ECOSYSTEM-BASED ADAPTATION TO CLIMATE CHANGE:

THE ROLE OF URBAN PROTECTED AREAS IN THE CITY OF CAPE TOWN STRATEGIES TO ADAPT TO CLIMATE CHANGE

UNPEC program – Institute Libertas

Supervisor: Louise Lezy-Bruno

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Acknowledgements

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I want to express my deep regards to the researchers at the City of Cape Town, who take the time to present their work and to share their results. In particular Olivier CRESPO helps me a lot to meet the relevant scientists for my work and to discover the Cape Town area.

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Introduction

This research project is part of the Urban Protected Areas (UPA) Network program: “Urban National Parks in Emerging Countries and Cities” (UNPEC). UNPEC is an interdisciplinary program of both basic and applied research (2012-2015) working about Cape Town, Mumbai, Nairobi, Rio and their national parks. It is funded by the “Agence Nationale de la Recherche” in France.

In the context of those four case studies, the link and the interdependence between cities and parks, humans and nature seem obvious. However, parks and cities management are often independent activities which are not without tensions or conflicts, given the diversity of actors and their interests. The UNPEC program aims at understanding the implications and consequences of these dynamics.

For managers of national parks and local authorities, UNPEC and UPA Network provide an independent perspective on the interaction between cities and protected areas. The comparative dimension of this work also provides several opportunities to interact directly with their counterparts in other urban protected areas and participate in discussion on the common features of nature management in-and for-their urban contexts.

For researchers, UNPEC and UPA Network offer fertile ground for theoretical and empirical work on the multiple representations of nature in the cities, the social and spatial segmentation, the cultural dimensions of ecosystem services, the topic of risk management, the circulation and application of the global models or multi-scale interactions.

Within the UNPEC theme “Adaptation to Climatic Change Based on Ecosystems (EbA)”, this study deals with the role of urban protected areas in the City of Cape Town strategies to adapt to climate change. The focus on Cape Town is based on a six-month internship including one-month field experience in Cape Town (15th of March 2014 - 22nd of April 2014) to understand the local context, to develop contacts and to collect data both from basic research (in climatology, oceanography, economics...) and from the policy-makers in the municipality of Cape Town. The main partners who allowed this research project are the Environmental Directorate in the City of Cape Town, the University of Cape Town, South African National Parks (SANParks) and the ICLEI organization. This work has also been enriched by the participation at the international conference BiodiverCities 2014 (7th of April 2014 to 9th of April 2014) in Cape Town followed by the UNPEC workshop (9th of April 2014 to 11th of April 2014) at the University of Stellenbosch.

One of the starting approaches to climate change is the simulation of different sea level rise scenarios. The Figure 1 presents the consequences of 20 meters rise in sea level for the Cape Town Area. In this scenario, the peninsula would be parcelled out in an archipelago with two main islands remote from the continent. This would have ecological consequences including species range shifts, extinctions, ecosystems put out of balance, requiring safe protected areas as refuges. Urban areas would be destroyed resulting in movements of climate refugees to the continent and social inequalities in the capacity to adapt. The current limits of protected areas and urban areas should disappear and the relation between the Park and the City should be redefined. In light of the extent of the consequences and implications, the different predicted and possible scenarios of climate change have to be included in the City and the Park management and planning.
The methodology is based on the following research questions: What consequences of climate change for ecosystems, natural resources and people who depend on them? What relationship between the emergence and climate vulnerabilities? What assessment of the role of UPA in mitigation and adaptation of cities to climate change? How urban protected areas could help cities and people to tackle climate change? What implications of climate change for protected area design, management and governance? What policy recommendations to propose? The step by step methodology presented here for Cape Town aims at being replicable worldwide in order to compare the four cities and parks.

First, we will define the “Ecosystem based adaptation (EbA) to climate change” methodology. We will then present and discuss the scientific results used in this study regarding the predicted climate change scenarios and their consequences. Later, the local vulnerabilities, the impacts of climate change and the adaptation strategies will be discussed by sector. Finally, cartography of the Cape Town area will summarize the level of risk combining the hazard of climate change effects with the vulnerability and the exposure of the stakes due to human settlement and activities.
I Introduction to Ecosystem-based Adaptation

1. Definitions

At first glance, many recent adaptation strategies are hard engineering solutions, with the use of technologies and the design of climate-resilient infrastructure. However, uncertainties regarding the predicted effects of climate change, the short lifespan of infrastructure compared to the time scale of climate change, the lack of hindsight about the new technologies effects and the cost of these solutions are barriers to their efficiency.

The role of healthy ecosystems to contribute to climate change adaptation is being recognized. Ecosystem-based Adaptation (EbA) is defined as the “integration of sustainable use of biodiversity and ecosystem services into an overall adaptation strategy that can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change.” (Secretariat of the Convention on Biological Diversity, 2009).

As a result, ecosystem-based adaptation can contribute in increasing resilience and reducing vulnerability to climate change effects (A. Colls, 2009). First, it contributes to climate change mitigation, defined by the IPCC as an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (Intergovernmental Panel on Climate Change, 2001a). Indeed, the protection of ecosystems allows conserving carbon stocks, reducing carbon emissions and the restoration enhances carbon stocks. Moreover, it is an efficient approach to climate change adaptation, defined as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (Intergovernmental Panel on Climate Change, 2001a). For instance, healthy ecosystems are natural barriers to extreme events such as flooding, droughts, extreme temperatures, fires, hurricanes and cyclones. EbA can both mitigate the impacts and contribute to recovery from extreme events, which intensity and frequency are very likely to increase due to climate change.

Ecosystem-based Adaptation appears to be a relevant, efficient and applicable solution to mitigate and adapt to climate change and presents many advantages compared to infrastructure and engineering solutions. First, it is a widely applicable approach since EbA solutions can be designed at regional, national and local levels, at both project and programmatic levels, and benefits can be realized over short and long time scales. Ecosystem-based adaptation is more cost-effective than hard engineering solutions. The availability of these solutions for the rural or the poor communities can allow identifying the most vulnerable areas and communities. It can also been integrated to community-based adaptation, maintaining traditional and local knowledge and cultural values.

2. EbA in practice

EbA solutions consist of all ecosystem management activities to increase resilience and reduce the vulnerability of people and the environment to climate change (A. Colls, 2009).
These activities include:

- Sustainable water management, where river basins, aquifers, flood plains, and their associated vegetation are managed to provide water storage and flood regulation services;
- Disaster risk reduction, where restoration of coastal habitats such as mangroves can be a particularly effective measure against storm-surges, saline intrusion and coastal erosion;
- Sustainable management of grasslands and rangelands, to enhance pastoral livelihoods and increase resilience to drought and flooding;
- Establishment of diverse agricultural systems, where using indigenous knowledge of specific crop and livestock varieties, maintaining genetic diversity of crops and livestock, and conserving diverse agricultural landscapes secures food provision in changing local climatic conditions;
- Strategic management of shrublands and forests to limit the frequency and size of uncontrolled forest fires and to contribute to carbon storage;
- Establishing and effectively managing protected area systems to ensure the continued delivery of ecosystem services that increase resilience to climate change.

3. **Co-benefits**

In addition to the goal it is implemented for, ecosystem-based adaptation can provide multiple social, economic and cultural co-benefits for local communities and reduce vulnerability to other risks (United Nations Framework Convention on Climate Change, 2011). Healthy ecosystems provide natural resources (such as drinking water, food, raw materials...) and services (habitat, natural barriers against extreme events) essential for the livelihood. EbA solutions contribute to the sustainable use of the natural resources so as to ensure livelihood sustenance, food security, drinking water access. Then EbA meets the need of poverty reduction initiatives. It also contributes to conserve the biodiversity by enhancing protected areas, safeguarding threatened species and restoring degraded and fragmented ecosystems.
Figure 2: linkages between ecosystem services and human well-being (Millennium Ecosystem Assessment, 2005).

Figure 2 depicts the strength of linkages between categories of ecosystem services and components of human well-being that are commonly encountered. The arrows indicate the intensity of potential for mediation by socioeconomics factors and the intensity of linkages. For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation. This highlights the vital role of ecosystem services and the impossibility to compensate many of the natural resources with socioeconomic factors.

The additional achievements of ecosystem-based adaptation let introduce the acronym EbA+. EbA+ moves beyond utilizing biodiversity and ecosystem services as low-cost, low-technology solutions to climate change, showing how investments in biodiversity and ecosystem services can provide direct and sustained livelihood benefits to local communities, such as improved livelihoods, poverty alleviation and job creation outcomes.

4. **Full definition**

To summarize, EbA can be seen as a three-way synergy between climate change adaptation, biodiversity and ecosystem conservation and socio-economic benefits, as illustrated on Figure 3.
Ecosystem Based Adaptation (EbA) integrates biodiversity and ecosystem conservation, socioeconomic benefits and climate change adaptation outcomes. EbA+ builds on this further, to deliver tangible and sustainable livelihoods benefits for affected communities. Biodiversity and ecosystem conservation, socioeconomic and climate change adaptation outcomes can be paired to create Community Based Natural Resource Management (CBNRM-), Community-Based Adaptation (CBA-) and Climate Change Integrated Conservation Strategies (CLICS-) type projects. EbA may draw from these related approaches, but what distinguishes EbA projects is the combined achievement of these outcomes. (Guy Midgley, 2012)

EbA aims at combining the goals of the three following types of projects. Community Based Natural Resource Management (CBNRM) is the management of all natural resources by all concerned stakeholders. Communities managing the resources have the legal right, the local institutions and the economic incentives to take substantial responsibility for sustained use of these resources. Community-Based Adaptation (CBA) projects work to empower people to plan for and cope with climate change impacts by focusing on community led processes grounded in the priorities, needs, knowledge and capacities of communities. Climate Change Integrated Conservation Strategies (CLICS) are climate-resilient conservation plans that often result in spatial and related types of planning products. These guide planning for ecosystem service corridors and protected areas that are resilient to climate change. Finally, Ecosystem based Adaptation can be defined as the achievements of conservation of ecosystems resources and services by the concerned communities; climate change adaptation strategies designed by the threatened communities; socio-economic benefits for local communities allowed by the integration of climate change adaptation in broader planning and managements strategies.
5. **Principles of actions**

Given the complexity and diversity of EbA goals, those strategies should be designed, implemented and monitored carefully in order to be efficient. They also require taking into account the possible conflicts of uses and services provided by ecosystems. It is therefore important that decisions to implement ecosystem-based adaptation are subject to risk assessment, scenario planning and adaptive management approaches that recognize and incorporate these potential trade-offs. Design, implementation and monitoring of EbA actions can be based on action principles. The generalized list of the 9 EbA principles and indicators presented on Table 1 will be used to assess the City of Cape Town adaptation strategies (Nazmul Huq, 2013).

