The Republic of Uganda

MINISTRY OF WATER AND ENVIRONMENT

CLIMATE CHANGE DEPARTMENT

# Economic Assessment of the Impacts of Climate Change in Uganda

## Case study: Economic assessment of climate change in Kampala urban area

October 2015

This document has been prepared by the Baastel consortium, composed of:

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# ACRONYMS

| Acronym | Definition |
|---|---|
| CBA | Cost-Benefit Analysis |
| CCD | Climate Change Department |
| CDKN | Climate Development Knowledge Network |
| CGCM | Coupled Global Climate Models |
| CIS-NCCP | Costed Implementation Strategy-National Climate Change Policy |
| CLM | Climate Limited-area Modelling |
| $CO_2$ | Carbon Dioxide |
| COSMO | Consortium for Small-scale Modelling-climate model |
| CRED | Center for Research on the Epidemiology of Disasters |
| CRMAS | Climate Change Risk Management and Adaptation Strategy |
| C40 | C40 Cities Climate Leadership Group |
| DFIF | United Kingdom Department for International Development |
| DWRM | Directorate of Water Resource Management |
| EAC | East African Community |
| ECMWF | European Centre for Medium-range Weather Forecast |
| EIA | Environmental Impact Assessment |
| GDP | Gross Domestic Product |
| GKMA | Great Kampala Metropolitan Area |
| GPCC | Global Precipitation Climatology Centre |
| ICLEI | International Council for Local Environmental Initiatives |
| IMB | Inner Murchison Bay |
| IPCC-AR5 | Intergovernmental Panels on Climate Change Fifth Assessment Report |
| KCC | Kampala City Council |
| KCCA | Kampala Capital City Authority |
| KDMP | Kampala Drainage Master Plan |
| KIIDP | Kampala Institutional and Infrastructural Development Project |
| KPDP | Kampala Physical Development Plan |
| KPDP -CIP | Kampala Physical Development Plan – Capital Investment Plan |
| KSPA | Kampala Special Planning Area |
| LCDCR | Low Carbon Development and Climate Resilient |
| LPG | Liquefied Petroleum Gas |
| MAAIF | Ministry of Agriculture, Animal Industry and Fisheries |
| MEMD | Ministry of Energy and Mineral Development |
| MFPED | Ministry of Finance, Planning and Economic Development |
| MoLG | Ministry of Local Governments |
| MoWT | Ministry of Works and Transport |
| MLHUD | Ministry of Land, Housing and Urban Development |
| MWE | Ministry for Water and Environment |
| NWSC | National Water and Sewerage Corporation |

| | |
|---|---|
| NAPA | National Adaptation Programme of Action |
| NCCP | National Climate Change Policy |
| NEMA | National Environmental Management Authority |
| NDP | National Development Plan |
| NPA | National Planning Authority |
| NPV | Net Present Value |
| NWSC | National Water and Sanitation Corporation |
| OPM | Office of the Prime Minister |
| RCP | Representative Concentration Pathway |
| SSP | Shared Socio-economic Pathway |
| SWOT | Strengths, Weaknesses, Opportunities and Threats |
| UBOS | Uganda Bureau of Statistics |
| UNEP | United Nations Environment Programme |
| UN-HABITAT | United Nations Programme for Human Settlements |
| UNMA | Uganda National Meteorological Authority |
| UNRA | Uganda National Road Authority |
| USAID | United States Agency for International Development |
| VSL | Value of Statistical Life |

# EXECUTIVE SUMMARY

Kampala is a crucial demographic and economic pole in East Africa. It is located on the northern shores of Lake Victoria, situated between 1,120 and 1,306 m above sea level, and characterized by flat-topped hills surrounded by wetland valleys. Although recent studies have provided significant insights, there are still important gaps in understanding the impacts of climate change on Uganda's capital. This study aims i) to assess the impacts of climate change and their costs for Kampala; and ii) to conduct a cost benefit analysis (CBA) of some specific adaptation options, both based on scientifically produced climate projections for the city. In order to achieve these objectives, the methodology combines qualitative and quantitative approaches.

While average near-surface temperatures increased by about 1°C between 1979 and 2005, rainfall did not change significantly between 1951 and 2005 in Kampala. Estimates of temperature increase range from 1.5 to 3°C by 2095. Precipitation is expected to decrease slightly. There are no robust projections regarding the frequency and intensity of heavy rains, although recent history and literature suggest that they have been increasing and will increase with climate change.

In addition to a qualitative analysis, this study provides an estimate of damage and an estimate of the cost of adaptation. Given data limitations, the former focuses on damages using scenarios of the same and double the frequency of floods in terms of deaths, people affected and buildings destroyed and damaged in the period 2013-2050, while the latter focuses on the costs of climate proofing buildings and roads against the projected temperatures and precipitation under RCP4.5 and RCP8.5 in the period 2015-2050. In addition, the study conducts a CBA of the physical improvement of the drainage system of four of the eight catchments of the city.

The results show that

- In a business as usual scenario for floods alone, current annual damages of between US$1.3 million and US$7.3 million in 2013 could rise to between US$3.7 million and US$17.6 million by 2025 and between US$33.2 million and US$101.7 million by 2050 if the intensity and frequency of extreme events leading to flooding do not change, and to much more if they increase.
- The total costs of climate proofing buildings and roads against the projected temperature and precipitation changes between 2015 and 20150 would be approximately US$3.7 billion under a RCP 4.5 scenario, and at least to US$3.3 billion under a RCP 8.5 scenario
- Adaptation must be the result of careful decision-making processes, with only two of the four drainage improvement projects showing a positive net present value depending on the climate scenario.
- Both the private sector and the government have a role to play. Although the cost of climate proofing infrastructure will largely fall on the private sector, the local, and to a certain extent, central governments must decisively work towards adaptation.

In this context, the study recommends that:

- Plans developed under the Kampala Physical Development Plan (KPDP, 2012) are revised in light of the climate projections. The plans for the degraded and non-degraded wetlands and the lakefront are of particular priority given their relevance in shaping particularly vulnerable areas.
- Building codes are revised vis-à-vis climate projections, promoting bio-climatic designs and the use of appropriate materials.
- Adaptation is mainstreamed into Kampala's Low Carbon Development and Climate Resilient (LCDCR) Strategy.
- The application and enforcement of tools, such as Environmental Impact Assessments, is strengthened to ensure the protection of wetlands.
- Climate resilience is ensured in all new construction and the modifications of existing buildings.

- The opportunities and challenges that informality represent are taken into account
- Evidence and research on climate change impacts is improved.
- Uncertainty is acknowledged and other tools, such as multi-criteria analysis, are used when assessing adaptation strategies.

# SUMMARY

## o *Introduction*

Over recent years, the anthropogenic forcing of the climate system and the impacts of climate change on African cities has received increasing attention. While the impact of climate change on cities is being increasingly studied, the knowledge on climate change and African cities is still poor. Although there are notable exceptions, such as Johannesburg and Nairobi, non-coastal cities have in general been overlooked. In addition, existing studies are not typically based on specific climate projections for the city they study. They also generally do not assess the economic costs of either the current and likely future impacts of climate change or the cost of reducing them through adaptation measures. Furthermore, adaptation options have not typically been the subject of cost-benefit analyses (CBA). These caveats have not only reduced the extent of climate change mainstreaming in local planning and investment, but might have also contributed to maladaptation in African cities.

The inland city of Kampala illustrates the state of the knowledge on African cities and climate change. A crucial demographic, social and economic pole in East Africa, the capital of Uganda has received considerable attention over recent years, including holistic and specific approaches, particularly on flooding. Although these studies have provided significant insights and have proposed useful mitigation and adaptation strategies, they are not based on specific climate projections for the city and do not provide estimations of costs, or of the impacts of climate change or of the cost of adaptation. Moreover, adaptation options have not been the subject of cost-benefit analyses.

## o *Objectives and methods*

This study aims to fill these gaps, with two specific objectives: i) to assess the impacts of climate change and their costs for Kampala; and ii) to conduct a CBA of some specific adaptation options, both based on scientifically produced climate projections for the city. The study hopes to contribute to the evidence base on non-coastal African cities and illustrate the importance of urban areas in promoting climate resilience in Uganda.

In order to achieve these objectives, the methodology combines qualitative and quantitative approaches. The qualitative analysis uses a comprehensive examination of the impacts of climate change and helps understand some of the causes behind these impacts. The economic assessment (quantitative assessment) provides valuable figures, informing local budgeting and decision-making. The lack of crucial data has however reduced the scope of the economic analysis. In spite of this limitation, the estimates offer vital inputs for promoting climate compatible development in the capital of Uganda.

## o *Results*

While average near-surface temperatures increased by about 1ºC between 1979 and 2005, rainfall did not change significantly between 1951 and 2005 in Kampala. Projections predict temperatures to increase by around 1.5ºC to 2095 under Representative Concentration Pathway (RCP) 4.5 and to increase by around 3ºC over the same period under RCP8.5. In both cases precipitation is expected to decrease slightly by 20mm over a 12 month running mean. There are no robust observations and projections regarding the frequency and intensity of heavy rains, although registers and literature suggest that they have been increasing and will increase with climate change. In any case, Kampala's rainstorms typically happen suddenly, both during and outside of the two wet seasons.

In this context, the qualitative analysis shows that climate change has had important impacts in Kampala. The most significant impacts have come from increased precipitation that leads to flooding. Floods have caused deaths; destroyed and damaged buildings, mobility and transport, and energy distribution infrastructure; increased the costs and challenged the feasibility of water supply; led to health problems; and negatively affected livelihoods, in terms of damages to commercial and industrial infrastructure, disruption of transport, disease outbreaks and food security. In addition, droughts have reduced water supply and energy generation, damaged and disrupted navigation infrastructure and transport, and affected livelihood in terms of increased cost of energy, decreased food production and health problems. The impact of rising temperatures is less documented, although there are arguments regarding its impacts on transport infrastructure, water levels of Lake Victoria and health.

The urban poor living in informal settlements (about 60% of Kampala's population) are those who suffer most from the impacts of climate change, especially from flooding. Not only are they typically more exposed, but they also have less capacity to recover.

The qualitative analysis helps explain these impacts. The facts are that rainstorms typically happen suddenly and are intense and the topographic and hydrological characteristics of the city do favour flooding. The shallowness and low topographic gradients of Lake Victoria make the lake particularly sensitive to changes in water levels, and temperatures favour vector-borne diseases. Current impacts are driven not only by the threats, but also by exposure and vulnerability. Impacts from flooding are exacerbated by the location of human settlements in low-lying valleys and wetlands. This is due to the lack of appropriate policies and their inadequate implementation and enforcement. These stem from critical institutional and administrative deficits and, some argue, the political economy of the city. The development of hill tops and low lying areas has increased vulnerability. The clearing of vegetation in the hills has increased water runoff and the encroachment of human settlements onto wetlands has also reduced the capacity of these ecosystems to capture, store and dissipate surface water run-off. Insufficient, poorly designed and poorly maintained urban infrastructure, and wastewater and solid waste management deficits are also crucial. Moreover, climate change adaptation has so far been approached rather indirectly. The effectiveness of adaptation in Kampala is related not only the physical structure of the city, but also to the socio-economic, institutional and political dynamics that have led to it.

The likely future impacts of climate change are in this context uncertain, as they are conditional not only on the specific climate conditions, but also on the level of development and how this reduces exposure and vulnerability, indirectly through development or directly through specifically designed adaptation strategies. We make a full set of reasonable assumptions to develop the economic assessment of the impacts of climate change. This study produces an estimate of damage and an estimate of the costs of adaptation. Given the data limitations for many impacts and sectors, the estimates do not consider all the impacts of climate change in all the sectors of the economy. The estimate of damage uses scenarios of the same and double the frequency of floods in terms of deaths, people affected and buildings destroyed and damaged in the period 2013-2050[1]. The estimate of costs of adaptation focuses on the costs of climate proofing buildings and roads against the projected temperatures and precipitation under RCP4.5 and RCP8.5 in the period 2015-2050[2]. In addition, the study conducts a CBA of the physical improvement of the drainage system of four of the eight catchments of the city. The methods used for each economic assessment are clearly stated in the corresponding section. Concerns on uncertainty and areas for further research, both significant, are summarized below and discussed in the main text.

[1] The estimate of damage does not directly consider either slow onset trends (i.e. changes in temperature and precipitation) or extreme events other than floods, such as droughts and heat wave. In addition, it does not include costs to businesses from delays and disruption, for example.

[2] The estimate of costs of adaptation excludes important sectors such as health, water supply or ecosystems degradation.

The quantitative **results** of this study can be summarized as follows:

1/ **In a business as usual scenario the costs of climate change would be very significant.** For floods alone, , current annual damages of between US$1.3 million and US$7.3 million in 2013 could rise to between US$3.7 million and US$17.6 million by 2025 and between US$33.2 million and US$101.7 million by 2050 if the intensity and frequency of extreme events leading to flooding do not change, and to much more if they increase.

2/ **Adaptation will require significant investment.** The total costs of climate proofing buildings and roads against the projected temperature and precipitation changes between 2015 and 2050 would be approximately US$3.7 billion under a RCP 4.5 scenario, and at least to US$3.3 billion under a RCP 8.5 scenario.

3/ **Adaptation must be the result of careful decision-making processes**. Our cost benefit analysis shows that investment in a specific adaptation project to improve drainage has mixed results, with only two of the four projects showing a positive net present value (NPV), depending on the climate scenario.

4/ **Both the private sector and the government have a role to play.** Our estimates show that the cost of climate proofing infrastructure will largely fall on the private sector. Nevertheless, in Kampala, the local and, to a certain extent, central governments must decisively work towards adaptation, because:

i. it would need to climate proof public assets related to critical services such as hospitals, schools and transport facilities.
ii. policies are significant drivers of development, as they give clear signals and incentives to individuals.
iii. in a city with such generalized poverty, many of the residents in low-cost housing will need government support.

Given its role, it is crucial that the government assigns its funds appropriately both within and between sectors, for instance prioritizing buildings over roads.

- *Recommendations*

Given the above results, the study provides the following **recommendations**.

1/ **Policies, plans and regulations must be designed to mainstream climate change adaptation.** It is critical that the plans developed under the KPDP (2012) and the building codes are revised in light of climate projections, such as those provided in this study, in order to increase Kampala's resilience. The results of this study can be used to inform policies, plans and regulations that are currently being developed and those that will be formulated in the future. Kampala's Low Carbon Development and Climate Resilient (LCDCR) Strategy deserves particular attention.

2/ **Kampala needs not only to improve policies, but also to strengthen the application of tools, such as Environmental Impacts Assessments (EIA), and very significantly their enforcement, especially regarding the protection of wetlands**. Although a sensitive issue, political incentives must be reviewed, and modified as appropriate. In Kampala, not only the priority of competing values must be redefined in favour of sustainability and resilience (Taylor et al., 2014), but also, as Goodfellow (2013) suggests, it is vital to establish a new political game. As in Kigali, this should set political incentives to prioritize public interests over private gains. In this sense, champions for both adaptation and long-term organized sustainable development are needed.

3/ **Kampala needs to climate-proof its infrastructure.** There is no dilemma between allocating funds to policy guidelines or to climate-proofing infrastructure. Infrastructure is designed, constructed and reconstructed on a regular basis. It is critical that all new construction and the modifications of existing buildings contribute to climate change resilience. This should be the case even while existing policies are revised and new policies are designed and approved.

4/ **Working with informality**. The LCDCR, the land use plans and building codes, the enforcement systems and the investments for climate-proofing infrastructure need to take into account the particular characteristics of the city, especially the fact that about 60% of its inhabitants live in informal settlements. As Taylor and Peter (2014: 3) claim, in the African context, and certainly in Kampala, making a more resilient city necessarily implies working with slum dwellers to "upgrade their living and working conditions in ways that increase safety, security and well-being, while also increasing their participation and leverage in citywide processes of urban planning, management and investment". In this regard, the development of the LCDCR should ensure that the eight steps suggested by Taylor and Peter (2014) are integrated in the process so that the adaptation strategies properly take into account the opportunities and challenges that informality represents.

5/ **Further evidence and research is required to build on the initial findings of this study**. Several research exercises could particularly contribute to a better understanding of the impacts of climate change and adaptation options, including:

- Conducting further research on the impacts of climate change on health, water supply or ecosystems degradation;
- Shortlisting other adaptation options related to the improvement of physical infrastructure and conducting a CBA, including different areas of the city and more geographical detail;
- Evaluating the costs and benefits of socio-institutional and ecosystem-based adaptation options.

**6/ Improve the availability of climate and non-climate data for Kampala.** This is critical for the design and enforcement of policies, plans and regulations, implementation of climate-proofing actions and research to be feasible. KCCA should work on documenting the impacts of climate change, as well as consolidating more detailed data at smaller scales. This should be key to the development and implementation of the city's LCDCR strategy, which should have enough data to define where to conduct specific adaptation measures.

7/ **Take into account uncertainty.** Although it follows guidelines on best practices, the economic assessment provided in this study is limited in scope and conditional on the choices made. In this sense, the full economic impacts of climate change in Kampala remain to a certain extent uncertain. This implies several recommendations. Policy makers must understand the choices made, which have been clearly presented in the study to facilitate this. A greater number of perspectives and economic tools should moreover be used and a greater number of studies conducted, covering more possible outcomes and complementing the weaknesses of one perspective, tool and study with the strengths of others (Garcia and Markandya, 2014). In this context, CBA should be coupled with multi-criteria prioritization exercises. In addition, policy makers must plan for uncertainty, explicitly taking it into account in their decision-making. Finally, work must be done on the policy decision process, ensuring that the political decision process in which the economic assessment is considered is open, transparent and accountable.

# 1. INTRODUCTION

## 1.1. The economics of climate change

Research on the impacts of climate change has grown over recent years. Among the efforts, an increasing role is being played by economic methods, which seek to place a value in monetary terms on the different impacts. The economic assessment of the impacts of climate change is a complex exercise (Garcia and Markandya, 2014) [3]. As it will be argued in section 4.1, it involves critical decisions regarding the extent of climate change, the impacts, the coverage and other issues regarding intra-generational equity, the inclusion of adaptation or the extent of risk aversion. Although there are guidelines for good practices that help researchers decide, and the field has shown considerable progress, there is still uncertainty on the actual cost of the impacts of climate change as well on those of adaptation (e.g. Hallegate, 2009). This uncertainty is explained by the uncertainty on the methodologies themselves and data deficits, compounded by the fact that gathering the requisite data is sometimes more expensive than the outcomes justify.

Despite these limits, the economic assessment of climate change can be critical to inform budgeting and decision-making (e.g. IPCC AR5, 2014). Experience shows that economic valuation is an excellent driver of investment, both to assign existing financial and institutional resources towards sustainable development and to get additional external assistance from development partners. For instance, the World Bank's assessment of the cost of poor sanitation in Uganda helped local governments obtain funding to extend the coverage of this infrastructure during a period when budget allocations to sanitation were scarce. Although this has not been demonstrated in all cases (e.g. McKinsey, 2009), it is expected that economic valuation can promote climate change adaptation in many contexts..

In order to support the implementation of the National Climate Change Policy (NCCP) (2013), Uganda's Ministry of Water and Environment (MWE)'s Department of Climate Change, with support from the Ministry of Finance, Planning and Economic Development (MFPED) and the National Planning Authority (NPA), engaged in discussions with the Climate Development Knowledge Network (CDKN) to implement such an economic assessment in Uganda. Together with Makerere University, Metroeconomica and the University of Wolverhampton, Baastel has assessed the economic impacts of climate change at the national and sectoral levels, as well as implemented five case-studies at the local level. In addition to Kampala, the case-studies have focused on the regions of Karamoja (agriculture and livestock), Mount Elgon (coffee), Mpanga river basin (water and electricity), and Tororo and Kabale (health). The Kampala case study has been conducted in coordination with the Kampala Capital City Authority (KCCA), the governing body of the city.

[3] As part of the project, a methodological study was developed (Garcia and Markandya, 2014: The economic assessment of the impacts of climate change. A review of methodologies). This study assessed the state of knowledge on the methodologies for the economic assessment of the impacts of climate change, providing a comprehensive overview of existing methods. Given that it is a case study, this study on Kampala does not discuss conceptual and methodological issues in depth, and refers to the methodological study to those who are interested in that matter. In this sense, this case study deals with conceptual and methodological issues on the economic assessment of the impacts of climate change only to the extent needed for making the case study understandable.

## 1.2. The emergence of African cities in climate change studies

As the International Panel on Climate Change (IPCC) (2014) acknowledges and the United Nations Programme for Human Settlements (UN-HABITAT) (2011) stresses, cities play a pivotal role in climate change, as they hold more than half the world's population and most of its built assets and economic activities. Urban-based residents and their activities generate a high proportion of global greenhouse gas (GHG) emissions. In addition, many of the key climate risks are concentrated in urban areas, as a significant percentage of the built assets and the economic activities of urban centres are at high risk from climate change. The negative impacts of climate change on urban population's health, livelihoods (means of subsistence) and assets and urban economies and ecosystems are significant. Globally, action in urban centres is essential to ensure effective climate change mitigation and adaptation.

Although the above is true at a general level, all cities have their own particularities. While in general those in developing countries have not significantly contributed to climate change in the past, the pattern of their development will affect future emissions (UN-HABITAT, 2011). In addition, cities in developing countries are particularly vulnerable to the impacts of climate change. As IPCC Fifth Assessment Report (AR5) (2013: 3) claims, in many low and middle-income countries urbanization has been accompanied by "the rapid growth of highly vulnerable urban communities living in informal settlements, many of which are on land at high risk from extreme weather".

The former is particularly true for Africa (Simon, 2013). Over the last years climate change in African cities has received increased attention, partially redressing the still important rural bias of climate studies in Africa. Several African cities have integrated international networks working on cities and climate change, such as UN-HABITAT's Cities and Climate Change Initiative, which includes Kampala; the C40 Cities Climate Leadership Group (C40); and International Council for Local Environmental Initiatives (ICLEI)-Local Governments for Sustainability's five cities partnership. According to Simon (2013), a growing number of individual African local governments have also become increasingly aware of the impacts of climate change and are proactively addressing them. Under these two trends, Kampala (Mbasi, 2009; UN-HABITAT, 2010; Lwasa, 2010) and other cities have been studied so far.

