accessed at http://www.reliefweb.int/rw/RWFiles2007.nsf/FilesByRWDocUnidFilename/VBOL-6YPCN6-full_report.pdf/$File/full_report.pdf.
- *1996 Flood Archive*, consulted 19 October 2008.
- *Death toll from flooding in Jakarta climbs to 80*, Tele 5, 11 September 2007.
- *Number of deaths from floods in Jakarta climbs to 44*, ABC, 11 September 2007.
- *2007 Global Register of Major Flood Events*, consulted 19 October 2008.
- *Jakarta threatened by illness*, BBC, 11 September 2007.
- *Demographics and Civil Records Service, Penduduk Provinsi DKI Jakarta Januari 2008*, consulted on 13 October 2008.

3.2. Reduction in rainfall

It is generally agreed that rainfall will continue to decrease in arid and semi-arid areas as well as in certain other areas as a result of climate change.[15] The vast majority of these vulnerable areas are located in developing countries. A reduction in rainfall would have a negative impact on water supply to the population, industry and agriculture. Water sources or inland aquifers can become salinized (brackish) due to over-use and by a reduction in groundwater recharge due to reduction on rainfall.[16] Cities in developing countries suffering from this water shortage may not have sufficient economic resources to transfer large volumes of water from afar, or to use techniques for desalination of brackish water.[17]

Reduced access to potable water could result in the proliferation of various health-related or water-borne illnesses, affecting health systems in the country. A reduction in rainfall has also had a negative impact on the generation of hydroelectric energy in areas where it has occurred.

Box 5.3: Case study: Impact of climate change on the availability of water in Tirana, Albania

The territories which surround Albania have freshwater resources that are relatively abundant. Seven rivers run from the eastern borders to the western coast of Albania. Tirana, the capital, is located in the Ishëm river valley, some 30 kilometres from the coast. There are two rivers that cross the city: the Lana and the Tirana. Underground water is the only source of drinking water in Albania and this resource depends basically on rainfall.

In keeping with the result of climatic scenarios in the country, a reduction in rainfall in the country is expected, as well as a deterioration in the quality of water resources. Expenditure for the treatment of residual water is expected to increase. By 2100, it is estimated that there will be a serious reduction of water flowing in the rivers. Water quality in Albania will be degraded, not only as a result of climate change, but also due to industrial and agricultural activities. The districts of Tirana are located among the areas of the country that would be affected by these problems.

Source: Ermira Fida & Tatjana Hema (Co-ordinators), *The First National Communication of Albania to the United Nations Framework Convention on Climate Change.* Ministry of Environment of Albania (2002, Tirana).

69 IPCC, *Climate Change 2007; Synthesis Report (2007)*, pages 30, 46, 49 and 52; and Wilbanks *et al.* (2007), page 371.
70 Kundzewicz *et al.* (2007), pages 179 and 186.
71 Kundzewicz *et al.* (2007), page 194.

Examples of impact indicators for zones with an increase (↑) and a decrease (↓) in rainfall:

- Increase in water-borne illnesses (↑)(↓)
- Increase in health costs (↑)(↓)
- Quality of the water supply (↑)(↓)
- Increase in the occurrence of floods and landslides (↑)
- Increase in costs as a result of flooding (↑)
- Increase in the salination of aquifers (↓)

Box 5.4: Case study: Socio-economic impacts of the increase in rainfall and periods of drought in Kigali and surrounding areas

The most common direct effects of climate change on human settlements, the energy sector and the industrial sector in Rwanda are likely to be related to floods and landslides that follow intense rainfall after prolonged periods of drought and erosion. Rwanda is a very mountainous country, with very steep hillsides. Rain causes a high degree of soil erosion, because the lands generally lack anti-erosion systems. Intense rain very often causes severe landslides, which in turn cause serious damage to the road infrastructure as well as to houses.

Most of the industries in Rwanda are located in Kigali, in the Ruganwa River Valley and in the Nyabugogo River Valley. This area has a high propensity for flooding, which causes significant damage during the rainy season.

The decrease in water levels in Lakes Bulera and Ruhondo during periods of drought has greatly affected the production of hydroelectricity at the Ntaruka plant, with serious socio-economic implications. Drought also has implications for food security in the country.

Rwanda lacks the means to quantify the losses caused by climate change. In general, figures can be cited for human losses but it is difficult to measure the economic losses caused by the disasters associated with this global challenge.

Source: Ministry of Lands, Environment, Forestry, Water and Mines, Republic of Rwanda, *First National Communication under the United Nations Framework Convention on Climate Change* (2005, Kigali, Rwanda).

4. Extreme events

Many cities are more vulnerable to the impact of extreme weather events like cyclones, intense heat waves, heavy rainfall, massive fires, storm surges and intense flooding, which are likely to be exacerbated by climate change, rather than to gradual climate change itself.[72]

Economic costs can include crop damage with respect to urban and peri-urban agriculture, inactivity of industrial facilities because of destruction of supply networks for electricity and water, or fixed or mobile communications networks, or disruption to general city services such as transportation and cleaning.

City infrastructure can be impacted to different degrees by various extreme events, depending on their type and intensity. The water supply system in cities is among the services most affected by these phenomena. On occasion, because of more widespread events such as sea-level rise, penetration of salt water or severe drought, restoration of the service can take quite a long time.

Health service needs in the context of natural disasters are complex, including both direct casualties and secondary effects like disease exacerbated by flooding or disruption to water supply and drainage systems. Health services are therefore extremely vulnerable in the context of extreme events. Advance preparation of health care personnel and readiness of health care services and infrastructure is fundamental to ensure efficient functioning of these services during and after an extreme event.

Extreme events have the potential to cause damage to infrastructure, services, and certain ecosystems (like coral reefs) related to tourism, especially in small island States.[73] For these and other reasons, there can be a significant drop in tourist numbers following an extreme event. Tourism services can therefore be assessed as being vulnerable to extreme events. In several cases, after an extreme event, the economic losses from tourism revenue could be greater that the cost of damage to infrastructure.

Generally speaking, most cities are vulnerable to extreme events to a greater or lesser degree, but vulnerability increases when the economic potential is low and the social development is limited. Even for cities with a high economic potential, impacts of climate change are likely to be felt most acutely not only by the poor, but also by other segments of the population such as the elderly, the youth, powerless indigenous populations and immigrants.[74]

[72] Wilbanks *et al.* (2007).
[73] Wilbanks *et al.* (2007), pages 368-369; Mimura *et al.* (2007), page 702 and box 16.3.
[74] Wilbanks *et al.* (2007), page 374; Parry *et al.* (2007), page 64.

Exercise 5.1: Impacts of climate change

1. Is the possible impact of climate change on the city known? (Y or N)	
2. Is climate change assessment based on local studies instead of regional/global models? (Y or N)	

Degree of vulnerability by sectors	Climatic factors			
	Increase in temperature	Change in rainfall pattern	Sea-level rise	Increase in extreme events
Degree of vulnerability for each of the following areas. H = Serious consequences and a priority for action M = Important and should be considered in development plans for the city L = Not important				
Built environment (H, M, or L)				
Cultural and religious heritage (H, M, or L)				
Local economy, industry and business (H, M, or L)				
Production and distribution of energy (H, M, or L)				
Urban agricultural production (H, M or L)				
Health service needs/disease (H, M or L)				
Health services facilities (H, M, or L)				
Land use and availability (H, M, or L)				
Transport systems (H, M, or L)				
Recreation areas and parks (H, M, or L)				
Social equity system (H, M, or L)				
Water supply/management (H, M, or L)				
Tourism (H, M, or L)				
Human lives and well being (H, M, or L)				

CHAPTER VI:

Options for adaptation to climate change in cities

This section of the Manual refers to the issue of responses *(What are we doing?)* under the D-P-S-I-R (Drivers–Pressures–State–Impacts–Responses) framework. It is basically dedicated to actions for climate change adaptation in urban settlements. It is also critical to consider the implications of actions aimed at climate change adaptation (and mitigation) in cities on the achievement of other sustainable development goals.