<table>
<thead>
<tr>
<th>Principle</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Flexible management structure</td>
<td>Adaptive management approaches</td>
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<tr>
<td></td>
<td>Incorporate clear planning principles</td>
</tr>
<tr>
<td></td>
<td>Promote existing best resource management practices</td>
</tr>
<tr>
<td>2 Knowledge based adaptation</td>
<td>Build knowledge and awareness</td>
</tr>
<tr>
<td></td>
<td>Local science-management partnerships</td>
</tr>
<tr>
<td></td>
<td>Best available science and local knowledge</td>
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<tr>
<td>3 Maximum stakeholder involvement</td>
<td>Maximum stakeholders</td>
</tr>
<tr>
<td></td>
<td>Involving local communities</td>
</tr>
<tr>
<td></td>
<td>Multi-partner strategy</td>
</tr>
<tr>
<td>4 Variety</td>
<td>Work with uncertainties</td>
</tr>
<tr>
<td></td>
<td>Explore and prioritize potential climate change impacts</td>
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<tr>
<td>5 Multi-scale operation</td>
<td>Integration with development strategies</td>
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<tr>
<td></td>
<td>Support sectorial adaptation planning</td>
</tr>
<tr>
<td></td>
<td>Multi-sectorial approaches</td>
</tr>
<tr>
<td></td>
<td>Multiple geographical scales</td>
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</tbody>
</table>
Table 1: Major principles and indicators of EbA (Nazmul Huq, 2013)

This Table 1 highlights the main EbA guidelines. Ecosystem-based Adaptation should be based on flexible, participative and multi-stakeholder governance (principles 1, 3 and 6). Knowledge and awareness should integrate traditional population (principle 2) and should be assessed (principles 3 and 4). EbA principles also advocate multi-scale and multi-sectorial actions (principle 5). The actions should enhance the local resilience through maintaining and enhancing ecosystems and biodiversity (principles 8 and 9). Lastly, the EbA actions should provide social, economic and environmental benefits (principle 9).

The aim of the study is to assess the use of ecosystem-based strategies to mitigate and adapt to climate change in the City of Cape Town. To this end, it is necessary to understand the local opportunities and the local constraints for EbA implementation.
II Challenges in Cape Town

1. The City of Cape Town

The City of Cape Town is located in the Western Cape Province in South Africa (Figure 4). It is the second most-populated city in the country with 3.7 million people. The population is composed of “Coloured” (42%), “Black Africans” (39%), “White” (16%), “Indian or Asian” (1%). The main languages are Afrikaans, Xhosa and English. Regarding the economy, the city's real GGP was estimated at R188.4 billion (about 13 billion euros) in 2009.

The City of Cape Town has to face historical, economic, demographic and social issues which can reinforce vulnerability and difficulty to adapt to climate change. The recent history of Apartheid, implemented in 1948 and abolished in 1991, remain in the memories. For instance, protected areas were seen as tools for racially based oppression since Apartheid laws prohibited black people entering protected areas. This historical exclusion of Black people from environmental services under the Apartheid can explain the lack of use of protected areas by Black South African and the little

Figure 4: Map of South Africa with the locations of the provinces, including the Western Cape, and the provincial capitals, which is Cape Town for the Western Cape.
attention paid to environmental policy issues (Nigel Rossouw and Keith Wiseman, 2004). Economically, huge discrepancies remain, partly as a heritage from the Apartheid, even if the City of Cape Town is seeing economic growth. The growth of the population is 4% city-wide but 13% in the informal settlements. Townships are particularly facing major social issues such as poverty, unemployment (unemployment rate of 24% in the City), criminality, health issues (AIDS, alcoholism)...

Economic emergence of South Africa seems reinforcing local vulnerabilities to climate change. Urban growth and informal settlements expansion are increasing the population at risk, especially in the most risk-prone areas. The uneven benefits of development increase the inequitable distributions of associated risks across populations groups and locations, with rising vulnerability within marginalized population. The adoption of western consumption patterns by the emerging class has negative effects too. The first example is the increase in energy consumption, in the knowledge that energy supply is dependent mainly on one source, coal power stations, and one supplier, Eskom. The second example is the high rate of car ownership, increasing the gases emissions in the atmosphere, and explained partly by an inefficient and underdeveloped public transport system. Development is also associated with increasing pressure on lands and natural resources, especially water facing issues such as demand growth, increased agricultural requirements, increased industrial requirements, lack of access for poor people.

Despite the context, the City of Cape Town is also a rich biodiversity hotspot, in the heart of the Cape Floristic Kingdom, smallest and richest plant species hotspot on the Earth. The local ecosystem counts many endemic fauna and flora species, especially due to the Mediterranean climate. Therefore the national government of South Africa, the province of the Western Cape and the City of Cape Town are aware of the necessity of protected areas and their role in climate change strategies.

Anticipated effects of climate change have already been observed, like positive trends in temperature especially minimum temperature, variations in atmospheric circulation and rainfall patterns, increase in the intensity and frequency of very warm days particularly during January, April and August, damaging floods due to cut-off lows in March 2003 and April 2005 in the Western Cape. Knock-on effects are also suspected, such as soil moisture variations playing a feedback trend role in exacerbating drying due to climate change.

2. Urban protected areas in Cape Town

The Cape Town area enjoys an important network of protected areas, including a national park and municipal protected areas managed by the local authorities.

The best known protected area in Cape Town area is the Table Mountain National Park. It is located in the City of Cape Town but is managed at a national level by South African National Parks (SANParks). It is the only free and open-access park among the South African National Parks, except four controlled access pay-points (Cape Point, Boulders, Silvermine, Oudekraal) visible on Figure 5.
Table Mountain National Park (TMNP) is located within the Fynbos Floristic Region. It counts 2268 species of plants, including a lot of endemic species. Biodiversity conservation is dedicated to the high number of rare and threatened species and habitats. In addition to those natural assets, TMNP also presents 1000 sites of cultural heritage significance that captures the rich history and diverse cultures of the Cape. TMNP also counts more than 1000 km of marine protected areas, as illustrated.
on Figure 5. Marine biodiversity is also remarkable because of the transition area between the Atlantic Ocean and the Indian Ocean. Many endemic species need to be protected, particularly from poaching.

It welcomes more than 3 million visitors a year and 1 million paying visitors. With the iconic sites of Table Mountain and Cape Point, it is an important touristic asset for Cape Town and the country. It is also used as an open access and free recreational area by Cape Town residents for hiking, climbing, cycling, dog walking, horse-riding, paragliding... Those uses require infrastructure and facilities and management of the impacts on the environment. TMNP programs allow developing the social benefits of the park, especially education and green jobs.

In addition to this national park, the municipal government of the City of Cape Town administrates 31 nature reserves and natural areas, constituting the Biodiversity network. This network is a set of sites called Critical Biodiversity Areas and Critical Ecological Support Areas, the latter including corridors. The City also counts some Marine Protected Areas. Municipal nature reserves are presented on Figure 6.
The City of Cape Town includes one third of the Cape Floristic Region’s plants, with 319 and 13 extinct plant species. However, the municipality is facing many management challenges such as land conflicts with urbanization and agriculture, invasive species, water pollution, reduced water flows, fires, crime, poaching and over-exploitation of marine resources... (City of Cape Town Environmental Resource Management Department, 2014)

3. **Political background and legislation framework**

The implementation of an environmental policy in South Africa has occurred in the past ten years. This has been possible thanks to the “shift from a centralized, technocratic, rules-based, mechanistic approach to a decentralized, participative, cooperative governance framework” (Nigel Rossouw and Keith Wiseman, 2004). The establishment of democracy and consultative approaches has made possible the integration of environment at an important position on the national political agenda. Environmental policies have then been defined at all government levels.

At a national level, the State of South Africa has ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1997 and the Convention on Biological Diversity (CBD) in 1993. Furthermore, the 1996 Constitution obliges the State to protect the environment for the benefit of present and future generations by stating that (Republic of South Africa, 1996): “Everyone has the right: to an environment that is not harmful to their health or well-being; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that - prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.” This is a strong commitment of the Republic of South Africa, putting the environment high in regional and local government agenda.

At a regional level, the Western Cape of South Africa signed the National Environment Management Act in 1998. The Department of Environmental Affairs and Tourism (DEAT) published the South Africa’s Initial National Communication under the United Nations Framework: Convention on Climate Change (DEAT, 2000) and the National Climate Change Response Strategy for South Africa (DEAT, 2004). The Department of Minerals and Energy (DME) published the White Paper on Renewable Energy (DME, 2003) and the Energy Efficiency Strategy of South Africa (DME, 2005). Lastly, the Western Cape Department of Environmental Affairs and Development Planning published the Status Quo of Climate Change in the Western Cape (WCDEADP, 2005).

The municipality of Cape Town drafted the Integrated Metropolitan Environmental Policy (City of Cape Town, 2003) including the Biodiversity Management Strategy ; Air Quality Management Strategy ; Coastal Zone Management Strategy ; Energy and Climate Change Strategy ; Environmental Education and Training Strategy. Work is in progress in the City of Cape Town regarding the implementation of a formal adaptation strategy, a Municipal Adaptation Plan (MAP) for Climate Change (Pierre Mukheibir and Gina Ziervogel, 2007).

The legal framework has been implemented to define the conservation of the environment as a high priority. The remaining question is how these protected areas can be used to adapt to climate change.
4. **Methodology and data**

The fieldwork in Cape Town was prepared by an overview of the existing literature and a compilation of a bibliography. The UNPEC members provided the existing reports about climate change and EbA regarding the City of Cape Town. The main scientific publications were gathered thanks to the help of Pr. Roelof Burger from the North West University of South Africa and to personal research in France.

My fieldwork in Cape Town took place from the 15th of March to the 22nd of April. Basic research results come mostly from the University of Cape Town. I gathered relevant publications thanks to many meetings with climatologists from the Climate System Analysis Group, oceanographers from the Marine Research Institute, ecologists from the Environmental and Geographical Department. Relevant information was gathered from the African Climate & Development Initiative (ACDI) seminars and the Climate System Analysis Group (CSAG) seminars. A substantial number of publications were available at the University of Cape Town and the main results of the work in progress were regularly presented. The University of Cape Town also documents the Western Cape adaptation strategy.

My work in the Environment Directorate of the City of Cape Town allows me to understand the mitigation and adaptation strategies to climate change at local level. Both full technical reports, in particular regarding coastal management and sea-level rise, and awareness booklets dedicated to general public were available.

Concerning the national level, SANPARKS has realized scientific studies about the potential effects of climate change in the national parks, particularly Table Mountain National Park. Unfortunately, the work is fragmented and still in progress, as a consequence results are not published yet. The Fynbos Node of the South African Environmental Observation Network (SAEON) provides interesting publications.

Additional information about local strategies has been provided by the International Council for Local Environmental Initiatives (ICLEI).

This report aims at compiling and analyzing the basic research information and the local adaptation strategies relative to climate change.