In spite of all this work, the knowledge on climate change and African cities is still poor. On the one hand, coverage has been limited. Although Johannesburg, Kampala and Nairobi have been studied, non-coastal cities have generally been overlooked, with a larger number of studies in coastal cities (Cape Town, Dar es Salaam, Lagos, Maputo, Mombasa, Port Louis, Walvis Bay). Moreover, existing studies are not typically based on specific climate projections for the city they study. As a result, analyses often develop generic arguments, rather than contributing to an understanding of the complexity of climate change. This is compounded by a lack of data on the economic costs of the current and likely future impacts of climate change. Existing studies take a qualitative approach to assess impacts, but rarely provide a quantitative assessment. In addition, with exceptions (Cartwright et al., 2013 for Durban), adaptation options have not been the subject of CBAs, partly due to the special difficulty that these exercises entail at the urban-scale. The uncertainties mentioned above regarding the economic assessment of the impacts of climate change are in fact particularly acute at the local level given the increased uncertainty about future climate conditions and the damage function, and the problems related to the attribution of costs and benefits. All the above shortcomings might have not only reduced the extent of climate change mainstreaming in local planning and investment, but might have also contributed to maladaptation in African cities.

# 1.3. Climate change studies in Kampala

Map 1. Map of East Africa localizing Kampala


Source: Encyclopædia Britannica

Located on the northern shores of Lake Victoria (Map 1), situated between 1,120 and 1,306 m above sea level, and characterized by flat topped hills surrounded by wetland valleys, the capital of Uganda is a crucial demographic and economic pole in East Africa. With an area of 195 sq. km, the city has a little over 1.5 million people (preliminary results of the 2014 Census). According to the Kampala Physical Development Plan (KPDP) (2012: 191), the Great Kampala Metropolitan Area (GKMA) currently has around 3 million people. In addition to a significant percentage of the country's population (about 9% if the GKMA is considered), the capital of Uganda concentrates critical economic assets and political powers. Institutionally, the city is governed by KCCA, which is an organization operating at the central level.

Climate change in Kampala has received considerable attention over recent years, including holistic (Mbasi, 2009; UN-HABITAT, 2010; Lwasa, 2010) and specific approaches, particularly on flooding (UN-HABITAT, 2013). As a result, there are valuable qualitative studies on the impacts of climate change on infrastructure (buildings, transport, energy, water and sanitation), livelihoods (including energy production) and ecosystems (including its effects on water supply). There are also interesting studies with respect to the factors that explain the impacts mentioned above, regarding threats, exposure and vulnerabilities.

However, although these studies have provided significant insights and have proposed useful mitigation and adaptation strategies, they 1) are not based on specific climate projections for the city, and 2) do not provide data on costs of climate change or adaptation. While UN-HABITAT (2010) simply takes the projections for the country from the IPCC AR4, UN-HABITAT (2013) considers the impact of a particular extreme event under different policies, assuming that climate change would increase the frequency of this event. None of the studies conduct in this sense a robust analysis of the likely impacts of climate change. Further, none of the studies regarding climate change in Kampala provide estimations of costs, either of the impacts of climate change or of the cost of adaptation. While the available general assessment of the impacts of climate change in Kampala (UN-HABITAT, 2010) does not address this issue at all, the flood risk assessment (UN-HABITAT, 2013) offers only some insight on who should pay for each adaptation strategy, without calculating how much the amount could be. Moreover, adaptation options have not typically been the subject of CBAs and/or other economic tools.

# 1.4. Objectives of the study

In this context, this study aims to assess the economic cost of the impacts of likely future climate change in Kampala based on detailed climate projections for the city. In particular, the study seeks two specific objectives:

i) to assess the impacts of climate change and their costs for Kampala; and
ii) to conduct a CBA of some specific adaptation options, both based on scientifically produced climate projections for the city.

The study hopes to contribute to the evidence base on non-coastal African cities and illustrate the importance of urban areas in promoting climate resilience in Uganda and Africa.

## 1.5. Scope and structure of the study

In order to achieve these objectives, this work conducts a quantitative modelling of climate projections for Kampala, a qualitative assessment of the impacts of climate change, a partial quantitative assessment of the costs of these impacts and a quantitative CBA of a set of specific adaptation measures. The methodology therefore combines qualitative and quantitative approaches. The qualitative analysis allows a comprehensive examination of the impacts of climate change and helps understand some of the causes behind these impacts. The economic assessment provides valuable figures for informing local budgeting and decision-making. It is important to note that the economic assessment presented in this study is not as comprehensive as the institutions and researchers involved would have liked. The assessment depends on data availability and this is currently poor, likewise in other African cities (e.g. Durban –Cartwright et al., 2013). In order to keep the exercise robust, this study uses alternative data sources and reasonable assumptions to the extent possible, which are all explicitly presented. As will be explained in the methodology section, the economic assessment is, in any case, conditional on the choices the study makes.

The rest of this report is structured in five sections:

- Section 2 focuses on climate variability and change. The first part of the section presents current climate variability; the second provides the climate projections for the city.
- Section 3 conducts a qualitative assessment of the impacts of current climate variability. First the study examines the impacts of current climate variability regarding both temperature and rainfall on a sectoral basis, in order to provide as much detail as possible. Second it discusses the causes of these impacts in terms of threats, exposure and vulnerability, analysing as well adaptation efforts.
- Section 4 conducts an economic assessment of the impacts of climate change. The first part presents very briefly some conceptual and methodological issues regarding this type of exercise. The second part discusses the scope of the analysis and the methods that have been followed. The third part discusses the estimated cost of the likely impacts of future climate change, providing estimates of damages and of the cost of adaptation.
- Section 5 develops a cost-benefit analysis (CBA) of some important adaptation measures, namely those related to the physical improvement of the drainage system of four of the eight catchments of Kampala. There are other areas where adaptation actions will be needed but data required to conduct such analysis is not available.
- The last section sums up the arguments and draws implications for policy, providing some recommendations.

# 2. EVIDENCE OF CLIMATE VARIABILITY AND CLIMATE CHANGE PROJECTIONS

## 2.1. Evidence of climate variability in Kampala

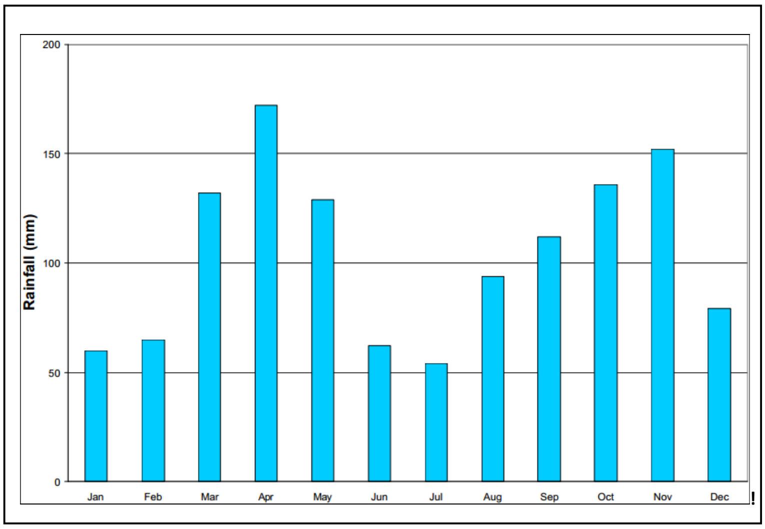
### 2.1.1. "Normal" climate in Kampala

Despite its proximity to the equator, Kampala has a tropical rather than a typical equatorial climate. According to UN-HABITAT (2013: 12), this is due to its high altitude, its long distance from the sea, its relief and its proximity to the large water mass of Lake Victoria.

The daily temperature mean ranges between 20 and 22ºC annually, with an average high of 27-28°C and an average low of 17-18ºC. Moderate temperatures characterize Kampala.

UN-HABITAT (2013) and Rautenbach (2014) have estimated long-term precipitation data (1943-1999 and 1951-2005, respectively). Kampala receives an annual rainfall of between 1,750 mm and 2,000 mm per year. Kampala, features two annual rainy seasons; the first runs from March to May, peaking in April; and the second runs from August to November, peaking during October and November (Figure 1). Although the first one is shorter, it is also more intense, with April typically seeing the heaviest amount of precipitation. The main dry season is from December to February, with a secondary dry season during June and July.

**Figure 1 - Long-term mean monthly rainfall in Kampala. 1943-1999**



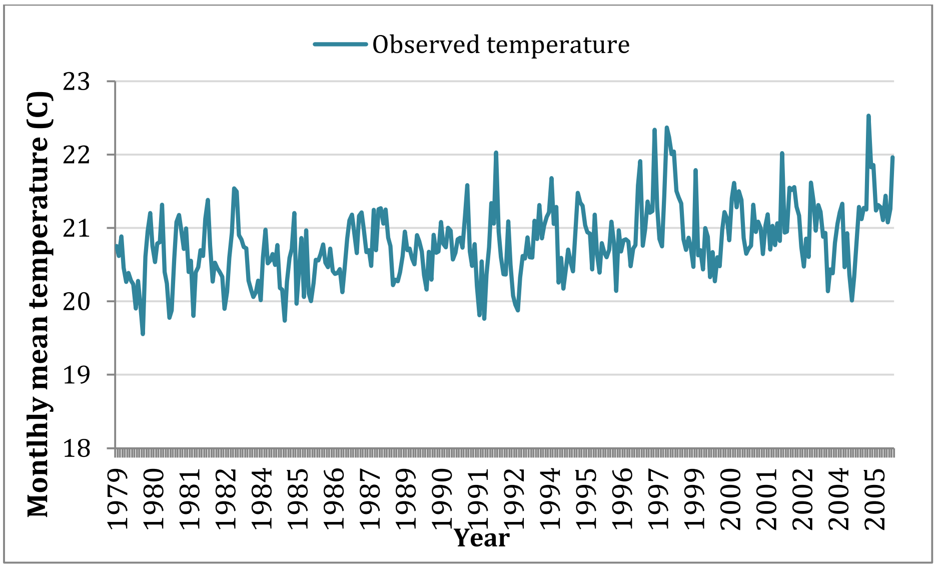

Source: UN-HABITAT (2013)

It is important to note that although the two wet season patterns presented above prevail, there is high chance of heavy rains to occur even in relatively dry months of the year (UN-HABITAT, 2014: 13). In fact, in Kampala rain is generally convective: rainstorms are highly localized, often covering less than 10 square kilometres, intense (violent) and of short duration, usually lasting an hour or less (Douglass et al., 2008; and UN-HABITAT, 2013). They also happen suddenly, with little lead-time for warning, as they are fast moving. Unexpected rains occur in both the wet and the dry seasons. This convective nature makes rainstorms particularly damaging, as they can occur when people and responsible authorities might not be prepared (UN-HABITAT, 2010).

### 2.1.2. Recent climate variability and change in Kampala

According to the monthly averaged data from the European Centre for Medium-range Weather Forecast (ECMWF) Reanalysis (ERA-Interim), average near-surface temperatures have increased in Kampala between 1979 and 2005 by about one degree Celsius (Figure 2).

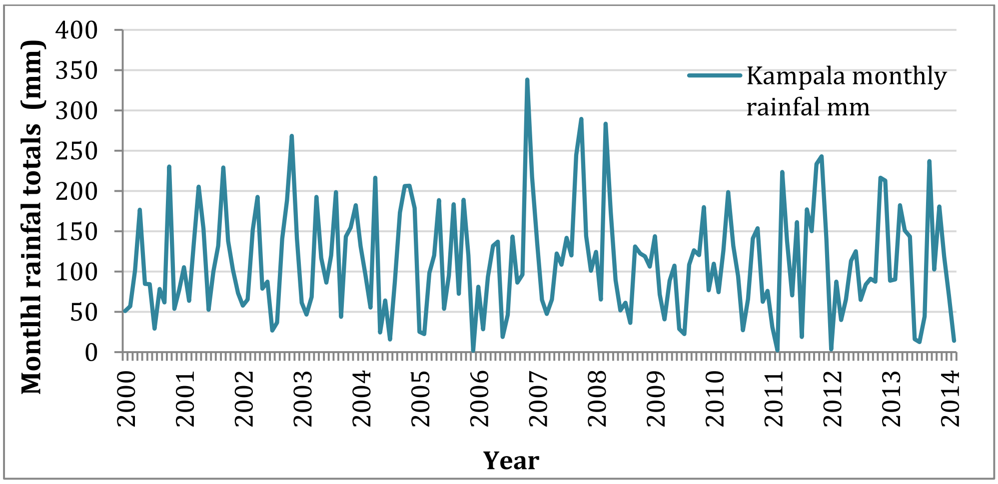
**Figure 2 - Kampala domain area averaged observed ERA-Interim reanalysis monthly near-surface temperature averages (°C). 1979-2005.**




Source: Rautenbach (2014)

According to the data provided by the Uganda Bureau of Statistics (UBOS), in contrast, rainfall did not change significantly in Kampala between 2000 and 2014 (Figure 3).

**Figure 3 - Kampala monthly rainfall. January 2000 – February 2014. In millimetres (mm)**




Source: UBOS (2014)

However, there is a general opinion that climate variability has increased. According to officials from the Office of the Prime Minister (OPM), rainfall is now more difficult to predict, as heavy rains occur more frequently in times when they are not expected. According to MWE officials, the frequency of prolonged periods of extreme events, such as heavy precipitation, leading to floods, and lack of precipitation (droughts) has increased. The representative of the NGO Act Together stressed that long periods of heavy rain and droughts are more common. Douglas et al. (2008) claim that, according to the residents in the Kalerwe, Katanga and Bwaise districts of the city, storms have become more erratic, unpredictable and frequent, as well as more severe. Existing data do not provide reliable information on specific heavy rains.

## 2.2. Projected future climate conditions

Climate projections at a local scale were not available for Kampala before this project. UN-HABITAT's (2010) climate change assessment of the city, and the UN-HABITAT (2013) study for flooding or the city's physical development plan (2012) did not use detailed projections for the city.

As part of this study, the University of Pretoria has produced downscaled projections[4] for Kampala[5]. In particular, the study provides future (2006 to 2095: 90 years) climate model simulated projections for rainfall and near-surface temperatures, under conditions of a medium-to-low $CO_2$ Representative Concentration Pathway (RCP 4.5) and a high $CO_2$ Representative Concentration Pathway (RCP 8.5). The Representative Concentration Pathways show the potential cumulative measure of anthropogenic emissions of greenhouse gases, which are used by the Intergovernmental Panel on Climate Change's AR5. RCP4.5 shows a moderate level of mitigation of greenhouse gases, resulting in some shifts in climate patterns globally, while under RCP 8.5 far less mitigation takes place, resulting in much stronger changes in climate globally[6] (Meinhausen, et al., 2011; Riahi et al., 2011).

Given that extended range observational station data was not available for this study, as an alternative, estimated and reanalysed data was considered for observations. For rainfall, total monthly data was downloaded from the Global Precipitation Climatology Centre (GPCC) provided by NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, for the period 1951 to 2005 (55 years). For near-surface temperature, monthly averaged data was downloaded from the European Centre for Medium-range Weather Forecast (ECMWF) Reanalysis (ERA-Interim) for the period 1979 to 2005 (27 years).

The study applied dynamic (from models) and statistical (from observed data) downscaling. Regarding dynamic downscaling, the study employed the Consortium for Small-scale Modelling-climate mode (COSMO) model of the Climate Limited-area Modelling (CLM) community to downscale the Coupled Global Climate Models (CGCMs) that were used in the IPCC AR5. For the statistical downscaling, a methodology proposed by Hawkins et al. (2013) was applied.

The study corrected the results of the dynamic analysis, which had systematic errors, with the statistical downscaling, making the results more representative of observations. The results are the following:

Temperatures

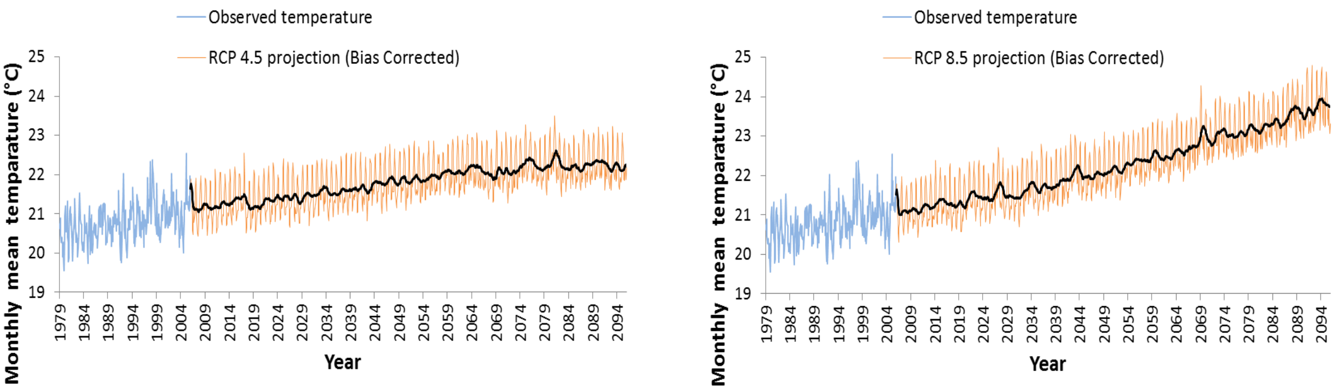
[4] By downscaled projections we mean that projections at the global scale have been used to produce projections at the local scale, particularly for Kampala.

[5] The following lines are a summary of the report developed by Rautenbach (2014) as part of this project. For the full report, see Rautenbach (2014). For the purpose of dynamic downscaling, the Kampala domain (32.56ºE to 33.00ºE ; 0.0ºN to 0.44ºN) was selected according to the position of the four CCLM 4.8 RCM grid points which were located nearest to the Kampala city. These grid points are 0.44 º (≈50km) apart. Spatial averaged values of rainfall and near-surface temperatures, calculated across the four grid points, were regarded as the *dynamical downscaled* climate for Kampala.

[6] See e.g. http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html for an overview of the four RCPs.

- Under RCP 4.5, the simulation exercise predicts near-surface temperatures to increase by approximately 1.5 °C by the end of the century (2095). As can be observed in Figure 4, the 12-month average could be higher in some periods, for instance around 2080; and the average near-surface temperatures in some months could go as high as 23°C.
- Under RCP 8.5, the simulation exercise predicts near surface temperatures to increase by approximately 3°C by the end of the century (2095). As can be observed in Figure 5, the 12-month average could be higher in some periods, for instance around 2070; and the average near-surface temperatures in some months could go as high as 24°C.

**Figure 4 and 5 - Kampala domain area averaged observed ERA-Interim reanalysis (blue) monthly near-surface temperature averages (°C) with bias corrected CCLM 4.8 RCM near-surface temperature projections (orange), under conditions of the RCM 4.5 (left) and 8.5 (right) pathways. The black lines represent 12-month running averages.**



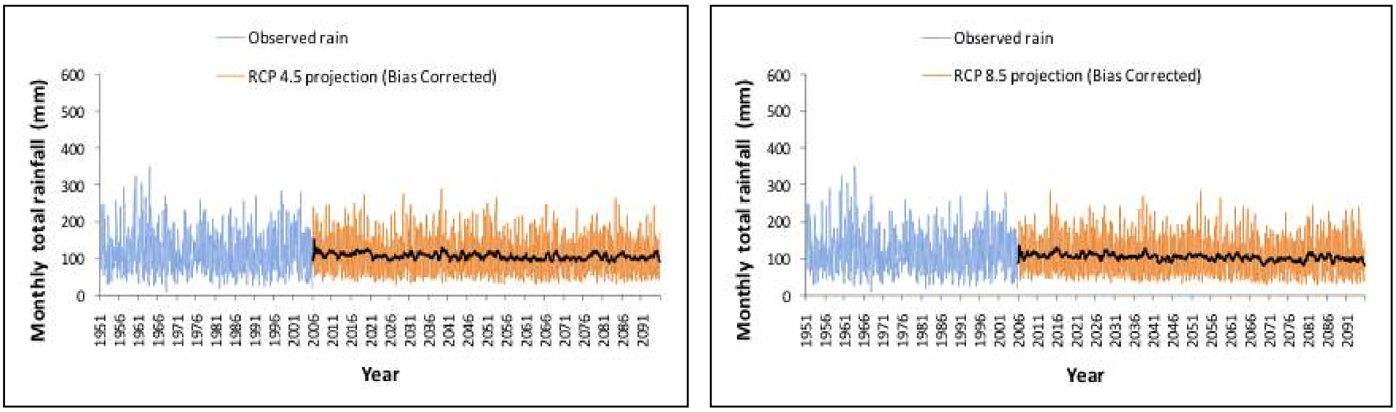

Source: Rautenbach (2014)

Rainfall

- Under RCP 4.5, the simulation exercise predicts annual rainfall not to change significantly along the century, with a small decline in the annual rainfall average of approximately 20 mm over a 12 month running mean (Figure 6).
- The prediction does not change significantly under RCP 8.5: the simulation exercise predicts as well a small decline in the annual rainfall average of approximately 20mm over a 12-month running mean[7] (Figure 7).

[7] It is important to note that these projections for annual rainfall are based on the most recent work by the IPCC, that is, IPCC AR5, and that they are in agreement with most of the projections produced before (United Kingdom Department for International Development –DFID; United States Agency for International Development -USAID) based on IPCC AR4. The annual rainfall projections provided here differ, in contrast, with the German Climate Fact Sheet, which was based on IPCC AR4, and is not in line with the projections of DFID and USAID.

**Figure 6 and 7 - Kampala domain area averaged observed GPCC (blue) monthly rainfall totals (mm) with bias corrected CCLM 4.8 RCM rainfall projections (right, orange), under conditions of the RCM 4.5 (left) and 8.5 (right) pathway. The black lines represent 12-mont running averages.**




Source: Rautenbach (2014)

The climate projections for Kampala are summarized in Table 1 below.

**Table 1 - Near-surface and precipitation projections under RCP 4.5 and RCP 8.5 for Kampala 2006-2095. Summary.**

| Parameter | RCP 4.5 | RCP 8.5 |
|---|---|---|
| Monthly totals of rainfall (mm) – bias corrected | The projected 12-month running mean shows a decrease of approximately 20mm over the period 2006 to 2095. | The projected 12-month running mean shows a decrease of approximately 20mm over the period 2006 to 2095. This is very similar to the RCP 4.5 projection. |
| Monthly averages of near-surface temperature (ºC) – bias corrected | The projected 12-month running mean shows an increase of approximately 1.5ºC over the period 2006 to 2095 | The projected 12-month running mean shows an increase of approximately 3.0ºC over the period 2006 to 2095 |

Source: Rautenbach (2014)

Unfortunately, the assessment of changes in the frequency and intensity of extreme events was not part of this project, given the complexity of such predictions. As UN-HABITAT (2013:27) acknowledges, "climate predictions for Uganda (and Kampala in particular) in terms of rainfall are very uncertain (…) there is little certainty whether heavy rainfall events will increase in magnitude or occur more frequently". UN-HABITAT's (2013: 3) consideration of a higher frequency of heavy storms (i.e. what is now a 1 in 10 year event may become a 1 in 6 year event) with climate change is, as they stress, just an assumption. However, registers and literature suggest that the frequency and intensity of extreme events has been increasing and will increase with climate change.

