The Republic of Uganda

MINISTRY OF WATER AND ENVIRONMENT

CLIMATE CHANGE DEPARTMENT

Economic Assessment of the Impacts of Climate Change in Uganda

National Level Assessment:

Infrastructure Sector report

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LIST OF ACRONYMS

Acronym	Definition
CRED	Centre for Research on the Epidemiology of Disasters
GDP	Gross Domestic Product
GNI	Gross National Income
GSI	Geotechnical site investigation
GoU	Government of Uganda
NCCP	National Climate Change Policy
NDP	National Development Plan
PPP	Purchasing Power Parity
RCC	Reinforced Cement Concrete
RCP	Representative Concentration Pathways
SSP	Socioeconomic Scenarios
URCS	Red Cross Society
UGX	Uganda Shillings
US CPI	United States Consumer Price Index
VSL	Value of a Statistical Life

EXECUTIVE SUMMARY

Uganda's infrastructure is currently subject to major impacts from climate variability: this is not a problem only for the future but very much something that needs to be addressed urgently. In this report an estimate is made of the costs of making the country's infrastructure more resilient to climate change and variability as well as the costs of damages to infrastructure from extreme events. The methodology used to estimate the costs of making the existing and future infrastructure more resilient is that used by the World Bank in its major adaptation cost study. This has been applied at a detailed level to obtain estimates of the additional costs for new buildings, roads etc. as well as the additional costs of maintaining them in the face of increased climate stress. In the case of extreme events the estimates are based on expected damages, given the past frequency of such events. They include damages to life and property and take account of increased values over time.

Cost of making infrastructure more climate resilient

The key findings for the cost of making infrastructure more climate resilient are the following:

1. Infrastructure is divided into residential buildings, non-residential private buildings, public infrastructure, and roads, railways and bridges. Total costs are estimated the range of US$52-66 million for the period 2015-2020 but for the period 2045-2050 they are as high as US$638-1,157 million. New construction accounts for around 37% percent of total costs; the rest is additional maintenance.

2. Total costs for the whole period 2015-2050 vary considerably by socio-economic and climate scenario. With a more climate friendly scenario (average temperature increases over the next 50 years are 1.5 to 2°C) total costs to 2050 are around US$2 billion while with a less friendly scenario (one with little mitigation action and average temperature increases over the next 50 years are 2 to 3°C) they go up to US$3 billion.

3. The most affected sector is residential buildings, which account for around half of all costs due to climate change on the infrastructure sector as a whole. Next are public buildings, which account for a quarter and then comes other private non-residential infrastructure with 16%. In fact, if we take the infrastructure sector as a whole, it is buildings that account for most of the costs (92%). Transport is relatively less impacted (accounts for 8 to 10% of the cost to infrastructures due to climate change) but costs are still significant: US$194 to US$250 by 2050 depending on the socio-economic and climate scenario chosen. This is mainly the result of projected decline in precipitation: with an increase in precipitation transport costs would play a bigger part.

4. The estimates do not include any costs of additional infrastructure to deal with climate events. 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).

Extreme events

As far as extreme events are concerned, estimates have been made based on the frequency of such events in the past and the damages they caused. Damages included in the study are loss of life and injury, damage to property, costs to persons due to dislocation and inconvenience and disaster relief. If there is no increase in frequency or intensity to 2050 then the damages, which are currently put at between US$20-130 million a year (depending on how you value the loss of life), rise to US$39-234 million by 2025 and to US$189-838 million by 2050. As a percent of projected GDP the damages do not increase. The assumption of no changes in frequency or intensity of such events is questionable. Although the climate models do not provide any quantitative statement of an increase, recent evidence indicates that an increase is occurring and it is therefore reasonable to assume that it is likely to continue. Assuming a doubling of frequency every 25 years would result in damages of around US$77-467 million by 2025 and US$738-3294 million by 2050. In this case damages as a share of projected GDP increase although even then they are only around 0.1-0.3 percent of GDP in 2050. The figures are average of expected damages; a particular event similar to the El Nino floods of 2007 would represent very significant costs in 2025 and 2050. It is interesting also to note that there is not much difference in damage costs between the socioeconomic scenarios.

Cost of adaptation

The estimates reported above of the costs of making infrastructure climate resilient (but excluding extreme events) are also estimates of the costs of adaptation: it is implicitly assumed that such measures are justified. Hence these adaptation costs range from US$52-66 million a year in 2020 and US$638-1,157 million in 2050. The estimates in this study from 2015 to 2030 amount to between US$300 million and US$370 million.

These figures can be compared with those in the Government's Costed Adaptation Strategy document (Government of Uganda, 2012), which estimates a total cost for transport and works of US$1.05 billion over the next 15 years (i.e. to 2030). The difference between the two estimates partly lies in the different approaches and partly in the items covered. This report has done a more detailed assessment of climate resilience needs but it has not evaluated the costs of site investigations for future infrastructure development or the costs of water catchment protection. These two items would add US$394 million to our estimates, giving a total figure of between US$694 million and US$764 million, which is about 30 percent less than the GoU estimate.

Adaptation priorities

Based on the review of the material the report concludes that highest priorities in the infrastructure adaptation programme are for:

- climate proofing public buildings,
- developing standards for transport and infrastructure planning, and
- integrating climate change-resilient standards into existing infrastructure risk assessment guidelines.

All of these must precede the necessary new investments in infrastructure. Other components of the programme are also of priority, especially to ensure that new construction respects the climate resilience requirements but will be rolled out over the next 15 years.