5. **Actors**

The actors of Cape Town adaptation strategy is summarized in Table 2.
<table>
<thead>
<tr>
<th>Actors involved</th>
<th>lead agency</th>
<th>coordination mechanisms</th>
<th>how participation is organized</th>
<th>evaluation of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Government</td>
<td>Department of Environmental Affairs and Tourism ; Department of Minerals and Energy</td>
<td>large communication gap between the national and local spheres of government ; no national government contribution to local governments’ knowledge base in terms of diagnostic, technical or institutional knowledge</td>
<td>National Environmental Advisory Forum (NEAF) but this forum has not been established</td>
<td>strong commitment to climate change mitigation and adaptation ; strategic national framework for sustainable development confusing the responsibilities of national, provincial and local government</td>
</tr>
<tr>
<td>Provincial Government</td>
<td>Department of Environmental Affairs and Development Planning (WCDEAPP)</td>
<td>peer pressure mechanism as different political parties control the provincial and the local legislature ; informal interaction between the provincial and the municipal government departments but differences in political control, each with their own policies and goals, has resulted in a lack of formal structures linking the two organizations with respect to climate change</td>
<td></td>
<td>shown itself to be committed to climate change mitigation and adaptation</td>
</tr>
<tr>
<td>South African National Parks</td>
<td>Table Mountain National Park</td>
<td>Difficulties of coordination because of the different locations of the four scientific offices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City of Cape Town</td>
<td>Environment Directorate (8.74 staff to every 1000 people and municipal budget per capita in 2002/2003 R3297.67)</td>
<td>knowledge provided by academic institutions (UCT in particular) ; projects such as the Framework for Adaptation to Climate Change in the City of Cape Town based on coordination efforts between the different environmental services in CCT</td>
<td>broad communication and organization of environmental events ; promoting adaptation strategies in all opportunities such as World Design Capital 2014</td>
<td>Very dynamic and innovative work ; Cape Town has been crowned Global Earth Hour Capital 2014</td>
</tr>
<tr>
<td>NGOs</td>
<td>International Council for Local Environmental Initiatives (ICLEI) ; South African Climate Action Network</td>
<td>Important contributor to the City for technical and institutional knowledge and capacity ; consulting to assist the City in achieving its technical knowledge needs and to provide additional capacity ; ICLEI assists councils in promoting carbon emission reductions ; ICLEI provides the technical knowledge required to conduct a greenhouse gas inventory for the city and develop a state of energy report and an action plan to reduce GHG emissions</td>
<td>Results are not passed by council for publication and thus only limited information is readily available in Cape Town</td>
<td>Indispensable technical and institutional support to the City of Cape Town</td>
</tr>
<tr>
<td>academic institutions</td>
<td>University of Cape Town , University of Pretoria, University of Stellenbosch, Rhodes University,</td>
<td>conducting research for the city on a consultancy basis and has been actively involved in scenario-modelling for the city to develop tools to assess the impacts to energy use with</td>
<td>knowledge base support for the City of Cape Town ; projects for the Western Cape government</td>
<td>Effective base knowledge support</td>
</tr>
</tbody>
</table>
University of the Witwatersrand and without policy interventions

| Energy Crisis | Eskom (electricity public utility in South Africa); City of Cape Town | The power crisis has led Eskom to work in partnership with the City of Cape Town to develop a response strategy, which includes a broad-scale media and communication and demand-side management (DSM) campaign | Mass media campaign resulting in an effective peak demand reduction | Effective energy-saving measures: replacement of 4.5 million incandescent lights with Compact Fluorescent Light (projected 227 MW reduction); distribution of 100,000 geyser blankets (target of a 6.75 MW saving); liquefied petroleum gas (LPG) appliances to replace 100,000 two-plate stoves and 30,000 electric hobs (projected load reduction of 200 MW) |

| Cape Action Plan for People and the Environment (CAPE) funded by the Global Environment Facility (GEF) | Partnership of government and civil society aimed at conserving and restoring the biodiversity of the Cape Floristic Region and the adjacent marine environment, while delivering significant benefits to the people of the region. The CAPE program is coordinated by the World-Wide Fund for Nature South Africa (WWF-SA). | Broad awareness campaign to general public; Steering Committee and consultation for stakeholders with a direct responsibility for implementing the action plan; public involvement of interested or affected parties | One of the most advanced of ecoregion-based conservation; effective combination of stakeholder involvement with an explicit, quantitative planning procedure |

Table 2: Actors involved in the City of Cape Town adaptation strategies to climate change. The underlined actors have been met in Cape Town. The italic ones have been contacted by emails. Information concerning the other ones is based on existing literature.

To summarize, the national and provincial governments are committed to the protection of the environment and the related adaptation to climate change and implement the legislation framework allowing EbA to climate change. The national government also administrates Table Mountain National Park throughout SANParks. Relevant work about climate change is being done in SANParks about EbA to climate change but there coordination, organizational framework and communication of the results could be improved. The Municipality of Cape Town is responsible for the nature reserves management and for the implementation of local EbA strategies. This city is very dynamic and innovative regarding EbA, despite the need for a better communication with the provincial and regional governments. Coordination between SANParks managing Table Mountain National Park and the City of Cape Town managing the municipal nature reserves is in progress. This cogeneration is necessary to develop more coherent and homogenous strategies in the CCT. SANParks, the Western Cape government and the City of Cape Town rely on the well-established basic knowledge delivered by the University of Cape Town. Communication and coordination between researchers and practitioners is remarkable here. ICLEI also provides a solid technical and institutional support to the CCT and participates in the coordination of all these actors.
6. **Opportunities and constraints**

The City of Cape Town has recently integrated environment as a conservation priority in adaptation strategies. However, a very dynamic and active work has been done during last years. It is interesting to look at the the local opportunities and constraints, presented on Table 3, regarding Ecosystem-based Adaptation Strategies. The analysis and assessment of those elements allow to understand the conditions of EbA efficiency and the ways to overcome difficulties. It makes this example a driving force for the three other urban national parks.

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Constraints</th>
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<tbody>
<tr>
<td><strong>Research</strong></td>
<td>• institutional constraints and technical capacity</td>
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<td></td>
<td>• lack of field data in physical oceanography and</td>
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<td>marine biology</td>
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<td>• uncertainties in extreme events modelling</td>
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<td>• scale problems in hydrological and agricultural</td>
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<td>systems</td>
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<td>• uncertainties limiting the detail of regional</td>
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<td>projections:</td>
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<td>- natural variability (impossible to set the</td>
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<td>definitive limits of natural variability nor to</td>
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<td>establish how much of the change in variability</td>
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<td>is due to anthropogenic factors)</td>
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<td>- future emissions (much of the projected</td>
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<td>change is dependent on how society responds to</td>
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<td>reducing greenhouse gas emissions)</td>
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<td>- uncertainty of the science (current</td>
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<td>understanding of the regional dynamics of the</td>
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<td>climate system of the African subcontinent is</td>
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<td>limited)</td>
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<td>- downscaling (development of regional-scale</td>
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<td>projections of change from the global models</td>
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<td>introduce an uncertainty that limits the</td>
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<td>confidence in the magnitude of the projected</td>
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<td>change)</td>
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<td><strong>Knowledge base support</strong></td>
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<td>• loss of institutional knowledge when the issue</td>
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<td>champion leaves (3 times in Cape Town)</td>
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<td><strong>Funding</strong></td>
<td>• reductions in available funding from both the</td>
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<td>public and private sectors and in institutional</td>
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<td>support for atmospheric science and physical</td>
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<td>oceanography (limitations in ship time and</td>
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<td>instrumentation in oceanography)</td>
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<td>• poor availability of research funds by</td>
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<td>comparison with some other countries with a</td>
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<td>similar gross domestic product per capita</td>
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<td>• discrepancies between research areas (impact</td>
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<td>of human-induced climate change over-funded)</td>
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<td>leading to distortions in local expertise and</td>
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<td>training</td>
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<td>• difficulties to raise funds from government</td>
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<td>and donor sources to purchase land, and to</td>
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<td>secure ongoing revenue streams for effective</td>
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<td>management of new protected areas</td>
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### Table 3: Opportunities and constraints in the City of Cape Town for EbA strategies. They are presented for the main support basis necessary for EbA efficiency.

| Political support and implementation | • Environment right in the Constitution and commitment by the ANC to establish an effective system of environment management  
• commitment of provincial government  
• legal requirement for all municipalities to have an Integrated Development Plan and Spatial Development Framework  
• volunteer, motivated and dynamic Municipal Government  
• dedicated legal, policy and planning tools for biodiversity management and conservation, linked to legislation for broader environmental management | • fragmentation of environmental aspects (such as water, forests and land) and environmental administrative functions among different national government departments and different spheres of government  
• challenging processes of implementation and ongoing stakeholder involvement  
• the lack of a clearer separation between the implementation and monitoring functions of government  
• the democratic relationship between policy, government institutions and civil society is on a precarious and unsustainable pathway  
• pace and scale of implementation need to be stepped up, using and refining new and innovative mechanisms such as contractual agreements and biodiversity offsets |
| Communication | • the role of media in assisting Cape Town to implement climate change measures  
• public participation, state-of-environment reporting and environmental education  
• agreement that providing its citizens with knowledge and information equipped them with the means of effective participation in governance | • the lack of consultation with local government and recognition of the role played by local councils in environment management  
• the lack of coordination with the civil society in the implementation and monitoring of policy  
• the failure to follow up key commitments in the policy  
• need to make the maps, guidelines and associated information available to a wide range of end-users |
| Competing priorities | • the principles of biodiversity planning (including setting explicit biodiversity targets) providing a rational, constructive platform for engaging with sectors whose interests are different from those of the biodiversity sector  
• the role of ecosystem-based adaptation is recognized by decision makers and is seen as part of a developmental agenda, rather than being a separate green agenda competing for resources | • poverty, crime, state performance and civic responsibility  
• national challenges such as an unemployment rate of 29.3%, an official HIV/AIDS infection rate of 9.8% and 17% of the population living without formal housing |

After examining the range of challenges Cape Town is facing, this study focuses on the issue of climate change and its consideration in local strategies. How does Cape Town take advantage of this framework to address climate change in terms of basic knowledge and mitigation/adaptation strategies? How the urban protected areas of the City of Cape Town can be assets to reduce vulnerability and contribute to climate change adaptation?
III Addressing climate change

1. Predicted climate change scenarios

   a. Presentation of the scenarios

The predicted climatic scenarios from South Africa and the Cape Town Region are based on the Intergovernmental Panel on Climate Change results (IPCC), and particularly on the Special Report on Emissions Scenarios (SRES) range of future greenhouse gas emissions presented here (IPCC, 2000). The main assumption is a CO2 doubling concentrations from preindustrial levels by 2050. Most studies about South Africa show consistent results with the IPCC scenarios described in the Special Report on Emissions Scenarios range of future greenhouse gas emissions (IPCC, 2000), with a special focus on the B1 low scenario and the A2 high scenario. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological changes are more fragmented and slower than in other storylines. This SRES A2 scenario is combined with a high climate sensitivity of 4.5°C, climate sensitivity describing the estimated equilibrium global-mean surface air temperature change following a doubling of atmospheric carbon dioxide concentration. The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives. The SRES B1 scenario is combined with a low climate sensitivity of 1.5°C (IPCC, 2000).

![Figure 7: Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures (IPCC, 2007)](image-url)
Figure 7 shows on the left panel the global GreenHouse Gas (GHG) emissions (in GtCO2-eq) in the absence of climate policies. Six illustrative SRES marker scenarios are presented (colored lines) and the 80th percentile ranges of recent scenarios published since SRES (post-SRES) (gray shaded area) is illustrated. Dashed lines show the full range of post-SRES scenarios. The emissions include CO2, CH4, N2O and F-gases. On the right panel, the solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the 20th-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the Figure 7 indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios at 2090-2099. All temperatures are relative to the period 1980-1999.