One of the objectives of this section is to cover one of the main gaps in efforts to adapt to climate change: the gap between the scientific, academic and conceptual work available (on the supply side) and the concrete needs of decision makers in urban centres (on the demand side).

1. Climate change adaptation strategies

6.1. Basic concepts

Two basic strategies for response to climate change can be identified: "adaptation" and "mitigation".

According to the Intergovernmental Panel on Climate Change (IPCC), adaptation includes "*initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones.*"

Box 6.1: Examples of adaptation actions

Types of adaptation	Examples
Preventive	Diversifying rainfall removal by promoting rainwater storage, permeable surfaces and drainage pipelines
Reactive	Expanding drainage infrastructure as a major way to accommodate heavy precipitation events
Autonomous	Farmer's decision to change timing and species planted based on observed weather changes
Planned	Changes in the water allocation to ensure biodiversity protection, agriculture and drinking water supplies.

Source: Livia Bizikova, Tina Neale and Ian Burton, *Canadian Communities' Guidebook for Adaptation to Climate Change, Including an approach to generate mitigation co-benefits in the context of sustainable development*, First Edition (2008, Environment Canada and University of British Columbia, Vancouver)

Adaptation is necessary in order to deal with the impacts of climate change and it has become unavoidable due to the implications of past greenhouse gas emissions. There are certain impacts for which adaptation constitutes the only available and convenient response.

The costs and benefits of climate change on cities vary according to different factors such as city location (temperate and polar regions, coastal areas and river banks, mountainous regions, deserts, etc.) and city size (small, medium or large). In the case of adaptation, both costs and benefits are important to consider at the local level. At present, there are no exhaustive assessments of the costs and benefits of adaptation, but there are efforts in that direction such as a report by the World Bank on the *Economics of Adaptation to Climate Change*.[1] Some exercises through which municipal stakeholders can assess the "cost of doing nothing" are included in UN-Habitat, *Participatory Vulnerability and Adaptation Assessment: A toolkit based on the experience of Sorsogon City, Philippines* (draft, 2010), pp. 30-31.

1.2. Capacity for adaptation and existing barriers

The *capacity for adaptation* differs from one society to another and within societies. This capacity for adaptation is dynamic and various factors influence it, such as:

- income;
- availability of natural resources;
- social and institutional networks;
- education and training of human capital;
- level of human development;
- access to technology;
- terms of trade and international finance;
- political will of governments.

A high economic capacity does not always translate into actions that reduce vulnerability. Examples of this are deaths caused by heat waves in Europe in 2003, and socio-economic and human destruction caused by Hurricane Katrina in the New Orleans area of the U.S. in 2005.

There are barriers, limitations and costs to adaptation. These barriers and limitations can be natural, environmental, economic, social, psychological, and behavioural or can take the form of gaps in knowledge and communication.

1.3. Options for adaptation, main actors and sectoral focus

By the same token, the range of possible options for adaptation is broad and includes technological, behavioural, administrative, and policy options, among others (see examples in Box 6.2).

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75 See World Bank, *The Economics of Climate Change: A Synthesis Report* (final consultation draft, 2010).

Box 6.2: Examples of adaptation actions	
Types of response	**Examples**
Technological	Sea defenses
Behavioural	Altered food and recreational choices
Managerial	Altered farm practices
Policy	Planning regulations

Source: IPCC (2007)

These actions involve different actors such as families, independent farmers, private enterprises, non-governmental organizations and national planning agencies.

Very often, planned adaptation measures are not applied in isolation, but rather as integrated actions within broader sectoral projects in areas such as water resource planning, strengthening coastal defenses and disaster risk reduction.

Adaptation measures are usually applied in sectors such as agriculture, tourism, human health, water supply, coastal management, urban planning and nature conservation.

1.4. Ecosystem-based adaptation

The development of infrastructure in order to adapt to climate change can be costly and require significant financial, human and technical resources, and may at times exacerbate impacts on the natural environment. Conversely, EbA options have often proven to be less costly to implement and result in superior environment and social benefits.[76]

[76] World Bank, *Convenient Solutions to an Inconvenient Truth: Eco-system Based Approaches to Climate Change* (2009).

Box 6.3: Infrastructure- vs. ecosystem-based adaptation				
Issues	**Infrastructure development option**	**EbA option**	**Case Study Example**	**Additional benefits**
Flood	Construction of physical barriers	Protection of forest habitat	North-eastern Argentina is particularly prone to flooding and under climate change the intensity and frequency of these events are likely to increase. A "Flood Protection Programme" has been developed that includes enforcing flood defence strategies, maintenance of flood defence installations, implementation of early flood warning systems and environmental guidelines for flood-prone areas and flood emergency plans. Protection of natural forest serves as part of the flood defence system. The use of natural forests is a low-cost solution compared to the alternative of developing infrastructure.	Habitat and biodiversity protection, water regulation, soil protection
Soil erosion/ water supplies	Build irrigation systems, relocate agriculture production into forested areas	Protect local forests	In Madagascar, conservation and sustainable management of 2.2 million hectares of forest was estimated to cost $97 million but would result in $150-180 million in benefits and maintain water flows and reduce soil erosion impacts. The project has since been expanded to 6 million hectares	Payments for biodiversity conservation, ecotourism revenues, watershed protection, improve welfare of local population
Quality of water supply	Build a wastewater treatment plant	Restore wetlands	Cities in Hubei Province located along the Yangtze River embarked on initiatives to restore the region`s wetlands by removing harmful aquaculture practices and infrastructure and reconnecting the flow between the lakes to the river. Conversely, a city in Sichuan province (located on the same river basin) built a wastewater treatment plant, however, because of the high cost, the system does not remove organic pollutants or dissolved nitrogen and phosphorus, which increases the risk of nutrient pollution in the surrounding waters. The EbA option has provided superior benefits compared to the construction of the new treatment plant	Potable water, protection and enhancement of biodiversity, provision of flood protection services

Source: IPCC (2007)

Adaptation strategies that focus on strengthening the natural environment and its ecosystem services may also prove to be more effective at building resilience to the impacts of climate change with the additional social and environmental benefits that are often a result of the positive feedbacks from such initiatives.[77] Ecosystem-based adaptation (EbA) considers the ecosystem services that people depend on and focuses on protecting, maintaining or rehabilitating them in order to adapt to climate change. To date, the majority of EbA strategies have been adopted in rural settings, very few concrete examples exist in the urban context. Nonetheless, in urban environments there are plenty of opportunities to implement EbA, whether within the core of the city or its surrounding areas, on which the city is often dependent for food and water supplies, soil conservation, forestry resources, and energy production.

Box 6.4: Case Study – Bogota, Colombia

The city of Bogota and its surrounding area is dependent on the high mountain ecosystem of Chingaza Massif for food and water supplies, water regulation, soil protection, and hydro power production. Climate change is expected to reduce the glaciers in the region by 78% and moorlands by 56% putting at risk 80% of the population who live in the region and depend on mountain ecosystems for these services. Colombia is addressing its vulnerability to climate change through the implementation of the *Integrated National Adaptation Plan,* which includes EbA and aims to restore the high mountain ecosystems. Colombia's plan is an example of EbA in practice at the national, regional and local level using technological, behavioural, managerial and policy adaption strategies.[78]

Box 6.5: How EbA can be applied in various types of adaptation response

Technological

- Water and carbon modeling and monitoring

Behavioural

- Cultural adaptation—changes in the ways that the land is used and will be used, while simultaneously incorporating local knowledge into plans, e.g., choosing native plants for restoration based on local knowledge of the environment.
- Communities using climate information to develop early warning systems for fires, landslides, and floods.

Managerial

- Improvement in productive agricultural ecosystems. Practices proposed for different farming systems, which were developed by local farmers including the use of tree fences, organic fertilizers, home gardens, and diversification of products.

Policy

- Implementation of Integrated National Adaptation Plan
- Colombia National Parks Strategy for Participatory Ecological Restoration updated to ensure water regulation and an increase in carbon sequestration. The strategy was developed with local communities
- Incorporation of EbA in land use and territorial planning that maintain structure and health of ecosystem services
- Incorporation of EbA into regional watershed management plans
- Farm Plan developed by local farmers to incorporate sustainable farming practices

[77] IUCN. *Ecosystem-Based Adaptation: A natural response to Climate Change* (2009)
[78] Ibid.