As far as extreme events are concerned, the Government of Uganda's Costed Implementation Strategy of the National Climate Change Policy (NCCP) proposes a number of actions under risk management, with a total cost to 2030 of US$12 million. Of the actions in the government programme the highest priority is for:

- measures to improve early-warning systems and preparedness to avoid or minimize the adverse impacts of climate change,
- development and implementation of a climate change-induced disaster risk management strategy,
- strengthening of the National Emergency Coordination and Operations Centre, and
- establishment of a national contingency fund.

There are also other items that have been suggested in the literature that have not been costed but that should be considered in more detail.

If we compare the cost of the projected adaptation programme for disaster risk reduction, it represents only a fraction of the damages estimated from disasters. Hence if such programme can reduce damages by even a small amount (i.e. around 7 percent) they will, under the most conservative assumptions, generate a rate of return of at least 10 percent. Of course the case for the individual components in the strategy is not proven by this comparison and more work is needed to link the programmes to reductions in damages but there is some evidence to support them.

1. INTRODUCTION

Climate change/variability has had significant socio-economic impacts on infrastructure and housing across Uganda, in particular through floods, droughts and changes in seasonal rainfall. The effects of disasters related to drought and floods across the country exhibit increasing levels of spatial and temporal variability. Beyond immediate effects such as loss of life, injury and displacement, the widespread destruction of property, livelihoods and infrastructure these effects have pushed back Uganda's socio-economic development for many years and yet there is limited preparedness for handling environment related disasters. (Kajubi and Mukwaya, 2014)

Flooding is especially a problem, with roads becoming impassable, causing serious problems in mobility. Rains spell disaster and lack of sleepless nights for both those in flood-prone areas, and the authorities who are responsible for the running and maintenance of the infrastructure supposed to control the immense amounts of runoff water from the rains. Floods in 1961/62, 97/98 and in 2007 saw widespread infrastructure damage, displacement and destruction of livelihood assets. Hence the problems of climate variability for infrastructure is not a matter for the future: it is very much a present day problem and needs urgent action.

In this report we estimate the costs of damage to infrastructure from the climate variability and from future climate change and make a preliminary assessment of measures to address these phenomena. According to previous studies, a major impact from climate change is on the infrastructure of a country (World Bank 2010). Of total estimated costs of adaptation the percentage accounted for by infrastructure ranges from 17% (if a dry scenario is assumed) to 33% (if a wet scenario is assumed). The estimates are based on the additional costs of construction for new infrastructure (to make it more climate resilient) as well as the additional costs of maintenance of infrastructure under a changed climate. They also include a component of additional infrastructure required to meet the demands created by climate change (e.g. additional demand for energy for cooling when temperatures increase) and the damages caused to infrastructure from extreme events.

In this report estimates have been made of the costs of adapting infrastructure in Uganda to climate change, based on the World Bank approach as set out in World Bank (2010a). This methodology was developed with a large number of experts in the field and has been subjected to extensive peer review. As set out in the Economic Model paper (Baastel Consortium, 2014a), the infrastructure sectors covered are the following: transport, human settlements and public infrastructures[1]. Human settlements in turn are divided into residential units and non-residential buildings.

The approach can be described further as follows. Section II provides the basic data from which the scenarios are derived. Section III reports the estimates of the costs of upgrading infrastructure to make it resilient to climate change. For each sector an estimate is made of the stock of assets to 2050. Next the incremental costs of construction is made for assets so they are proofed against climate change for the duration of their lives, as well as the additional maintenance costs for new and existing assets due to climate change. Given data limitations a number of assumptions had to be made to arrive at figures for the current and future stocks and these are described below. The basis for calculating the direct costs is explained and figures presented. Finally this section gives the results for the costs of adaptation for the changes in average climatic conditions attributable to climate change. In Section IV there is a discussion of the additional costs arising from additional infrastructure needed to deal with climate change. Section V provides estimate of costs to infrastructure from extreme events. Section VI discusses the implications of the estimates for adaptation and Section VII concludes the note.

[1] The buildings in this category are items like schools, hospitals, ports, airports, government offices and all other buildings maintained and owned by the government.

This report was written by Anil Markandya and Tim Taylor of Metroeconomica with important contributions from Lammeck Kajubi. We gratefully acknowledge the helpful comments and suggestions provided on initial results by Government of Uganda officials and others during the mission to Uganda in September 2014.

2. BASELINE SCENARIOS

Before going into the details of the estimates it is essential to lay out the forecasts for Gross Domestic Product (GDP) and the climate scenarios that underlie the forecasts. The results presented here combine two Socioeconomic Scenario Pathways (SSP), as defined by IPCC, with two Representative Concentration Pathways (RCP), also defined by IPCC. The SSP scenarios chosen are SSP1 and SSP5 and are described as follows.[2]

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.

The corresponding GDP estimates for Uganda are given in Table 1.

The RCP pathways chosen for the climate assessment are RCP4.5 and RCP8.5. RCP 4.5 is associated with a +4.5 W.m-2 radiative forcing (≈553 ppm CO2) in 2100. RCP 8.5 is a more extreme concentration pathway, which is associated with a +8.5 W.m-2 radiative forcing (≈1284 ppm CO2) in 2100. Further details of the RCP scenarios can be found in Baastel Consortium (2014b). The national temperature and precipitation for Uganda are given in that report and the relevant sections for this analysis are reproduced below as Table 2.

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.

Table 1. GDP Projections for Uganda to 2050 US$2005 Billion.

Year	2010	2015	2020	2025	2030	2035	2040	2045	2050
SSP1	38.4	50.6	71.1	105.1	159.6	243.7	366.8	540.3	776.1
Growth % p.a.		5.7%	7.0%	8.1%	8.7%	8.8%	8.5%	8.1%	7.5%
SSP5	38.4	50.6	71.3	108.2	173.3	281.4	445.1	681.7	1009.9
		5.7%	7.1%	8.7%	9.9%	10.2%	9.6%	8.9%	8.2%

Source: OECD, taken from IIASA

[2] 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.