In the South-West part of South Africa, the average temperature is projected to increase by 1.1° by 2050s under the B1 low scenario and + 3.2° under the A2 high scenario, as illustrated on Figure 8 (Mike Hulme, 2001). These changes in temperature are consistent with the average change in global temperature. The increase in temperature is likely to be larger inland of the coastal mountains and smaller on the coast.

Under the B1 low scenario, there are no significant changes in rainfall by 2050s. Under the A2 high scenario, projections consist in a decrease in rainfall by 2050s. Precipitation for December, January and February are predicted to decrease from 10% to 20% in the southern part of South Africa and 17% in the eastern part. Precipitation for June, July and August are predicted to decrease from 10% to 20% in the southern part, 17% in the western part and 8% in the eastern part of South Africa (Mike
Hulme, 2001). Other results from General Circulation Models suggest late summer increases in precipitation in the interior and to the east of the province and early and later winter decrease in precipitation in the south-west (Michael E. Meadows, 2006).

Deep changes in atmospheric circulation are expected. The main consequences are likely to be a decrease in the frequency of low pressures during early winter, an increase in the frequency and intensity of heavy rainfall events (Simon J. Mason, 1999), longer dry spells, increase in the frequency and intensity of storms, more frequent brown haze and smog in the Cape Town area.

The trend in sea-level rise is about 2 mm per year in the last decade, which is consistent with the accepted global rate of sea level rise over the same period. Important changes in currents are already observed, in particular the warming of the Agulhas Current System as a result of wind changes (M. Rouault, 2010). Expected consequences of this warming are changes in the marine biodiversity, effects on the upwelling cells and their specific ecosystems, increase in evaporation and atmospheric humidity.

b. Discussion about the scenarios

Predicted scenarios about climate change are based on a set of Global Climate Models (GCM) and coupled models obtained by combination of the GCMs. However, the GCMs do not have sufficient spatial resolution for South Africa and a fortiori for the Cape Town area, as we can see on Figure 8. Coupled models don’t succeed in modeling local atmospheric and oceanic systems at the Cape Town area scale, neglecting the winter rainfall and the Benguela upwelling cells (M. Rouault, 2010). As a result there is a need for high-resolution regional information regarding future climate by scientists in disciplines that require climate information (e.g. hydrologists), as well as decision- and policy-makers, and by those assessing climate change impacts, adaptation and vulnerability. Research is in process to downscale the Global Climate Models for Africa, through the COordinated Regional Downscaling EXperiment (CORDEX) Africa Analysis campaign, developed by the Climate Systems Analysis Group at the University of Cape Town (Chris Lennard, 2012). CORDEX is producing high resolution climate data of an identical resolution over specified regional domains using forcing data from either analyses of observations (1988-2010) or from global climate models (1950-2100). This downscaling is performed using multiple regional climate models (RCMs) as well as statistical downscaling (SD) techniques. An ensemble of simulations are produced which will be analyzed to further understand atmospheric processes over Africa, how these may change into the future as well as the impacts these changes may have in many regions of the continent. Specific sets of analysis metrics for both model validation and assessment of projections are being developed for each region.

Regarding data availability, meteorological stations provide reliable field observations and supplement the satellite data. However, weather measures are quite recent in South Africa and the Cape Town area. As a result, historical climate studies are limited because of the length of time available. For example, Figure 9 is a photography of the meteorological station situated in Cape Point. In Cape Point, the first trace gas measurements started in 1977 and the meteorological station was built in 1995. It is one of the twenty-two observatories of the World Meteorological Organization’s network that tracks long-term chemical and physical changes in the atmosphere.
Figure 9: Photography of the Cape Point Weather Station at Cape Point in South Africa, showing the main buildings and the air intake mast (Karlsruhe Institute of Technology)

This meteorological station is under the management of the South African Weather Service (SAWS), a public entity under the Department of Environmental Affairs and Tourism. The remarkable fact is that the meteorological station is not only a source of weather observations but also a tourist attraction. One of the awareness panels addressing information about climate change to general public can be seen on Figure 10.

Figure 10: Awareness panel at Cape Point in South Africa. It explains the role of this Weather Station in the worldwide atmosphere watch network. It also highlights the increase of carbon dioxide in the atmosphere, main concern about climate change (Karlsruhe Institute of Technology).
In Oceanography, there is a lack of field data from oceanographic campaign (M. Rouault, 2010). Indeed, only satellite data are available and they don’t provide enough information about the vertical section of the oceans and their physical and biological characteristics. Field observations would also be necessary to check the information provided by the satellite data, complicated to interpret. To sum up, involvement and investment need to be increased to obtain reliable local field observations about atmosphere and ocean circulations.

The main study (Mike Hulme, 2001) about predicted scenarios in Africa is based on the SRES scenarios developed by the IPCC. The IPCC synthesis is criticized because it is too political. Indeed, the summary for policy-makers appears bowdlerized because of the consultation process. This process consists in a very slow review line by line, to get consent of all countries involved. And contention is over getting the adequate language and not over the scientific results. Countries have centric points of view and they refuse their country names to be cited in the report for instance (ACDI , 2014). So compromising with all the countries result in a loss of scientific information (Philippe Collet , 2014). As a consequence, the IPCC scenarios and results need to be studied carefully in order to exclude the political compromise from the reliable scientific data.

The choice of the scenarios by the IPCC can also be discussed. The IPCC exclude alternative climate change scenarios such as the abrupt climate change prediction. Since changes have been gradual so far, the IPCC scenarios are projected to be similarly gradual in the future, making possible for most nations to manage the effects of climate change. However, some researchers suggest that this gradual climate change could lead to an abrupt rupture of the climatic system. This theory predicts a relatively abrupt slowing of the ocean’s thermohaline conveyor, which could lead to harsher winter weather conditions, reduced soil moisture, and more intense winds in certain regions. An example of abrupt scenario (Peter Schwartz, 2003), patterned on the historical event that occurred 8200 years ago, predicts: a decrease of 5°C over Asia, North America and 6°C in Northern Europe; an increase of 4°C in key areas throughout Australia, South America and Southern Africa; severe droughts all over Europe and Eastern North America; enhanced winds and winter storms especially in Western Europe and North Pacific. In such a scenario, the world would have been destabilized due to food shortages, decreased availability and quality of fresh water and disrupted access to energy supplies. This prediction even explores the resulting conflict scenario. This abrupt change scenario learns that adapting to the worst abrupt climate change is an effective way to deal with the long-term climate change effects predicted by the gradual scenarios. A pioneering study on coastal management has been done by the City of Cape Town, considering extreme scenarios of sea-level rise rather than the gradual average rate of sea-level rise (III 2 f) Coastal zone / coastal infrastructure).

For each sector, the vulnerability of climate change is estimated as the combination of the local context and stakes and the local predicted effects of climate change. The adaptation strategies implemented to reduce the assessed risk are then presented. This step by step methodology developed by the City of Cape Town (Pierre Mukheibir, 2006) aims at being replicable for a later comparison with Rio de Janeiro, Nairobi and Mumbai.
2. Sectorial vulnerabilities and adaptation strategies to climate change

a. Urban water demand

Local context
Water demand and supply is of major concern in the City of Cape Town since water demand is threatening to exceed the yield of water. Indeed, the water demand growth at an unconstrained rate of 2.7% to 3.7% per year, leading to a water deficit. Two thirds of the demand is due to domestic consumption.

Predicted climate change impacts
Climate change is likely to cause drier conditions and more irregular precipitation with the increase of heavy rainfalls. This will increase stresses and use conflicts on water demand.

Implemented adaptation strategies
Water restrictions consist in restricting the use of water for some activities to specific times, and disallowing other activities to reduce the demand on the limited water resources. Water tariffs can be used as market-based allocations, in order to adapt rapidly to changing conditions of supply and reduce the demand in case of water shortage. The reduction of leaks programs consists in upgrading and improving the water supply lines so as to reduce the unacceptable losses of water and to reduce treatment and distribution costs. Reducing the off-peak water pressure throughout a pressure management program allows reducing lost water from undetected leaks. Finally, awareness campaigns are expected to contribute in reducing the domestic water consumption. This includes incentives (in the form of rebates for ratepayers and businesses that install rainwater tanks, re-use their grey water and install low-flush toilets) and regulations (requirement for all new buildings to be installed with water saving devices, such as low-flush toilets and rainwater tanks).

b. Urban water supply

Local context
The Western Cape is facing a high variability in water resources, with surface and groundwater exploited at an unsustainable rate. The main challenge is meeting the growing demand of the City of Cape Town area and eradicating basic service backlog in the townships. The same water is also necessary for wetlands, rivers and estuaries. Sufficient water must be left in the rivers to maintain acceptable levels of ecological integrity and wastewater effluent standards must be met to reduce the impact on river water quality.

Predicted climate change impacts
Even if quantitative effects of climate change on water resources are limited, increased variability in rainfall and water recharge is expected. More intense and frequent droughts are likely to induce water shortage. Major alteration of hydrological resources and runoff reductions will be climate change consequences. To summarize, water resources are expected to be more scarce and variable.
**Implemented adaptation strategies**

Supply-side interventions are necessary in short-term and medium-term planning so as to meet the growing water demand. The Berg River Water Management Area (WMA), major supplier to the Western Cape Metropolitan Area, is under two schemes. The first one consists in increasing the water supply capabilities from the Breede WMA to the Berg River WMA (BKS (Pty) Ltd, 2003). The second one is the augmentation of the Voëlvei Dam by 2015.

The Table Mountain Group aquifer, already used for irrigation and municipal use, is expected to have a great potential for water supply to the Cape Town Metropolitan Area. The project (City of Cape Town, 2002) is in progress in order to know the productivity, rate of recharge and sustainability of the aquifer.

Other short-term to medium-term schemes include the Cape Flats Aquifer, the Lourens River Diversion Scheme and the Eerste River Diversion Scheme.

Investment in recycling technology and recycling infrastructure can allow the development of effluent re-use. Incentives can be used to promote recycling in industries and wet processes systems and to encourage the re-use of grey water at a domestic level.

Water harvesting can also been developed and encouraged in order to promote installation of rainwater tanks for use on gardens, swimming-pools, sewage.

Seawater use can be explored for swimming-pools and sewage.

Lastly, desalinization is becoming a viable option thanks to the improvement of technology. The price of desalinated water is becoming more and more interesting if desalination is provided by green energy.

c. Storm water and flood managements

**Local context**

Storm-water and flood infrastructure are really extensive in the City of Cape Town with 150 000 gullies/intakes, 5500 km of pipes and culverts, extensive surface channel systems in both formal and informal areas and 650 detention ponds. Storm-water drains exist in the Cape Town area but they are prone to blockages. Sand is blown from the Cape Flats during dry summer and obstructs the drainage of the rainwater during the rainy seasons, and more specifically during times of unpredicted heavy storms and intense rainfalls. Leaves also block the storm-water drains. This results in flooding of property and infrastructure.