Box 6.6: Examples of Ecosystem-based Adaptation

Climate change impacts	Adaptation Strategy	Policy/Programme	Case Study	Additional Benefits
Floods, salt intrusion, coastal erosion, risk of death and injuries, loss of property, impacts on livelihoods, displacement of populations, adverse consequences for tourism sector	Restore coastal ecosystems, e.g., reforest mangroves, wetland restoration, protect coral reefs, remove man-made coastal flood defences to allow the return of natural salt marshes	Develop reforestation programmes, implement a network of Marine Protected Areas (MPA), integrate sea level rise in land use policies, limit coastal development, increase ground level in reclamation projects	Green Coast Programme–Tsunami affected areas in Indonesia, Sri Lanka, India, Thailand, Malaysia are rehabilitating coastal ecosystems. In Aceh and Nias, 893 ha of coastal land has been replanted with mangroves (1.6 million seedlings) in order to provide protection from floods and storm surges.[79]	Provides new employment opportunities (replanting) and income generation, enhances fisheries and prawn cultivation, enhanced food security, biodiversity protection
Loss of biodiversity, reduced productivity of fisheries, loss of livelihoods, reduced food supplies, loss of tourism value, loss of natural protection from wave surges	Protect coral reefs, diversify resource extraction, encourage small-scale aquaculture	Implement a network of MPA, develop a multiple use zoning plan including "No Take Zones"	Kimbe Bay in Papua New Guinea established a network of MPAs that was designed based on the local community`s traditional use and needs. The marine resource strategy addresses overfishing and hunting of rare species, while still permitting access to certain sections of the reef for extraction purposes.[80]	Maintains food security, diversification of livelihoods, provides new sources of income through eco-tourism and sport fishing, protects cultural traditions and values

[79] Ibid.
[80] Ibid.

Creation of heat islands, smog, increased energy demand for cooling, increased water demand, greater risk of death, reduction in quality of life	Maintain and enhance urban green spaces, urban reforestation (e.g., along roadways), green roofs	Incorporate green spaces in urban planning, pass environmental legislation protecting local environment, provide tax incentives to homeowners for tree maintenance, pass a green roof policy for all new developments, "road-side" greenery programme whereby all roads are lined with trees.[81]	Curitiba, Brazil has been successful in enhancing tree cover and green space in the city thanks to a progressive holistic urban development plan. Green space has increased from 1 m^2 per inhabitant in 1970 to 52 m^2 in 2007.[82]	City beautification, enhanced property values, attracts business and investment, contributes to tourism value, enhances recreational values, reduces energy use, air pollutants and wind speeds, contributes to wastewater processing
Reduced water quality, increased risk of soil erosion and landslides, risks to health, disruption/ damage of infrastructure and property	Soil conservation through reforestation in erosion-prone areas, protect urban and peripheral watersheds	Protect watersheds and forests outside city centre, implement urban reforestation projects, protect existing urban blue spaces	Rio de Janiero began an urban reforestation project in 1986 that aimed at controlling soil erosion, reducing landslides and flood risks. The project has been successful at augmenting native tree cover in the city which protects the soil and provides employment to local residents.[83]	Generates new employment opportunities, increases urban food supply (use of fruit trees), reduces land degradation

81 World Bank (2008).
82 Sustainable Cities, *Curitiba: The Green Capital* (2010).
83 UNFCCC, *Local Coping Strategies Database* (2010), available at http://maindb.unfccc.int/public/adaptation/.

Reduced agriculture production, land degradation, reduced urban food supplies	Diversify crop production, agroforestry, intercropping, urban gardens/roof gardens	Implement policies that encourage urban gardens through facilitating access to unused spaces, leasing public lands for agriculture, recognition of land rights	1) Havana, Cuba—40% of households are involved in urban agriculture. The city produces 25,000 tonnes of food annually on 2,439 hectares of land. Using *Organopónicos,* raised nutrient rich compost bed containers are installed on paved or poor soils, which has allowed the city to achieve intense vegetable production.[84] 2) Cairo has succeeded in the widespread implementation of rooftop gardens, growing organic fruits and vegetables on balconies, roofs, terraces and construction walls. The project has required little capital or human resource investments.[85]	Enhances food security and diversification of household diets, contributes to household income, increases green space, contributes to water regulation and air quality, provides of fuel wood and reduces pressure on surrounding forests
Reduced urban water supply, land degradation and reduction in agricultural production	Adapt urban land uses and surrounding areas to reduced water resources, revival of traditional technologies such as terracing to collect rain water, infiltration ditches, small barrages, water mirrors and rustic canals, water conservation practices	Implementation of Integrated Water Resource Management (at basin level), distribute rights to land and water resources to local communities, allocation of water permits based on the limits of the river's flow	Indigenous farmers in Cayambe, Ecuador facilitated the removal of cattle in the area, cleaned out old water channels and banned burning of land. These initiatives have allowed them to increase the supply of water to farms by 10%.[86]	Contributes to the revival of traditional and local knowledge, protects and enhances water supplies, enhances food security

84 Climate Institute, *Green Roofs for Urban Food Security and Environmental Sustainability* (2008).
85 FAO, *"Climate-Smart" Agriculture—Policies, Practices, and Financing for Food Security, Adaptation, Mitigation* (2010, The Hague Conference on Agriculture, Food Security, and Climate Change).
86 Vidal, J. (09/24/2010) *Glacial Retreat: Ecuador`s ticking environmental timebomb*, The Guardian, accessed at http://www.guardian.co.uk/global-development/poverty-matters/2010/sep/22/ecuador-water-climate-change-vidal.

Reduced urban water supply	Rainwater harvesting, water storage and conservation techniques, water re-use	Incentives that encourage capture of rainwater, rebates for water efficiency measures	Bangladesh has implemented a system of rainwater collection using gutter and pipes to collect rooftop water. Water that is harvested is used for drinking and cooking.[87]	Improves health and sanitation
Impacts on surrounding rural areas including agricultural land and production (loss of crops, infestation of pests and disease) which urban centres are dependent on	Plant a diversity of crops, practice terracing techniques, use of organic fertilizers, changes to tillage practices, maintain mulches, agroforestry systems, protection of pollinators, and revival of traditional farming practices	Ensure urban policies emphasize role of surrounding rural areas and agricultural systems, design policies that support local agriculture production, offer financial incentives to support local food production	1) In Chiawa, Zambia, farmers are provided with short-term weather forecast data to improve management decisions and change planting dates. The incorporation of drought tolerant crops, promotion of agroforestry practices, and reduced tillage technologies have all contributed to enhancing farming production.[88] 2) In Beni, Bolivia, the re-introduction of pre-Colombian agriculture practices based on camellones (a system of dykes and raised fields) has been implemented to address the impacts that climate change was having on agriculture production in the area. The system, based on indigenous knowledge, has been successful at protecting seeds and crops from floods, reduces the need to clear forested areas, and plants grown in the channels, purify the water and act as soil fertilizer.[89]	Revival and conservation of indigenous knowledge, contribution to food security and household nutrition, fuel wood security, generation of income, reduces pressure on forestry ecosystems

87 UNFCCC (2010).
88 IUCN (2009).
89 Oxfam, Climate Change Adaptation in Practice—Rescuing the Past: Using Indigenous Knowledge to Adapt to Climate Change in Bolivia (2009)

1.5. Links between adaptation, mitigation and sustainable development

In general, cities where sustainable development is widely practiced are likely respond more successfully to climate change. Policies that strengthen adaptive capacity to climate change would normally also promote sustainable development, and vice-versa.

Actions for addressing climate change (adaptation and mitigation) should be integrated in such a way that they can strengthen the synergies and reduce potential conflicts with other areas of sustainable development.

Box 6.7: Actions for adaptation in cities – Implications for mitigation	
Actions for adaptation	**Effects on mitigation**
Introduction of air conditioners to deal with high temperatures	*Negative effect:* Increase in the consumption of energy.
Planting of trees in cities to reduce the effect of heat islands.	*Positive effect:* Contributes to the biological capture of carbon.