# 3. Qualitative Assessment of the Impacts of Climate Variability and Change in Kampala

The qualitative analysis shows that climate change has had important impacts in Kampala. The most significant impacts have come from increased intensity and frequency of heavy rains leading to flooding. Floods have caused deaths; destroyed and damaged buildings, negatively affected mobility and transport, and energy distribution infrastructure; increased the costs and challenged the feasibility of water supply; led to health problems; and negatively affected livelihoods. In addition, droughts have reduced water supply and energy generation, damaged and disrupted navigation infrastructure and transport, and affected livelihood. The impact of rising temperatures is less documented, although there are arguments regarding its impacts on transport infrastructure, water levels of Lake Victoria and health.

The qualitative analysis helps explain these impacts. The convective rain pattern and the topographic and hydrological characteristics of the city favour flooding. The shallowness and low topographic gradients of Lake Victoria make the lake particularly sensitive to changes in water levels, and temperatures favour vector-borne diseases. Current impacts are driven not only by the threats, but also by exposure and vulnerability. Impacts from flooding are exacerbated by the location of human settlements in low-lying valleys and wetlands. This is due to the lack of appropriate policies and their inadequate implementation and enforcement. These stem from critical institutional and administrative deficits and, some argue, the political economy of the city. The development of hill tops and low lying areas has increased vulnerability. While the clearing of vegetation in the hills has increased water runoff and the encroachment of human settlements onto wetlands has also reduced the capacity of these ecosystems to capture, store and dissipate surface water runoff. Insufficient, poorly designed and poorly maintained urban infrastructure, and wastewater and solid waste management deficits are also crucial. Moreover, climate change adaptation has so far been approached rather indirectly. An effective adaptation policy for Kampala would need to address not only the physical structure of the city, but also the socio-economic, institutional and political dynamics that have led to it.

## 3.1. Evidenced impacts of climate variability in Kampala

According to the existing data, the academic literature and the information gathered in the interviews, climate variability is affecting Kampala significantly. Both changes in temperature and rainfall variability have had impacts in the city so far.

### 3.1.1. Rainfall

#### 3.1.1.1. Rainfall excess - Floods

In Kampala the most significant climate change impact has come from increased precipitation that leads to flooding (UN-HABITAT, 2010, 2013, 2014; Lwasa, 2010). The UN Desinventar database gives information on frequency and impact for different hazards, including floods, rains and storms, for Kampala for the period 1993-2014. According to this database, in that period there were 11 flooding events in the city. Sliuzas et al. (2013)

found that severe flooding in many areas along the primary channel in the Lubigi catchment with depths of up to 2m and durations of more than 24 hours occur quite often.

Lwasa (2010) argues that the frequency of flooding has increased over recent years. This is also the case for Busega residents. While it was not a critical issue before, it is now a critical problem, especially in the last 3 years. Flooding was particularly severe during the last rainy season (March, April and May 2014). The impacts of flooding were greater than the full previous year. The International Disaster Database, collected by the Center for Research on the Epidemiology of Disasters (CRED), provides some insights in this regard, albeit the information is provided at the national level, and not for Kampala. While the database includes data for Uganda from as early as 1990, all the floods registered in the database have occurred in the last 20 years[8]. In the last 20 years, 18 floods have been registered (0.9 per year); 8 were registered in the last ten years (0.8 per year). The database registered flood events in August 2007, November 2008, August 2011, August 2012, and May 2013.

According to existing literature, the impacts of flooding are significant, affecting residential and productive (commercial and industrial) assets and communication and utility (transport, energy and water and sanitation systems) infrastructure, as well as livelihoods, health and ecosystems. Section 4 provides some quantitative estimates for the damages from flooding for the period 2013-2050 covering deaths, people affected and houses destroyed and damaged. The following sections present a qualitative analysis of the current impacts of flooding more broadly.

- *Buildings and housing*

According to government officials (OPM, MWE and Ministry of Land, Housing and Urban Development - MLHUD) and academic literature (UN-HABITAT, 2010; Lwasa, 2010), housing is significantly affected by flooding. The UN Desinventar database registers the destruction of 123 homes (9 per year) in Kampala due to flooding from 1993 to 2014. This is particularly problematic in slums, where the buildings are often in or around wetlands, and the construction is poor (Act Together). In the Busega area, the destruction of perimeter walls and housing has been registered by community leaders (Kabikwa and Matovu). When this happens, households typically find accommodation with friends, while they save money to rebuild their houses. The time it takes them to find this money depends on income, but is in general relatively short: more or less one month.

- *Mobility and transport infrastructure*

According to the Climate Change Risk Management and Adaptation Strategy (CRMAS) for the Transport Sector (2012) and different government officials (OPM, MLHUD, MWE), transport is considerably affected by flooding. In particular, flooding affects the safety, efficiency, cost effectiveness and punctuality of transport. Extreme rainfall events and floods have the greatest impact on the transport sector.

This is particularly true in Kampala. In the case of the capital city, the roads and bridges, the railway line and the navigation infrastructure are strongly impacted by flooding[9]. Extreme rainfall events and floods often lead to short term breakdowns and sometimes cause permanent damage on road infrastructure. The CRMAS report for the Transport Sector (2012) registered, for instance, a more rapid degradation of materials, leading to a loss of strength and bearing capacity of roads and pavements. Roads have also been blocked due to fallen trees, damaged buildings and vehicles during intense storms. In addition to roads themselves, storms and floods damage supplementary infrastructure, such as street lighting, flyovers and traffic signs. According to this report, storms and floods have also caused damage to vehicles, and increased the risk of accidents. Railway lines and

[8] Note that according to this database, in order for a disaster to be entered into the database at least one of the following criteria has to be fulfilled: i.) 10 or more people reported killed; ii.) 100 people reported affected; iii.) a call for international assistance; iv.) declaration of a state of emergency.
[9] Note that the CRMAS report for the Transport Sector (2012) is based on interviews to up to 400 people in the country and does not clearly distinguish between potential and actual impacts. Although we have tried to include only actual impacts, it must be read with caution.

Lake Victoria's navigation infrastructure are also vulnerable. However, there are no specific references to the actual impact of floods in the Lake's navigation infrastructure, although the document stresses that this can happen in the future, or the railway lines.

Infrastructure on low-lying areas is particularly affected by flooding in Kampala. The recent Environmental Impact Assessment (EIA) of a key transport infrastructure project (Greater Kampala Roads Improvement Project) in the Central Business Centre (the most congested section of Kampala)[10], found, for instance, that critical infrastructure of the city, such as the roads around the Clock Tower, the Fire Brigade Centre and the ShopRite-Shall shopping centre, are significantly prone to flash flooding (UNRA, 2014). While in other areas more intense and frequent storms and flooding can wash away bridges and roads, and cause landslides, this is not common in the city given the moderately sloped hills in Kampala.

The disruption of traffic has critical economic and social costs[11]. Whenever traffic is disrupted, people and goods are not able to move across the city properly. Given the economic centrality of Kampala, the impacts of floods on the city's transport have far reaching economic and social consequences at country level. UN-HABITAT (2010) claims, for instance, that flooding affects fuel transport and distribution by making rail and road transportation inaccessible and deteriorates critical bridges. According to the CRMAS report for the Transport Sector (2012), transport represented 7% of GDP in 2009. The impact of flooding hampers the operation of an already poor mobility system (Vermeiren et al., 2012).

- *Energy distribution network*

According to the Ministry of Energy and Mineral Development (MEMD) of Uganda, floods have often resulted in the disruption of the energy distribution network. UN-HABITAT (2010) states that "the increased intensity and frequency of severe weather events impacts on energy infrastructure, by causing destruction of, for instance, power plants, transmission lines and power lines in and around the city". UNRA (2014) found that the power station in the Mukwano Road area is frequently affected by flooding. Although energy infrastructure can require repairs after floods, damages are not typically great, according to MEMD officials. According to UN-HABITAT (2010), the disruption of rail and road transport indirectly affects energy supply, as fuel is typically brought to the city by train from the coast and distributed by trucks.

- *Water and sanitation infrastructure*

According to officials from the National Water and Sewerage Corporation (NWSC), floods in Kampala do not affect water and sanitation infrastructure directly. Outside Kampala floods have sometimes washed infrastructure away; but this is not the case in the capital city. In that sense, floods do not imply an additional direct cost to NWSC. Floods do, however, have an indirect impact on NWSC's budget, through water treatment, as well as affecting sanitation in informal settlements. Both issues are discussed in greater detail below.

- *Livelihoods*

There is an overall agreement that flooding has high economic and social costs for the city. Floods affect livelihoods in at least four ways:

[10] The Road Project is within the Central Business District of Kampala Capital City and covers the congested section from off the Clock Tower Roundabout to off the Hotel Africana Roundabout along Queensway (3.2km) as well as the extended section from Kibuye Roundabout to Jinja Road after the Cemetery. The main objective of the project is to decongest the Centre of Kampala City as well as the congested Roundabouts that are located along the congested section of the project road.

[11] Lwasa, 2010; CRMAS Transport Sector, 2012; Sliuzas et al., 2013

1/ Floods affect commercial and industrial infrastructure (OPM, MWE). Both the physical spaces such as shops or industrial spaces can be physically destroyed or damaged, as well as the assets that are located in them, from merchandise to machines. Flooding affects both formal and informal shops, such as street markets.

2/ Flooding often leads to the disruption of transport. As a result, many workers and goods are not able to get to their workplace or market, disrupting personal livelihoods and the productive system in general. This is particularly felt in human settlements that are far and not well connected, both within Kampala and the Greater Kampala Metropolitan Area.

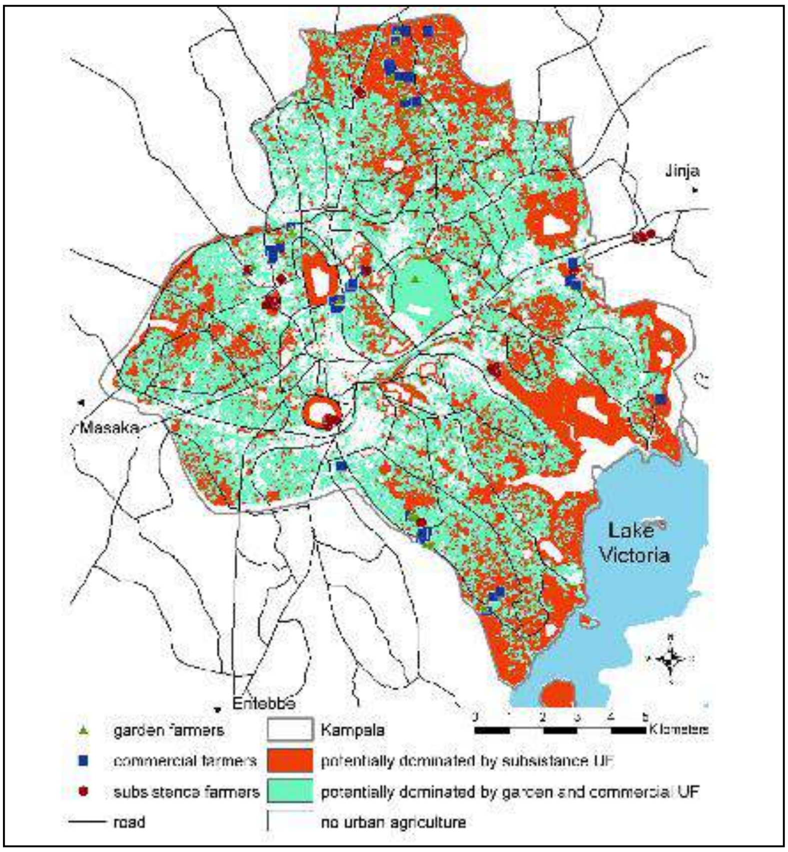
3/ Flooding typically leads to disease outbreaks, which reduce the productivity of the labour force and increase costs of health treatment (discussed in greater detail below). While sometimes workers are simply unable to work, often their productivity is significantly lower.

4/ Flooding directly and indirectly affects food security[12]. Directly, floods affect both farming around wetlands and fishing in Lake Victoria. UN-HABITAT (2010) claims, for instance, that floods lead to crop failure. In Busega, community leaders indicated that flooding typically destroys the production of crops, on which they largely rely. This is critical since, according to UN-HABITAT (2014: 182), "almost half the city's households are involved in the production of food, from all socioeconomic groups, and produce up to 60% of the cities food supply". Vermeiren et al. (2013) argue, in this sense, that urban farming is a significant source not only of food, but also of employment, as many residents are part or full time employed in this sector. According to Vermeiren et al. (2013), about 59 $km^2$ of land is available currently in Kampala for urban farming. Of it, subsistence farmers use around 56% (33$km^2$) of available land for urban farming, while the garden and commercial farmers together occupy around 45% (26 $km^2$). Map 2 illustrates the spatial distribution of farming in the city[13].

Floods also affect food security indirectly. As stated above, they affect transport infrastructure, which is key to bringing to the city products that have been cultivated or produced elsewhere in the country or abroad. Floods can lead in that sense to an increase in food prices. Unfortunately, there is no information available on how flooding has specifically affected Kampala's food production and security so far.

[12] Douglas et al., 2008; Mbasi, 2009; UN-HABITAT, 2010; Vermeiren et al. 2012, Lwasa et al., 2014
[13] Although, according to some informants, the maps is not precise on several areas, such as around Makerere University, the map is the most robust and updated one available regarding farming in Kampala.

Map 2 - Kampala urban farming system mapping




Source: Vermeiren et al. (2013: 46)

### o *Water pollution*

One of the main impacts of flooding is associated with water pollution. The sewerage infrastructure is scarce (about 8% of the population is served by a central sewerage system, according to UN-HABITAT (2014)) and most of it is old. Floods lead to the pollution of open water, which has two broad categories of impact on human populations, on water supply and on health.

1/ Flooding affects **water supply** through the impact on the quality of the water of Lake Victoria[14]. Kampala's polluted storm water and the Bugolobi Sewage Treatment plant discharge into the lake, in particular into the Inner Murchison Bay (IMB). The city and other two parishes get their water supply also from IMB[15]. Lake Victoria is one of the only sources of drinking water supply in Kampala.

The pollution loads arriving at the IMB have been increasing over the last 15 years. Given the limited exchange of water from the IMB with the outer lake water, the accumulation of pollutants has resulted in an immense deterioration of water quality in the IMB. Oyoo (2009) found that Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN) and Total Phosphorus (TP) were above the recommended standards by the National Environment Management Authority (NEMA). According to the Inception Report of the Lake Victoria Water and Sanitation (WatSan) Project (2014: 12), "loads are indeed now at the point where

[14] NWSC, MWE; Vermeiren et al., 2012; UN-HABITAT, 2014
[15] According to the Inception Report of the Lake Victoria Water and Sanitation Project (2014), the Kampala Water and Sewerage Service Area (KWSSA) includes Kampala and the adjacent parishes of Wakiso and Mukono Districts. KWSSA currently depends on the three production plants in Ggaba (Ggaba I, II and III) with a combined production capacity of 230,000m3/d and 75% average capacity utilization. The abstraction point of the three water treatment plants is located in the Inner Murchison Bay (IMB).

the IMB offers an ever increasing conductive environment for blooms of cyanobacteria, commonly known as blue green algae". Flooding increases the amount of polluted water that comes into the lake, exacerbating the situation.

The costs to address this problem are multiple and high. The suitability of the water in IMB as a drinking water supply source has decreased such that it needs complex and expensive treatment. According to Oyoo (2009), the water treatment cost increased fourfold since 2000, mainly due to increased chemical dosage, as was highlighted by government officials (NWSC, MWE, KCCA). These costs are passed on to the consumers. More importantly, floods are threatening the potential suitability of the water of the IMB. According to Oyoo (2009), the suitability as drinking water supply source may not be sustainable in the near future. Indeed, Oyoo (2009: 6) warns that "the use of aluminium sulphate as the major coagulant for treating the water to level acceptable for drinking is soon reaching the maximum allowable limit for human consumption". According to the Inception Report of the Lake Victoria WatSan Project (2014), NWSC extended the abstraction point further (210 metres) into the IMB (off the southern side of Kiruba Island) in order to get better quality raw water, together with other goals, as we will discuss below. NWSC calculates that this had a cost of 6.5 million euros.

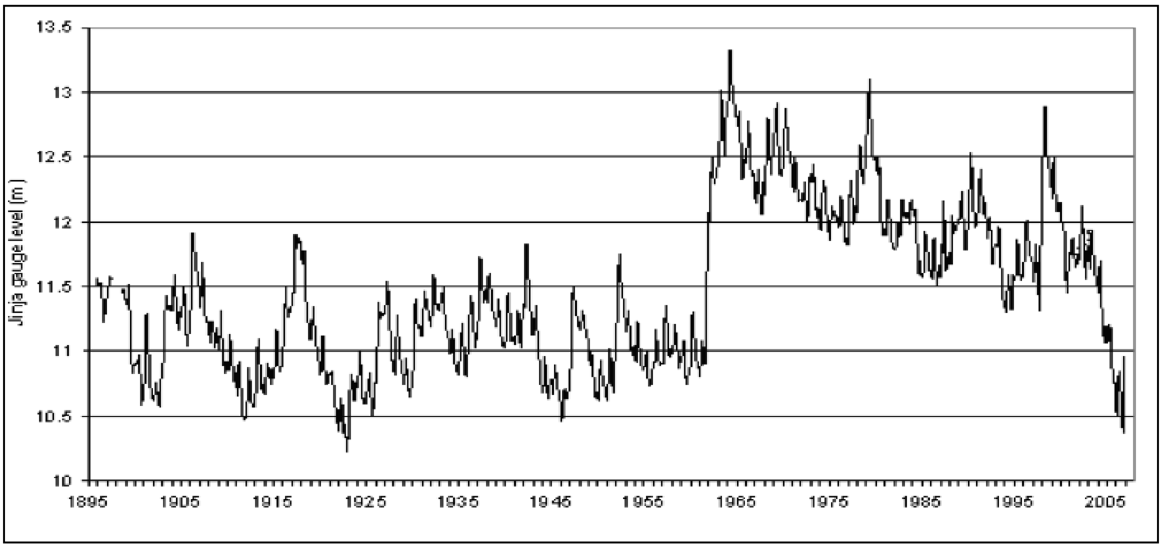
2/ Polluted water following flooding is associated with **health problems**[16]. Floods frequently cause outbreaks of waterborne diseases such as cholera, dysentery and diarrhoea. Pit latrines, which are shallow due to the height of the water table in the flood plains where many Kampala residents live, overflow with human waste and faecal matter in the flood waters, which in turn floods into shallow wells used for drinking water. According to UN-HABITAT (2010), most of the slum dwellers in Kampala do not have access to running water; their main source of water is natural springs, which get contaminated during flooding (in 2010 only 67% of the population in Kampala was served with safe water). Lwasa (2010) affirms, for instance, that malaria, dysentery and cholera epidemics have increased in Kampala since 1997 following the El Niño oscillations. Between 2003 and 2010, cholera outbreaks have occurred every year, particularly during the rainy seasons.

#### 3.1.1.2. Insufficient rainfall - droughts

Climate variability has also affected water availability, which is closely related to the water table levels in Lake Victoria. According to the Vulnerability Assessment of Ugandan Water Resources to Climate Change (2009), the levels of the Lake have historically fluctuated significantly. Nicholson (1998) found that the levels of the Lake were low during the early 19th century, rose very significantly in the 1870s, reverted back to low levels in the 1880s and suddenly rose after 1960s. More recently, the levels of the Lake decreased dramatically between 2002 and 2006, falling 1.6 metres to reach the second lowest historical level, and the lowest levels since the 1960s.

[16] According to government officials (KCCA, MLHUD, MWE, NWSC), institutional reports (Vulnerability Assessment of Ugandan Water Resources to Climate Change, 2009), slum residents (Busega area) and academic literature (Kulabako et al., 2007; Mbasi, 2009; Lwasa, 2010; Byaruhanga and Ssozi, 2012; Sliuzas et al., 2013; UN-HABITAT, 2010, 2014)

Figure 8- Observed water levels of Lake Victoria. 1895-2007




Source: Uganda's national security and the future of Lake Victoria (Tindimugaya, 2014)

The water balance of Lake Victoria is dominated by rainfall, evaporation and River Nile outflow. According to Njiru et al. (2012) and Semazzi et al. (2012), about 85% of the water entering Lake Victoria is directly from precipitation while rivers contribute 15%. According to the same sources, under normal circumstances, outflow is limited primarily to evaporation, which accounts for some 85% of the water leaving the lake. The lake's high degree of dependency on rainfall and evaporation rates means that any changes to these variables can have a noticeable impact on lake water levels and its integrity.

In this context, according to different analysts, the drop in the water level of Lake Victoria in 2006/2007 was the result of a prolonged decrease in the regional rainfall precipitation, after a strong 1997-1998 El Niño (MWE, 2009)[17], the management of the Jinja dam (CRMAS Transport Sector, 2012), and the completion of Kiira hydropower station (UN-HABITAT, 2014). The lake's receding water levels in 2006/2007 impacted on water supply, energy generation, navigation and fisheries. Although lake water levels have been increasing and stabilizing since 2007, the 2006/2007 drought provides important insights on the current and potential future impacts of climate change in Kampala.

It is important to note that Lake Victoria is in any case a regional asset, relevant beyond Kampala. Approximately 30 million people benefit from it, directly or indirectly. The lake is shared by Tanzania (51% of the lake's surface), Uganda (43%) and Kenya (6%). The drainage basin includes the neighbouring countries of Rwanda and Burundi. This leads to transboundary conflicts. 90% of Uganda's water is transboundary and therefore anything the country does has implications for other Nile Basin countries. Ugandans are concerned also about the impact of their neighbours' water abstraction and management activities on Uganda. Unmetered abstractions in Kenya and Tanzania may cause lake levels to drop and the operator of the dams -Eskom- can do little about it except through negotiation. According to the East Africa Global Water Partnership and Nile Basin Initiative representative in Entebbe, this is in any case far from being a problem currently; the abstraction of water by these neighbouring countries is "negligible". The potential increase in water abstraction from influent tributaries translates in any case into a transboundary and international issue, and Uganda needs to be able to work with the upstream states in determining how much water is flowing into Lake Victoria. These issues affect Uganda's relationships with Sudan and Egypt, and also have an important role to play in managing hydropower production at Jinja. Participation in the newly launched Lake Victoria Basin Commission should be of significant

[17] Note that we refer here at the regional level, at the whole basin; the data does not necessarily echo the rainfall data of Kampala.

value, constituting a powerful adaptation option. The 2006/2007 dry spell created, for instance, tensions between Kenya, Uganda and Tanzania.