Table 2. Comparison of results under the RCP 4.5 and RCP 8.5 concentration pathways for Uganda.

Parameter	RCP 4.5	RCP 8.5
Annual temperature changes from the median	In +50 years to present: +1.5ºC to +2ºC in most continental parts of Uganda In +80 years from present: +2ºC to +2.5ºC in most of Uganda.	In +50 years to present: +2ºC to +3ºC in most continental parts of Uganda In +80 years from present: +4ºC to +5ºC in most of Uganda.
Annual rainfall changes from the median	In both +50 and +80 years: -5 mm (mostly in the northern half) to -10mm per month (mostly in the southern half). Up to -70mm per month over lake Victoria.	In both +50 and +80 years: -10mm to -20mm (mostly in the northern half) to -30mm per month (mostly in the south). Over -100mm per month over lake Victoria.

In addition some estimate has to be made of changes in extreme events. The climate scenarios do not provide data on such changes so we have assumed that current frequencies of such events will prevail, with impacts on a larger stock of assets as the economy grows.

3. ESTIMATES FOR INFRASTRUCTURE

3.1. Estimates of the Stock of Infrastructure

Stock estimates were required for residential housing, non-residential buildings and public infrastructure as of 2014. The estimates were derived as follows.

3.1.1. Residential Buildings

There is no direct estimate of the value of the stock or of the surface area of all buildings although the National Development Plan (NDP) states that there were 5.28 million residential units in 2009. An estimate of the value of these units was made by taking the figure for the value of total additions to the sector in that year (UGX1,332 billion) and the percent increase of the current stock (5.6%) that that addition represented. This gave a figure for 2009 of UGX23,786 billion or US_{2002}\$13.6 billion. The 2009 estimate was then used to obtain a figure for 2014 by taking the data on growth in the sector between the two dates and converting to $US\$_{2014}$ to arrive at a figure of US\$19.5 billion.

For future values, it was assumed that the stock would 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.

3.1.2. Non-Residential Buildings

For non-residential buildings there was no direct estimate available. 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[3]. 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 value in middle income countries.

3.1.3. Public Buildings

For public 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 estimate based on capital stock estimates for Uganda for that year from the University of Groningen and University of California, Davis Capital stock data[4]. 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. Future public infrastructure capital stock was assumed to grow with GDP but adjusted for the fact that public sector capital has grown a little slower from 2000 to 2012 than all capital (the ratio of the two rates has been approximately 0.74).

3.1.4. Roads, Railways and Bridges

3.1.4.1. Roads

For roads the main document that has been used is the Transport Master Plan (Government of Uganda, 2008). The current road network is divided into paved roads and unpaved roads. Paved roads currently amount to 4,016 km and national plans indicate that another 3,600km will be added by 2023. After that there are no figures available but it has been assumed that a similar rate of addition will apply to 2050. For unpaved roads we have inferred from the data on the total network that about 2,100km of unpaved roads will be built by 2023. Most of the plans are for upgrading of existing roads rather than adding new ones. Beyond that we assume a similar rate of addition to 2050.

3.1.4.2. Railways

For railways the current functioning network is only 330km. The Transport Master Plan indicates that another 1,240km could be added by 2025 although this is very tentative. This extension has been included but, following the Master Plan, no further additions are assumed.

3.1.4.3. Bridges

The Uganda National Roads Authority (UNRA) lists 519 bridges in the country, with a total span of 8,720 meters (span for a number of small bridges is not provided). Types vary and include, steel truss, reinforced cement concrete (RCC), box culvert, bailey, composite and timber. Bridges are damaged and even swept away by heavy rains with regularity. In 2013 for example an estimated 19 bridges were swept away in just one district (Kasese) (Kajubi. and Mukwaya, 2014). The Ministry of Works and Transport has plans for strengthening a number of bridges in the coming years but limited separate plans are available for them. In the period 2008-2013 the government allocated US$58 million for bridge schemes amounting to about 2.8 percent of the road budget. A similar share of the budget is assumed of future road budgets (Uganda Transport Mater Plan).

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

3.2. Basis for Calculating the Direct Costs of Climate Change

The calculations of the costs of climate change are based on assumptions from the World Bank study referred to earlier (2010a). They divide the process into two: additional costs for new construction and additional costs for maintenance.

3.2.1. Additional Costs for New Construction

The following assumptions are made based on the World Bank (2010) study:

Buildings:

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

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.

Bridges:

- A 3.13% increase in base cost for each additional foot of clearance of bridge height. Increase in clearance will be needed to cope with increased precipitation as determined by local conditions.

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 buildings and roads etc. 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.

3.2.2. Additional Costs for Maintenance

Additional costs have been calculated as follows:

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 one percent increase in rainfall. US costs are US$930/km/yr.

Railroads:

- 0.14% of construction costs increase per one degree increase in maximum temperature
- Construction costs in the US are taken as US$404,000 per km.

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

3.3. Results for Infrastructure Costs of Changes in Average Climatic Conditions due to Climate Change

The direct costs of climate changes to 2050 are given in Table 3 and Table 4. Table 3 considers the SSP1/RCP4.5 combination and Table 4 provides the SSP5/RCP8.5 combination. The following points emerge from the analysis. Costs are per year and are reported in five year blocks.

1. Costs start out quite small but build up over the period to 2050. In the 2015-2020 block they range from US$52-66 million but by 2045-2050 block they are as high as US$638-1,157 million.

2. New construction accounts for around 37 percent of total costs; the rest is additional maintenance.

3. Total costs vary considerably by socio-economic and climate scenario. With the more climate friendly scenario the total cost to 2050 is around US$2 billion while with the less friendly one with little mitigation action it goes up to around US$3 billion.