Source: IPCC (2007)

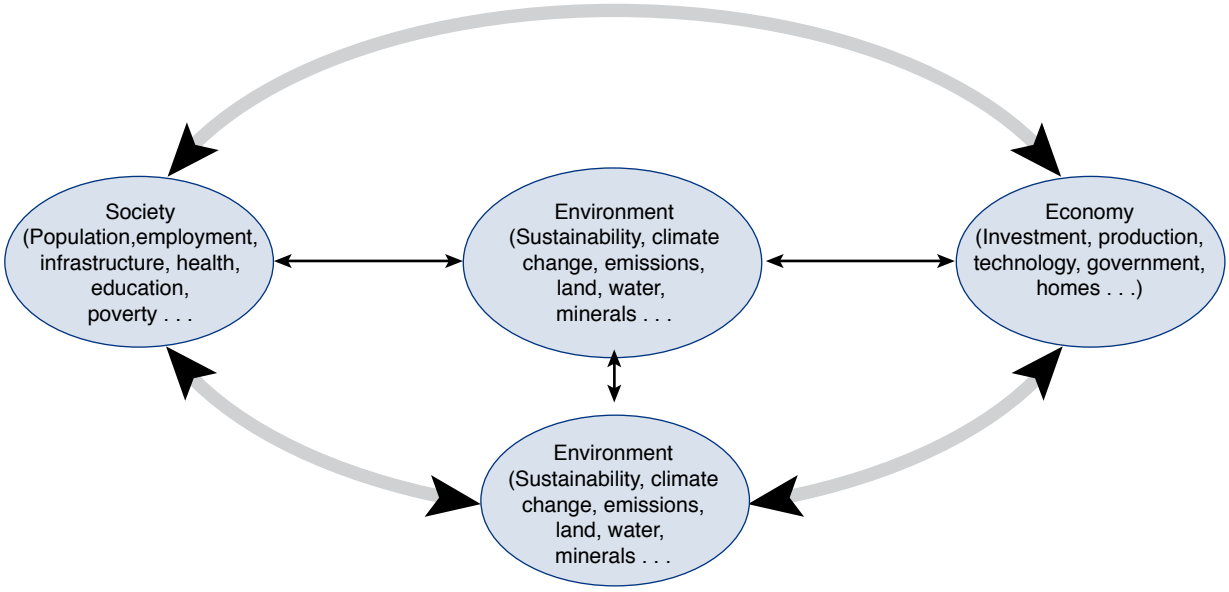
Studies of actions for adaptation in the context of sustainable development often consider:

- the complexity and diversity of the themes relating to adaptation;
- the levels and scales involved in adaptation;
- the trans-disciplinary themes linked to adaptation;
- the dynamic drivers that underpin climate change, global change and sustainability;
- the locally specific nature of the themes relating to adaptation.

Based on these considerations, the implementation of coherent strategies for adaptation, within a sustainable development agenda, requires the adoption of multi-disciplinary approaches in order to satisfy the requirements of decision-makers at the local level. These approaches are consistent with the need for multi-disciplinary and trans-disciplinary dialogue on themes relating to climate change, which facilitate links between the scientific community, decision makers and city dwellers.[90]

[90] See Jäger, Jill, *Climate Tools and Information to Support Adaptation* (Vienna, Austria)

Figure 6.1: Sub-system diagram for studying and evaluating adaptation options in cities, and their link to sustainable development



(**adapted from Jäger, Jill**, *Climate Tools and Information to Support Adaptation* (Vienna, Austria))

1.6. Tools to implement climate change adaptation and climate change "mainstreaming"

A variety of types of instrument are available to implement actions aimed at climate change adaptation. One important question is whether it is desirable to have a separate, cross-cutting plan for climate change adaptation or the environment, or whether it will be more effective to include adaptation actions in city-wide or sectoral development plans. Generally speaking, a specific climate change adaptation plan is likely to be effective when it benefits from a legal mandate or strong political support that will ensure it is taken into account in the relevant sectors. Whereas if other types of planning document, including sectoral plans (covering areas like transportation) have more political support, then incorporating adaptation actions within these documents is likely to be a higher priority.[91]

Zoning regulations and **building standards** can also be adjusted to take into account the likely effects of climate change (e.g., a likelihood of increased flooding and disaster risk in certain areas of the city).

[91] For more information on approaches like integrated development planning, city development strategies and eco city planning, see Cities Alliance, ICLEI and UNEP, *Liveable Cities: The Benefits of Urban Environmental Planning* (2007), pp. 33-38.

Box 6.8: Case Study–Bangkok, Thailand[92]

Built on a swampy floodplain along the Chao Phraya River near the Gulf of Thailand, Bangkok—home to more than 10 million people—is located in an area highly vulnerable to climate change. In fact, the Bangkok Assessment Report on Climate Change 2009 reveals that the city is already experiencing the impacts of climate change. In particular, Bangkok and its suburbs are experiencing more severe and frequent flooding as well as an increase in the number of days hotter than 35˚C. This may have serious implications for the country's economy, including its tourism industry.

The Bangkok Assessment Report on Climate Change 2009 sets out a number of adaptation options for climate-proofing the city. These include improving the local public health infrastructure and disease surveillance and prevention programmes; creating early warning systems for extreme weather events; and implementing stricter zoning and building codes to minimize damage from storms and sea level rise.

The publication *Liveable Cities: The Benefits of Urban Environmental Planning* makes a distinction between policy, process, planning and management instruments, and lists a number of examples:

Figure 6.2: Examples of Instruments for Climate Change Adaptation

Instrument type	Examples
Policy instruments	• Creation of an information office, or other training, information or awareness raising • Voluntary branding or labelling • Economic instruments (e.g., taxes on emissions or products, tax refund schemes, tradeable permits, environmental subsidies and performance bonds) • Bans, standards, quotas, licensing and other regulatory instruments
Process instruments	• Visioning conference (e.g., bringing together stakeholders to develop the city's vision for climate change adaptation) • Baseline study (e.g., of the city's physical and environmental assets)
Planning instruments	• A simple, jargon-free environmental profile of the city based on already available data • SWOT analysis (strengths, weaknesses, opportunities and threats) • Rapid Ecological Footprint (REF) Assessment • Development of a monitoring system and indicators (see Chapter VI, section 2) • Strategic Environmental Assessment (see below)
Management instruments	• Environmental budgets (see below) • Environmental audits

Adapted from Cities Alliance, ICLEI and UNEP, *Liveable Cities: The Benefits of Urban Environmental Planning* (2007)

Strategic environmental assessments ensure that the environmental impact of policies and

[92] Bangkok Metropolitan Administration, Green Leaf Foundation and United Nations Environment Programme, *Bangkok Assessment Report on Climate Change* 2009. More case studies are available in documents such as: World Bank, *Climate Resilient Cities—A Primer on Reducing Vulnerabilities to Disasters* (Washington, DC, 2009); Cities Alliance, ICLEI and UNEP, *Liveable Cities: The Benefits of Urban Environmental Planning* (2007); International Institute for Environment and Development, *Climate Change and the Urban Poor: Risk and Resilience in 15 of the World's Most Vulnerable Cities.*

programmes in a **development strategy** (e.g., a City Development Strategy) are identified, assessed and taken into account. SEAs are best conducted as early as possible in the development of a strategy planning process.[93] Among other things, they can consider how environmental impacts of policies and programmes interact with the expected impacts of climate change, and provide an entry point for climate change adaptation into the city planning process.