- *Water supply*

Droughts affect Kampala in terms of domestic drinking water supply (Lwasa, 2010; Inception Report Lake Victoria WatSan Project, 2014). As noted above, a significant percentage of Kampala's fresh water supply draws directly from Lake Victoria, where the only available and functional treatment plant is located. According to NWSC officials, existing pipes could not pump water due to the drop of the level of the Lake and water supply was restricted. In this context, NWSC had to extend the pipelines further (210 metres) and deeper into the Lake. As mentioned above, the corporation spent about 6.5 million euros in the extension of pipes related with Kampala (there are three main pipe lines: Ggaba -for Kampala- Jinja and Entebbe. Kampala's extension was the most expensive; Entebbe's cost 4.1 million euros, Jinja's 2.5 million euros). The extension of the abstraction point of Ggaba sought as well to get better quality raw water, given the high level of pollution of the water that was closer to the city.

- *Energy generation*

According to MEMD, droughts have been particularly problematic for energy production. The fall in the water levels of Lake Victoria reduces the capacity of electricity generation. According to Mann et al. (2014), the current installed capacity for hydroelectricity is 630MW, distributed as follows: Nalubaale (completed in 1954) has a capacity of 180MW, Kiira (completed in 2000) of 200 MW, and Bujagali (completed in 2012) of 250 MW.

The fall of the water level of the lake affected power generation in 2006-2007. According to the Vulnerability Assessment of Ugandan Water Resources to Climate Change (2009), at the time the combined installed capacity of the two existing power stations (Nalubaale -the oldest: built in the 1960s and upgraded in 1990s to 180MW- and Kiira -built between 2000 and 2006; 200 MW) was 380MW, equal to a water flow rate of 1150 m3 s-1 (cumecs). For several reasons, the generators could not run at their maximum output. "During the extended (regional) drought of 2006, power generation came under severe pressure. On February 2006, the operator of the dams -Eskom- received an instruction from the Directorate of Water Resource Management (DWRM) to reduce water outputs to 850 cumecs. In August, flows were reduced to 750 cumecs (about 120 MW) because of declining lake levels"[18].

Although this dramatically affected the livelihoods of people through the country (CMRAS Transport Sector, 2012), according to MEMD officials, it was particularly severely felt in Kampala, which has a concentration of economic activity and, accordingly, energy demand.

In response to the decrease in hydropower capacity, the government introduced subsidies to help companies and households buy alternative energy sources. In particular, the Government waived tax on diesel products and generators, as a backup system. This triggered a surge in usage of diesel for power generation across the country and increasing carbon dioxide ($CO_2$) emissions (UN-HABITAT, 2010). Households and companies often bore costs that were not covered by subsidies; for example some companies had to reduce production as a result of limited energy availability.

It is important to have in mind, in any case, that electricity is not the main energy source in Uganda and Kampala. According to a recent study by Mann et al. (2014: 10), electricity accounts for only 1.4% of the national energy supply, which consists mainly (88.9%) of biomass fuels, with petroleum accounting for 9.7%. Nationwide, less than 7% of the population is connected to the electrical grid. According to the National Urban Policy (2014), only 39% of urban dwellers use electricity in Uganda. The information for Kampala is old. UN-HABITAT (2010: 10) uses information from 1996. At that time, wood fuel use was dominant, with 75% of households, 10% of

[18] Vulnerability Assessment of Ugandan Water Resources to Climate Change, 2009: 22

commercial, and 5% of industry relying on wood for energy, while charcoal production met 10% of energy needs in the city. This has obviously critical implications in terms of deforestation and $CO_2$ emissions (carbon production through deforestation and carbon dioxide emissions through combustion). According to UN-HABITAT (2010), demand for energy comes mainly from residential use, followed by commercial and industrial uses[19].

- *Navigation and fisheries*

According to the Climate Change Risk Management and Adaptation Strategy for the Transport Sector (2012), Lake Victoria's navigation is particularly vulnerable to variations in water levels, due to the shallowness (less than 90 metres at its deepest) and low topographical gradients of the lake. There is evidence on the impacts of droughts. In 2006, the water receded by 50 m, affecting shipping and fishing industries, as ships could not get to the port. Among other things, this affected tourism to the islands in the lake (such as Ssese).

- *Livelihoods*

Droughts have affected livelihoods directly, primarily through decreased food production. This is particularly critical for those who rely on self-provision or the income provided by selling agricultural products, which according to UN-HABITAT (2014) constitute a considerable share of Kampala's residents. For those who acquire most of the food in markets, regional and international dynamics may be more crucial.

According to UN-HABITAT (2010), droughts are also associated with health problems in Kampala, such as diseases caused by a lack of water for adequate sanitation, such as eye and skin infections. This can affect the productivity of the labour force. Droughts can also indirectly impact livelihoods through increased cost related to energy, for instance.

### 3.1.2. Rising temperatures

There is no quantitative information on the impacts of rising temperatures on buildings and housing, and water, sanitation and energy infrastructure in Kampala. The Climate Change Risk Management and Adaptation Strategy for the Transport Sector (2012) does identify damages that can arise as a result of rising temperatures on transport. In particular, the report argues that heat days can cause damage to road infrastructure, particularly to paving/pavements, such as melting the asphalt, and lead to an increase in the risk of accidents, as they increase the discomfort and exhaustion of drivers and impair their concentration and can lead to melting tyres or wearing tread, during the dry season.

It is worth noting that rising temperatures have affected the water levels of Lake Victoria through increased evaporation, and therefore, as discussed when examining droughts, have had an impact on water provision infrastructure, energy production and navigation infrastructure.

In addition, rising temperatures increase health risks related to infectious diseases, both vector-borne, such as malaria, and water-borne, such as typhoid and cholera, which has reoccurred in Kampala quite frequently in the last decade. Heat waves should also be a subject of concern, as increasing temperatures combine with the heat island effect associated with dense urban areas. It must be noted, in any case, that Kampala has a moderate climate, and as such heat waves have not been as strong as in other cities in Africa. There is no specific evidence of this impact.

[19] More details can be found in the Energy Sector Report prepared as part of this economic assessment study.

## 3.2. Explaining the impacts of climate change

There is a sensible and reasonable discussion about the extent to which the impacts described above can be exclusively attributed to climate change. Many government officials (KCCA, MLHUD, MWE, NWSC) are cautious of speculating. There are two issues here: i.) whether there is evidence of increasing threats related to climate change (how do you distinguish in the short run between climate variability and climate change); and ii.) whether exposure and/or vulnerability have increased (stakeholders typically point at what they call "human activities"). Some claim that much of what is happening, especially regarding floods, has nothing to do with climate change.

The impacts of climate variability and change are the consequence of the interaction of these three elements that make up risk – hazard, exposure and vulnerability.

In general, the impacts described above are the result of the particular weather and topographic conditions of Kampala and Lake Victoria; the exposure of the population, mainly related to the significant location of human settlements in wetlands and low-lying areas; and their vulnerability, in terms of the design and management of human settlements.

### 3.2.1. Rain pattern, topography and hydrogeology

As presented above, in Kampala, rainstorms are highly localized (often covering less than 10 square kilometres), intense (violent) and of short duration (usually lasting an hour or less) (Douglas et al., 2008). Generally, they also happen suddenly, with little lead time for warning, as they are fast-moving.

The topographic and hydrogeological characteristics of Kampala are also worth noting. Mild slopes and wetlands characterize the city. A UN-HABITAT (2013: 1) study on floods highlighted that in Kampala "there are no rivers to speak of; rather excess surface water accumulates in a natural drainage system that consists of several interconnected permanent and seasonal wetlands that together comprise eight different water catchment areas". Kulabako et al. (2007) stress, at this point, that Kampala is defined not only by a significant share of flat, low-lying areas, but also by its high water table and the shallowness and high permeability of the soil horizon (or zone) above the water table. If the first accumulates water and does not favour high flow velocities, the second implies that short rains quickly recharge the aquifer, leading to flooding of these areas. Crucially, the third reduces the contact time between the infiltrating water and soil, favouring the transportation of surface contaminants into the shallow aquifer.

The shallowness and low topographical gradients of Lake Victoria also make the Lake particularly sensitive to changes in water levels, which are mainly driven, as we have noted above, by precipitation.

Finally, temperatures are mild, which favours vector-borne diseases, but moderates the impact of the heat island effect of urban areas.

### 3.2.2. Exposure

But if these conditions imply certain threats, they do not necessarily imply damage. This is the result of exposure and vulnerability regarding the impacts of both heavy rain and droughts.

#### 3.2.2.1. Exposure to flooding

While the conditions highlighted above favour flooding of low-lying areas and wetlands, they do not necessarily imply flooding of human settlements. The impacts of flooding, and of flooding associated with climate change, can only be explained taking into account the exposure of people and their assets.

Impacts from flooding are exacerbated by the location of human settlements in low-lying valleys and wetlands[20]. According to UN-HABITAT (2013), even with large clean channels, water would accumulate in the central valleys much faster that it could evacuate. It would be impossible to prevent flooding of houses, industries and other functions without massive side impacts for the population due to relocation from hazard prone areas. Human settlements are simply too exposed.

Although regulations clearly exclude wetlands between hills from development, these have been increasingly encroached (Vermeiren et al., 2013), increasing the number of structures and occupants exposed to flooding. According to satellite data, 21% of the built-up area in 2010 was situated in the low-lying wetland zones in and around the city centre (Vermeiren et al., 2012)[21]. UN-HABITAT (2010) found, in this sense, that about 45% of residential buildings and sanitary facilities are located in flood prone areas, and that industry has historically been located in wetlands. According to UN-HABITAT (2013), between 2004 and 2010 there was a substantial increase in urban development within the 1 in 10 years flood zone. "Not only has the number of buildings in this zone almost doubled but the size of the buildings has been increasing at an even higher rate" (UN-HABITAT, 2013: 51).

The encroachment of wetlands has indeed been massive. According to Byaruhanga and Ssozi (2012), 31 out of 172 square kilometres of the city (around 18%) was covered in wetlands in 2002. However, according to several reports (UN-HABITAT, 2010, Kahangirwe, 2012; based on NEMA 2000/01), by that time only 3.3% of the total wetland area had not been degraded (in 1993, only 13% was degraded; in 1999, 46%). Byaruhanga and Ssozi (2012) show, for instance, that more than half (2.9 out of 5.29 sq. km) of the Nakivubo wetland, which is one of the largest wetland systems in the city, had already been reclaimed as early as 1998. "The Nsooba-Lubigi and the Kinawataka wetland systems have equally been affected", they affirm. According to the Kampala Physical Development Plan (KPDP) (2012), the city's wetlands have been abused for over a century and have been degraded to the point that the city has lost its form, attractiveness and identity as the "Garden City of Africa".

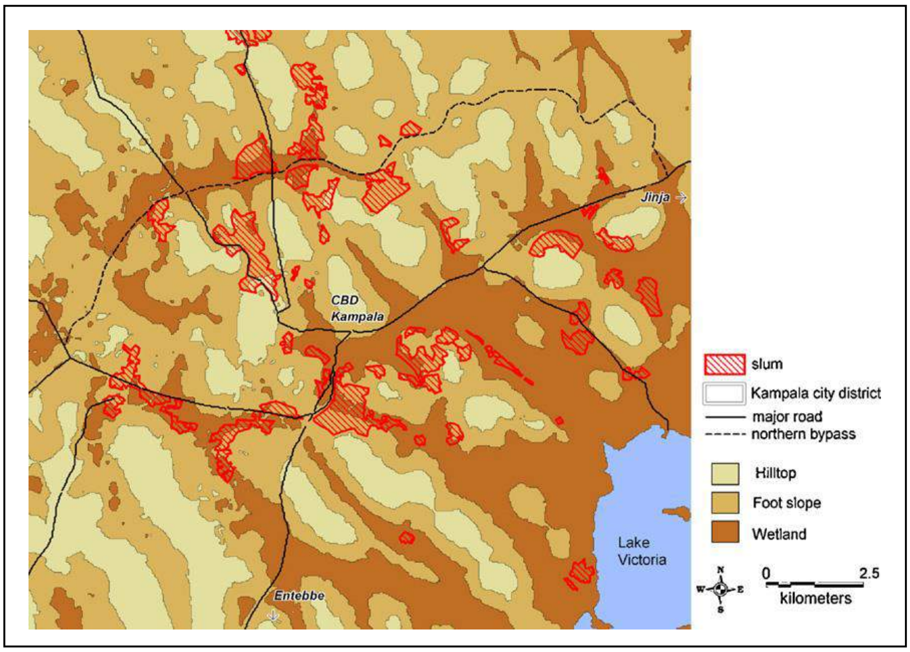
Wetlands have been encroached for the development of housing, productive infrastructure (commercial, such as shopping malls, and industrial, such as factories), communication infrastructure, such as roads, and productive activities, such as farming.

Regarding housing, wetlands have been massively encroached by the development of residential areas, mainly high-density slums, which are often constructed near and partially inside them. Map 3 illustrates this relationship.

[20] Douglas et al., 2008; Lwasa, 2010; Vermeiren et al., 2012; Vermeiren et al. 2013; Mhonda, 2013; UN-HABITAT, 2010, 2013; residents in Bwaise -Douglas et al., 2008, and Busega -this study

[21] According to Vermeiren et al. (2012: 2004-205), "foot slope areas form the largest topographic class (60% of the total study area) and comprise 61% of the present-day built-up", while "the hilltop areas form green low-density, upper class neighbour- hoods and house 18% of all built-up area".

**Map 3- Location of slums in relation to wetlands in Kampala**




Source: Vermeiren et al. (2012: 202)

These slums are typically informal in several ways, from land regulations to housing standards, and from employment to provision and access to services (Taylor and Peter, 2014). According to Vermeiren et al. (2012), these areas are attractive since they are relatively free from government policing, are easily accessible, and provide economic and employment opportunities (p. 201). Byaruhanga and Ssozi (2012) use the term urbanized rural life to describe the economic activities of these slums. These practices disregard existing regulations of urban farming, which were issued in 2005. These oblige urban farmers to obtain a permit which allows them to farm everywhere in the city apart from officially excluded land such as wetlands, together with parks and land to be developed (Vermeiren et al., 2013). Besides farming (Vermeiren et al., 2013; Lwasa et al., 2014), unemployed migrants utilize "papyrus for making craft, palm and wetland woods for fuel, (or/and) clay mining for brick and tile-making", Byaruhanga and Ssozi (2012: 192) affirm, as was also highlighted by Kabumbuli and Kiwazi (2009). The energy issue cannot be overemphasized. As we have noted, a small percentage of the residents of Kampala uses electricity, the remaining inhabitants largely relying on wood fuel and, to a lesser extent, charcoal as sources of energy, thus contributing to the depletion of the urban based environmental systems.

Wetlands have also been illegally converted by investors for the establishment of supermarkets, leisure parks, factories and small-scale business, such as welding and metal fabrication or carpentry (Byaruhanga and Ssozi, 2012). But illegal development has not been, in any case, the only driver of encroachment. UN-HABITAT (2010) affirms that spatial planning explicitly located industries in wetlands for almost 75 years (between 1920, when spatial planning was first implemented in the city and 1994). Kahangirwe (2012) argues that the development of physical infrastructure has been and is sometimes still promoted at the expense of ecological infrastructure, playing an important role on wetland degradation.

The problem, Kahangirwe affirms, is structural and is closely associated with the application of Environmental Impact Assessment (EIA). On the one hand, there are problems regarding legislation, which only covers big projects, and ignores both small and medium-scale projects and policies and programs that go beyond projects (ignoring therefore strategic environmental assessments). On the other hand, there are vital caveats regarding its implementation, since not only is it not universally implemented, but it is rarely comprehensive, focusing on the planning and construction phases, and placing very little or no emphasis on operation and maintenance (post-construction monitoring, evaluation and follow-up). In general, Kahangirwe (2012: 112) found that there is an unfortunate trend "where rather than develop existing vacant land, nearly all developers have found it more profitable, and perhaps convenient, to develop natural ecosystems like wetlands and natural forest reserves". The land itself and the provisioning services of wetlands are favoured compared to their ecological functions and regulating services, which will be discussed below.

These deficits are related to institutional and administrative deficits, such as a lack of resources (manpower, tools, technology, experience), and enforcement capacity and systems (KPDP, 2012). As the strengths, weaknesses, opportunities and threats (SWOT) analysis of institutional capacity conducted by UN-HABITAT (2010) reveals, there is a huge amount of work ahead in terms of capacity building. According to their assessment, there is a need for more technical human resource capacity and for training at managerial and technical staff levels in different areas, from advocacy to vulnerability assessment. Other studies (Mbasi, 2009; UN-HABITAT, 2013; KCCA, 2012) echo this conclusion, outlining the challenge of enforcement. The metropolitan condition of some climate change impacts, such as floods, increase the governance challenge.

Some point, however, to a more delicate issue: political economy. NEMA government officials claim, for instance, that the main problem regarding wetlands is the lack of enforcement, and that the main cause of this is political. In the officials' opinion, environmental laws are consciously overridden by political considerations. Many places should have been spared (flood abatement places), but have been developed due to political compromises. NWSC officials affirm as well that lack of enforcement is the result of lack of institutional capacity, corruption and political factors. This has considerable consequences: (i) it leads to environmental degradation; (ii) it gives perverse signals: not only is the law violated, but also informs people that it can be violated; (iii) it generates strong frustration among environmental officials. This is even acknowledged in institutional documents such as the KPDP (2012). Political interference is well documented in the academic literature. Goodfellow (2013) explains the encroachment of wetlands referring to political resources and incentives to explain it. According to him, these explain the differences with otherwise similar cities, as Kigali, Rwanda. Lambright (2014) and Resnick (2014) provide more evidence on the area of service delivery. Political economy issues are also highlighted but less critically by Douglas et al. (2008) regarding floods (priority of powerful people), Kahangirwe (2012) regarding the implementation of environmental impact assessment tools, and Byaruhanga and Ssozi (2012) in general. It is important to note, in any case, that crucial institutional changes have been implemented quite recently. KCCA has been operating for around 3 years now. Although for some national government officials the transition from the Kampala City Council (KCC) to KCCA is taking long, and technical elements must be strengthened, academic literature argues that the impacts of the re-centralization are so far unclear (Goodfellow, 2013; Lambright, 2014).

#### 3.2.2.2. Exposure to drought

Regarding droughts, exposure to climate change is also significant. The city is very sensitive to changes in water levels on Lake Victoria, which is the only water supply for the city, and the main producer of electricity for the city. Water levels on Lake Victoria are very sensitive to changes in climate variables. As noted above, around 85% of the water entering the Lake is directly from precipitation, while around 85% of the water leaving the lake is through evaporation, related to temperatures. The lake's high degree of dependency on rainfall and evaporation rates means that any changes to these variables can have a noticeable impact on lake water levels and its integrity and, therefore, in water supply and the production of electricity.

### 3.2.3. Vulnerability

The impacts described in the first section cannot be understood by referring to the threat and the exposure alone. Impacts of climate change on infrastructure, health and livelihoods are also the result of considerable vulnerability.

<u>The first driver of vulnerability to flooding is related to land use</u>[22]. On the one hand, it is associated with the development of the hill tops, clearing them of natural vegetation and therefore reducing infiltration of rainfall and increasing runoff[23]. On the other hand, it is associated with exposure, that is, the location of human settlements in wetlands. The encroachment of low-lying valleys and wetlands not only increases exposure, but increases vulnerability as well, as it reduces their capacity to capture, store and dissipate surface water run-off. It is important to note in this sense that wetlands perform key ecological and regulating functions: (i) they capture water storm and regulate its flow, preventing floods; (ii) they contribute to purifying water; (iii) they act as carbon sinks. In this context, the encroachment of the wetlands has left no room for storm water to drain, reducing its absorption capacity and increasing run off. According to Douglas et al. (2008), the construction of settlements has increased runoff by six fold. In addition, it has contributed to the silting of Lake Victoria through Nakivubo channel and its tributaries and the loss of carbon sinks.

At city level, UN-HABITAT (2013) found that the number and size of buildings increased in all the divisions of the city in the period 2004-2010: in total the building roof area increased by 262% in the period. According to Fura (2013), only in the upper Lubigi catchment, for instance, the built-up area cover increased at an annual growth rate of 6.85% and the vegetation land cover decreased at a rate of 3.5% in the period, contributing to the imperviousness of the land surface and, therefore, to runoff and, it follows, to higher risk of flash flooding. According to UN-HABITAT (2013) this is a metropolitan (cross-border) problem: runoff from the two basins where building roof area has most increased is directed outside KCCA.

<u>The second driver of vulnerability to heavy rains is insufficient, poorly designed and poorly maintained urban infrastructure</u>. Urban drainage infrastructure is scarce[24]: according to Sliuzas et al. (2013: 4-5), although the KDMP of 2002 proposed the upgrading of eight major drainage channels in the city, "to date the Nakivubo drain which evacuates storm water from the city to Lake Victoria has been completed and the Lubigi drainage channel upgrading commenced in 2012 and is yet to be completed". In this context, "frequent, high intensity tropical rain storms almost inevitably generate extremely high run-off that quickly exceeds the capacity of the urban storm water drainage system" (p. 2). According to UN-HABITAT (2013), secondary and tertiary drainage systems are particularly inadequate.

Urban infrastructure is also typically poorly designed. In his study of the upper Lubigi catchment, Mhonda (2013) found that the existing drainage system has insufficient capacity to drain heavy rainstorm events (e.g. 2 year return period and above). Likewise, Sliuzas et al. (2013) found that some culverts, as those underneath the Northern Bypass, are insufficiently dimensioned, and the primary drain is relatively narrow and shallow.

In addition, urban infrastructure is poorly maintained. OPM officials affirm that the main cause of flooding resides more on the poor maintenance of the drainage system than on the lack of the infrastructure itself. The system could potentially work, but the absence of regular desilting makes it inefficient, they claim. According to Douglas et al. (2008), the main drainage channel, originally two metres deep, was at the time of the study only 30 centimetres deep as a result of an accumulation of sediment and rubbish. Mhonda (2013) found that the

[22] Douglas et al., 2008; Oyoo, 2009; Lwasa, 2010; Byaruhanga and Ssozi, 2012; Kahangirwe, 2012; Vermeiren et al., 2012; Vermeiren et al., 2013; Mhonda, 2013; Fura, 2013; UN-HABITAT, 2013; National Urban Policy, 2014.
[23] Douglas et al., 2008; Lwasa, 2010; Mhonda, 2013
[24] Douglas et al., 2008; Oyoo, 2009; Lwasa, 2010; Sliuzas et al., 2013; UN-HABITAT, 2013

condition of the drainage system, often full of solid waste, critically contributed to flooding in the upper Lubigi catchment.