**Predicted climate change impacts**

Due to climate change, intensity and frequency of storm water are expected to increase. As a result the costs of losses to the public and private sectors will also increase. For instance, the March 2003 and April 2005 floods cost R260 millions of damage in the Western Cape, in addition to human and health consequences.
**Implemented adaptation strategies**

An ongoing monitoring and early warning system can contribute in reducing the impacts of extreme events. Impacts can also be reduced through flood reduction infrastructure such as detention ponds and weirs. The design of resilient infrastructure and buildings has to include low-income housing. Storm-water drainage and sewage treatment have to be design and constructed to resist to the projected heavy rains and floods. An ongoing maintenance of storm-water drains to clear them of sand build-up and rubbish can ensure their efficiency.

d. Terrestrial ecosystems

**Local context**

The Cape Town area is a biodiversity hotspot thanks to its fauna and flora. Characterized with his Mediterranean climate, this area presents endemic ecosystems. It counts around 9000 flowering plant species, among them 70% is endemic. It also includes the Cape Floral Kingdom, the smallest and richest floristic hotspot in the world. It presents an amazing biodiversity with half of the country’s plant species, including endemic and endangered species.

This area also presents a rich fauna with important pollinators of the Fynbos plants, vital to the ecosystems equilibrium.

The national government and the City of Cape Town are aware of the biodiversity richness and aims at protecting it through the establishment of the Table Mountain National Park and 31 municipal Nature reserves.

**Predicted climate change impacts**

Changes in temperature, rainfall, winds are expected to have huge consequences on ecosystems. Natural responses to climate change are expected to be very different depending on the species. The main results are presented for representative animal species (Barend F. N. Erasmus, 2002) and Proteaceae species (G.F. Midgley, 2003). Climate change impacts especially need to be anticipated in protected areas (M. C. Rutherford, 1999).

Some species are expected to take advantage of climate change, since 17% of representative animal species and 39% of studied Proteaceae present range expansions. However, more species are likely to suffer from climate change. Range contractions are expected for 78% of animal species and 42% of Proteaceae. The Fynbos biome is expected to lose from 51% to 65% of its area (G.F. Midgley L. H., 2002). Extinctions are expected to occur for 2% of the animal species and 18% of Proteaceae.

Important shifts are expected due to change in temperature and water availability. Fauna and flora species are likely to move eastward or south-eastward reflecting the east-west aridity gradient across the country. Smaller westward shifts are also projected due to the altitudinal gradient. The feasibility of these shifts depends on the ability of the species and the availability of the land. As a result range contractions and extinctions are likely to be worse than predicted due to the range shift difficulties.

Endemic ecosystems will also be threatened by alien species invasion. Invaders are more likely to take advantage of the increase in CO2 concentration, the increased nitrogen deposition or the
increased habitat fragmentation (Jeffrey S. Dukes, 1999). Specific responses of the alien species in South Africa need to be studied in order to determine the most threatening species. For instance, the annual grasses from Europe are likely to reduce their expansion, which is a positive effect of climate change for ecosystems. However, shifts in distributions of these grasses into pristine regions at higher latitude pose a threat to the natural vegetation by altering fire regimes (F. Parker-Allie, 2009).

**Implemented adaptation strategies**

Adaptation strategies are to be thought and implemented at a local level. Indeed, the variability of climate change effects and ecosystems response is understandable at this scale and the actions are applicable to a protected area scale.

Monitoring indicator species is necessary to enable an improved understanding of how species respond to climate variability and change (L. Hannah, 2002). This can allow prioritizing species most at risk under climate change.

Predicted impacts need to be taken into account in protected areas zoning. Indeed, modelling ecosystems range changes and shifts could allow projecting the potential expansion or relocation of the existing protected areas. New protected areas will also be necessary to capture the range of environmental conditions vital for ecosystems and modified by climate change and habitat loss (Christopher R. Pyke, 2005). Ecological corridors have to be modelled and designed in order to allow range shifts within protected areas and to new protected areas (P. Williams, 2005).

In addition, an indirect strategy to reduce climate change impacts is to reduce the other human-induced stresses on ecosystems.

Alien plant management and associated pro-active fire management need to be reinforced, prioritizing the most threatening alien species for ecosystems and for fires.

A greater involvement of public sector and commercial land managers in reducing the impact on ecosystems is also desirable.

e. **Marine ecosystems**

**Local context**

The Western Cape presents a rich marine biodiversity due to the overlap of the distributions of the organisms of the cold Benguela and the warm Atlantic currents and the overlap of the Indian Ocean and the Atlantic Ocean ecosystems. 2 000 marine species have been identified in False Bay with 61% endemic to South African waters and 14% of these endemic to False Bay itself. 80 rare and endangered species need to be protected in False Bay. So as to conserve this rich and fragile marine biodiversity, 7 marine protected areas have been implemented adjacent to the municipality.
Predicted climate change impacts
Climate change is expected to affect the sea surface temperature and then the current systems. The Agulhas Current system is already warming, with possible consequences on the marine biodiversity. Changes in sea surface temperature can also affect the upwelling systems and their rich ecosystems.

Implemented adaptation strategies
No-take areas need to take into account species routes, individual variation in area use and the spatiotemporal distribution of fish and fishers. Creation and expansion of refuges for migratory fish species can also allow protecting migratory processes.

f. Coastal zone / coastal infrastructure
A remarkable study about sea-level rise and coastal management has been realized by the City of Cape Town. It is organized in five phases addressing the model of sea-level rise due to climate change; the identification of the risks and implications of the predicted sea-level rise; the sea-level rise risk assessment including the costs of the impacts; the sea-level rise adaptation and risk mitigation measures; the full investigation of alongshore features of vulnerability on the City of Cape Town coastline and their incorporation into the City of Cape Town Geographic Information System (GIS).

The completeness of this study, from basic research to adaptation strategy assessment, has to be highlighted.

It is also exemplary with reference to the three scenarios under consideration.

Indeed, the Scenario 1 called the “Present Day Very Worst Case Scenario” results from the simultaneous occurrence of an extreme tide and an extreme storm, an event with a nominal return period of 500 years. This scenario is almost certain to occur over the next 25 years, because of the mean sea-level and the increase in intensity and frequency of storms. This would cause an increase in the mean sea level (approximated by the Land Levelling Datum) of 2m in sheltered environments (sheltered and hard, rocky or armored, sections of the coast), 4.5m in exposed environments (exposed sandy beach and low-lying sections of the coast, subject to erosion from the storm), 6.5m in very exposed environments (very exposed sandy beach and low-lying sections of the coast, subject to extreme erosion).

The Scenario Two called the “Scenario at the End of the Next Decade” predicted after the acceleration in sea level rise which is expected to add 50 cm to base levels. This scenario is to be expected whenever an extreme storm occurs at the same time as any (fortnightly) spring high tide in the spring or autumn. With the expectation that extreme storms will become more frequent, this Scenario at the End of the Next Decade is a realistic rather than an unusual event for the end of the next decade. The consequences would be the same as the first scenario, with increase in sea-level from 2m to 6.5m in the different sections of the coastline. What is striking is the potential and realistic extent of sea-level rise.
The Scenario Three called the “Polar Ice Sheet Melt Scenario” is taking into account the melting of the Greenland and West Antarctica Ice Sheets. There is much uncertainty about the extent and the timing of the melting of the polar ice sheets and their eventual contribution to sea level rise and coastal inundation. Consequently, this scenario is fundamentally different from the earlier scenarios. It focuses on the mean sea level and changes to be expected from the ice melt alone, so as to provide an everyday scenario for these circumstances. Because storms are excluded, all the coastline sections experience the same sea level rise. This scenario take into consideration the LLD, the sea-level increased by 2m, by 4m meters, by 6 meters moving steadily upwards in steps of 2m to sea-level increased by 12m.

These scenarios aim at preparing adaptive planning for the very worst consequences of sea level rise on the City of Cape Town.

**Local context**

This exhaustive study is justified by the exposure of the City of Cape Town to sea-level rise. The CCT administers 307 km of coasts valuable for the ecological ecosystems such as the African penguins, the environmental services, the economic assets such as housing and tourism, social assets with recreational and amenity areas. The coastline has been overexploited and damaged resulting in the destabilization of the dunes and the natural ecosystems. Sea-level rise risk has been increased due to the development exceeding the high-water line by far or at a too-low elevation above mean sea-level.

**Predicted climate change impacts**

The sea-level is expected to rise due to climate change, even if the extent of sea-level is uncertain and controversial. The most optimistic scenarios to the worst scenarios agree to predict greater tidal influence, increased coastal erosion, more frequent and severe storms. These impacts threaten coastal infrastructure such as the coastal railway system, the roads along the sea, the sewerage lines and pump stations, damages on the dams... The monetary value to the direct risk of sea-level rise, combining the probability of occurrence of the scenario and the potential cost to the City, is expected to be R4.9 billion (about 335 million euros) in the first Scenario One, R20.2 billion (about 1.38 billion euros) in the Scenario Two and R11.0 billion (about 753 million euros) for the Scenario Three, as shown on Table 4.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Assumed probability of occurring in the next 25 years</th>
<th>Value of real estate at risk</th>
<th>Value of tourism revenue at risk</th>
<th>Value of public infrastructure at risk</th>
<th>Total potential cost to the City</th>
<th>Value of the risk to the city</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>0.95</td>
<td>R3,255 billion</td>
<td>R750 million</td>
<td>R167.3 million</td>
<td>R900 million</td>
<td>R94.8 million</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>0.85</td>
<td>R19,459 billion</td>
<td>R1.44 billion</td>
<td>R408.25 million</td>
<td>R2,197 million</td>
<td>R230.2 million</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.20</td>
<td>R44,460 billion</td>
<td>R3.60 billion</td>
<td>R635.80 million</td>
<td>R5,702 million</td>
<td>R358.6 million</td>
</tr>
</tbody>
</table>

Table 4: Summary of assumptions and estimated risk to the Cape Town coastline (City of Cape Town, 2008).
**Implemented adaptation strategies**
The first advisable responses are socio-institutional and include vulnerability mapping, monitoring of key sites, risk communication, applying legislation, applying a coastal buffer zone, prevention of sand mining, research and monitoring, early warning system, heightened disaster management system and insurance market correction. The second conceivable strategies are biological and based on protection and restoration of dune cordons with vegetation and kelp beds. Infrastructural responses have to be considered thirdly and include sea-walls, groynes, barrages and barriers, raising infrastructure, revetments, rock armor, dolosse and gabions, off shore reefs, beach nourishment, water pumps, beach drainage.

**Local context**
Freshwater systems and wetlands are suffering from urban development, with canalized rivers, infilled and drained wetlands. Runoff patterns are also altered. As a result water quality is declining, with negative effects for human health and welfare as well as the ecological integrity of the city’s rivers and vleis. Wetlands and river areas reductions compromise the potential community interaction and enjoyment.

**Predicted climate change impacts**
Due to increased temperature and increased evaporation, freshwater systems will be disturbed. Indeed, increased saline intrusion in coastal areas and a lack of freshwater in estuaries for flushing and maintaining salinity profiles are expected. In the event of storm water drainage failure and flooding, sewerage intrusions can be responsible for a decrease in the quality of freshwater. Climate change can also compromise valued aquifer resources such as the Cape Flats Aquifer.

**Adaptation strategies**
Rivers and wetlands need to be protected and restored, so as to conserve their associated freshwater aquatic systems, their biodiversity and their role as ecosystem corridors.