Climate change screening is a way of establishing information on the impacts of climate change on development activities, so that these linkages can be taken into account,[94] with a **focus at the project level** (e.g., specific infrastructure development projects).[95] A number of methodologies and tools for climate change screening have been developed and applied by various institutions and agencies.[96]

Environmental budgets ensure that the environmental assets of the city are systematically measured and considered by decision makers. They can be based on environmental indicators measured in physical quantities, they do not necessarily need to attempt to place a dollar value on the natural resources. The environmental budgeting cycle runs in parallel with the financial budgeting cycle with which the public, decision-makers and senior administrators are already familiar and, for instance, may allow the city to assign different stakeholders "quotas" of environmental assets (such as air quality) that they may use during the course of the year.[97]

2. Indicators of adaptive capacity in cities

As a first approach to a system of indicators for evaluating the adaptive capacity of cities to deal with the impacts of climate change, the set of community-based[98] preparedness indicators of the International Federation of Red Cross and Red Crescent Societies could be used as a reference. This is a local system of indicators for preparedness for disaster events that recognizes three types of indicators:

93 Cities Alliance, ICLEI and UNEP, *Liveable Cities: The Benefits of Urban Environmental Planning* (2007), pp. 29-30.
94 United Nations Development Programme (UNDP), *Screening Tools and Guidelines to Support the Mainstreaming of Climate Change Adaptation into Development Assistance—A Stocktaking Report* (2010), p. 15.
95 Ibid., p. 29.
96 Ibid., p. 16. This document analyzes a number of the tools available for climate change screening, see table on p. 21 of that document.
97 Based on Cities Alliance, ICLEI and UNEP, *Liveable Cities: The Benefits of Urban Environmental Planning* (2007), p. 30.
98 See International Federation of Red Cross and Red Crescent Societies. *Disaster Risk Reduction and Preparedness Indicators. (Indicadores de reducción de riesgos y preparación ante desastres).* Synthesis Document. First Edition, June 2007.

Result indicators, which refer to concrete products or services that are offered to the population to ensure the acquisition of skills, expertise and knowledge.

Change indicators, which refer to changes in perception, relationships, attitudes and actions of the stakeholders. These are key indicators of response strategies (adaptation to climate change, in this case). When these changes are consolidated, there is a tendency to reinforce the sustainability of the actions undertaken.

Indicators related to institutional arrangements required to ensure the sustainability of response actions undertaken.

Based on the general classification expressed above, indicators can be developed in seven basic areas:

Area 1: Degree of preparedness among the local population
- Local expertise (training)
- Tools for preparation (guides and manuals)

Area 2: Local organization of population
- Local committees
- Environmental monitoring and assessment

Area 3: Infrastructure
- Design and maintenance of existing infrastructure (e.g., resistant construction techniques)
- Infrastructure capacity in productive systems (e.g., agriculture)

Area 4: Availability of local plans and procedures
- Early warning systems
- Emergency plan

Area 5: Services
- Codes, norms and standards for services
- Access to communication services

Area 6: Information
- Learning from past experiences
- Access and use of information

Area 7: Investment priorities
- Maintenance
- Protection

Box 6.9: Example of a combination of result, change and institutional indicators for one of the areas previously mentioned.		
Area 3: Infrastructure design and maintenance		
Result	**Change**	**Institutional**
Disaster resilient construction techniques are available	Populations construct disaster resilient homes	Authorities enforce regulations for disaster resilient design and construction

Source: International Federation of Red Cross and Red Crescent Societies. *Disaster Risk Reduction and Preparedness Indicators (Indicadores de reducción de riesgos y preparación ante desastres).* Synthesis Document. First Edition, June 2007.

Climate change adaptation actions can also be assessed by using several indicators during the different stages of implementation. Indicators proposed by the International Strategy for Disaster Reduction (ISDR) for measuring the implementation of the Hyogo Framework for Action can be also useful in this context. ISDR identifies the following set of indicators:[99]

- *Indicators of inputs* – to measure the financial, administrative and regulatory resources being applied, such as budgets expended, or the staff time applied.
- *Indicators of outputs* – to measure the immediate and concrete deliverables achieved with the inputs, such as houses strengthened, or the number of people trained.
- *Indicators of results* – to measure the results at the level of beneficiaries, in social and economic terms, such as the fraction of population receiving early warnings, or with houses free from flooding risk.
- *Indicators of impact* – to measure the overall impact on the society, such as reduced vulnerability to hazards, or security of livelihoods.

Specific indicators and targets are an essential foundation for monitoring and evaluation. Are the adaptation actions the city is carrying out having their intended effect? See Exercise 9 and UN-Habitat's *Planning for Climate Change: A Resource Guide for Urban Planners*, Module D, for more detail and tools on this issue.

[99] See ISDR, Guidance on Measuring the Reduction of Disaster Risks and the Implementation of the Hyogo Framework for Action (2008, United Nations, Geneva, Switzerland).

Exercises for Evaluating Options for Adaptation to Climate Change in Cities[100]

Respond to the following questionnaire based on the indicators for adaptation to climate change, according to the information available for your city. Try to replicate this questionnaire for the urban municipality (or sector) most vulnerable to climate change in your city.

Exercise 6.1: Classify the main adaptation actions in your city:

- Are they preventative or reactive?
  - ___Preventive or ___ reactive (corrective)?
- How are they funded?
  - ___Private or ___ public?
- How are they led?
  - ___Autonomous or ___ planned?
- What type of actions are undertaken (evaluate on a scale of 0 to 5)?
  - ___Technological
  - ___Behavioural
  - ___Managerial
  - ___Policy change

Exercise 6.2: Evaluate the degree of social organization for undertaking climate change adaptation actions, and the role of the main stakeholders in the city under study:

- Percentage of urban municipalities (or smaller political or administrative jurisdictions) identified as vulnerable that have response organizations (e.g., emergency or climate change adaptation committees)
- Number of persons directly involved in response organizations (e.g., emergency or climate change adaptation committees)
- Importance of inter-institutional networks in the promotion of adaptation activities (Evaluate on a scale of 0 to 5)
- Participation of civil society institutions in response organizations (e.g., emergency or climate change adaptation committees) (Evaluate on a scale of 0 to 5)
- Participation of governmental institutions in response organizations (e.g., emergency or climate change adaptation committees) (Evaluate on a scale of 0 to 5)
- Actions aimed at social groups with a high degree of vulnerability (e.g., children, the elderly, single mothers, etc.) (Evaluate on a scale of 0 to 5)

[100] These exercises were adapted from the methodology on indicators presented in the International Federation of Red Cross and Red Crescent Societies, *Disaster Risk Reduction and Preparedness Indicators (Indicadores de reducción de riesgos y preparación ante desastres), Synthesis Document*, First Edition (2007).

Exercise 6.3: Characterize the sectoral focus of adaptation and assess the links with mitigation in the city under study:

- Highlight sectors in which climate change adaptation actions have been take over the past five years (Evaluate on a scale of 0 to 5)
  - ___Residential and commercial sector/Urban planning
  - ___Industry/Waste management
  - ___Transport
  - ___Energy supply
  - ___Tourism
  - ___Human health
  - ___Water supply
  - ___Coastal management
  - ___Agriculture/Forestry
  - ___Nature conservation
  - ___Other (mention)

Identify the synergies and conflicts between the adaptation actions undertaken in the city and actions aimed at mitigation of climate change (Evaluate on a scale of 0 to 5)

Sectors	***Synergies with mitigation***	***Conflicts with mitigation***
Residential and commercial sector/ Urban planning		
Industry/Waste management		
Transport		
Energy supply		
Tourism		
Human health		
Water supply		
Coastal management		
Agriculture/Forestry		
Nature conservation		
Other (mention)		

Evaluation of the linkages between adaptation, mitigation and sustainable development based on five basic criteria[101] for action (Evaluate on a scale of 0 to 5):

- ___Preventive actions
- ___Collaboration between different stakeholders
- ___Integration (articulation of current priorities in comparison with longer term objectives; consideration of potential synergies and conflicts)
- ___Flexibility (possibility for periodic adjustment of the response strategies)
- ___Practical content (record and systematization of past experiences, wide use of information and existing methodologies)

Exercise 6.4: Evaluate the availability of local instruments and mechanisms for adaptation in the city under study:

- Availability of an early warning system (EWS) in the city with respect to the impacts of climate change (Yes/No)
- EWS coverage (% of the urban population)
- Availability of maps of risk zones and relocations, as a part of land management in urban municipalities or sectors identified as vulnerable (% of vulnerable municipalities or sectors)
- Existence of databases and information systems available to local authorities in vulnerable urban municipalities or sectors (% of vulnerable municipalities or sectors)
- Existence of legislation and rules which incorporate measures for adaptation (Assess on a scale of 0 to 5)
- Degree of compliance with existing rules and legislation which incorporate measures for adaptation (Assess on a scale of 0 to 5)
- Explicit incorporation of measures for adaptation and risk management into local economic development plans (Assess on a scale of 0 to 5)
- Explicit incorporation of measures for adaptation and risk management into local social development plans (Assess on a scale of 0 to 5)
- Simulation exercises with the required quality (Assess on a scale of 0 to 5)
- Increase or (decrease) over the past year in the degree of community preparation to deal with emergencies related to climate change[102]
- Existence of plans for the periodic monitoring and evaluation of local emergency systems or other adaptation actions in vulnerable municipalities or sectors (% of vulnerable municipalities or sectors that have these plans)
- Impact of periodic monitoring and evaluation of the local emergency systems and other adaptation actions in vulnerable municipalities, in terms of adjustments to the emergency or adaptation plans (Assess on a scale of 0 to 5)

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101 See Livia Bizikova, Tina Neale and Ian Burton, *Canadian Communities' Guidebook for Adaptation to Climate Change, Including an approach to generate mitigation co-benefits in the context of sustainable development*, First Edition (2008, Environment Canada and University of British Columbia, Vancouver). Note: the basic criteria were taken from this source and adjusted to the objectives of this Manual.

102 Express this qualitative assessment as follows: (+++) = significant increase; (++) = moderate increase; (+) = slight increase; (0) = no noticeable change; (-) = slight decrease; (--) = moderate decrease; (---) = significant decrease.

Exercise 6.5: Assess the investment in infrastructure and services associated with adaptation actions in the city under study:

- Public investment in protection works aimed at climate change adaptation in the city (Approximate value and % of total annual public investment)
- Public investment in infrastructure work that incorporates adaptation measures (Approximate value and % of total annual public investment)
- Incorporation of actions for adaptation into public investment undertaken in the city over the past year (Assess on a scale of 0 to 5)
- Urban or suburban area reforested over the last five years (hectares, variation in % in relation to the previous five-year period)
- Urban or suburban area that applies sustainable agricultural practices (hectares, variation in % in relation to the previous year)
- Existence of building codes and standards that respond to the threats identified (Assess on a scale of 0 to 5)
- Application of construction codes and standards that respond to the threats identified (Assess on a scale of 0 to 5)
- Impact of the main trends in commerce and international finance on the adaptation capacity of the city[103]

Exercise 6.6: Evaluate the status of existing information and training on adaptation and adaptation actions in the city under study:

- Population with basic communication service (% of the vulnerable population)
- Dissemination of information on risks and response strategies to climate change in mass media (TV, radio, written press) (Assess on a scale of 0 to 5)
- Inclusion of lessons learned from previous experiences in local adaptation plans (Assess on a scale of 0 to 5)
- Participation of local governments in the generation and diffusion of information (Assess on a scale of 0 to 5)
- Participation of institutions of civil society in the generation and diffusion of information (Assess on a scale of 0 to 5)
- Participation of the population in the generation and diffusion of information (Assess on a scale of 0 to 5)
- Degree of training of the urban population on options for adaptation and risk management (Assess on a scale of 0 to 5)
- Degree of inclusion of information / capacity building / training in options for adaptation and risk management at various levels of the educational system: primary, secondary, tertiary (Assess in each case on a scale of 0 to 5)

[103] Express this qualitative assessment as follows: (+++) = significant positive effect; (++) = moderate positive effect; (+) = slight positive effect; (0) = no noticeable effect; (-) = slight negative effect; (--) = moderate negative effect; (---) = significant negative effect.

Exercise 6.7

Review the Exercise 5.1. What sectors did you feel were likely to be most seriously affected by specific climatic factors in the future (boxes that scored 3-5)?

- Compare with the sectoral focus of existing adaptation options that you identified in the first part of Exercise 6.3. Are the sectors best covered at the moment the same as the sectors likely to be most strongly affected by climate change in the future, or are there significant gaps?
- Which areas of adaptation are best covered by the city at the moment—in particular areas that scored 3-5 in Exercises 6.4-6.6? Can you map these against the sectors you felt were most likely to be affected by specific climate hazards in the future, in Exercise 5.1?
- Based on the outcome of this mapping exercise, can you identify any specific climate hazards that are likely to address particular sectors of the city in the future, but that are not adequately addressed by adaptation actions at present?

Exercise 6.8[104]

Taking into account the results of the previous exercises, (Exercises 1 to 7), prepare a general evaluation of the actions for adaptation to climate change in the city under study, based on the following integrated criteria[105] (Assess each case on a scale of 0 to 5):

- Economic, social and environmental sustainability:
  - ___Co-benefits with respect to mitigation
  - ___Total environmental benefits
  - ___Equity
  - ___Reduction in implementation costs
  - ___Reduction in operation and maintenance costs
- Effectiveness:
  - ___Feasibility (for proposed new adaptation options, are they feasible across a wide range of plausible scenarios?)[106]
  - ___Reliability (proven success of similar actions in the past)

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104 UN-Habitat, *Planning for Climate Change: A Resource Guide for Urban Planners* (draft, 2010) includes tools that can help to prioritize, implement, monitor and evaluate actions aimed at climate change adaptation, as a part of an overall strategic planning process. See, e.g., Feasibility Checklist on page 77, Strategy Tables on page 81, Governance Gap Checklist on page 89, monitoring and evaluation section from page 89, as well as the Monitoring Framework Worksheet on page 130.

105 Livia Bizikova, Tina Neale and Ian Burton, *Canadian Communities' Guidebook for Adaptation to Climate Change, Including an approach to generate mitigation co-benefits in the context of sustainable development*, First Edition (2008, Environment Canada and University of British Columbia, Vancouver).

106 UN-Habitat recommends considering the following aspects: **(1) Local relevance and suitability**—Are there any material or cultural differences that may constrain the opportunity for action in this location? **(2) Stakeholder acceptability**—Will local residents accept this action or approach in their area? **(3) Technical feasibility**—Will the necessary design, implementation and maintenance support be feasible? (**4) Ease of implementation**—Can this action be implemented at the local level? Can it be implemented within a reasonable timeframe? **(5) Relative effectiveness**—How well will this action work relative to other options? **(6) Relative cost**—Is this a multi-million dollar action or a quick fix? Are other options more cost-effective? UN-Habitat, Planning for Climate Change: A Resource Guide for Urban Planners (draft, 2010), pp. 77-78.

- Inclusion of criteria of risk and uncertainty:
  - ___Response to risks of imminent damage
  - ___Response to risks of potentially catastrophic or irreversible damage
  - ___Application of the precautionary principle
- Degree of opportunity:
  - ___Collateral benefits for the community
  - ___Benefits other than positive environmental impacts ("*No-regrets"* options)
  - ___Existence of "windows of opportunity" for implementation
- Viability of implementation:
  - ___Degree of public acceptance
  - ___Availability of funds
  - ___Existing capacity (information, technical, personnel, resources)

Exercise 6.9: Monitoring and evaluation

- Can you identify any existing actions the city is taking related to climate change adaptation that have established clear goals or targets?
- If so, is the city monitoring or evaluating whether these actions are achieving their intended purpose? If not, what are the major barriers?
  - Lack of relevant data?
  - Lack of political commitment to monitoring and evaluating the effectiveness of these actions?
  - Lack of funding for monitoring and evaluation?
  - Other?
- Can you develop specific institutional, change and results indicators (see Box 6.8) for additional proposed adaptation actions in the city, taking into account the results of Exercise 6.8?
- How likely is it that monitoring and evaluation of each of these indicators will benefit from the following (Assess on a scale of 0-5)
  - Adequate data
  - Political commitment to monitoring and evaluation
  - Financial resources for monitoring and evaluation
- If you have identified any likely barriers to effective monitoring and evaluation in the previous question, can the indicators be adjusted to address them? For instance, if data availability is a problem, can you identify indicators that use readily available sources of data for the city (e.g., census data)?