Finally, related to the previous points, there are critical deficits regarding wastewater and solid waste management[25]. First, according to UN-HABITAT (2014) and the Inception Report of the Lake Victoria WatSan Project (2014), only 8.4% of Kampala is served by the public sewerage system connected to the Bugolobi sewage treatment works. Although a second plant is constructed at Lubigi with the same capacity (200 m3/day), the remaining residents rely so far on latrines, septic tanks and open sewer systems. These systems pollute freshwater and groundwater sources, particularly following flooding, which affects latrines, although these are typically constructed over a high platform. According to the KPDP (2012: 11), "the primary threat to Kampala's valuable ecosystems is the absence of an appropriate sewage system to deal with the effluent produced by human habitation". Moreover, poor solid waste management and garbage dumping practices also contribute to flooding. According to the KPDP (2012), currently solid waste collection, recycling and disposal systems are very weak in the city, with inadequate logistics, unauthorised dumping, burning of waste, and inadequate landfill, and no composting facilities perspective. According to UN-HABITAT (2010), in 2010 the city had only one land fill managed by the council, with only about 40% of the waste in the Kampala administrative area collected and disposed of within it. Kulabako et al. (2007) found that the shallow groundwater in Bwaise, a representative slum, was severely polluted and identified multiple sources of contamination, including animal rearing, the construction of pit latrines, solid waste dumping and grey water/storm water disposal in unlined channels. In this context, according to UN-HABITAT (2014), urban municipal loads account for 77% of pollution into Lake Victoria, the major water source.

<u>As far as droughts are concerned, vulnerability is also significant</u>. The city has not identified and developed alternative water supply sources to Lake Victoria, such as, for instance, water harvesting systems, and the extension of the pipes into the lake seems to be limited. In addition, although the city does not rely significantly on electricity for energy, the current power system is very exposed to the effects of climate change and the city and the government have not significantly promoted alternative forms of generating electricity, particularly renewable ones, such as solar panels. Moreover, although there has been some progress in the trans-boundary management of Lake Victoria, the fact that water abstraction and management by neighbouring countries such as Tanzania, Kenya, Rwanda and Burundi affect the Lake's water levels constitutes a source of vulnerability, as Kampala, in particular, and Uganda, in general, are affected by the practices of third parties that they cannot fully control.

### 3.2.4. Adaptation

The preceding analysis of threats, exposure and vulnerability explains the physical, institutional and political context in which efforts to adapt to climate change are taking, and will take, place in Kampala. According to government officials interviewed, adaptation is still something very new in Uganda and Kampala. Although some sectors, such as water and transport, have already conducted sectoral assessments (Vulnerability Assessment of Ugandan Water Resources to Climate Change, 2009; Climate Change Risk Management and Adaptation Strategy for the Transport Sector, 2012, respectively), climate change is still in the process of being mainstreamed, more in terms of awareness than in terms of actual design and implementation of specific actions. In general, both at the national and the local levels, climate change information has rested in technical pockets without influencing top level management and decision-making, such as investment planning (MFPED, MoWT and KCCA officials, respectively).

A recent report by the Overseas Development Institute (Tumushabe et al., 2013) on climate change finance confirms that adaptation to climate change has yet to mature in the country. In their valuable analysis of climate

[25] Kulabako et al., 2007; Oyoo, 2009; Kahangirwe, 2012; KPDP, 2012; UN-HABITAT, 2013, 2014

change relevant public expenditures that appear in the national budget of Uganda over the period 2008/9 – 2011/12 at the national scale and in two districts (Tororo and Ntugamo) (it is difficult to track climate change expenditure in public sector budgets), the report found not only that resources are small, but they are unreliable and not particularly relevant. According to Tumushabe et al. (2013), the on-budget climate change relevant spending was indeed smaller than initially planned in the period. On-budget expenditure represented approximately 0.2% of GDP and less than 1% of government expenditure. This contrasts with the figure of 1.6% of GDP, which was recommended in the Implementation Strategy of the Climate Change Policy. In addition, only around half of planned expenditure was spent in each of the four years. Moreover, the study found that most of the programmes identified were of low relevance, the objective of expenditure not being explicitly related to climate change. "There appears to have been limited domestic investment aimed specifically at climate change actions. Instead, a great deal of expenditures passes through programmes that aim at other impacts, and therefore only a part of the expenditure can be considered climate change relevant", Tumushabe et al. (2013: viii-ix) claim.

The situation in Kampala seems to follow the same pattern. A local adaptation policy that addresses all climate change issues in an integrated, systematic and strategic way is clearly missing in the city, as the climate change assessment for it (UN-HABITAT, 2010) has not been translated into a unified body of policy. Although there is some progress mainly in terms of policy documents and institutional structures[26], so far climate change has indeed been approached rather indirectly, which is not necessarily a problem and can be a good way of integrating climate change (Taylor et al., 2014)[27]. Government officials (KCCA, MLHUD, MWE) claim that, although not many things have been done explicitly on climate change, a significant amount of the promoted actions do have indirect, implicit benefits in terms of climate change adaptation (and mitigation).

Kampala has indeed paid increasing legislative attention to environmental sustainability and climate change adaptation over the last years. KCCA has, for instance, been involved in projects that address aspects of adaptation to climate change, including the Kampala Infrastructure and Institutional Development project, the Kampala Integrated Environment Management project and the KDMP, together with projects that deal with mitigation of climate change, mainly in the fields of waste management and transport. All the aforementioned projects were conceived and implemented without a climate change dimension but driven largely by poverty alleviation, slum improvement and response to the increasing need for infrastructure.

The capacity of these measures to effectively address critical issues regarding the exposure and vulnerability to climate change is however limited, given the enforcement problems highlighted above. There are also fiscal capacity constraints, as according to Stren (2012), Kampala has US$29.2 per capita to spend in total. The absence of energetic champions, which have demonstrated to be key in other cities, such as Cape Town or Durban (Taylor et al., 2014), has limited the progress on adaptation, which, as in these other cities, has not been able to redefine the priority of competing values in favour of sustainability and resilience. The effectiveness of adaptation in Kampala is related not only to the physical structure of the city, but also to the socio-economic, institutional and political dynamics that have led to it.

### 3.2.5. Vulnerable groups

According to both government officials (MLHUD) and academic literature (UN-HABITAT, 2010; Vermeiren et al., 2012), climate change affects the urban poor living in slums and informal settlements most severely. The Inception Report of the Lake Victoria WatSan project (2014: 13) notes that around 60% of the population of

[26] Besides the creation of the Department of Climate Change, there have been changes in the sectoral ministries. A MoWT official affirmed that while some years ago there was only one climate change focal point at the Ministry, there are now four climate change focal points.
[27] The development of the National Urban Policy, which is still a draft, is eloquent. According to MLHUD officials, the first draft did not take climate change into account. In the feedback, this appeared as a critical caveat. Consultants have been conducting a lot of consultation and putting emphasis on this issue, among other changes. Ministry officials hope that climate change will be seriously considered in the final draft. Some issues have, in any case, considered so far. In that sense, there has been some progress in the last years.

Kampala, that is, more than 700,000 inhabitants, are currently living in informal settlements, covering around 25% of the total surface of the city. According to the same report, almost half of the residents of these areas earn on average less than US$ 1.25 per day, which, in terms of purchasing-power parity, was considered as the international absolute poverty line by the World Bank at the time of the study. According to the study, Katwe, Kinawataka, Natete, Ndeeba, Bwaise, Kalerwe, Katanga and Kivulu stand out among Kampala's slums.

The urban poor living in slums and informal settlements are particularly affected by certain impacts of climate change, given their high-risk locations and that they lack the infrastructure and services to withstand its effects (Taylor and Peter, 2014). They are particularly vulnerable to flooding, as they largely locate in flood prone areas. In particular, it especially affects their houses and buildings. Given the poor quality of the construction, flooding often leads houses to collapse. As presented above, in the Busega area, the destruction of perimeter walls and housing has been registered by community leaders (Kabikwa and Matovu). Flooding affects greatly as well the livelihoods of slum dwellers, including their commercial and small-scale industrial infrastructure and food production, on which many slum dwellers rely. In addition, accessibility to the slum becomes very difficult with flooding, and those residents who work outside the slum are often unable to get to their workplaces. Community leaders affirm that these impacts are common in the Busega area. The urban poor living in informal settlements are also particularly hit in terms of water supply and disease outbreaks, as they often lack access to piped water and the water they drink becomes easily polluted given that public services, such as waste collection and management, are minimal (Kulabako et al, 2007; UN-HABITAT, 2010). Droughts affect them as well through the impact on food production and water supply. The urban poor living in slums are less affected than other urban residents by the impacts of flooding on energy infrastructure and of drought in hydropower generation, as they typically rely on energy sources other than electricity, such as fuel wood and charcoal. The decrease of lake water levels affects them also less in terms of treated domestic water supply.

In any case, it is important to note that not only are the urban poor typically more affected, but they also have less capacity to recover.

# 4. ECONOMIC ASSESSMENT OF THE COST OF THE IMPACTS OF CLIMATE CHANGE IN KAMPALA

This section presents two kinds of estimates of the economic costs of the impacts of climate change in Kampala:

- Estimate of potential damages due to climate change, with a specific focus on the cost of damages to humans and physical capital caused by extreme events, namely flooding, to 2050, with the same and double frequency.
- Estimate of the cost of adaptation, with a specific focus on the cost of climate proofing as far as possible new and existing buildings and transport infrastructures against the projected temperature and precipitation changes to 2050.

The two estimates provide crucial insights regarding the magnitude of costs:

- Costs to climate proof infrastructure are significant: between US$3.2 billion and US$3.7 billion over the 2015-2050 period, between US$560 million and US$600 million only over the period 2015-2030. These figures are undiscounted so expenditures, which are presented for five year intervals in different periods can be compared, and the reader can see how they evolve over time.
- Costs increase with time, to a large extent due to population growth. Costs start out quite small but build up over the period to 2050 as the level of construction increases. In 2020 they range from US$11-13 million a year but by 2050 they are as high as US$380-485 million. In terms of percentage of GDP they go up from 0.03-0.04% in 2015 to around 0.1% in 2050. In per capita terms they go up from US$2-3 in 2015 to US$27-34 in 2050.
- Total costs vary considerably by socio-economic and climate scenario. With the more climate friendly scenario (RCP4.5) the total cost to 2050 is around US$3.2 billion. With the less friendly scenario (RCP8.5), with little mitigation action, total cost goes up to US$3.7 billion (27% greater). However, the difference between scenarios is not significant until the end of period.

The estimation also provides relevant information on the distribution of the cost of adaptation.

- New construction and additional maintenance account for relatively similar costs (additional maintenance accounts for just above half of total costs).
- Buildings account for most of the costs (99.8%). Transport only accounts for 0.2%. This is partly due to the negligible impact of precipitation on adaptation costs. The climate scenarios show a decline in precipitation over the period. As this component has a greater effect on transport, the costs for that sector are reduced.
- Within buildings, the most affected sector are residential buildings, which account for around 72% of all costs. Next are non-residential private buildings, which account for 23%, and then comes public infrastructure with 2%. The burden of climate change adaptation will therefore fall significantly on the private sector. Although the public sector's share is small, action in that sector is urgent, as it concerns critical services such as hospitals, transport facilities, schools etc. Given the affordability problems of low cost housing, some of the costs theoretically borne by the private sector may need government support. We will further discuss the role of the government on adaptation in the policy recommendations sector.

Several issues must be taken into account.

- These figures are based on projected population and physical infrastructure growth contained in the Kampala Physical Development Plan (2012). The planning literature (e.g. Vermeiren et al., 2012) considers that the City could grow to as much as 25 million people by 2050. In that case damages would be close to double the figures given above.

- As highlighted above, the estimates report costs based on the climate projections as summarized in Table 1. Since that table indicates a fall in precipitation there is no expected increase in costs of new and existing roads and bridges from that variable.
- The costs of additional infrastructure to deal with climate events are not included in this assessment. A preliminary scan of the sources of such expenditure in the World Bank study revealed that either the item could not be justified for Uganda (e.g. additional roads to meet demand for travel due to higher temperatures); or that it would be covered in another sector study (e.g. demand for health, energy and water services).

In the preceding sections we have analysed the impacts of climate change in Kampala in a qualitative way, based on the existing literature, the information provided by key stakeholders in the city and our own analysis. In this section we conduct an economic assessment of the impacts of climate change in the city, giving figures to the likely future impacts of it. The preceding qualitative analysis helps us better understand the numbers provided in this section, putting them in context.

## 4.1. Conceptual and methodological aspects of the economic assessment of the impacts of climate change

### 4.1.1. Conceptual aspects

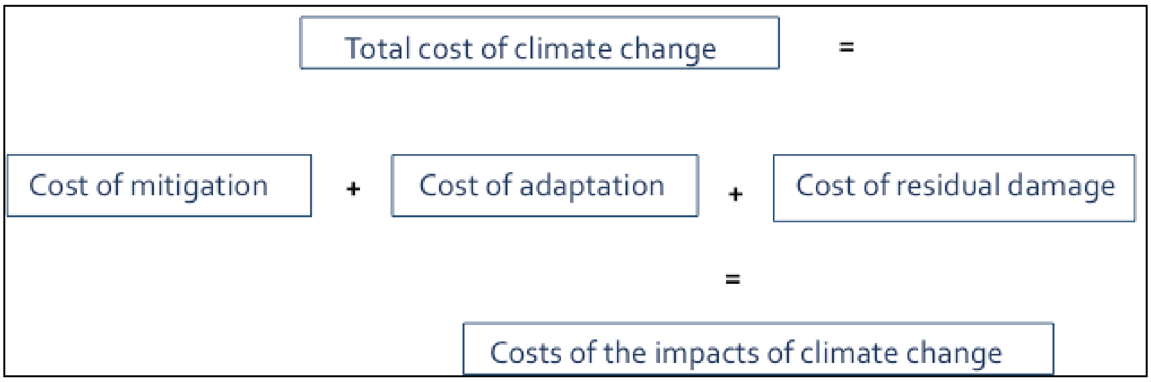
According to Fankhauser (2010: 24), the total costs of climate change include three elements:

- the cost of mitigation,
- the costs of adaptation, and
- the cost of residual damage.

The first refers to the cost associated with the reduction of the anthropogenic forcing of the climate system, diminishing the extent of future climate change (cost of mitigation). The second refers to the cost of reducing the impacts of such a change (cost of adaptation). The third refers to the cost of impacts that can be neither mitigated nor adapted to and that remain after such actions have been taken (cost of residual damage). As UNEP (2013) argues, the costs of the impacts of climate change can be defined as the sum of the costs of adaptation and the cost of residual damage. In this sense, two different economic assessments of the impacts of climate change are typically done. While estimates of damages refer to the total costs of the impacts of climate change, estimates of adaptation refer to only one part of them, as they do not consider the cost of residual damage.

This conceptual relationship is explained in Figure 9.

Figure 9 - Total costs of climate change

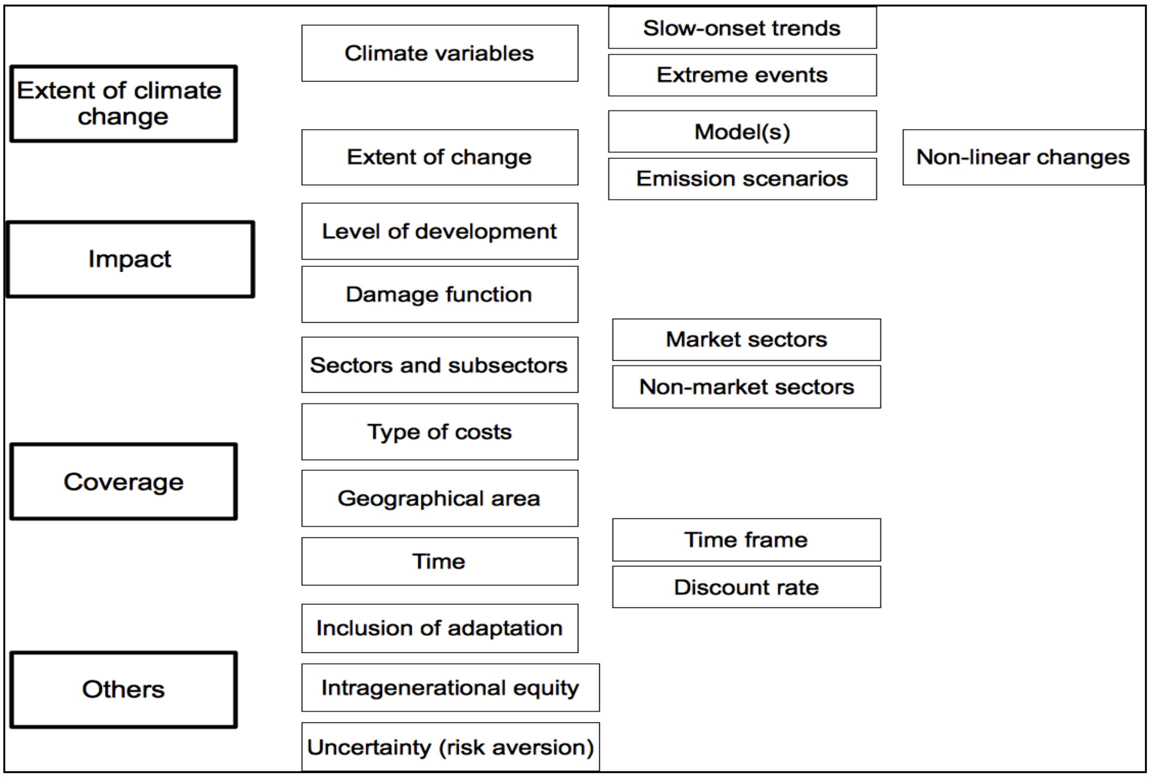



Source: Adapted from Fankhauser (2010)

### 4.1.2. Methodological aspects

The economic assessment of the impacts of climate change is a complex exercise that requires a significant number of decisions. In particular, it requires an estimate of the degree of climate change (climate variables and extent of change), the impacts (level of development and damage function), the coverage (sectors and subsectors, types of costs, geographical area, time frame and discount rate) and other issues regarding intra-generational equity, the inclusion of adaptation or the extent of risk aversion (Garcia and Markandya, 2014). This is presented in Figure 10.

Figure 10 - Choices for the economic assessment of the impacts of climate change.




Source: Garcia and Markandya (2014)

Estimates of these different categories not only include uncertainty, but also involve considerable ethical choices. Guidelines for good practices significantly help in making them. For instance, in order to be sound the approach to the costs of the impacts of climate change should be as comprehensive as possible. These decisions are often critically conditioned by the availability of data.

## 4.2. Scope of this study

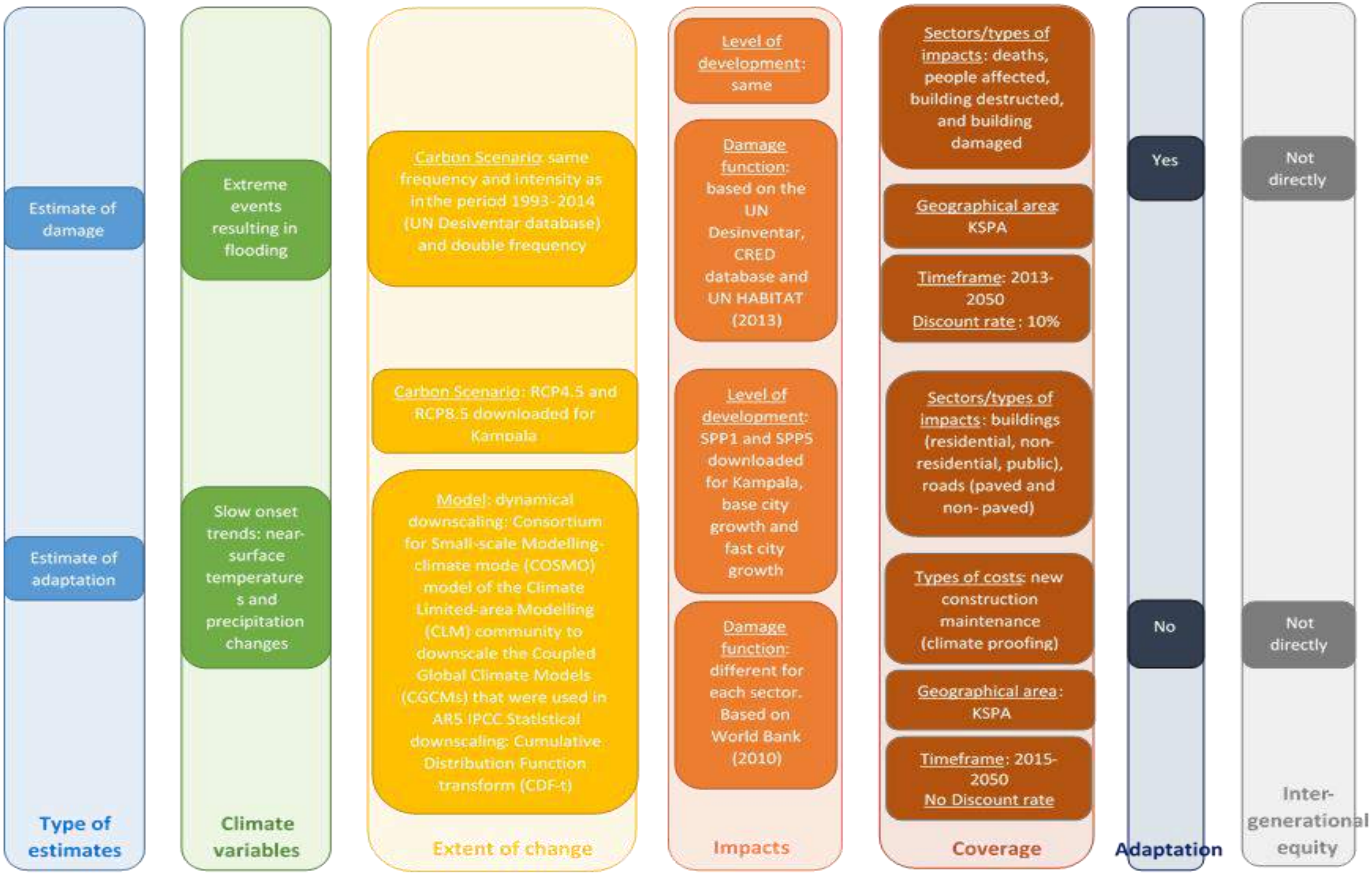
The development of this study clearly illustrates the importance of data availability. Constructed from primary data, estimates in this study have indeed had little to draw on in terms of local studies of impacts in the city. Our review shows that the existing institutional data is poor not only regarding the assessment of the past and current cost of climate variability and change, but also regarding basic, reference information that could be used to produce such an assessment. In particular, information on the sectoral cost of the impacts of climate change in Kampala is scarce. Quantitative assessments of particular types of impacts (floods or droughts) are not available for entire sectors, but only for some issues, such as the cost of extending the pipes further into Lake Victoria. This lack of data has not allowed us to conduct an economic assessment of the impacts of climate change in sectors such as water supply, health and agriculture in the city.