4. The most affected sector is residential buildings, which account for around half of all costs due to climate change on the infrastructure sector as a whole. Next are public buildings, which account for 25% and then comes other private infrastructure (i.e. non-residential private buildings) with 16%. In fact, if we take the infrastructure sector as a whole, it is buildings that account for most of the costs (92%). Transport is relatively less impacted (accounts for 8 to 10% of the cost to infrastructures due to climate change) but costs are still significant: US$194 to US$250 million depending on the socio-economic and climate scenario chosen. This is partly due to negligible impact of precipitation on adaptation costs of transport infrastructure. Indeed, the climate scenarios show a decline in precipitation over the period, when precipitation is the climate variable that has more effect on transport costs.

5. The estimates report costs based on the climate projections as summarized in Table 2. 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. This does not mean that heavy rainfall is irrelevant. Its impacts on infrastructure are evaluated separately in the next section.

6. Not included in this assessment are the costs of additional infrastructure to deal with climate events. 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). Details are discussed in Section IV.

Table 3: Estimates of Adaptation Costs for Infrastructure in Uganda. US$2014 Million

Case of RCP4.5 and SSP1

Table 4: Estimates of Adaptation Costs of Selected Infrastructure Sectors in Uganda US$2014 Million

Case of SSP5/RCP8.5

4. COSTS OF ADDITIONAL INFRASTRUCTURE NEEDED DUE TO CLIMATE CHANGE

The World Bank has carried out some cross section analysis of the demands for infrastructure across countries, seeking to explain them in terms of several variables, including climate related ones such as temperature and precipitation. Population weighted measures of the climate variables were constructed using climate data for grid cells in each of the countries. Demand for a range of infrastructure services is found to be a function of these climate variables. The key results are summarized in Table 5

Table 5: Demand for Infrastructure from WB Study and Relevance to Uganda.

Area	Result	Application to Uganda
Electricity Generation Capacity	Increase in temperature reduces generating capacity (but increases load for items such as AC)	The cross section result reflects lower net energy demand probably due to less heating and is not applicable to Uganda where there is no heating demand. Reduced thermal efficiency at higher temperatures may apply
Water Demand	Increased demand with temperature for municipal water demand	Relevant for Uganda as increased needs for many uses are temperature dependent.
Water and Sewerage	Decreased coverage with temperature	Application to Uganda unclear. We propose not to include it.
Roads	Impact of temperature on road length varies with specification Impact of precipitation on total road length is to increase it. Share of paved roads in total goes up with temperature range and down with precipitation range	Application to Uganda unclear. We propose not to include it..
Public Infrastructure	Hospital beds and No of doctors vary with temperature but at a rate that depends on GDP. It is negative for low GDP but increases as GDP goes up. Precipitation is positively related to hospital beds.	Links are complex. In Uganda it is hard to see why increases in temperature should decrease hospital beds or doctors. Precipitation declines could result in less beds and ore doctors but again reasons are not clear. We propose to not include such impacts.

Source: World Bank (2010)

The matter of interest to this study is the implication of the findings for the likely changes in demand for infrastructure in Uganda. The link between temperature and electricity generation capacity for example is probably a combination of factors, an important one of which is demand for space heating. Since space heating is not a source of demand in Uganda this link is unlikely to be important. The relation between temperature rise and thermal efficiency as estimated in some UK studies comes out at about a 3% fall in efficiency for a temperature increase of around 2.5°C. There is, also a possible additional demand for air-conditioning. This is discussed in the energy sector review. In other cases such as sewerage, roads and public infrastructure it is difficult to establish a credible pathway for increased or reduced demand as a function of climate. The one case where increased demand with temperature rise may apply is water.

5. COSTS OF EXTREME EVENTS

The costs of extreme events are derived from data on droughts, floods and storms in Uganda over the last 81 years (1933-2014). The source is the Global Disaster Assessment Database collated by the United Nations Office of Disaster Risk Reduction[5]. It documents 1,512 such events in Uganda over the said period, resulting in 2,165 deaths, 11,812 injuries, 29,180 people relocated, over 8.6 million people affected and 21,450 houses destroyed[6]. On average the data show that here have been the following consequences of disasters in the country (Table 6):

Table 6: Average Impacts of Climate Related Disasters in Uganda per Year (1933-2014)

Deaths per year	26.7
No of injuries	146
Houses destroyed	265
Houses damaged	55
No of victims	29
No affected	106,902
No relocated	5,587
Roads damaged (Mt.)	3,159

Source: UNRISD

In order to calculate the costs of these impacts data are needed from current events, as well as a method of estimating the costs to be attached to a loss of life. The amount of economic data available are very limited. Two recent events for which economic information is available are the El Nino floods of 2007 and the floods in Kasese in May 2013. These are described briefly.

[5] http://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=uga#more_info. The number affected refers to the 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.

[6] The dataset did not contain one event for which data were collected separately: the El Nino of 2007 in which 1,525 people were estimated to have died, 11,000 hospitalised and 150,000 displaced. These data were added to the deaths and relocations in the database to arrive at the numbers in Table 5.

5.1.1. Floods in Kasese – May 2013

The data for Kasese are reported in Kabuji and Mukwaya (2014). Heavy rains and flash floods led to significant damages in Kasese in May 2013, with significant impacts on infrastructure and human health. Table 7 identifies some of the major impacts. Figures 1 and 2 provide some illustration of impacts – it can be seen that significant disruption to transport and damage to homes resulted.