Exercise 6.10: Integrating climate change adaptation into development planning

- Select a few of the most important existing, development plans that govern your city (they could include plans at the municipal, provincial and national level)?
  - Do any of the important adaptation actions for your city need to be included in any of these plans?
  - Is there any opportunity to influence these plans? If so, what are the main opportunities, and when do they arise? Is any specific information needed to support an intervention in these policies or plans?
  - Are there additional partners that need to be involved (see Exercise 1.1)?
- What are the most important development plans that are underway affecting your city (they could be at the municipal, provincial or national level)? Repeat the exercise in the previous question with respect to these plans under development.
- Are you aware of any major development projects in the city that are being planned or underway? Have these projects adequately considered the possible impacts of climate change on the projects themselves? Also, have these projects adequately considered how they will affect the city's vulnerability to climate change? Repeat the exercise in the previous questions.
- Does the city have a specific climate change adaptation plan, an environmental plan or an environmental budget?
  - Would these tools be acted on in practice in your city?
  - If not, what are the main barriers?

Annex I:

Glossary of key terms[107]

Adaptation
Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. *anticipatory* and *reactive*, *private* and *public*, and *autonomous* and *planned*. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc.

Adaptation benefits
The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.

Adaptation costs
Costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.

Adaptive capacity
The whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures.

Aggregate impacts
Total impacts integrated across sectors and/or regions. The aggregation of impacts requires knowledge of (or assumptions about) the relative importance of impacts in different sectors and regions. Measures of aggregate impacts include, for example, the total number of people affected, or the total economic costs.

Anthropogenic
Resulting from or produced by human beings.

Anthropogenic emissions
Emissions of greenhouse gases, greenhouse gas precursors, and aerosols associated with human activities, including the burning of fossil fuels, deforestation, land-use changes, livestock, fertilisation, etc.

Arid region
A land region of low rainfall, where *low* is widely accepted to be <250 mm precipitation per year.

[107] Glossary of Terms used in the *IPCC Fourth Assessment Report, Glossary of Synthesis Report*, accessed 22 November 2010 at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_appendix.pdf

Barrier
Any obstacle to reaching a goal, adaptation or mitigation potential that can be overcome or attenuated by a policy, programme, or measure. *Barrier removal* includes correcting market failures directly or reducing the transaction costs in the public and private sectors by, e.g., improving institutional capacity, reducing risk and uncertainty, facilitating market transactions, and enforcing regulatory policies.

Carbon dioxide (CO_2)
A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass and of land use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1.

Climate
Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. In various parts of the Fourth Assessment Report, different averaging periods, such as a period of 20 years, are also used.

Climate-carbon cycle coupling
Future climate change induced by atmospheric emissions of greenhouse gases will impact on the global carbon cycle. Changes in the global carbon cycle in turn will influence the fraction of anthropogenic greenhouse gases that remains in the atmosphere, and hence the atmospheric concentrations of greenhouse gases, resulting in further climate change. This feedback is called *climate-carbon cycle coupling*. The first generation coupled climate-carbon cycle models indicates that global warming will increase the fraction of anthropogenic CO_2 that remains in the atmosphere.

Climate change
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human

activities altering the atmospheric composition, and climate variability attributable to natural causes. See also *Climate variability*.

Climate scenario
A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as about the observed current climate. A *climate change scenario* is the difference between a climate scenario and the current climate.

Climate sensitivity
In IPCC reports, *equilibrium climate sensitivity* refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. Due to computational constraints, the equilibrium climate sensitivity in a climate model is usually estimated by running an atmospheric general circulation model coupled to a mixed-layer ocean model, because equilibrium climate sensitivity is largely determined by atmospheric processes. Efficient models can be run to equilibrium with a dynamic ocean.
The *transient climate response* is the change in the global surface temperature, averaged over a 20-year period, centred at the time of atmospheric carbon dioxide doubling, that is, at year 70 in a 1%/yr compound carbon dioxide increase experiment with a global coupled climate model. It is a measure of the strength and rapidity of the surface temperature response to greenhouse gas forcing.

Climate system
The climate system is the highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, and the interactions between them. The climate system evolves in time under the influence of its own internal dynamics and because of external forcings such as volcanic eruptions, solar variations and anthropogenic forcings such as the changing composition of the atmosphere and land-use change.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (*internal variability*), or to variations in natural or anthropogenic external forcing (*external variability*). See also *Climate change*.

External forcing
External forcing refers to a forcing agent outside the climate system causing a change in the climate system. Volcanic eruptions, solar variations and anthropogenic changes in the composition of the atmosphere and land-use change are external forcings.

Extreme weather event
An event that is rare at a particular place and time of year. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability density function. By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate event*, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season).

Greenhouse gas (GHG)
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Integrated assessment
A method of analysis that combines results and models from the physical, biological, economic and social sciences, and the interactions between these components in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it. Models used to carry out such analysis are called *Integrated Assessment Models*.

Mitigation
Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks.

Mitigative capacity
This is a country's ability to reduce anthropogenic greenhouse gas emissions or to enhance natural sinks, where ability refers to skills, competencies, fitness and proficiencies that a

country has attained and depends on technology, institutions, wealth, equity, infrastructure and information. Mitigative capacity is rooted in a country's sustainable development path.

Mitigation potential
In the context of climate change mitigation, the mitigation potential is the amount of mitigation that could be—but is not yet—realized over time.
Market potential is the mitigation potential based on private costs and private discount rates, which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake. Private costs and discount rates reflect the perspective of private consumers and companies.
Economic potential is the mitigation potential that takes into account social costs and benefits and social discount rates, assuming that market efficiency is improved by policies and measures and barriers are removed. Social costs and discount rates reflect the perspective of society. Social discount rates are lower than those used by private investors.
Studies of market potential can be used to inform policy makers about mitigation potential with existing policies and barriers, while studies of economic potential show what might be achieved if appropriate new and additional policies were put into place to remove barriers and include social costs and benefits. The economic potential is therefore generally greater than the market potential.
Technical potential is the amount by which it is possible to reduce greenhouse gas emissions or improve energy efficiency by implementing a technology or practice that has already been demonstrated. No explicit reference to costs is made but adopting 'practical constraints' may take implicit economic considerations into account.

Scenario
A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a *narrative storyline*. See also *Climate scenario*.

Spatial and temporal scales
Climate may vary on a large range of spatial and temporal scales. *Spatial scales* may range from local (less than 100,000 km^2), through regional (100,000 to 10 million km^2) to continental (10 to 100 million km^2). *Temporal scales* may range from seasonal to geological (up to hundreds of millions of years).

Structural change
Changes, for example, in the relative share of Gross Domestic Product produced by the industrial, agricultural, or services sectors of an economy; or more generally, systems transformations whereby some components are either replaced or potentially substituted by other ones.

Sustainable development

The concept of sustainable development was introduced in the World Conservation Strategy (IUCN, 1980) and had its roots in the concept of a sustainable society and in the management of renewable resources. Adopted by the World Conference on Environment and Development in 1987 and by the Rio Conference in 1992 as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. Sustainable development integrates the political, social, economic and environmental dimensions.

Annex II:

The Global City Indicators Program[108]

The Global City Indicators Program is structured around 21 "themes" organized into two Categories that measure a range of city services and quality of life factors. These Categories and themes are listed below:

City Services – includes services provided by city governments and other entities.

- Education
- Recreation
- Governance
- Social Services
- Transportation
- Wastewater
- Energy
- Fire and Emergency Response
- Health
- Safety
- Solid Waste
- Urban Planning
- Water

Quality of Life – includes critical contributors to overall quality of life, but are not the direct responsibility of any local service provider.