In this context, this study presents two kinds of estimates of the economic costs of the impacts of climate change in Kampala.

- First, it provides an estimate of potential damages due to climate change, with a specific focus on the cost of damages to humans and physical capital caused by extreme events, namely flooding, to 2050, with the same and double frequency.
- Second, it provides an estimate of the cost of adaptation, with a specific focus on the cost of climate proofing as far as possible new and existing buildings and transport infrastructures against the projected temperature and precipitation changes to 2050.

More details on the scope of the economic assessment of this study is provided in Figure 11. Note that the two estimates consider different elements and cannot therefore be directly compared.

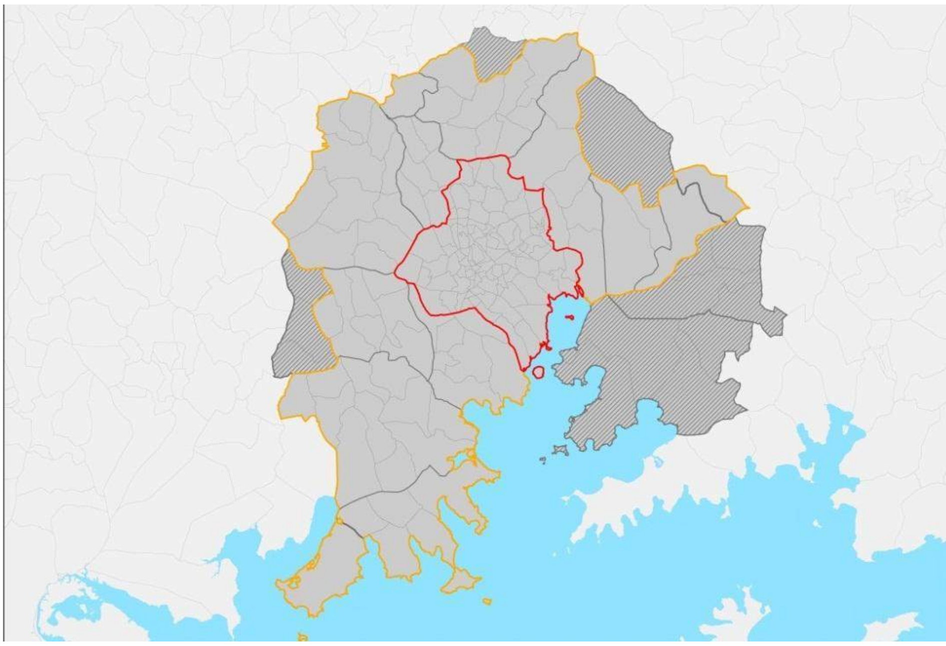
**Figure 11. Scope of the economic assessment**




* KSPA: Kampala Special Planning Area

The study of the costs of the impacts of climate change covers the Kampala Special Planning Area (KSPA), as defined by the Kampala Physical Development Plan (2012), the main planning document of the city, and from where the study has taken data on population, housing, transport infrastructure, etc. The area considered under the KSPA is wider than Kampala and the GKMA. Map 4 illustrates the boundaries of the KSPA.

**Map 4. Kampala Special Planning Area**



Note: The red line represents the boundary of Kampala. The yellow line represents the boundary of the GKMA.
Source: KPDP (2012: 12)

This study provides first estimates of the cost of damages and costs of adaptation for Kampala and an urban area in Uganda, following the IPCC methodology and considering specifically downscaled slow onset trends and some extreme events, such as flooding. Although incomplete, the study selects the most critical issues, regarding both damages from extreme events and adaptation strategies. While flooding is the most important extreme event for the city (see 2.2.1.1), climate proofing buildings and roads seem not only necessary, but also strategic to significantly improve resilience in the city, as the qualitative analysis has shown (see 2.3 and 2.4). In addition, the study provides some insights on which types of impacts are likely to represent greater costs (death, people affected or buildings destroyed or damaged for damages; and buildings or roads, and which type of building for adaptation).

However, it is also important to recognize the limitations of the study. The estimate of damage does not directly consider either slow onset trends (i.e. changes in temperature and precipitation) or extreme events other than floods, such as droughts and heat waves, which could be relevant. In addition, focusing on flooding, it does not assess the portion of total climate change damage that flooding damage might comprise. Moreover, it covers only the impacts of floods in terms of loss of life, damage to property and effects on persons due to disturbance of economic activity. Costs to businesses from delays and disruption are not included. The estimate of costs of adaptation includes only infrastructure, and therefore ignores important sectors such as health, water supply or ecosystems degradation, and other soft adaptation measures. In this sense, a more comprehensive estimate of damage and/or adaptation would likely indicate greater damage and adaptation costs. Furthermore, in terms of geographical detail, the estimates do not provide disaggregated data, so they do not inform about where in the city the costs of damages and/or adaptation could be greater, and, in this sense, which population could be more affected. Finally, given that they consider different climate variables and types of impacts, the estimate of damage cannot be compared to the estimate of adaptation to calculate if adaptation is cost-effective. A proper cost-benefit analysis for some adaptation strategies is provided below. As discussed above, given data limitations, this is the best the study team could do.

The two estimates provided in this study have some particularities. In the next section we explain all the choices made, including assumptions, when conducting the assessment.

## 4.3. Methodology

### 4.3.1. Estimates of damage

As discussed above, Kampala is subject to frequent heavy rains, resulting in flooding. Damages caused by such events are commented on in qualitative terms but it is difficult to find much quantitative data on them. As we have noted, the one source that has some information is the UN Desinventar database, which gives information on frequency and impact for Kampala. In Table 2 we present the figures for Kampala from 1993 – 2014 for floods, rains and storms. In that period there were 11 events, resulting in 38 deaths, 67,713 people affected and 123 homes destroyed and around 21,000 homes damaged.

In order to value these damages we work on an 'expected annual event' basis. Damage estimates from the above events are converted to an annual average and these are then valued assuming no change in frequency or intensity. The case of a possible increase is considered separately.

The basis of the valuation is as follows:

- For deaths we apply a Value of Statistical Life (VSL). The basis for this is discussed in the National Infrastructure Report that is part of this project. Considering different reasonable methods, estimates for 2014 for Uganda are estimated to be between US$81,256 and US$2.1 million per life lost.
- For people affected we use estimates from the CRED database where economic damages are reported by country. Unfortunately there are not enough events that are valued for Uganda to provide a reasonably reliable estimate but there were a reasonable number for East Africa, which indicated a value per person affected of US$35. At the same time the one data point for Uganda was the 2013 flood where damage per person affected was US$117. Hence we take this range to obtain estimates of damage per person affected.
- For homes we have taken the value of an average dwelling in the country, which is the value of all dwellings divided by the number of dwellings in the country. This is estimated at US$18,600 (See the discussion in the previous section).
- In addition a further estimate has been made of damages to buildings that does not result in destruction but involves damage and loss of household inventory. This has not been included in the CRED or other databases. For Kampala, we take the number of buildings in the one-in-ten year flood zone and assume that, without further preventive measures, such a flood would cause damage equal to 2% of the construction cost of the building[28]. From the UN-HABITAT Report on flood risks in Kampala, the estimated number of buildings in 2010 at risk was 17,362. Assuming trend annual growth of 6.5% (KCCA 2012a)[29] this number can be assumed to have gone up to 20,972 by 2013, with a total

[28] Damages estimates per building due to a one in ten year flood could not be found for Uganda or other countries in the region. Estimates for Europe are around 0.5% of property value or about 1% of the costs of construction (Foudi et al., 2015). Damages are likely to be higher in Uganda where construction is more flimsy so we have taken damages at 2%. Of course for individual properties damages can be very high – you may lose the entire dwelling, for example. But averaged across properties in a zone, with many suffering no damage and others only minor damage, a doubling of the European figure seems reasonable.

[29] This is based on the estimate of the growth in dwellings in Kampala as made by KCCA. Note that it is higher than the city's population growth rate, which is 5.1% p.a. over the period, given that there is a housing shortage that will be corrected over time.

value of US$390 million. On the basis of a one in ten year flood and an average 2% damage per event the expected annual damage to buildings would be US$0.8 million.

The VSL values as well as the value of homes and infrastructure and other damages are assumed to increase over time based on per capita GDP. The number of deaths is also assumed to increase with population.

**Table 2. Economic Assessment of Impacts of Floods and Rains in Kampala: Data Sources and Methods**

| Impact | Source | Data | How Valued | Estimates |
|---|---|---|---|---|
| Deaths | UN Desinventar database data for Kampala Plus CRED database for damages to affected persons | Numbers killed 1993-2014 (38) equal to 2.7 deaths per year. | Value of statistical life increased over time to reflect per capita GDP growth. Estimates are per year | Range of US$0.22 to 5.7 million in 2013. |
| People Affected * | | Number affected 1993-2014 (67,713) equal to 4,837 per year. | Based on estimates in CRED database for East Africa, damages per person affected are $35-117. These increase over time with per capita GDP growth. | Range of US$0.17 to 0.57 million per year. |
| Building Destruction | | Number houses destroyed 1993-2014 (123) equal to 9 per year. | Valued based on average construction cost for residential buildings as calculated above, which gives a figure of US$18,600 per dwelling. This increases over time with per capita GDP. | US$160,000 per year. |
| Damage to Buildings | UN HABITAT (2013) Report. | Number of houses affected in flood zones of Kampala approx. 21,000. | Buildings valued using costs of construction. Damages Damage per event set at 2% of construction cost | US$0.8 million per year |

http://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=uga#more_info

* The number of persons who suffer indirect or secondary effects related to a disaster. This refers to the number of people, distinct from victims, who suffer the impact of secondary effects of disasters for such reasons as deficiencies in public services, commerce, work, or because of isolation. If the information refers to families, calculate the number of people according to available indicators.

This study considers as well a possible increase in the frequency of floods. Although, as noted above, there is no formal climate projection on increased frequency of extreme events or of their intensity, recent evidence indicates an increase. The CRED database identified 16 major flooding events and 9 major droughts in Uganda between 1900 and 2011[30]. It is striking that 8 out of the 10 most severe floods and droughts during this period were within the last 20 years (CRED, 2014). These include major events occurring in 2001, 2002, 2005 and 2008 (UNDP, 2013). In Karamoja severe droughts are now occurring every two to three years as opposed to approximately every five years in the past (USAID, 2011). Given this status of information, a second estimate has been made, assuming that the frequency of extreme events doubles by 2050 and increases linearly between 2013 and 2050.

Regarding the discount rate, the study uses 10% in real terms, which is commonly used by multilateral agencies such as the World Bank to appraise projects in developing countries. The Government of Uganda did not recommend researchers to use a different discount rate.

[30] http://www.emdat.be/

## 4.3.2. Estimates of the cost of adaptation

The economic assessment of the cost of climate-proofing buildings and transport infrastructure as far as possible in Kampala uses a methodology developed in the World Bank's 2010 Costs of Adaptation Study (World Bank, 2010).

### 4.3.2.1. Climate scenario

The estimate of the cost of adaptation of this study is based on specific forecasts for economic output of the city and climate scenarios. In particular, the results presented in this study are based on combining two Socioeconomic Scenarios Pathways (SSP), as defined by IPCC, with two Representative Concentration Pathways (RCP), also defined by IPCC. Both sets of scenarios have been downscaled for the Kampala area.

The RCP pathways chosen for the climate assessment are RCP4.5 and RCP8.5 that have been described above. The temperature and precipitation for Kampala have also been explained above. It is important to remember that temperature increases under RCP4.5 are estimated at around 1.5ºC to almost the end of this century, while under RCP8.5 it is estimated at around 3ºC over the same period, and that in both cases precipitation is expected to decrease 20mm over a 12 month running mean.

### 4.3.2.2. Level of development

o *General development*

The SSP scenarios chosen are SSP1 and SSP5 and are described as follows [31]:

- SSP1 assumes that: "relatively good progress is made towards sustainability, with sustained efforts to achieve development goals, while reducing resource intensity and fossil fuel dependency. There is rapid development of low-income countries, a reduction of inequality (globally and within economies), rapid technology development, and a high level of awareness regarding environmental degradation. The world is characterized by an open, globalized economy, with relatively rapid technological change."
- SSP5 stresses conventional development oriented toward economic growth as the solution to social and economic problems through the pursuit of enlightened self-interest. The preference for rapid conventional development leads to an energy system dominated by fossil fuels, resulting in high GHG emissions and challenges to mitigation.

These scenarios have been downscaled to the level of the city of Kampala by taking the share of the population of the country that is in Kampala and estimating that its share of national output (GDP) is 50% of the country's GDP[32] (we refer to this as "City GDP"). In 2010 KSPA had about 3 million people. Projections are for faster growth of the city relative to the rest of the country, so that by 2040 it will have 12 million inhabitants and by 2050 around 14 million[33]. Its share of GDP is assumed, however, to remain at 50%, assuming that other cities will grow in economic importance and Kampala will not dominate the economic landscape any more than it does now[34]. The corresponding GDP estimates for Uganda are given in Table 3.

[31] Further details of the projections are available from https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=series. When you get to the site you need to log in as a guest.
[32] http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/AFR/2013/06/18/090224b081c7d836/1_0/Rendered/INDEX/ProjectoInformooProjecto2oooP133590.txt.
[33] Based on KCCA (2012). Under Business as Usual the population will grow to around 12 million by 2040. After that we assume city growth at the same rate as the national population.
[34] This assumption seems reasonable. It is not uncommon for a metropolis of a country to account for around half of GDP.

**Table3. GDP and Population Projections for the City of Kampala**

| | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| City GDP SSP1 $ Bn. | 19.2 | 25.3 | 35.6 | 52.6 | 79.8 | 121.8 | 183.4 | 270.2 | 388.0 |
| Growth p.a. | | 5.7% | 7.0% | 8.1% | 8.7% | 8.8% | 8.5% | 8.1% | 7.5% |
| City GDP SSP5 $Bn. | 19.2 | 25.3 | 35.6 | 54.1 | 86.6 | 140.7 | 222.6 | 340.8 | 505.0 |
| Growth p.a. | | 5.7% | 7.1% | 8.7% | 9.9% | 10.2% | 9.6% | 8.9% | 8.2% |
| City Population (Mn.) | 3.00 | 3.66 | 4.46 | 5.80 | 7.39 | 9.42 | 12.00 | 13.10 | 14.30 |

Sources: See text

In this analysis SSP1 has been combined with RCP4.5 and SSP5 with RCP8.5. Although the two are not proven to go together there is a strong presumption that SSP1 is consistent with the more climate friendly RCP and SSP5 is consistent with the less climate friendly RCP.

### o *Estimates of the stock of infrastructure*

Stock estimates are required for the city's residential housing, non-residential buildings and public infrastructure as of 2014. The estimates are derived as follows.

#### Residential Buildings

The KCCA (2012) estimates that in 2011 the city had 800,000 housing units with an average area of 55M$^2$ (Kampala Physical Structure Plan). The aim is to increase this to 1.5 million by 2022, each with 70 M$^2$, and to 2.2 million in the "long term", each with 78 M$^2$. We assume that the plan to attain 1.5 million units is realized but over a period to 2025 and at the same time the goal of increasing average space of 78m$^2$ is also realized[35].

The value of the cost of construction for existing and future stock has been derived from estimates of costs of construction in 2011 obtained from a study by Mayer of the University of Oregon (Mayer, 2011). He estimated that a unit providing basic shelter costs around US$9/M$^2$ to construct (including all construction and planning costs), while a unit providing what could be referred to as housing of a reasonable standard would cost US$440/M$^2$. We have used these figures, adjusted for the increase in prices between 2011 and 2014 and interpolated for other categories of housing that are classified in the KCCA (2012) report referred to above to get unit costs for them[36]. The categories of housing are (in order of quality): basic housing (one up from basic shelter), improved housing (two up from basic shelter) and higher standard (one up from reasonable standard). Given the number of units in each category the estimated construction cost for the stock in 2011 (in 2014 prices) was US$15 billion and an average cost per unit of US$18,600. Allowing for the increase in stock and quality to 2014 gives a value for that year of US$19.9 billion.

From 2025 onwards it is assumed that the stock will grow along with GDP, but historic data show that the real estate sector grows a little slower than GDP: the ratio of the two growth rates is 0.68 between 2004 and 2009. Hence future growth was adjusted for this difference.

[35] Note that this assumption allows for some slippage in the programme given that the Uganda Government aims have been evidenced to not be met in other areas. However, it is reasonable to assume that the aims of the programme will be achieved at some point in time.

[36] When there are values for low and high cost categories, intermediate categories can be estimated by taking a weighted average of the two limits.

### Non-Residential Buildings

For non-residential buildings there was no direct estimate available for Kampala or other Ugandan or African cities. Studies from other countries indicate that the ratio of non-residential floor space to all floor space ranges from 18% in China to around 33% in the EU and USA[37]. Given that in the case of Uganda it is likely to be much lower, we assume an initial ratio of 13% in 2014. Over time, however, the stock grows with GDP so that by 2050 it is around 23% of the total stock, closer to the value in middle income countries.

### Public Buildings

For social infrastructure an estimate was made based on investment data from 2005 -2012. Data are provided in the Uganda Bureau of Statistics Statistical Abstracts on such investment as well as in total capital formation. An initial value for 2004 was estimated based on capital stock estimates for Uganda for that year from the University of Groningen and University of California, Davis Capital stock data[38]. The share of total capital stock that was made up of social infrastructure was estimated at 12.7% (the share of public construction investment in total capital formation). This gives an estimate of the capital stock in 2014 of US$7.8 billion. The share of these buildings in Kampala was assumed to be in proportion to the City's share of GDP (i.e. 50%). Future social infrastructure capital stock was assumed to grow with GDP but adjusted for the fact that social capital has grown in the country a little slower than all capital (the ratio of the two rates has been approximately 0.74).

### Roads and Railways

#### *Roads*

For roads the main document that has been used is the KCCA (2012) Kampala Upgrading Structure Plan, which states that the 2012 network of roads in the City amounted to 1,976 km, of which 1,241 km were paved. The plan, if fully realized, is to extend this by 2022 to 2,153km, of which 1,314 will be paved. The kilometres of highways within the paved category would increase by 177km. We assume this plan will be realized in full but by 2025. Thereafter we assume a similar rate of addition will apply.

#### *Railways*

There are no firm plans for a railway line or other such system for Kampala although a number of documents mention various options.

## o *Direct costs of climate change (need of adaptation)*

The calculations of the costs of climate change are based on assumptions from the World Bank (2010a) study referred to earlier. They divide the process into two: additional costs for new construction and additional costs for maintenance. The cost of climate-proofing infrastructure includes actions to reduce damages from subsidence due to higher temperatures and rainfall as well as well as damages from increased precipitation. Materials used to withstand higher temperatures cost more and that additional cost has been estimated and included in the calculations.

### Additional Costs for New Construction

The following assumptions are made based on the World Bank Study referred to above:

Buildings:

- 0.8% increase in base cost per 10cm increase in precipitation
- 0.22% increase in costs per incremental change in temperature = (0.5°C)

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[37] http://energycodesocean.org/sites/default/files/resources/WBCSD_EEB-Facts&Trends-FullReport.pdf
[38] http://research.stlouisfed.org/fred2/series/RKNANPUGA666NRUG

Paved Roads:

- 0.29% increase in costs per incremental change in temperature = 1ºC and then for each 3ºC increase

Unpaved Roads

- 0.8% for each 1% increase in maximum precipitation. Base cost is US$13,000 per km for unpaved roads in the US.

For capital investments of the kind being considered here, the design is set to cope with the temperature or precipitation during the entire lifetime of the structure, which is taken to be 50 years. So plants built in 2010 have to withstand climate changes to 2060 and those built in 2045 have to be able to withstand climate changes 80 years from now – i.e. in 2095. This implies some over engineering because for most of their lives the infrastructure will not face such climate extremes. On the other hand there is some uncertainty in the estimates and the precautionary principle would advise allowing for possible increases at the upper end of the range.

### Additional Costs for Maintenance based on the World Bank Study

Buildings:

- % increase in precipitation X 0.15 X Baseline construction costs where precipitation increase are measured in units of 10cm
- % increase in temperature X 0.28 X Baseline construction costs

Paved Roads:

- % increase in precipitation X 0.04 X Baseline construction costs where precipitation increase are measured in units of 10cm
- % increase in temperature X 0.36 X Baseline construction costs

Unpaved Roads:

- 0.8% per 1% increase in rainfall. US costs are US$930/km/yr.

Maintenance costs apply to increases in temperature and rainfall during the five year periods from 2015 to 2050. It is assumed that increases in earlier periods will be linear relative to the increase at the end of the period.

Maintenance costs of paved roads only apply to roads built prior to 2015: new roads adapted to climate change do not have additional costs.

It is important to note that there is no increase in costs due to climate change on unpaved roads given that climate change projections produced by Rautenbach (2014) do not predict an increase in precipitation.

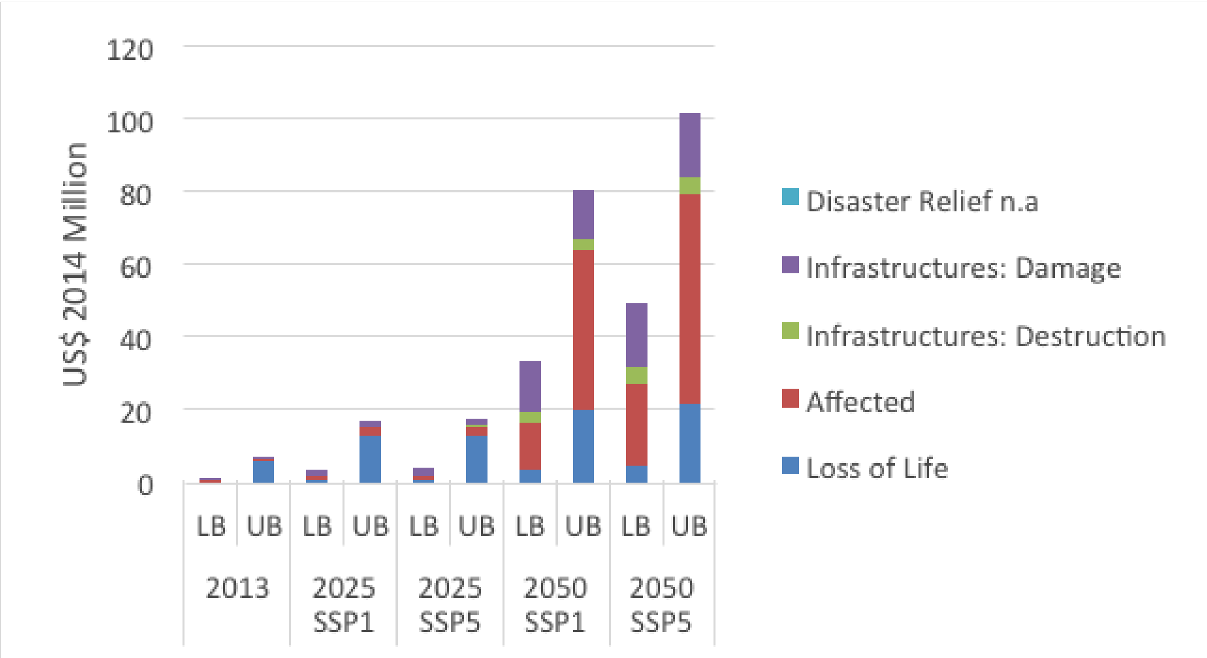
# 4.4. Economic assessment of the impacts of climate change in Kampala

## 4.4.1. Estimates of damage

This study provides estimates of damage to 2050 for the same frequency of flooding as at present and a doubling of the frequency[39]. If the intensity and frequency of extreme events leading to flooding do not change, current annual damages of between US$1.3 and US$7.3 million in 2013 could rise to between US$3.7 and US$17.6 million by 2025 and between US$33.2 million and US$101.7 million by 2050. In terms of GDP, current damages could rise from between 0.003 and 0.016% in 2013 to between 0.004 and 0.016% in 2025 and between 0.004 to 0.01% of GDP in 2050. The increase is the result of a growing population and assets that are worth more. There is not much difference between the RCP scenarios, as there is no assumed change in extreme events by scenario.