Some information is available on two aspects of this event: disaster relief expenditure and costs of repairs to roads and buildings. Disaster relief expenditure by the IFRC amounted to Swiss Francs 293,166 (US$316,218) (IFRC, 2013). The costs of repairing major bridges and road networks were estimated at 5 billion shillings (approx. US$2 million) in the aftermath of the floods (The Insider, 2013). This estimate rose to 35 billion shillings (US$13.7 million) (MK News Link Agency, 2014). Damage to the hospital included the loss of the mortuary, the paediatrics ward and an X-ray machine, for which funds were requested from the Department of Health (The Insider, 2013).

Table 7: Major impacts of Kasese floods in May 2013

Impact type	Description
Mortality	10 lives lost
Water borne disease	Increased risk of water borne disease due to water supply damage
Displacement	25,445 forced from homes, Red Cross distributed 3300 shelter and NFI kits
Housing	Severe damage to almost all housing units in Bulembia district and Kilembe town
Infrastructure:	
Bridges	19 bridges washed away
Hospitals	Damage to Kilembe Mines hospital, including loss of equipment.
Sewage treatment	Damage to sewage treatment
Water supply	Destruction of water supply systems
Energy	Three hydropower plants on River Mubuku affected

Figure 1: Flood damaged to a paved road.

Source: Retrieved 30th June 2014 from http://www.wvi.org/uganda/gallery/kasese-floods-destroy-roads-homes

Figure 2: Flood damage to homes and a road in Kasese, Southwestern Uganda

Source: Retrieved 30th June 2014 from http://anglicanaid.net/urgent-disaster-relief-devastating-flooding-in-south-western-uganda/

5.1.2. El Nino floods of 1997/8

The El Nino floods of 1997/8 were highlighted in the first National Communication to the UNFCCC. Heavy rain from mid-November to early December led to significant loss of life through flooding and landslides. It impacted particularly the east of the country (FAO, 1998).

A summary of the impacts is given in Table 8.

Table 8: of impacts of El Nino floods in Uganda in 1997/8.

Impact category	Summary
Health – mortality	Estimated that 1,000 died in flood related accidents Estimated that 525 people died due to cholera related to the floods
Health – Morbidity	11,000 hospitalised and treated for cholera
Displacement	150,000 displaced
Infrastructure	Damage to trunk and rural road infrastructure costed at US$400 million (US$752 million, 2013 prices)
Agriculture	300 ha wheat destroyed Tea plantations flooded 60% fall in coffee exports due to transport disruption in October and November
Water supply	Infiltration of water resources and flooding of some pumping stations

Source: Based on First National Communication to UNFCCC

5.2. Expected costs of climate-related extreme events in Uganda

The aim of this exercise is to estimate the expected damages from climate related events in the country in monetary terms. This requires firstly costing the loss of life, which is one of the main components of damage from extreme events. Such loss is usually valued in terms of the Value of a Statistical Life (VSL). VSL is the value attached to a loss of an anonymous' life and is used among other things to make decisions about investment safety. If, for example, a safety barrier on a road would cost US$10 million to install and can be estimated to avoid 5 deaths per year for the next 20 years then it is justified if the VSL is greater than US$100,000. This value is a socially determined number, partly based on individual attitudes to safety.

To our knowledge, no primary study of VSL exists for Uganda. Hence we transfer values from the US case to the Ugandan context[7], adjusting for income and income elasticities between 0.3 and 1. Taking the US Environmental Protection Agency value of US$7.4 million, inflating using the US Consumer Price Index and adjusting for Purchasing Power Parity GNI (Gross National Income) per capita leads to estimates of a VSL for Uganda in 2013 of between US$81,256 (e=1) and US$2.1 million (e=0.3)[8].

The other components that have been valued are serious injuries, numbers affected, damage to infrastructure and costs in terms of disaster relief. As far as injuries are concerned a typical value used in the literature is 8 percent of the VSL. This percentage has been applied to the expected number of such injuries as given in Table 6.

For infrastructure we have taken the data from the Kasese and El Nino events for which estimates are available for both infrastructure damage and deaths. The ratio in terms of damages in millions of dollars per death range from 0.5 to 1.4. This range has been used to estimate expected loss of infrastructure.

[7] To the best of our knowledge, no estimate for the value of a statistical life exists in the African context. Use of estimates from the US and adjusting for differences in income is consistent with the current state-of-the-art until such time as a study is conducted in the African context.
[8] Such a method of obtaining VSL has been used quite frequently in studies of the costs of extreme events. The elasticities of 0.3 and 1 are the limits of values recommended by Navrud and Lindhjem (2011). Estimates have been made on this basis in integrated assessment models to calculate total climate damage costs. See Stern, 2006, OECD, 2008.

For people affected we used estimates from the Centre for Research on the Epidemiology of Disasters CRED database where economic damages are reported by country. There are not enough events that are values for Uganda to provide a reasonably reliable estimate but there were enough 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 person affected.

Finally for disaster relief the one estimate available indicates a cost of around US$12 per person relocated. This figure has also been used.

5.3. Costing impacts in 2025 and 2050

In order to cost impacts in the future the following assumptions have been made:

1. Loss of life is valued at the VSL of the year in question. VSL increases with per capita GDP in accordance with the elasticities of 0.3 or 1, as given above. It also increases proportionally with population
2. Injury costs also increase along with VSL as explained above.
3. Costs per person affected are taken to range from US$35-117, and rise with GDP.
4. Infrastructure costs are related to number of deaths, with damages ranging from US$0.5 to US$1.4 million in 2013. Over time these cost rise in proportion with per capita GDP.
5. Disaster relief costs rise in proportion with per capita GDP.
6. There is no formal climate projection on increased frequency of extreme events or of their intensity. At the same time the recent evidence indicates an increase in such frequency. As noted in the agricultural sector report, while 16 major flooding events and 9 major drought occurred between 1900 and 2011 it is striking that 8 out of the 10 most severe floods and droughts 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 two tables are reported: one with no increase in frequency and one in which frequency of extreme events doubles by 2025 and doubles again by 2050.