**h. Health**

**Local context**
The Cape Town area is suffering a HIV/AIDS epidemic with an infection rate of 9.8% of the city population and 17% of the population living without formal housing in South Africa. Other diseases such as tuberculosis are threatening the population, especially in townships.

**Predicted climate change impacts**
Recent studies examine the possible effects of climate change on diseases transmission. Larger distribution and extended seasonal transmission of malaria are expected, with an increase from 39 to 67 million people at risk of malaria during one-month in Sub Saharan Africa (M. van Lieshout, 2004). There is also a potential increase in HIV/AIDS as an opportunistic virus linked to the intensification of other climate-related stressors (such as reduced food security) on vulnerable populations. The distribution of dengue could become larger. Animal diseases that are carried by insects and livestock diseases are expected to increase. Increased temperature can cause increased food-borne infections.
such as salmonellosis. Diarrhoea and dehydration are likely to increase due to water shortage and pollution.

Implemented adaptation strategies
There is a need for increased awareness of climate-related health impacts. Improved construction, regulations for building informal housing and improved sanitation can contribute to minimize health impacts of poor living conditions. Increased support for public health facilities in dealing with diarrhoea and dehydration is also important.

i. Energy demand and supply

Local context
Historically, Cape Town has been highly dependent on power from coal power stations nearly 2000 km away. It has been disadvantaged by its dependency on one source, coal, and one main supplier, Eskom. Moreover, cheap electricity has also meant very low levels of energy efficiency in households and production processes.

Nowadays, the City of Cape Town is facing a triple challenge: a high carbon footprint, poor energy security and vulnerability to the impacts of climate change. South Africa has been hit with unanticipated national electricity supply constraints resulting in black out and tariff increases, due to the high dependence on coal power stations and Eskom. Urban sprawl is increasing the energy issues and strengthening social inequalities. Indeed, energy demand is dominated by the transport sector. The weak and under-resourced public transport system results in high levels of car ownership and traffic congestion. The low-income households are facing severe energy problems such as shack fires, paraffin poisoning, poor indoor and outdoor air quality.

Predicted climate change impacts
As a mitigation measure to climate change, South Africa and the City of Cape Town need to initiate a transition to low-carbon energies. Cape Town has to assess the vulnerability of the energy infrastructure to the climate change impacts, particularly allowing power cut in the case of extreme events.

Implemented adaptation strategies
Cape Town has already started the diversification of its energy sources, developing nuclear power stations, liquid fuels, natural gas and renewable energies. It should keep reducing dependence on fossils fuels, especially introducing the use of cleaner fuels such as natural gas into the fossil fuel mix and increasing the use of renewable energy (solar, wind, wave ...). An effort can also be done on energy efficiency and efficient resource use. To reduce the carbon footprint, there is a need for a reliable, safe and clean public transport network. This energy transition has to ensure social sustainability, meaning that all households have to access to safe and affordable energy sources.
j. Human settlement / livelihood

**Local context**
Human settlements and infrastructure can be threatened by climate change impacts, in particular in the coastal areas as seen previously. However, the most threatened population is located in the townships. In 2005, the City on Cape Town was counting around 98000 dwellings, where 400 000 people live, corresponding to 13% of the Cape Town population. Urban growth is very fast in townships since informal settlements increase by around 13% a year.

In addition to all the difficulties (unemployment, poverty, health issues, crime...) they are facing, the poor living in the informal settlements are the most vulnerable to climate change. Townships are mostly located in risky areas and communities can’t afford infrastructure to decrease their vulnerability to climate change such as flooding. Ecosystem-based Adaptation is the only option to address climate change in these vulnerable areas, both in terms of costs and of communities’ acceptance.

**Predicted climate change impacts**
Climate change is likely to have many impacts on human settlements such as homes and household items. Effects on livelihoods are expected on money, pensions, savings, natural assets, social assets like support networks and food security. Impacts on economic sectors such as insurance, banks, transport and communication infrastructure can occur. Larger consequences are likely to affect the poor and the Cape Flats informal settlements, the most risk-prone areas.

**Implemented adaptation strategies**
Adaptation strategies have to be prioritized to the most risk-prone areas and the most vulnerable people. Coastal management is dealing with sea-level rise, flooding and storm risks (III 2 f) Coastal zone / coastal infrastructure). Sustainability is a key strategy to ensure livelihoods whatever the climate change impacts and it is promoted through municipal strategies including support for household reduction of water, energy and other resources. Regarding informal settlements, the first step is to assess vulnerable livelihoods, thanks to ongoing information and data gathering. Then disaster risk can be reduced in informal settlements thanks to improved infrastructure planning and management.

k. Fire management

**Local context**
Fires are a major threat to the City of Cape Town Area, especially in the Cape Flats townships. An increase in personal and infrastructure loss has been observed, mostly due to increased densities in the informal settlements.

**Predicted climate change impacts**
Hotter, drier and windier conditions exacerbated because of climate change will reinforce the frequency and intensity of fires. The spread of alien invasive plant is also likely to raise the fire hazard.
**Implemented adaptation strategies**
Increased training in ecological fire management is required to control the necessary burning of the Fynbos vegetation. Firefighting capacity has to be increased, thanks to greater training and investment in effective firefighting means such as aircraft. The removal of plantations in risky areas and the control of alien invasive plants are effective preventive actions against fires. The installation of fire breaks between vegetation and residential areas are needed to reduce the human losses and infrastructure damage. The erosion protection, avoiding the loss of top soil due to post fire rains, has to be integrated in fire management.

### Local context
In South Africa, recent studies by Statistics South Africa revealed that some 45% of the population lived below the poverty line and about one in ten households experienced “some form of hunger” every month. Poverty, hunger and malnutrition are the main challenges in South Africa. Food access and food security are complex issues linked to agricultural production systems, market’s dynamics, nutrition, people’s habits and preferences, social security system...

**Predicted climate change impacts**
Changes in temperature and rainfall are likely to pose problems to agriculture (N.J. Walker, 2008). Increased water-use, resource-use and land-use conflicts will be strengthened. Disastrous effects of extreme events on agriculture are likely to increase hunger.

**Implemented adaptation strategies**
Research has been promoted in South Africa through the opening of the Centre of Excellence (CoE) in Food Security at the University of the Western Cape. Research activities at the CoE would be carried out in four thematic area: food creation, which covered production, processing and preservation; food distribution, which concerned markets, livelihoods and value chains; food consumption, which involved health, nutrition, choice and behavior; and food governance, which would focus on safety, standards, policy and rights. The aims are to identify how global and national food systems were changing and how this affected the sustainability, availability, access and attributes of food and to develop and identify policies, technologies, interventions and products that would enable access to affordable and nutritious food in an ecologically, economically, socially and politically sustainable manner (Greve, 2014).

Effective adaptation strategies in agriculture are worth considering to ensure food security through a conversion from “conventional” agriculture towards carbon-and energy neutral production. A remarkable project of sustainable agriculture has been undertaken in Nuwejaars Wetland Special Management Area (Guy Midgley, 2012). In this project, land use is based on biodiversity conservation, eco-tourism, carbon- and energy-neutral production.

In particular in the metropolitan area of Cape Town, urban agriculture is very important. The City aims at promoting community gardens projects. Those projects rely on the use of green areas in public spaces to ensure long-term sustainability production of food in the City. Grants are also provided by the City of Cape Town to allow vulnerable communities and households to produce own food. The City of Cape Town has to and support as many urban agriculture projects as possible.
m. Atmospheric pollution

Local context
Around 15,000 tons per day of industrial and domestic by-products emissions (CO2, SO2, NO2, PM10...) are emitted into the Cape Town’s atmosphere. And the ambient pollutant concentrations resulting from burning emissions has been increasing during the next decade in the range of 3-22%. Cape Town also suffers from brown haze phenomenon, whom 40% is due to diesel and 25% to petrol. Atmospheric inversions also trap emissions from factories and cars over the Cape Town metropolitan region.

Predicted climate change impacts
As a result of climate change, increase in precipitation and increase in fires result in an increase in ambient pollutant concentrations. Brown haze days or pollution episodes are likely to increase by 5 to 10%. The respiratory problems and cancers associated with atmospheric pollution will possibly increase too.

Implemented adaptation strategies
Reduction of greenhouse gas emissions is the main adaptation strategy to reduce the atmospheric pollution and to reduce the extent of climate change. This can be done through the following measure: enforce the diesel black smoke legislation, introduce measures to reduce the number of smoking petrol vehicles, enforce the industrial black smoke legislation, initiate discussions with the oil industry about the potential benefits from fuel reformulation, initiate the upgrading of air pollution control capacity in the Cape Metropolitan Council, initiate the development of an air quality management system for Cape Town, re-assess the existing national air pollution legislation.

n. Tourism

Local context
According to a word association exercise performed on foreign visitors in 2006 by Western Cape Tourism Board, Cape Town is attractive thanks to its “beautiful, white, sandy beaches” (City of Cape Town, 2008). Not to mention Boulder’s Beach with the famous African penguins. Table Mountain and Cape Point are also two iconic places in Cape Town and main destinations for tourists.

Predicted climate change impacts
Climate change is likely to impact the landscapes and to reduce the environmental value, main assets of the Table Mountain National Park. A striking example outside Cape Town is the Kruger National Park, which is expected to loss 66% of the studied species, including 97% of the bird species and 52% of the Red-data and vulnerable species (Melissa Reddy, 2011). Sandy beaches and coastal areas will be damaged or lost, coastal tourism such boating or fishing will be shifted, touristic accommodation and restaurants will be damaged or destroyed. Those losses in tourism asset represent a huge economic loss for the City of Cape Town.

Implemented adaptation strategies
To ensure its sustainability, tourism has to be integrated in ecosystem-based adaptation strategies. Then tourism allows discovering and participating in climate change mitigation and adaptation. For instance, eco-tourism in lands offering biodiversity conservation and sustainable agriculture is promoted in the Nuwejaars Wetland Special Management Area (Guy Midgley, 2012)
3. **Ecosystem-based adaptation to climate change**

This study aims at highlighting the role of urban protected areas to adapt to climate change. The strategies presented previously include ecosystem-based solutions to address short-term, medium-term and long-term climate change. Some of the ecosystem-based adaptation strategies develop in Cape Town are illustrated below (Figure 11, Figure 13, Figure 14, Figure 13).