- Civic Engagement
- Economy
- Shelter
- Subjective Well-Being
- Culture
- Environment
- Social Equity
- Technology and Innovation

City performance relative to each of these themes is measured by a suite of several indicators, which collectively tell a "story". Overall, 94 indicators have been proposed (see Table 1). Recognizing the differences in resources and capabilities between developed and developing world cities, the overall set of 94 indicators has been divided into 27 "core" indicators, which all cities participating in the initiative would be expected to report on, 26 "supporting" indicators, which all cities would be encouraged, but not expected, to report on, and 41 desirable future

[108] Global City Indicators Facility, Themes (http://www.cityindicators.org/themes.aspx), accessed 22 November 2010.

indicators which are indicators that have been identified by the Partner Cities as being desirable but that for which a consistent, global methodology has not yet been identified. This set of global city indicators was selected based on significant input from the Partner Cities, ensuring that these indicators reflect city information needs and interests, and a rigorous screening process. The indicators must be:

- Available, up to date, and able to be reported on annually;
- Readily comparable among cities globally;
- Relevant for public policy decision making and/or linked to established goals (e.g., the Millennium Development Goals (MDGs));
- Cost effective to collect;
- Meaningful to cities across the globe regardless of geography, culture, affluence, size, or political structure;
- Understandable and not overly complex;
- Clear as to whether changes in the indicators are good or bad.

Table 1: Global City Indicators

Theme	Global City Indicators (Core indicators in bold, supporting indicators non-bold)
1. City Services	
Education	• **Percentage of children completing primary and secondary education: survival rate** - **Percentage of students completing primary education** - **Percentage of students completing secondary education** • **Student/teacher ratio** • Percentage of school-aged children enrolled in schools by gender - Percentage of male children enrolled in schools - Percentage of female children enrolled in schools
	Future Indicators - under discussion • Number of libraries per 100,000 population • Number of visits to library per 100,000 population • Performance on standardized tests • Number of institutions of higher learning within 500km • Percentage of city population enrolled in institutions of higher learning

Fire and Emergency Response	• **Number of firefighters per 100,000 population** • **Number of fire-related deaths per 100,000 population** • Response time for fire department from initial call
	Future Indicators - Under discussion • Emergency medical services indicator • Number of medical personnel per 100,000 population • Number of fire trucks per 100,000 population • Number of ambulances per 100,000 population • Response time for emergency services from initial call • Outcome indicators such as rates of fire or property damage and ultimate health/survival rates of patients
Health	• **Under age five mortality per 1,000 live births** • **Number of in-patient hospital beds per 100,000 population** • **Number of physicians per 100,000 population** • **Average life expectancy** • Number of nursing and midwifery personnel per 100,000 population
	Future Indicators - Under discussion • Annual HIV/AIDS death rate per 100,000 population • Disaggregation of immunization against infectious childhood diseases • Number of health care professionals per 100,000 population (physicians, nurses, other)
Recreation	• Square metres of public indoor recreation facility space per capita • Square metres of public outdoor recreation facility space per capita
	Future Indicators - under discussion • An indicator of recreational use levels • Recreation and Culture Index
Safety	• Number of homicides per 100,000 population • Number of police officers per 100,000 population • Violent crime rate per 100,000 population
	Future Indicators - Under discussion • Perception of safety • Juvenile crime (gangs and youth-related crimes)
Social Services	• Under Development
Solid Waste	• **Percentage of city population with regular solid waste collection** • **Percentage of the city's solid waste that is recycled** • Percentage of the city's solid waste that is disposed of in an incinerator • Percentage of the city's solid waste that is burned openly • Percentage of the city's solid waste that is disposed of in an open dump • Percentage of the city's solid waste that is disposed of in a sanitary landfill • Percentage of the city's solid waste that is disposed of by other means
	Future Indicators - Under discussion • Percentage of population participating in recycling program • Indicator to capture informal waste (waste-pickers, sorters, etc.)

Transportation	• **Km of high-capacity public transit system per 100,000 population** • **Km of light passenger transit system per 100,000 population** • **Number of personal automobiles per capita** • **Annual number of public transit trips per capita** • Number of two-wheel motorized vehicles per capita • Commercial Air Connectivity (number of nonstop commercial air destinations) • Transportation fatalities per 100,000 population
	Future Indicators - Under discussion • Total municipal road and transit expenditure per capita • Indicator regarding shape/condition of infrastructure • Urban accessibility index
Wastewater	• **Percentage of city population served by wastewater collection** • **Percentage of the city's wastewater that has received no treatment** • Percentage of the city's wastewater receiving primary treatment • Percentage of the city's wastewater receiving secondary treatment • Percentage of the city's wastewater receiving tertiary treatment
	Future Indicators - Under discussion • An indicator of wastewater treatment effectiveness • Percent of assimilative capacity of receiving water body used
Water	• **Percentage of city population with potable water supply service** • **Domestic water consumption per capita** • **Percentage of city population with sustainable access to an improved water source** • Total water consumption per capita • Percentage of water loss • Average annual hours of water service interruption per household
	Future Indicators - Under discussion • Disaggregate of percentage of city population with potable water supply service into three classes of household connection: shared facility, private distribution (trucks, donkeys, etc.) and other • Percent of treated water lost during distribution • Water quality (relative to national standards and boil water advisories) • Incidence of waterborne diseases • Water quality index
Energy	• **Percentage of city population with authorized electrical service** • **Total residential electrical use per capita** • Total electrical use per capita (kilowatt/hr) • The average number of electrical interruptions per customer per year • Average length of electrical interruptions (in hours)
	Future Indicators - Under discussion • Share of renewable energy use out of primary energy supply • Residential energy use per household by types of energy • Total energy use index

Finance	• **Debt service ratio (debt service expenditures as a percentage of a municipality's own-source revenue)** • Tax collected as percentage of tax billed • Own-source revenue as a percent of total revenues • Capital spending as percentage of total expenditures
	Future Indicators - Under discussion • Disaggregate of own-source revenue as a percent of total revenues into categories of property tax, sales tax, user fees and charges and other revenue sources
Governance	• Percentage of women employed in the city government workforce
	Future Indicator - Under discussion • Average number of days to get a business license • Requests for service response time • Under discussion to incorporate civic engagement in governance indicator • City governance index
Urban Planning	• **Jobs/Housing ratio** • Green area (hectares) per 100,000 population • Size of informal settlements as a percent of city area
	• Future Indicators - Under discussion • Frequency of official reviews of master plan/official plan • Percentage of land parcels with a registered title • Jobs/housing ratio • Mechanisms for enforcement; regulation, planning standards (building codes, zoning by-laws, informal)
2. Quality of Life	
Civic Engagement	• **Voter participation (as a percent of eligible voters)** • Citizen's representation: number of local officials elected to office per 100,000 population
Culture	• Percentage of jobs in the cultural sector
	Future Indicators - Under discussion • Attendance at cultural events per capita • Multiculturalism - under discussion • Creative cities index
Economy	• **City product per capita** • **City unemployment rate** • Percentage of persons in full time employment
	• Commercial/Industrial assessment as percent of total assessment • Investment levels • Competitiveness index

Environment	• **PM10 concentration** • Greenhouse gas emissions measured in tonnes per capita
	Future Indicators - Under discussion • Number of days per year exceeding recommended PM10 levels • Indicator linking air quality to respiratory problems • Sustainable cities/Climate change plans • Greenhouse gas emissions from municipal operation • Greenhouse gas index
Shelter	• **Percentage of city population living in slums** • Number of households that exist without registered legal titles • Number of homeless people per 100,000 population
	Future Indicators - Under discussion • Housing price/income ratio • Housing rent/income ratio • Homelessness
Social Equity	• Percentage of city population living in poverty
	Future Indicators - Under discussion • Cost of basic necessities or Market Basket Measure • Percentage of population receiving government financial assistance • Social Programmes • Gini Coefficient/income distribution • Social Capital Index
Subjective Well-being	• Subjective Well-being Index
Technology and Innovation	• **Number of internet connections per 100,000 population** • Number of new patents per 100,000 population per year • Number of higher education degrees per 100,000 population • Number of telephones (landlines and cell phones) per 100,000 population - Number of landline-telephone connections in the city - Number of cell phone connections in the city
	Future Indicators - Under discussion • Venture capital investment • Broadband penetration rate • Creativity index

Annex III:

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The thematic VIA Module is part of the Integrated Environment Assessments training manual, volume two.

It presents a methodology to assess vulnerability to, and impacts of climate change at national and sub-regional level. Supported by examples and exercises, the module describes the process for addressing climate change in the context of other development priorities to help in moving towards a more sustainable and resilient development pathway.

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