The results are shown in Table 9 and Table 10. For sensitivity, both upper bound (UB) and lower bound (LB) estimates are presented. With no increase in frequency, expected damages are currently estimated in the range of US$20-129 million a year, of which infrastructure losses are between US$13-37 million. By 2025 total damages rise to around US$38-234 million and by 2050 they are up to US$189-838 million. As a percent of projected GDP, however, these figures change only slightly and are never more than 0.1 percent of GDP. With the projected increase in frequency, however, the annual expected losses go up to US$39-234 million in 2025 and to US$189-838 million in 2050.

Table 9: Damages to Infrastructure and Human Capital from Extreme Events (No increase in Frequency) US$Mn.

	2013		2025 SSP1		2025 SSP5		2050 SSP1		2050 SSP5	
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Loss of Life	2.17	56.13	5.94	99.58	6.12	100.09	43.88	246.62	57.10	263.27
Injury	0.95	24.50	2.59	43.46	2.67	43.68	19.15	107.64	24.92	114.91
Number Affected	3.74	12.51	5.51	19.42	5.48	19.32	8.55	30.11	8.38	29.53
Infrastructure	13.18	36.62	24.48	68.02	25.33	70.36	116.55	323.80	154.66	429.68
Disaster Relief	0.07	0.07	0.13	0.13	0.13	0.13	0.61	0.61	0.81	0.81
Total	20.11	129.82	38.66	230.61	39.73	233.59	188.75	708.79	245.88	838.20
As Percent of GDP	0.044	0.286	0.037	0.219	0.037	0.216	0.024	0.091	0.024	0.083

LB: Lower Bound. UB: Upper Bound

Table 10: Damages to Infrastructure and Human Capital from Extreme Events (Frequency Doubles Every 25 Years). US$Mn.

	2013		2025 SSP1		2025 SSP5		2050 SSP1		2050 SSP5	
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Loss of Life	2.17	56.13	11.89	199.16	12.23	200.17	175.52	986.47	228.41	1053.07
Injury	0.95	24.50	5.19	86.93	5.34	87.37	76.61	430.57	99.69	459.64
Number Affected	3.74	12.51	11.02	38.84	10.97	38.64	17.10	60.23	16.77	59.06
Infrastructure	13.18	36.62	48.97	136.05	50.65	140.73	466.20	1295.22	618.63	1718.72
Disaster Relief	0.07	0.07	0.26	0.26	0.27	0.27	2.45	2.45	3.26	3.26
Total	20.11	129.82	77.33	461.22	79.46	467.17	737.88	2774.94	966.76	3293.75
As Percent of GDP	0.044	0.286	0.074	0.439	0.073	0.432	0.095	0.358	0.096	0.326

LB: Lower Bound. UB: Upper Bound

We need to recall that these figures are **expected annual damages** – i.e. over a large number of years they represent the average losses. In any one year the figures could be much higher, as we can see by looking at a repeat of the El Nino event in 2050. In that case estimated losses from mortality and infrastructure would be as shown in Table 11. Losses would be in the range US$5-19 billion from loss of life and US$11-15 billion for infrastructure.

Table 11: Estimated costs of a similar event as the 2007 El Nino floods in 2050 under different socioeconomic scenarios (US$ Mn.)

	Mortality	Infrastructure
SSP1	5,641 to 18,085	11,528
SSP5	7,341 to 19,306	15,013

Source: Own Calculations

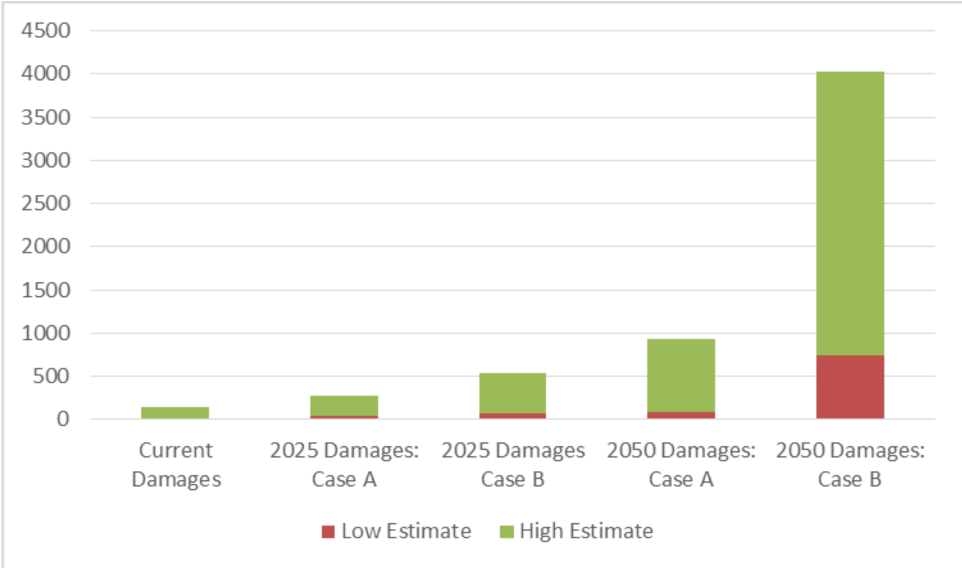
6. CONCLUSIONS AND ADAPTATION OPTIONS FOR UGANDA

6.1. Costs of Inaction

In the presence of climate change, infrastructure is affected in two ways: one through effects on the normal use of buildings, roads, railways etc.; and the other through damage done by extreme events, particularly heavy rains and flooding. The methodology adopted here does not estimate the costs of inaction for the first. Rather it takes the view that it is appropriate to adapt the national infrastructure to such change by making it more resilient. This means constructing new buildings, roads and other infrastructure to be proofed against such climatic impacts such as increases in temperature and precipitation and by increasing maintenance for all infrastructure so that it is not damaged by normal climatic events. Implicit in such an approach is the assumption that the costs of such adaptation are less than the costs of inaction. This is a standard assumption in the adaptation literature and has been used in all the previous assessment of the impacts of climate change on infrastructure.