![Figure 11: Water reservoir in Table Mountain National Park. The dam holds back the water flowing from the Disa River.](image)

![Figure 12: Removal of alien invasive plant in False Bay Ecology Park. This strategy is based on local communities, involved thanks to the creation of green jobs.](image)
a. Role of urban protected areas in the city mitigation to climate change

Urban protected areas have the potential to mitigate climate change by reducing the greenhouse gas in the atmosphere and so to limit the effects of climate change. The conservation of forests, important sink of greenhouse gas, contributes to mitigate climate change. The controversial destruction of the Tokai and Cecilia plantations to restore Fynbos should be considered by comparing the gas storage capacity of the plantations and the Fynbos. The conservation and restoration of inland wetlands also allow to store large amounts of carbon. In coastal zones, the restoration of kelp beds is a relevant mitigation strategy. Grasslands mangaments allow to reduce alien species invasion and therefore fires, responsible for carbonaceous aerosol emissions.
b. Role of urban protected areas in the city adaptation to climate change: ecosystem-based adaptation

Urban protected areas contribute in the adaptation of cities to climate change. Indeed, coastal defence through the maintenance and restoration of dunes cordons constitute natural coastal barriers. Coastal wetlands and estuary are efficient buffers against storm surges and refuge for species. Kelp beds are also wave energy dissipaters. The rehabilitation of river allows to prevent flooding. The sustainable management of upland wetlands, forests and floodplains contributes to the maintenance of water flow and water quality. Protected areas allow to manage the spread of invasive alien species that are linked to land degradation and that threaten food security and water supplies. The conservation of agrobiodiversity is essential to provide specific gene pools for crop and livestock adaptation to climate change. The management of marine protected areas allows to support fisheries. The conservation of clean water reservoir in the Table Moutain National Park is essential to water security.

c. EbA in Cape Town

Cape Town is exemplary by integrating ecosystem-based adaptation to address climate change. In most sectors likely to be affected by climate change, at least one adaptation strategy is based on protected areas and ecosystem services. The following Table 5 presents the EbA strategies implemented by the City of Cape Town. EbA strategies are defined as strategies to mitigate and adapt to climate change while meeting the EbA principles presented in Table 1. The EbA+ strategies are identified as strategies designed to adapt to climate change whilst providing social, cultural, economic or/and ecological co-benefits.
<table>
<thead>
<tr>
<th>SECTORAL VULNERABILITY TO CLIMATE CHANGE</th>
<th>MITIGATION AND ADAPTATION STRATEGIES</th>
<th>SOME EXAMPLES</th>
<th>EBA PRINCIPLES</th>
<th>INPUTS</th>
</tr>
</thead>
</table>
| Urban water supply                      | Table Mountain reservoirs           | The reservoir and the Waterworks Museum | • Adaptive management approaches  
• Incorporate clear planning principles  
• Resource conservation | Hiking attraction; the Waterworks museum as a cultural asset  
Ensure water security | |
|                                         | Table Mountain Group aquifer project |                            | • Adaptive management approaches  
• Promote existing best resource management practices  
• Local science-management partnership  
• Best available science and local knowledge  
• Explore a wide spectrum of adaptation options | Ensuring water access for the low-income and poor communities  
Meet water demand and avoid water restrictions and tariffs | |
| Terrestrial ecosystems                  | Relocation of protected areas and design of corridors | Source to Sea project for the Keysers River linking the people of the Cape Flats with Table Mountain National Park through the Tokai gateway (CAPE, 2009) | • Promote existing best resource management practices  
• Build knowledge and awareness  
• Involving local communities  
• Multi-partner strategy; work with uncertainties  
• Explore a wide spectrum of adaptation options  
• Multi geographical scales  
• Resilience vs resistance  
• Promote resilient ecosystems  
• Maintain ecosystem services | Recreational activities and tools to overcome the inequalities  
Educational opportunities through the promotion of the ecological and heritage | Creation of green jobs  
Ecological restoration of riverine corridors |
<table>
<thead>
<tr>
<th>Marine Ecosystems</th>
<th>Creation and relocation of no-take area zone</th>
<th>Six no-take areas in Table Mountain National Park, Langebaan Lagoon Marine Protected Area: Refuge for a Migratory Fish Species from fishing (Sven E. Kerwath, 2008)</th>
<th>• Enhancing biodiversity</th>
<th>significance</th>
<th>Creation of green jobs</th>
<th>Sustainable fishing</th>
<th>Protection from fishing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Build knowledge and awareness</td>
<td>• Best available science and local knowledge</td>
<td>• Multi-partner strategy</td>
<td>• Multiple geographical scales</td>
<td>• Resource conservation</td>
<td>• Enhancing biodiversity</td>
</tr>
<tr>
<td>Marine Ecosystems</td>
<td>Protection of African penguins (Boulder’s Beach)</td>
<td>Creation of buffer zones and larger no-take areas; artificial nest boxes (L. Pichegru, 2009)</td>
<td>• Resilience vs resistance</td>
<td>• Reducing non-climate stresses (fishing)</td>
<td>• Promote resilient ecosystems</td>
<td>Interest for tourism</td>
<td>Economic income from tourism (pay-point in Boulder’s Beach)</td>
</tr>
<tr>
<td>Coastal management</td>
<td>restoration of dune cordons with vegetation and kelp beds</td>
<td>• Explore a wide spectrum of adaptation options</td>
<td>• Reducing vulnerability to extreme events</td>
<td>• Manage long-term climate change</td>
<td>• Promote resilient ecosystems</td>
<td>• Maintain ecosystem services</td>
<td>• Enhancing biodiversity</td>
</tr>
</tbody>
</table>
|                  |                                             | Protected and restored beaches for local people and tourists | Creation of green jobs | Economic income from tourism | Kelp forest protection as a means to absorb energy from storm surge events thereby reducing the
<table>
<thead>
<tr>
<th>Category</th>
<th>Action</th>
<th>Benefits</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Freshwater and rivers</strong></td>
<td>Protection and restoration of wetlands and rivers</td>
<td>Protect freshwater and rivers from storms</td>
<td>Princess Vlei, protected from mall construction (BiodiverCities International Conference, 2014)</td>
</tr>
<tr>
<td></td>
<td>Promote existing best resource management practices</td>
<td>Enhance ecosystem services</td>
<td>Recreational areas, Restoring and linking the ecosystems (TMNP and Princess Vlei)</td>
</tr>
<tr>
<td></td>
<td>Involving local communities</td>
<td>Maintain biodiversity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Promote resilient ecosystems</td>
<td>Ensure long-term climate change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enhancing biodiversity</td>
<td>Understand trade-offs</td>
<td></td>
</tr>
<tr>
<td><strong>Fire management</strong></td>
<td>Removal of alien invasive species</td>
<td>Reduce economic losses due to fires</td>
<td>Table Mountain National Park (national project), False Bay Ecologic Park (municipal project)</td>
</tr>
<tr>
<td></td>
<td>Adaptive management approach</td>
<td>Create green-jobs</td>
<td>Creation of green-jobs</td>
</tr>
<tr>
<td></td>
<td>Involving local communities</td>
<td>Protect endemic species</td>
<td>Decrease in economic losses due to fires</td>
</tr>
<tr>
<td></td>
<td>Integration with development strategies</td>
<td>Promote resilient ecosystems</td>
<td>Protection of endemic species</td>
</tr>
<tr>
<td></td>
<td>Promote resilient ecosystems</td>
<td>Enhance biodiversity</td>
<td></td>
</tr>
<tr>
<td><strong>Food</strong></td>
<td>Sustainable agriculture</td>
<td>Support sectorial adaptation planning</td>
<td>Table Mountain National Park (national project), False Bay Ecologic Park (municipal project)</td>
</tr>
<tr>
<td></td>
<td>Community based management</td>
<td>Enhance sustainability</td>
<td>Sustainability of agriculture, Income from agriculture, Protecting the genetic diversity of crops</td>
</tr>
<tr>
<td></td>
<td>Promote existing best resource management practices</td>
<td>Ensure long-term climate change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multi-sectorial approaches</td>
<td>Ensure biodiversity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintain ecosystem services</td>
<td>Protect genetic diversity of crops</td>
<td></td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td>Oranjezicht</td>
<td>Build knowledge and awareness</td>
<td>Market day and long-term</td>
</tr>
<tr>
<td></td>
<td>Build knowledge and awareness</td>
<td>Ensure biodiversity</td>
<td>Protection of urban areas</td>
</tr>
<tr>
<td>Sector</td>
<td>Natural Capital Action</td>
<td>Sustainability Benefits</td>
<td>Endemic Species</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Agriculture</td>
<td>City Farm • vegetable garden in the informal settlements of Village Heights (BiodiverCities International Conference, 2014) • Integration with development strategies • Culturally appropriate • Collaboration and trust • Involving local communities • Resource conservation • Maintain ecosystem services</td>
<td>opportunities for educational talk and events</td>
<td>endemic species within the City</td>
</tr>
<tr>
<td>Tourism</td>
<td>Development of eco-tourism Nuwejaars Wetland Special Management Area (Guy Midgley, 2012) • Community based management • Promote existing best resource management practices • Multi-sectorial approaches • Maintain ecosystem services • Build knowledge and awareness • Involving local communities • Integration with development strategies</td>
<td>Communication tool No conflict for land-use: agriculture and tourism; economic income</td>
<td>Biodiversity conservation</td>
</tr>
</tbody>
</table>

Table 5: Ecosystem-based mitigation and adaptation strategies implemented in Cape Town to address climate change. The actions are presented for each sector vulnerable to climate change and illustrated with examples. The EbA label is justified by the compliance with the EbA principles. The “EbA+” label of the actions is justified by the co-benefits in addition to addressing climate change.
d. Local opportunities to develop EbA

As visible on the Table 5, CCT adaptation strategies are remarkable by the integration of EbA strategies. It is relevant to understand how Cape Town makes possible the choice of EbA in decision-making. The commitment of Cape Town to implement EbA to climate change has been allowed by the development of local opportunities. The national commitment to establish an effective system of environment management and the requirement for provincial and local governments provide the legal framework. The resulting implementation of an effective municipal strategy, the Integrated Metropolitan Environmental Policy, is evidence of the local commitment and gives the policy principles to work towards by 2020 regarding the environment. In this framework, adaptation strategies rely both on national and municipal level, administrating respectively Table Mountain National Park and the Municipal Protected Areas. The efficiency of both protected areas and the concertation between the government levels are the key-development factors of EbA. Future projects such as the consolidation of the Table Mountain National Park areas (Conservation Development framework) and the establishment of possible links and corridors between the national park and municipal protected areas should make EbA even more possible and relevant.

e. Policy recommendations

Lessons about EbA strategies to climate change can be learned from Cape Town. Indeed, these solutions can be given preference compared to hard engineering solutions. Since the most vulnerable population and areas are the most underprivileged, the lower costs of the “natural solutions” make possible mitigation and adaptation for the most threatened. They also involve local communities and allow to raise awareness to climate change. The efficiency of ecosystem-based strategies compared to hard infrastructure has to be taken into account. In particular, they present fewer risks of mal-adaptation than engineering solutions, given that maladaptation is defined as “an adaptation that does not succeed in reducing vulnerability but increases it instead” (IPCC, 2001). As a result, EbA strategies have to be given preference in term of cost-effectiveness. What’s more, EbA strategies provide additional benefits such as social, cultural, economic and ecological inputs. In addition to address climate change, EbA contributes to development and can easily be integrated in strategies not only designed to address climate change, making easier the acceptance by decision-makers. So mitigation and adaptation strategies to climate change based on urban protected areas should be recommended to policy-makers as a first strategy. Hard engineering have to be considered secondly and even it is necessary, managing ecosystems allow to complement, protect and extend the longevity of investments in hard infrastructure.

The study on Cape Town costal management intends to prioritize mitigation and adaptation measures to climate change exhaustively. Policy-makers have to consider firstly no-regret solutions, secondly institutional measures, thirdly biological measures and lastly physical measures. EbA solutions are part of no-regrets solutions with conservation of ecosystems and integration of coastal management in broader policies. The institutional solutions consist in preventing ecosystems damage by reenforcing legal framework in order to rely on ecosystem services to adapt to climate change. Biological measures involve ecosystems restoration, so as to give the potential to address
climate change back to the urban protected areas. In order to outline a methodology for policymakers, Table 6 presents the example of prioritization for adaptation measures to climate change in the Cape Town coastal areas.