**Table 4 and Figure 12 - Expected Annual damages from Floods and Related Events in Kampala with No Change in Frequency US$2014 Million**

| | 2013 | | 2025 SSP1 | | 2025 SSP5 | | 2050 SSP1 | | 2050 SSP5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LB | UB | LB | UB | LB | UB | LB | UB | LB | UB |
| Loss of Life | 0.22 | 5.70 | 0.75 | 12.64 | 0.78 | 12.77 | 3.59 | 20.18 | 4.77 | 21.97 |
| Affected | 0.17 | 0.57 | 0.72 | 2.41 | 0.74 | 2.49 | 13.15 | 43.96 | 22.25 | 57.15 |
| Infrastructure: Destruction | 0.16 | 0.16 | 0.38 | 0.38 | 0.39 | 0.39 | 2.80 | 2.80 | 4.73 | 4.73 |
| Infrastructure: Damage | 0.80 | 0.80 | 1.85 | 1.85 | 1.91 | 1.91 | 13.69 | 13.69 | 17.81 | 17.81 |
| Disaster Relief | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | | | | | | | | | | |
| Total | 1.35 | 7.23 | 3.71 | 17.29 | 3.82 | 17.55 | 33.23 | 80.63 | 49.56 | 101.66 |
| As Percent of GDP | 0.003 | 0.016 | 0.004 | 0.016 | 0.004 | 0.016 | 0.004 | 0.010 | 0.005 | 0.010 |



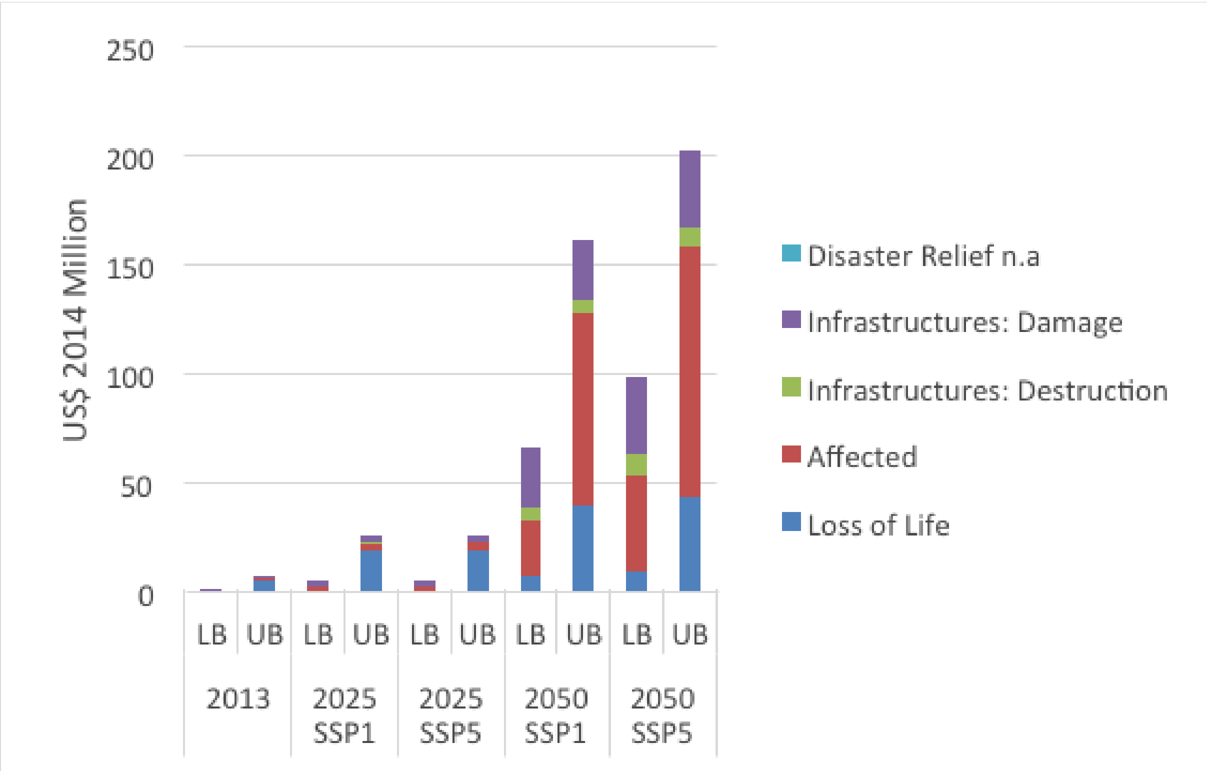

Source: See text.
LB: Lower Bound; UB: Upper Bound (represent results from different scenarios); n.a.: Not available

[39] The base case takes the rate of damages per year in the period 1993 to 2014. That is to say the damages over the period from all events are divided by the number of years. When we consider the doubling of frequency we multiply that damage per year by two.

If the frequency of extreme events doubles by 2050 and increases linearly between 2013 and 2050, damages in 2025 would range from US$5.6 to US$26.3 million and in 2050 from US$66.5 to US$203.3 million.

**Table 5 and Figure 13 - Expected Annual damages from Floods and Related Events in Kampala with Doubling of Frequency by 2050 US$2014 Million**

| | 2013 | | 2025 SSP1 | | 2025 SSP5 | | 2050 SSP1 | | 2050 SSP5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LB | UB | LB | UB | LB | UB | LB | UB | LB | UB |
| Loss of Life | 0.22 | 5.70 | 1.13 | 18.96 | 1.17 | 19.15 | 7.18 | 40.36 | 9.53 | 43.94 |
| Affected | 0.17 | 0.57 | 1.08 | 3.62 | 1.12 | 3.73 | 26.30 | 87.92 | 44.49 | 114.30 |
| Infrastructure: Destruction | 0.16 | 0.16 | 0.57 | 0.57 | 0.59 | 0.59 | 5.60 | 5.60 | 9.47 | 9.47 |
| Infrastructure: Damage | 0.80 | 0.80 | 2.78 | 2.78 | 2.86 | 2.86 | 27.37 | 27.37 | 35.62 | 35.62 |
| Disaster Relief | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | | | | | | | | | | |
| Total | 1.35 | 7.23 | 5.56 | 25.93 | 5.73 | 26.33 | 66.46 | 161.26 | 99.12 | 203.33 |
| As Percent of GDP | 0.003 | 0.016 | 0.005 | 0.025 | 0.005 | 0.024 | 0.009 | 0.021 | 0.010 | 0.020 |




## 4.4.2. Estimates of the cost of adaptation

### 4.4.2.1. Previous assessments

Before this study there was no assessment of costs of adaptation available for Kampala. The most relevant reference was the Costed Implementation Strategy of the National Climate Change Policy (CIS-NCCP) of the government. This document shows how much the NCCP believes Uganda must spend to ensure adaptation to (and mitigation of) climate change from 2013 to around 2030. The method used to estimate the additional cost for addressing climate change adaptation is based on the World Bank (2006) and the Stern Review (2006). They estimate that this cost is between 2 and 10% of gross domestic investment. They use three scenarios: best, 2%; medium, 5%; worst, 10%.

Unfortunately, the CIP – NCCP (2012) is not very useful to estimate the cost of adaptation in Kampala. First, it focuses on institutions and sectors, and not on geographical areas, such as Kampala. Although information on the costs borne by KCCA is an interesting reference, it only constitutes a partial estimate of the total cost of adaptation in the city, as other institutions also play an important role in reducing vulnerability to climate change. These include MWE, MoWT, MEMD, MLHUD or Ministry of Local Governments, among other ministries; NWSC; and the Kampala City Council.

Second, the data regarding KCCA is imprecise and incomplete. According to CIS-NCCP, KCCA is expected to spend over US$36 million on climate change relevant strategies in the period 2013-2018[40]. There is no clear information, however, on how much KCCA is expected to spend on (a) adaptation in that period, and (b) climate change in general and adaptation in particular in the period 2019-2030. Moreover, this information is hard to build, since the information for the costs for that period is organized by activities in which more than one institution appears. In addition, the assessment considers KCCA in a limited number of sectors, namely transport and works, and human settlements and social infrastructure, when it is likely to spend funds on adaptation also in other sectors.

Third, the scope of the study is somehow limited to estimate the cost of the impacts of climate change and the costs of adaptation in Kampala. For a more complete assessment, CIS-NCCP should study the costs to at least 2050, as does this study. In addition, an estimation of the cost of adaptation in Kampala would need to include some of the costs related to complementarity activities, both to cross-cutting and mitigation strategies. The "common policy priority mix" includes strategies as i.) the promotion of climate change education, awareness and capacity development; ii.) the support for policies and programmes that take into account the interactions between population dynamics, climate change and development; iii.) the promotion of climate change research and development and information exchange; iv.) transfer and diffusion of technology; and v.) the mainstreaming of gender. The CIS -NCCP estimates the total cost of these cross-cutting activities to be over US$89 million. Moreover some of the mitigation strategies, such as those associated with waste management, transport, and land use and land use change, also have impacts on the adaptation of Kampala to climate change.

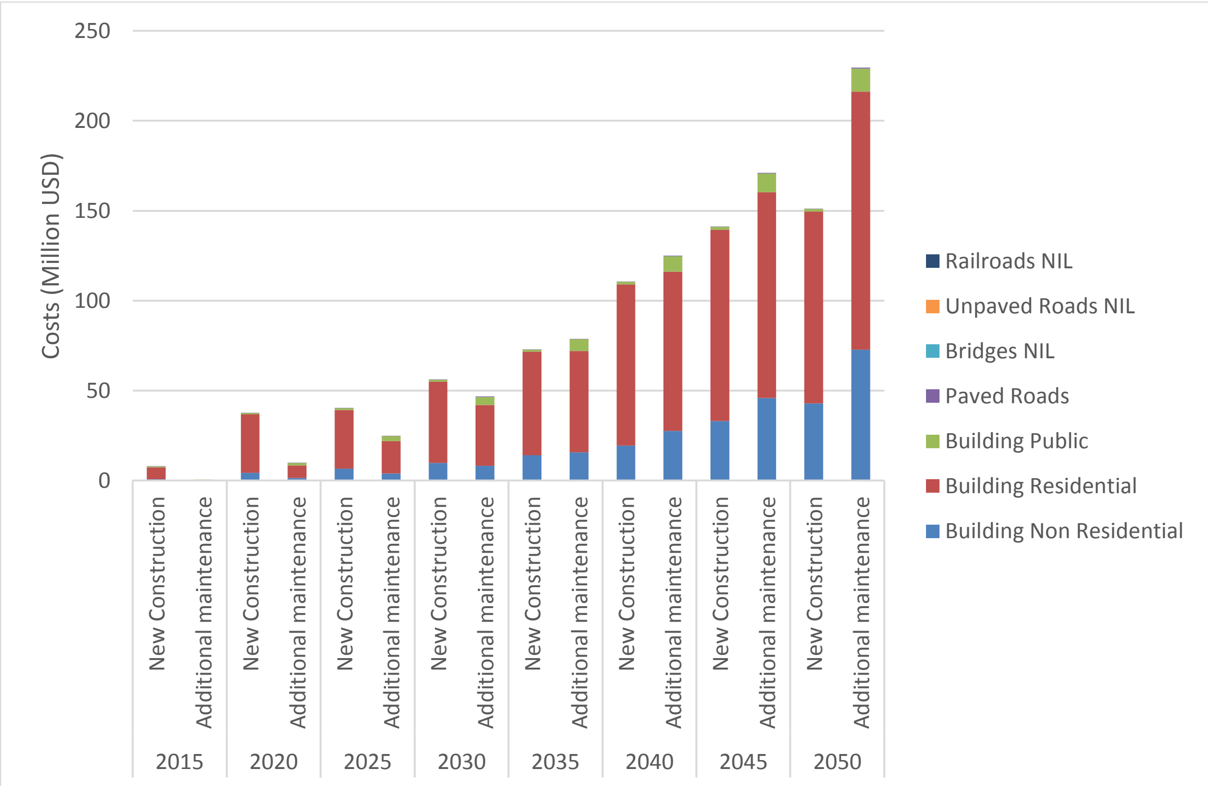
#### 4.4.2.2. Assessment of this project

This study seeks to complement existing studies. In particular, it estimates the cost to 2050 of climate proofing buildings and roads against the projected temperature and precipitation changes for the city. It is important to remember here that estimates are produced for SSP1/RCP4.5 and SSP5/RCP8.5. The results for the SSP1/RCP4.5 are illustrated below.

[40] The total cost of climate change-relevant strategies for all the ministries, departments, agencies and actors for the full period is over US$ 905 million. In terms of distribution, MoWT, MWE, MEMD and Local Governments are expected to bear the most significant costs, over US$100 million all of them. MLHUD and Ministry of Local Governments are assigned a very small sum, which suggest that the urban agenda has not yet been embraced. This information is given for each of the four years, if that is useful.

## Table 6 and Figure 14 - Estimates of Adaptation Costs of Selected Infrastructure Sectors in Kampala SSP1/RCP4.5 US$2014 Million. Base Case City Growth

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | Total |
|---|---|---|---|---|---|---|---|---|---|
| **New Construction** | | | | | | | | | |
| Buildings Non Residential | 0.7 | 4.2 | 6.5 | 9.7 | 14.0 | 19.3 | 33.1 | 42.8 | 326.0 |
| Buildings Residential | 6.5 | 32.6 | 32.6 | 45.2 | 57.6 | 89.7 | 106.4 | 106.7 | 1193.0 |
| Buildings Public | 0.6 | 0.8 | 1.0 | 1.1 | 1.2 | 1.5 | 1.5 | 1.5 | 22.9 |
| Paved Roads | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.9 |
| Bridges | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Unpaved Roads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Railroads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Total | 7.9 | 37.7 | 40.2 | 56.2 | 72.9 | 110.6 | 141.1 | 151.0 | 1543.8 |
| | | | | | | | | | |
| **Additional Maintenance** | | | | | | | | | |
| Buildings Non Residential | 0.0 | 1.4 | 3.9 | 8.2 | 15.6 | 27.6 | 45.9 | 72.8 | 438.5 |
| Buildings Residential | 0.3 | 7.0 | 17.9 | 33.7 | 56.5 | 88.6 | 114.3 | 143.4 | 1,154.1 |
| Buildings Public | 0.1 | 1.4 | 2.9 | 4.6 | 6.5 | 8.5 | 10.6 | 12.9 | 118.4 |
| Paved Roads | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 3.8 |
| Bridges | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Unpaved Roads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Railroads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Total | 0.4 | 9.8 | 24.8 | 46.7 | 78.7 | 124.9 | 171.1 | 229.5 | 1,714.9 |
| | | | | | | | | | |
| Grand Total | 8.3 | 47.5 | 65.0 | 102.9 | 151.6 | 235.4 | 312.2 | 380.5 | 3,258.7 |
| As Percent of City GDP | 0.03% | 0.13% | 0.12% | 0.13% | 0.12% | 0.13% | 0.12% | 0.10% | |

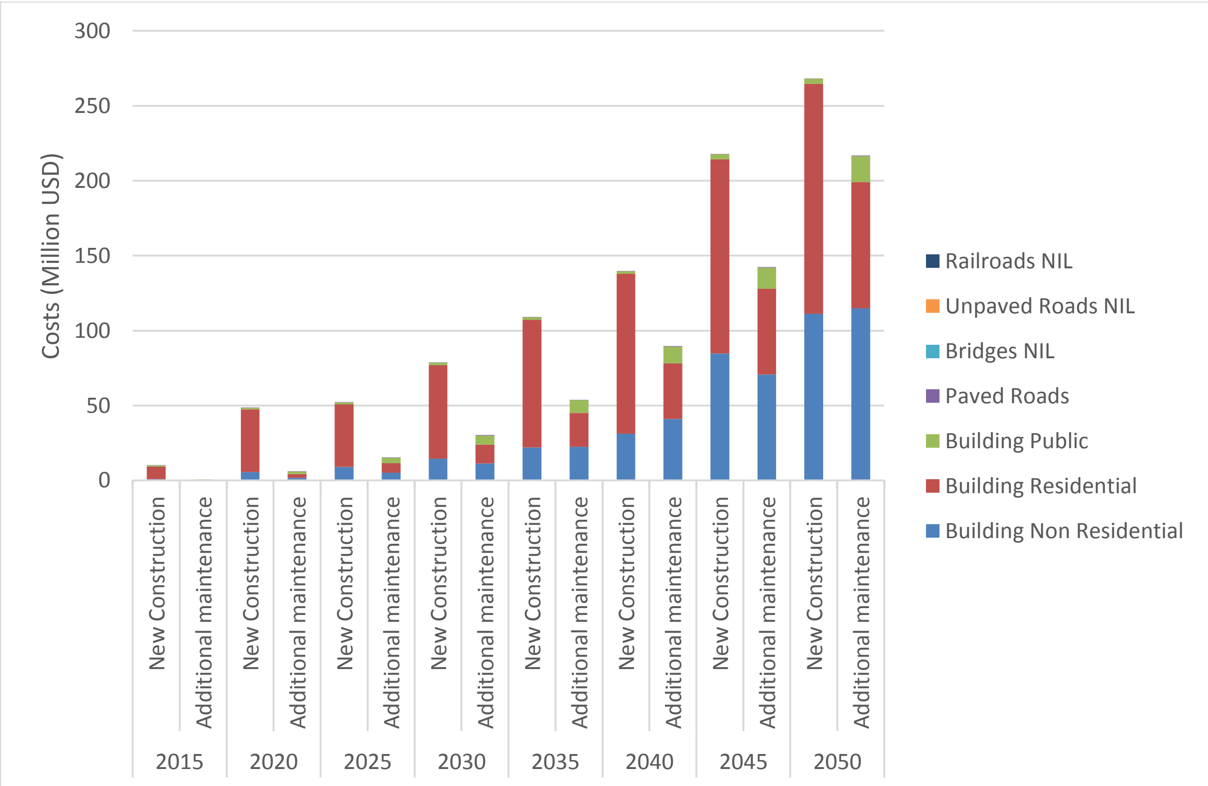



NIL indicates no expected cost.

The results for the SSP5/RCP8.5 are shown below.

## Table 7 and Figure 15 - Estimates of Adaptation Costs of Selected Infrastructure Sectors in Kampala SSP5/RCP8.5 US$2014 Million. Base Case City Growth

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | Total |
|---|---|---|---|---|---|---|---|---|---|
| **New Construction** | | | | | | | | | |
| Buildings Non Residential | 0.8 | 5.5 | 9.0 | 14.5 | 22.1 | 31.2 | 84.7 | 111.3 | 697.9 |
| Buildings Residential | 8.4 | 41.9 | 41.9 | 62.4 | 85.0 | 106.7 | 129.6 | 153.4 | 1573.0 |
| Buildings Public | 0.8 | 1.1 | 1.3 | 1.6 | 1.7 | 1.7 | 3.4 | 3.3 | 37.6 |
| Paved Roads | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 2.4 |
| Bridges | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Unpaved Roads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Railroads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Total | 10.1 | 48.5 | 52.3 | 78.6 | 109.0 | 139.7 | 217.9 | 268.2 | 2310.9 |
| | | | | | | | | | |
| **Additional Maintenance** | | | | | | | | | |
| Buildings Non Residential | 0.1 | 1.8 | 5.1 | 11.3 | 22.5 | 41.1 | 70.6 | 114.8 | 668.1 |
| Buildings Residential | 0.4 | 2.5 | 6.4 | 12.7 | 22.6 | 37.0 | 57.2 | 84.3 | 558.2 |
| Buildings Public | 0.1 | 1.8 | 3.8 | 6.0 | 8.5 | 11.2 | 14.2 | 17.3 | 157.2 |
| Paved Roads | 0.0 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 4.8 |
| Bridges | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Unpaved Roads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Railroads | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL | NIL |
| Total | 0.5 | 6.2 | 15.4 | 30.2 | 53.8 | 89.8 | 142.4 | 216.9 | 1,388.3 |
| | | | | | | | | | |
| Grand Total | 10.6 | 54.7 | 67.8 | 108.9 | 162.8 | 229.5 | 360.3 | 485.1 | 3,699.2 |
| As Percent of City GDP | 0.04% | 0.15% | 0.13% | 0.13% | 0.12% | 0.10% | 0.11% | 0.10% | |




NIL indicates no expected cost.

The two estimates provide crucial insights regarding the magnitude of costs:

- Costs to climate proof infrastructure are significant: between US$3.2 billion and US$3.7 billion over the 2015-2050 period, between US$560 million and US$600 million only over the period 2015-2030. These figures are undiscounted.
- Costs increase with time, to a large extent due to population growth. Costs start out quite small but build up over the period to 2050. In 2020 they range from US$11-13 million a year but by 2050 they are as high as US$380-485 million. In terms of percentage of GDP they go up from 0.03-0.04% in 2015 to around 0.1% in 2050. In per capita terms they go up from US$2-3 in 2015 to US$27-34 in 2050.
- Total costs vary considerably by socio-economic and climate scenario. With the more climate friendly scenario (RCP4.5) the total cost between 2015 and 2050 is around US$3.2 billion. With the less friendly scenario (RCP8.5), with little mitigation action, total cost goes up to US$3.7 billion (27% greater). However, the difference between scenarios is not significant until the end of the period.

The estimation also provides relevant information on the distribution of the cost of adaptation.