On the second pathway for climate change to impact on infrastructure, the study provides an estimate on inaction by estimating damages to the infrastructure itself as well as to human life. Estimates have been made of the expected costs in future years arising from climate related extreme events, based on the frequency of such events in the past and the damages they caused. Damages included in the study are loss of life and injury, damage to property, costs to persons due to dislocation and inconvenience and disaster relief. If there is no increase in frequency or intensity the damages, which are currently put at between US$20-130 million a year (depending on how you value the loss of life), rise to US$39-234 million by 2025 and to US$189-838 million by 2050. Note, however, that as a percent of projected GDP the damages do not increase. The assumption of no changes in the frequency or intensity of such events is questionable. Although the climate models do not provide any quantitative statement of an increase, recent evidence indicates that an increase is happening and it is therefore reasonable to assume that it is likely to continue. Assuming a doubling of frequency every 25 years would result in damages of around US$77-467 million by 2025 and US$738-3294 million by 2050. In this case damages as a share of projected GDP increase although even then they are only around 0.1-0.3 percent of GDP in 2050. The figures are average of expected damages; a particular event similar to the one that occurred in 2007 would represent very significant costs in 2025 and 2050. It is interesting also to note that there is not much difference in damage costs between the two socioeconomic scenarios considered (SPP1 and SPP5). Figure 3 summarises these results on the costs of extreme events.

Figure 3: Estimates for Damages Caused by Extreme Events in Uganda (US$Mn per Year)



Case A: No increase in the frequency of extreme events
Case B: Frequency of extreme events doubles every 25 years due to climate change

6.2. Adaptation to Climate Change

6.2.1. Key findings

The key findings for the cost of adaptation to climate change for infrastructure are the following:

1. Infrastructure is already impacted by climate variation and will be more so as climate change becomes more pronounced. The first component of the impact is estimated in terms of the costs of making existing and new infrastructure climate resilient and of maintaining it in the face of higher temperatures and changes in precipitation. **These costs are in the range of US$52-66 million in 2020 but by 2050 they are as high as US$638-1,157 million. New construction accounts for around 37% percent of total costs; the rest is additional maintenance**.
2. Total costs vary considerably by socio-economic and climate scenario. With the more climate friendly scenario the total costs to 2050 are around US$2 billion while with the less friendly one with little mitigation action they go **up to US$3 billion**.
3. The **most affected sector is residential buildings**, which account for around half of all costs due to climate change on the infrastructure sector as a whole. Next are public buildings, which account for a quarter and then comes other private non-residential infrastructure with 16%. In fact, if we take the infrastructure sector as a whole, it is **buildings that account for most of the costs (92%). Transport is relatively less impacted** (accounts for 8 to 10% of the cost to infrastructures due to climate change) but costs are still significant: US$194 to US$250 million by 2050 depending on the socio-economic and climate scenario chosen. This is mainly the result of projected decline in precipitation: with an increase in precipitation transport costs would play a bigger part.
4. The estimates do not include any costs of additional infrastructure to deal with climate events. 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).

The estimates in this study to 2030 amount to between $300 million and $370 million. These figures can be compared with those in the Government's NCCP Costed Implementation Strategy document (Government of Uganda, 2012), which estimates a total cost for transport and works of $1.05 billion over the next 15 years (i.e. to 2030). The Government of Uganda (GoU) figures are summarized in Table 12. The difference between the two estimates partly lies in the different approaches and partly in the items covered. This report has done a more detailed assessment of climate resilience needs but it has not evaluated the costs of site investigations for future infrastructure development or the costs of water catchment protection. These two items would add $394 million to our estimates, giving a total figure of between $700 million and $770 billion, which is about 30 percent lower than the GoU estimate.

Table 12: Government of Uganda Estimates for Infrastructure to 2030

Item	Cost (US$)
Integrate climate change into the existing infrastructure risk assessment guidelines and methodology	14,100,800
Building on work already underway, establish and enforce climate change–resilient standards for transport and infrastructure planning and development through monitoring and reporting systems	21,532,900
Integration of climate change into transport and infrastructure development	622,589,867
Promote and encourage water catchment protection in transport infrastructure development and maintenance	191,853,717
Climate-proof existing and future infrastructure by conducting geotechnical site investigations (GSIs) to determine whether areas are appropriate or inappropriate for infrastructural development	203,826,716
Total	1,053,904,000

Those figures are estimates of the costs of adaptation; it remains then to prioritize them and identify which agencies will be responsible for implementing corroborated actions. Table 13 provides some judgment on this, based on previous work and on national priorities. Based on the review of the material **the report concludes that highest priorities in the infrastructure adaptation programme are for:**

- **climate proofing public buildings,**
- **developing standards for transport and infrastructure planning, and**
- **integrating climate change-resilient standards into existing infrastructure risk assessment guidelines**.

All of these must precede the necessary new investments in infrastructure. Other components of the programme are also of priority, especially to ensure that new construction respects the climate resilience requirements but will be rolled out over the next 15 years.