<table>
<thead>
<tr>
<th>First resort – no regrets options</th>
<th>Second resort – “additional” institutional measures</th>
<th>Third resort – additional biological measures</th>
<th>Last resort – additional physical measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>No further land reclamation from the sea</td>
<td>Enforce coastal buffer zone – blue line</td>
<td>Dune stabilisation and planting</td>
<td>Beach and dune replenishment</td>
</tr>
<tr>
<td>No further wetland and estuary degradation</td>
<td>Early warning system</td>
<td>Proactive estuary and wetland rehabilitation</td>
<td>Sea walls</td>
</tr>
<tr>
<td>No further dune degradation and development</td>
<td>Correct insurance market failures and under-pricing of sea-level rise risk</td>
<td>Kelp bed protection and ensuring kelp remains on exposed beaches at key times</td>
<td>Barrages and barriers</td>
</tr>
<tr>
<td>Maintain storm water infrastructure</td>
<td>Managed retreat where necessary</td>
<td></td>
<td>Raising infrastructure</td>
</tr>
<tr>
<td>Integrate sea-level rise into spatial planning</td>
<td>Social and geographical vulnerability mapping</td>
<td></td>
<td>Revetments, dolosse, rock armour</td>
</tr>
<tr>
<td>Incorporate with disaster risk management</td>
<td>Risk communication</td>
<td></td>
<td>Beach drainage</td>
</tr>
<tr>
<td>Decentralise strategic economic infrastructure and services</td>
<td>Apply the requisite legislation</td>
<td></td>
<td>Off-shore reefs</td>
</tr>
<tr>
<td></td>
<td>Prevent sand mining of coastal dunes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Additional research into rates of change and causes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Stylized sequencing sea-level rise options available to the City of Cape Town in terms of preference and order in which they should be considered (City of Cape Town, 2008).

To summarize and provide an effective tool to policy-makers, a mapping of the risk relative to climate change can delimit the priority areas in the City of Cape Town.
IV Cartography of the risk typology to climate change

This part aims at assessing the risk of climate change taking into account both the natural hazard due to climate change and the local stakes in the Cape Town areas. The natural hazard consists in considering the predicted and the possible effects of climate change and the scenarios worth considering, as developed previously (III 1 Predicted climate change scenarios). The stakes threatened by climate change include both the ecosystems and the population.

1. Urbanization in Cape Town: vulnerability to climate change

The following map of urbanization in Cape Town presents the vulnerability to climate change due to the density of population. In the urban areas, climate change impacts on human settlement, livelihood, health, security, economic activities, governance functions, trade... Urban areas are characterized by their location, the natural environment, the density of population, the income of the population and the economic activities. Those characteristics allow to define four types of urban areas associated with four levels of stakes vulnerability.

Urbanization in Cape Town: vulnerability to climate change

<table>
<thead>
<tr>
<th>I. Localization of urban areas</th>
</tr>
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<tbody>
<tr>
<td>1. Residential areas</td>
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<tr>
<td>- Urban structure</td>
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<td>- Periurban areas</td>
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<tr>
<td>- Townships</td>
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<tr>
<td>2. Economic activity areas</td>
</tr>
<tr>
<td>- Industries</td>
</tr>
<tr>
<td>- Agriculture</td>
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<tr>
<td>3. Tertiary sector</td>
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<tr>
<td>- City centre</td>
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<tr>
<td>- City Hall</td>
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<tr>
<td>- Port</td>
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<tr>
<td>- University of Cape Town</td>
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</tbody>
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<table>
<thead>
<tr>
<th>II. Localization factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physical factors</td>
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<tr>
<td>- Topography</td>
</tr>
<tr>
<td>- Littoral</td>
</tr>
<tr>
<td>- Ocean currents</td>
</tr>
<tr>
<td>- Benguela current (cold)</td>
</tr>
<tr>
<td>- Agulhas current (hot)</td>
</tr>
<tr>
<td>2. Human factors</td>
</tr>
<tr>
<td>- Administrative boundaries</td>
</tr>
<tr>
<td>- Urban roads</td>
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<tr>
<td>- Tourists roads</td>
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<tr>
<td>- Table Mountain National Park</td>
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<tr>
<td>- Municipal protected areas</td>
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<tr>
<td>- Marine protected areas</td>
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</tbody>
</table>

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<tr>
<th>III. Typology of urban areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Centre: the historical heart as a showcase</td>
</tr>
<tr>
<td>Wealthy residential areas (majority White population)</td>
</tr>
<tr>
<td>Periurban areas with middle- and low-income population (majority Black and Coloured population)</td>
</tr>
<tr>
<td>Protected areas</td>
</tr>
</tbody>
</table>
Urbanization in Cape Town: vulnerability to climate change
2. Urban protected areas in Cape Town: vulnerability and resilience to climate change

Although protected areas and their ecosystems are also vulnerable to climate change, they can contribute to mitigate and adapt to climate change. Among the assets provided by the urban protected areas, it is necessary to identify the resources and services to be protected for their resilience in the context of climate change. Therefore the most valuable protected areas regarding climate change are identified.
Urban protected areas in Cape Town: Vulnerability and resilience to climate change
3. **Predicted impacts of climate change in Cape Town**

This synthesis map presents the predicted impacts of climate change in Cape Town. It combines the vulnerabilities to climate change, in other words the two previous maps, and the predicted impacts of climate change resulting in the assessment of the risk related to climate change.

Climate change scenario chosen here focuses on a sea-level rise of 20 meters and is based on the flood map simulation (Alex Tingle, 2006). Regarding the different climate change scenarios presented, this scenario can be considered realistic in case of ice sheet melting. However, it can be considered as a worst-case scenario because of the uncertainties remaining on the extent and the timing of sea level rise. The point here is not to evaluate the extent and the timing of sea level rise but to raise awareness about need to consider the possible impacts of climate in planning and management of the City and the Parks. Other impacts of climate change such as the ecosystem range shifts are also presented as hypotheses, because of the uncertainties and the lack of data at this scale. The cartography of those scenarios result in the assessment of the risk related to climate change in the Cape Peninsula.
In this scenario, the peninsula of Cape Town becomes an archipelago with two main islands. The most risk-prone areas (red) are the ones combining the likelihood to be under water with high density of population. They include in particular the center of the City of Cape Town, with its historical heritage and the local government, and a part of the Cape Flats, with the poor, more vulnerable to climate change. Those areas are likely to disappear, resulting in movement of climate refugees towards the continent. The area at the end of the peninsula (dark green) is likely to be deserted, because of its isolation from the continent and from the urban areas. The second island includes densely populated areas (purple) and protected areas (light green). This area would become remote from the continent, with more difficult supply in water, energy, food. However it includes mountain refuges, two marine ecosystems and many environmental services. We can imagine that this island will concentrate rich people, mostly White people. The rest of the population is likely to move to the safe areas on the continent (yellow). Climate change is likely to result in social inequalities and segregation, making think of the Apartheid.
Conclusion

Cape Town has been shown as a model for its strategies to mitigate and adapt to climate change, and particularly for ecosystem-based adaptation.

Well-established basic knowledge is provided by skilled and dynamic researchers from the universities such as the University of Cape Town, despite the fact that research on climate change impacts can be broaden in particular at the scale of the Cape Peninsula. Technical support is also offered by international organizations of governments such as ICLEI. The practical application of this knowledge is allowed by an efficient communication between them and the local government of the City of Cape Town. Communication between the City of Cape Town and SANParks is also a success. Local government communicates with the provincial and the national level but it can be improved.

The implementation of the adaptation strategies by the Municipality of Cape Town is exemplary. Indeed, climate change issues are addressed in management, planning and development in all sectors. They are integrated in broader strategies so as to homogenize and coordinate the actions. The City of Cape Town is very active in adapting to climate change even if uncertainties and lack of data remain regarding climate change. The study about Cape Town Coastal Management is particularly relevant to deal with climate change. This study is not about the assessment of uncertainties or level of confidence of the predicted impacts of climate change. The choice is to consider different scenarios of climate change and their possible impacts. The scenarios are presented in terms of probability and are more extreme than the IPCC scenarios. Impacts of those scenarios are studied exhaustively including modeling, physical impacts, sectorial effects, economic costs, adaptation measures, guidelines for policy-makers. This study from A to Z is also remarkable for its local scale.

Priority is given to the mitigation and adaptation strategies based on urban protected areas and environmental services. Table Mountain National Park, administrated by SANParks, is successful in compromising ecological conservation with recreational and touristic uses. The City of Cape Town administrates municipal protected areas, advocating protection and restoration. Promising projects are about establishing links between the national park and municipal protected areas by ecological corridors. Those urban protected areas are considered as support for short, middle and long-term development for climate change strategies. Ecosystem-based Adaptation is considered as a “no regret solutions”. It presents the best cost-effectiveness and the fewer risks of maladaptation (City of Cape Town, 2008) compared to hard engineering solutions and provide multiple co-benefits for ecosystems and population. As a result EbA is an efficient and suitable strategy for policy-makers to address climate change.

Mapping predicted impacts of climate change combined with local stakes such as urbanization and protected areas provide an assessment of the risk related to climate change. The most risk-prone areas are identified and localized, allowing prioritization of the most threatened population and ecosystems. Those maps are an efficient communication tool to involve policy-makers. It is therefore necessary to improve knowledge about climate change impacts at local scale and to precise the localization of those effects. It is also interesting to map a set of scenarios, from optimistic scenario to worst-case scenario, so as to compare the possible impacts of climate change.
To sum up, climate change is likely to impact human settlement, economic activities, ecosystems, social inequalities and to disrupt the relations between the city and the urban protected areas. In light of the extent and diversity of climate change impacts in Cape Town, it should be interesting to integrate climate change impacts in the study of the three other parks within the UNPEC program. Cape Town, Rio de Janeiro, Mumbai, Nairobi and their parks will inescapably undergo climate change and the possible effects of climate change should be taken into consideration as quickly as possible by policy-makers. As an example, Mumbai and Rio de Janeiro as coastal cities would probably be affected by sea-level rise. Figure 15 and Figure 16 represents flood maps for Mumbai and Rio de Janeiro for 20 meters rise in sea level.

Figure 15: Flood map of the Mumbai area simulated for 20 meters rise in sea level. Data are from the NASA. (Alex Tingle, 2006)
In the scenario of 20 meters sea-level rise, both urban areas would suffer extended destructions whereas the national park would be preserved due to its higher elevation. Urban protected areas could then receive climate refugees, at the coast of the environment protection. The relation between the City and the Park would be deeply destabilized and redefined because of sea-level rise. Nairobi could suffer from changes in precipitation such as increase in the intensity or frequency of extreme rainfall or droughts.

Exhaustive studies about climate change impacts, similar to the coastal management study in Cape Town (City of Cape Town, 2008), are required. But straightforward simulations of climate change effects such as sea-level rise can be a first step to integrate climate change into the UNPEC program.
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