- New construction and additional maintenance account for relatively similar costs (additional maintenance accounts for just above half of total costs).
- Buildings account for most of the costs (99.8%). Transport only accounts for 0.2%. This is partly due to negligible impact of precipitation on adaptation costs. The climate scenarios show a decline in precipitation over the period. As this component has a greater effect on transport, the costs for that sector are reduced.
- Within buildings, the most affected sector is residential buildings, which account for around 72% of all costs. Next are non-residential private buildings, which account for 23%, and then comes public infrastructure with 2%. The burden of climate change adaptation will therefore fall significantly on the private sector. Although the public sector's share is small, action in that sector is urgent, as it concerns critical services such as hospitals, transport facilities, schools etc. Given the affordability problems of low cost housing, some of the costs theoretically borne by the private sector may need government support. We will further discuss the role of the government on adaptation in the policy recommendations sector.

Several issues must be taken into account.

- These figures are based on projected population and physical infrastructure growth contained in the Kampala Physical Development Plan (2012). The planning literature (e.g. Vermeiren et al., 2012) considers that the City could grow to as much as 25 million people by 2050. In that case damages would be close to double the figures given above.
- As highlighted above, the estimates report costs based on the climate projections as summarized in Table 1. Since that table indicates a fall in precipitation there is no expected increase in costs of new and existing roads and bridges from that variable.
- The costs of additional infrastructure to deal with climate events are not included in this assessment. A preliminary scan of the sources of such expenditure in the World Bank study revealed that either the item could not be justified for Uganda (e.g. additional roads to meet demand for travel due to higher temperatures); or that it would be covered in another sector study (e.g. demand for health, energy and water services).

# 5. COST BENEFIT ANALYSIS OF SOME ADAPTATION STRATEGIES

## 5.1. Introduction

So far CBAs of adaptation strategies have been rare in Kampala. The only available information is provided by the World Bank regarding the Nakivubo Channel Rehabilitation, which was implemented from 2002 to 2004 by the Kampala City Council. The first and most important component of the project aimed to alleviate the frequent and increasing incidence of flooding in the city. In particular, it included 8.7 km of channel rehabilitation, widening of side drains and improved drainage of critically affected city localities. According to the World Bank, civil works had a planned cost of US$13.6 million, and an actual cost of US$16.9 million (124%), while consultancy services for construction supervision had a planned cost of US$0.96 million, and an actual cost of US$1.43 million (149%). According to the same institution, the investment solved a flooding problem rated by 85% of those in the social impact assessment as serious. In the questionnaire 74% of respondents stated this had led to smoother business operations; 65% benefited from the elimination of property damage; 61% from better road communication and 50% to less disruption of industrial activity. The World Bank estimates an economic rate of return of 25%.

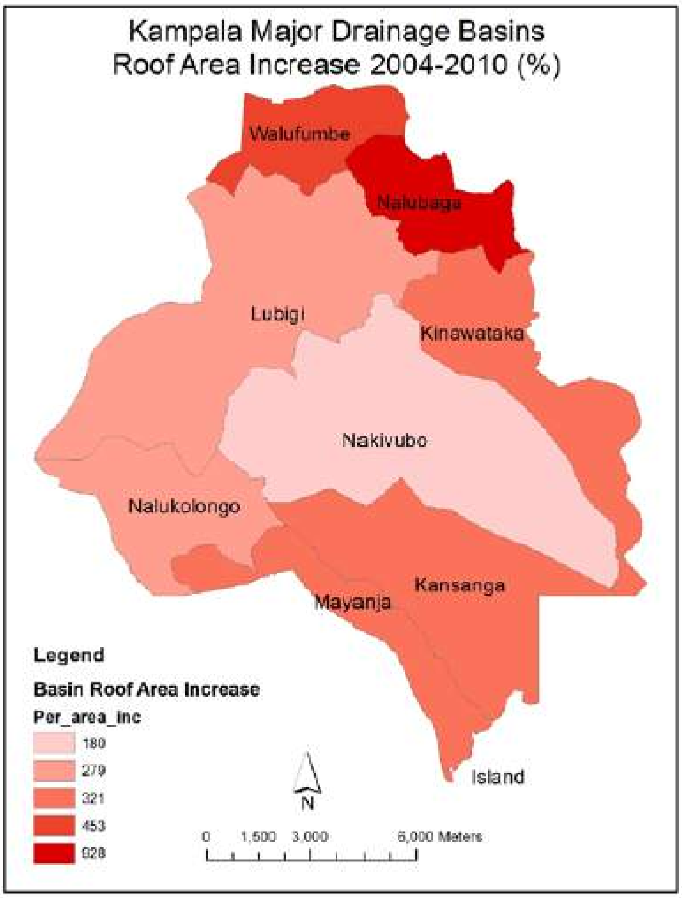
In this report we deal with the costs and benefits of adaptation strategies in two ways. We do not conduct a particular CBA for the expenditure detailed above for climate proofing buildings and roads. The assumption is being made that expenditures to make these infrastructures more resilient is justified on the grounds that the benefits exceed the costs. The same was assumed in the global studies of climate impacts (e.g. the World Bank 2010 study).

Instead, we make an attempt to estimate possible benefits and costs for some projects that address current climate variability as well as some possible future climate change. In particular we look at possible reductions in losses from flooding in four (Nakivubo, Kinawataka –phase 1 and 2-, Lubigi and Nalukologo) of the eight catchment areas of the city, as shown in Map 5, given the importance of this strategy to reduce the impacts of floods, the main climate event in the city.

## 5.2. Costs and benefits in terms of reductions in damages per flood event

Costs of improved physical drainage systems are given in the KPDP CIP (2012). These costs are compared against possible benefits from reduction in losses of flooding, derived from the estimates of expected damages as given in the previous section (Table 4 and 5). The basis for allocating the damages by catchment is explained below. The study has calculated the Net Present Value (NPV - the difference between the present value of the benefits and the present value of the costs), using a 10% discount rate. A positive NPV indicates that benefits outweigh the costs of an action; a negative NPV indicates that costs outweigh benefits.

**Map 5 - Drainage Basins in Kampala**




Source: UN-HABITAT (2013)

Damages per flood event in each of the areas is estimated as follows:

- Expected flood damages in the categories of loss of life, numbers affected and infrastructure destruction and damage are divided into the catchments in proportion to the roof area in catchment that lay in the 10 year flood zone in 2010. Estimates of these areas are taken from UN-HABITAT (2013, Table 4.2). The respective shares are given in Table 8 of this report.
- Reductions in damages that can be expected as a result of the proposed drainage programs is in the range of 42-58%. This is according to the UN-HABITAT (2013) interventions in the Lubigi district. We assume the new plans for the other districts will achieve the same reductions, represented by an average value of 50%.
- Damages to property are only a part of the damages. They do not include damages to roads, industrial activity etc. We could not obtain estimates for damages to other sectors for Uganda but in other countries residential property damage is around half the total (Galarraga et al. 2011). We take this percentage to apply to damages in the catchment areas from floods.
- Data from Tables 4 and 5 are used to estimate annual expected damage for four catchments where programmes are being launched: Kinawataka (Phase I and 2), Lubigi, Nakivubo and Nalukolongo. The data provided in these tables are for no climate change (only variability) and doubling of flooding frequency, but no change in value of actual infrastructure or number of people. Since those Tables only gives values at five year intervals we have obtained values for missing years by linear interpolation.
- Benefits are evaluated for a period of ten years from date of completion of the project. Extending the period further has many uncertainties and does not change the conclusions significantly.

### Table 8 - Share of Flood Damages By Catchment Zone

| Catchment | Roof Area in 10 Year Flood Zone (M2) | % of Total |
|---|---|---|
| Kasanga | 128,127 | 5.3% |
| Kinawataka | 255,143 | 10.6% |
| Lubigi | 696,588 | 28.8% |
| Mayanja | 25,650 | 1.1% |
| Nakivubo | 765,841 | 31.7% |
| Nalubaga | 26,519 | 1.1% |
| Nalukolongo | 497,826 | 20.6% |
| Walfumbe | 20,170 | 0.8% |
| Total | 2,415,864 | 100.0% |

Source: UN-HABITAT (2013)

The resulting benefits and costs are summarised in Table 9.

### Table 9 - Net Benefits From Flood Control Programmes in 4 Catchments of Kampala

| | | | NPV $ Mn. At 10% Discount Rate | | | |
|---|---|---|---|---|---|---|
| | Cost of Program | Start Date | No Change in Frequency | | Increased Frequency | |
| Catchment Area | $ Mn. | | Lower B | Upper B | Lower B | Upper B |
| Kinawataka 1 | 11.0 | 2013 | -7,971 | -2,002 | -7,544 | -11 |
| Kinawataka 2 | 9.5 | 2015 | -5,284 | 195 | -4,726 | 2,683 |
| Lubigi | 6.6 | 2015 | -560 | 14,401 | 9,874 | 36,420 |
| Nakivubo | 4.3 | 2015 | 1,505 | 17,953 | 12,975 | 35,212 |
| Nalukolongo | 10.0 | 2015 | -4,189 | 6,503 | 3,267 | 17,722 |

Note: The fixed costs of the planning and evaluation of $500,000 has been divided equally across the five projects.
Sources: See text.

The results can be summarised as follows:

- In the case of Nakivubo the NPV of the project is positive under the case of no increase in flood frequency and irrespective of whether we take the lower or upper bound of damages avoided.
- If the frequency of floods increases so that by 2025 it is 50% higher than it was in the period 1993-2011 then the NPV is positive for the projects in Lubigi and Nakulongo as well.
- With the upper bound of damages avoided and no increase in frequency of floods all projects except Kinawataka 1 have an NPV that is positive.
- The NPV for Kinawataka 1 is close to being positive only when we take an upper bound of the avoided damages and an increase in flood frequency.
- Given that there are scenarios in which the analysis suggests the investment is not worth it, the proposed projects need further scrutiny.
- Where the NPV is negative at a 10% discount rate a sensitivity analysis indicates the following. Firstly, for Kinawataka 1, a positive NPV can result with the upper bound of damages avoided if the discount rate is 6%. With the lower bound of damages avoided, however, no discount rate gives a positive NPV. In the cases of Kinawataka 2 and Nalukolongo the same applies – no discount rate will give a positive NPV for the lower bound case.

The CBA of adaptation options conducted in this report is limited by data availability. The CBA of physically improving drainage systems developed above is preliminary and would need some more work and resources to refine the results. More information on local conditions in each catchment area would allow a more accurate assessment of damages avoided that we could make based on the UN Desinventar database. In addition, it would be desirable to have information on the stock of housing in each area as well as other assets at risk. In this sense, the results, such as the low benefit relative to cost of Kinawataka, must be taken as preliminary, as items such as possible damages to infrastructure other than housing could not be valued accurately due to a lack of data. More accurate data on local conditions may change the conclusions but would require further data collection. Moreover, not only is the analysis of this infrastructure limited, but it also ignores other potentially significant adaptation options, such as improving the institutional setting and protecting ecosystems in order to increase the resilience of social systems.

In spite of these limitations, our analysis shows that efforts to increase adaptation through the physical improvement of drainage systems makes in most of the cases social sense, and must therefore be strengthened, but that detailed CBA should be conducted to determine the net present value of each investment, evaluating those where NPV is not clear and prioritizing those where NPV is greater.

# 6. CONCLUSIONS AND POLICY RECOMMENDATIONS

## 6.1. Conclusions

The qualitative analysis shows that climate change has had significant impacts on Kampala and its residents. The most significant impacts have come from increased precipitation that leads to flooding.. In addition, droughts have resulted in decreases in welfare, mainly through the reduction in the water levels of Lake Victoria. The impact of rising temperatures is less documented. The urban poor are those who suffer most from the impacts of climate change. Those living in informal settlements, approximately 60% of Kampala's population (about 700.000 people), are particularly affected, especially by flooding in the wetland areas. Not only are the urban poor typically more exposed, but they also have less capacity to recover.

The qualitative analysis shows that the impacts of climate change in Kampala, and the urban poor in particular, are related to the nature of threats, exposure and vulnerability. Impacts from flooding are exacerbated by the location of human settlements in low-lying valleys and wetlands, which has increased significantly over the years and is still increasing. The encroachment of these areas has been the result of the development of housing, particularly slums, given the opportunities that these areas bring to low-income households; productive infrastructure; and transport infrastructure, such as the Northern Bypass road. This is due to the lack of appropriate policies, regarding for instance the application of the Environmental Impact Assessment tool, and inadequate implementation and enforcement of policies. This is also caused by critical institutional and administrative deficits and, some argue, the political economy of the city, which has crucial effects.

A number of factors are increasing vulnerability. The clearing of the hills has increased water runoff, and the encroachment of human settlements onto wetlands not only has increased exposure, but has also reduced the capacity of these ecosystems to capture, store and dissipate surface water runoff. Insufficient, poorly designed and poorly maintained urban infrastructure contributes to the high vulnerability of the city to heavy rains. Moreover, related to the previous points, there are critical deficits regarding wastewater and solid waste management that contribute to flooding and make its impacts worst.

The previous points explain the physical, institutional and political context in which efforts of adaptation to climate change are taking and will take place in Kampala. Adaptation is still in the process of being mainstreamed, more in terms of awareness than in terms of actual design and implementation of specific actions. In Kampala, climate change information has rested in technical pockets without influencing top level management and decision-making, such as investment planning. Although there is some progress, mainly in terms of policy documents and institutional structures, so far climate change has indeed been approached rather indirectly. The capacity of these measures to effectively address critical issues regarding the exposure and vulnerability of the city to climate change is however limited, given the enforcement problems highlighted above. The effectiveness of adaptation in Kampala is related not only to the physical structure of the city, but also to the socio-economic, institutional and political dynamics that have led to it.

The future likely impacts of climate change in this context are uncertain, as they are conditional not only on the specific climate conditions, but also on the level of development and how this reduces exposure and vulnerability, indirectly through development or directly through specifically designed adaptation strategies. The climate projections produced by Rautenbach (2014) as part of this project reduce uncertainty to a significant extent regarding likely future near-surface temperatures and precipitation. These projections suggest that the threats from temperatures are likely to increase, while the threats from mean precipitation are, in contrast, likely to slightly decrease. Considerable uncertainty remains however regarding the frequency and intensity of extreme events, such as heavy rains. In general, increased population and assets could increase the exposure to climate change. On the other hand, the government plans to explicitly seek to reduce exposure and vulnerability. It is however uncertain how effective these could be.

We have developed a full set of reasonable assumptions when developing the economic assessment of the impacts of climate change. These assumptions have been presented in the methodological section, while some considerations have been provided in the conceptual section. In essence, this study has produced an estimate of damage and an estimate of the costs of adaptation. The estimate of damage has focused on damages of the same and the double frequency of floods in terms of deaths, people affected and buildings destroyed and damaged in the period 2013-2050. The estimate of costs of adaptation has focused on the costs of climate proofing buildings and roads against the projected temperatures and precipitation under RCP4.5 and RCP8.5 in the period 2015-2050. The results of the quantitative assessment can be summarized as follows:

1/ **In a business as usual scenario the costs of the impacts of climate change would be very significant**. As we have noted, current annual damages of between US$1.3 and US$7.3 million in 2013 could rise to between US$3.7 and US$17.6 million by 2025 and between US$33.2 million and US$101.7 million by 2050 if the intensity and frequency of extreme events leading to flooding do not change and to much more if they increase.

2/ **Adaptation will require significant investment.** There are no estimates of full costs of adaptation and residual damages, but the estimates provided in this study are a matter of concern. As we have shown, the total costs of climate proofing buildings and roads against the projected temperature and precipitation changes between 2015 and 2050 would go to US$3.7 billion under a not climate friendly scenario, and at least to US$3.3 billion under a more friendly one. Naturally some prioritization in this programme should be possible, with those areas where possible damages are high and costs low being given priority.

3/ **Adaptation must be the result of careful decision-making processes**. Our CBA shows that investment in a specific adaptation project to improve drainage has mixed results, with only two of the four projects showing a positive NPV.

4/ **Both the private sector and the government have a role to play**. Our estimates show that the cost of climate proofing buildings and roads will largely fall on the private sector: buildings account for almost all the cost (99.8%); and private buildings account for most of the costs within the building category (95%). This does not imply that the public sector is irrelevant. Some adaptation actions will occur autonomously, as individuals and businesses respond to changes in the environment or markets in which they find themselves, both reacting to specific events and anticipating trends. These agents will generally have better information than the government on their specific situation and stronger incentives to act. The fact that, unlike mitigation, adaptation will in most cases provide local benefits that can be realised without long lag times is a clear stimuli. Market forces alone are, nevertheless, unlikely to be sufficient to strategically and efficiently address the serious risks from climate change[41]. In Kampala, the local and, to a certain extent, central governments have a crucial role to play. First, they would need to climate proof public buildings and roads. Although these investments make a small part of the total investments, they are vital and urgent, as they concern critical services such as hospitals, school or transport facilities. Second, policies are significant drivers of development, as they give clear signals and incentives to individuals. Third, in a city with such generalized poverty, many of the residents in low-cost housing would find it so difficult to afford climate adaptation that some of the costs theoretically borne by the private sector might need government support. Given its role, it is crucial that the local and central governments wisely assign their funds both within and between sectors.

[41] Market forces are unlikely to be sufficient for three reasons: i) uncertainty and imperfect information; ii) missing and misaligned markets, in the sense that the costs of adaptation would be private and certain, while the benefits would be uncertain and unlikely to be captured only or predominately by those investing in it, as adaptation has positive externalities in spaces and time; (some of the adaptation strategies have the technical feature of public goods, that is, non-excludable and non-rivalry); and iii) financial constraints and distributional issues.

## 6.2. Recommendations

In this context, several actions can be recommended.

1/ **Policies, plans and regulations must be designed to mainstream climate change adaptation and take into account the results of this study**. It is critical that the plans developed under the KPDP (2012) are revised in the light of the climate projections provided in this study in order to increase Kampala's resilience. The plans for the degraded and non-degraded wetlands and the lakefront should be particularly revised. It is also urgent that building codes are revised vis-à-vis climate projections, promoting bio-climatic designs and the use of appropriate materials. The results of this study should also inform the policies, plans and regulations that are currently being developed and those that will be formulated in the future. Kampala's LCDCR strategy deserves particular attention. Launched in February 2015, the process of its design should be finished by the end of 2016. It is critical that adaptation is fully considered, and the consideration on low carbon development does not leave behind the impacts of unavoidable climate change. In this sense, not only should the LCDCR strategy consider the costs provided here on its investment plan, but should also have in mind some of the priorities (e.g. buildings vs. roads) that have proved to be more salient in this study. In this regard, the LCDCR strategy should guide public investment and incentivize significant and appropriate private investment towards adaptation.

2/ **Kampala needs not only to improve policies, but also needs to strengthen the application of tools, such as EIA, and very significantly their enforcement, especially regarding the protection of wetlands**. Although a sensitive issue, political incentives must be revised, and when appropriate adequately modified. In this sense, in Kampala, not only adaptation requires redefining the priority of competing values in favour of sustainability and resilience, so that these are no longer embraced only when they align with pre-existing local development priorities (Taylor et al., 2014), but also, as Goodfellow (2013) suggests, the establishment of a new political game. As in Kigali, this should set political incentives to prioritize public interests over private gains. This could be achieved through different strategies, from the need to gain credibility to increased political competition. In this sense, champions for both adaptation and long-term organized sustainable development are needed. As some researchers (Goodfellow, 2013; Lambright, 2014) stress, the basis for this might be being built, although it is still too early to have a clear view on it.

3/. **Kampala should climate-proof its infrastructure**. There is no dilemma between allocating funds to policy guidelines or to climate-proofing infrastructure. Infrastructure is designed, constructed and reconstructed on a regular basis. It is critical that all new construction and the modifications of the existing buildings contribute to climate change resilience. This should be the case even while existing policies are revised and new policies are designed and approved.

4/. **Working with informality.** The LCDCR, the land use plans and building codes, the enforcement systems and the investments for climate-proofing infrastructure need to take into account the particular characteristics of the city, especially the fact that about 60% of its inhabitants live in informal settlements. As Taylor and Peter (2014: 3) claim, in the African context, and certainly in Kampala, making a more resilient city necessarily implies "accepting informality as a core part of the fabric of the city… and working with informal settlements and the informal economy as part of the overall city system". In this sense, adaptation will include "upgrading the living and working conditions of slum dwellers in ways that increase safety, security and well-being, while also increasing their participation and leverage in citywide processes of urban planning, management and investment" (Idem). In this regard, the development of the LCDCR should ensure that eight steps suggested by Taylor and Peter (2014) are integrated in the process so that the adaptation strategies properly take into account the opportunities and challenges that informality represent.

5/ **Further evidence and research is required to build on the initial findings of this study**. Several research exercises could particularly contribute to a better understanding of the impacts of climate change and adaptation options. On the one hand, it would be interesting to continue the line of this case-study, shortlisting other adaptation options related to the improvement of physical infrastructure and conducting a CBA, including different areas of the city and more geographical detail. On the other hand, some of the issues not covered in this case-study could prove significant. In particular, research on the impacts of climate change on health, water supply or ecosystems degradation, and more importantly the costs and benefits of socio-institutional and ecosystem-based adaptation options could be especially useful. Studies in other African cities show that soft adaptation strategies are critical. In Durban, Cartwright et al. (2013) found that socio-institutional interventions were the most efficient across all futures and time frames, followed by ecosystem-based adaptation measures, and that infrastructure-based strategies had the lowest benefit-cost ratios. Our qualitative analysis has shown the importance of institutional and ecosystem-based issues. Some of the studies that are currently undertaken, such as the World Bank study on the value of ecosystems in the city, can shed some light on these issues and provide some of the data needed to conduct those analyses.

6/ **Improve the availability of climate and non-climate data for Kampala**. This is critical for the design and enforcement of policies, plans and regulations, implementation of climate-proofing actions and research to be feasible. KCCA should work on documenting the impacts of climate change, as well as consolidating more detailed data at smaller scales. This should be key to the development and implementation of the city's LCDCR strategy, which should have enough data to define where to conduct specific adaptation measures.

7/ **Take into account uncertainty.** Although it follows guidelines on best practices, the economic assessment provided in this study is limited in scope and conditional on the choices made. In this sense, the full economic impacts of climate change in Kampala remain to a certain extent uncertain. This implies several recommendations. Policy makers must understand the choices made, which have been clearly presented in the study to facilitate this. A greater number of perspectives and economic tools should moreover be used and a greater number of studies conducted, covering more possible outcomes and complementing the weaknesses of one perspective, tool and study with the strengths of others (Garcia and Markandya, 2014). In this context, CBA should be coupled with multi-criteria prioritization exercises. In addition, policy makers must plan for uncertainty, explicitly taking it into account in their decision-making. Finally, work must be done at the policy decision process, ensuring that the political decision process in which the economic assessment is considered is open, transparent and accountable.

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