Table 13: Adaptation Measures for Infrastructure, Agencies Responsible and Priorities to 2030

Item	Amount to 2030 $Mn.	Agency Responsible	Timing and Critical Decisions	Priority
Private Non-residential buildings	33-46	Private sector (*)	Building codes need to be amended now and enacted over the next 15 years	High
Residential buildings	148-203	Private sector (*)		High
Public Buildings	66-91	Ministry of Works&Transport (*)	Government Regulations to be amended now and enacted of next 15 years	Very High
Paved Road	19-20	Ministry of Works&Transport (*)		High
Railroads	30-39	Ministry of Works&Transport (*)		High
Integrate climate change into the existing infrastructure risk assessment guidelines and methodology	14	Ministry of Water and Environment	Urgent need to develop capacity and implement methodology & monitoring	Very High
Establish and enforce climate change–resilient standards for transport and infrastructure planning and development through monitoring and reporting systems	22	Ministries of Works&Transport and Water&Environment		Very High
Promote and encourage water catchment protection in transport infrastructure development and maintenance	192	Ministries of Works&Transport and Water&Environment	Programme can be initiated now by designing measures to support catchment protection	Medium
Climate-proof existing and future infrastructure by conducting geotechnical site investigations (GSIs) to determine whether areas are appropriate or inappropriate for infrastructural development	204	Ministries of Works&Transport and Water&Environment	Ministries of Transport and Works and Water and Environment	High

(*) Most of the expenditures will be phased as and when the relevant investment in infrastructure are undertaken.

6.2.2. Extreme events

As far as extreme events are concerned, the Government's NCCP Costed Implementation Strategy proposes a number of actions under risk management, which are summarized in Table 14 below. The measures proposed are sensible and should contribute to reducing damages from future extreme events.

Of the actions in the government programme the highest priority is for:

- **measures to improve early-warning systems and preparedness** to avoid or minimize the adverse impacts of climate change,
- **development and implementation of a climate change-induced disaster risk management strategy,**
- **strengthening of the National Emergency Coordination and Operations Centre, and**
- **establishment of a national contingency fund.**

Other measures are also a priority and need to start now but will be rolled out in the coming 5-15 years.

However, one would need indicators to measure their success in terms of reduction of impacts if they are to be valued. Such indicators have not been developed and more detail would be needed at the local level to make such assessments.

Such detail is provided in part by Kajubi and Mukwaya (2014) who identify a number of measures that need to be taken urgently to deal with the consequences of extreme events. These include:

- The resettlement of displaced people back into stable homes. A number of organizations and donor agencies like Uganda Red Cross, Save the Children, Hima Cement Industry, Rweco and many more have been very active in this particular area but more needs to be done.

- Repair of damaged infrastructure and rechanneling of rivers to their original positions - A number of bridges like Katiri Bridge on Nyamwamba River in Kilembe and Mubuku Bridge on Mubuku River are under their final stages of repairing while a contractor has been procured to rechannel River Nyamwamba itself particularly in Kilembe and Bulembia to its original position. MWE has also undertaken the rehabilitation of 180 boreholes in Sironko, Bukedea, Kumi, Soroti, Amuria, Katakwi, Kaberamaido, Dokolo, Moroto, and Nakapiripirit and Kotido (as a response to the floods in north and eastern Uganda); drilling of 81 boreholes (31 for floods in north and eastern, 4 for cholera affected areas in the east, 46 in various parts of the country; and Water Tankers procured to boost water supply in emergency areas (MWE, 2009). URCS as part of its recovery phase for the floods and landslide victims, URCS has also drilled two bore holes, rehabilitated and disinfected 10 other boreholes and now serving 7,139 families.

- Ensure that communities rebuild more flood resistant shelters: a campaign focusing on the Teso subregion has been started aggressively by Uganda Red Cross. This has been combined with a large scale public information program on building safe houses and resilient livelihoods. Uganda Red Cross Society (URCS) has enabled the construction of over 8,000 flood-resistant houses for flood affected households. In Teso sub-region, at least 13 villages have started implementing recovery measures following the training of 50 community based volunteers in participatory safe shelter approach skills to reduce risks of flooding. Information, education and communication materials such as posters have been produced which show improved earth construction, and illustrate details of how to protect the house from flooding or termites:
    - The house and foundations should be elevated.
    - Foundations should be built with a large plinth beam of wattle and daub. This would need to be repaired by house owners after each small flood

  - A water proof barrier should be put the foundations to protect the walls and floors which are made of adobe blocks.
  - Walls made of sun dried mud blocks should be conical in shape
  - Proper materials to build more resistant earth blocks should be identified. Examples are clay from termite hills, and using mud mixed with cow dung to protect against termites.
  - Wood in direct contact with the earth should be treated to protect it from termites.

- Bio-engineering – to manage rock falls that damage newly constructed roads especially in hilly landscapes, the Uganda National Roads Authority has started the application of Vetiver grass technology at critical spots. This assessment recognised the application of Vetiver grass along the newly reconstructed Fort Portal Bundibugyo Lamia road to protect the road from bank erosion and lower maintenance requirements in the longer term.
- Rock falls (gabions) and retaining walls are being encouraged in all construction activities across the country. For example, the higher reaches of River Nyamwamba especially where flow velocities are too high and in the sections where the river is in direct contact with infrastructure and housing, this is planned as part of the broader recovery effort for the region.
- Training – URCS together with the communities have conducted vulnerabilities and capacity assessments, mapped out local hazards, identified areas at risk and developed preparedness action to reduce vulnerabilities. Communities have also been empowered with skills to reduce the impact of climate change, floods and drought which include planting of 1, 000 fruit trees along river banks, use of seasonal calendar for planting and timing, promotion of flood resistant crop varieties like rice and yams. The American Red Cross is working with the Uganda Red Cross and communities in Bududa, Manafwa and Butaleja Districts to conduct detailed assessments, train disaster response teams, create contingency plans and establish early warning systems to help ensure that communities are better prepared for future disaster.

These are examples of current adaptation measures that will need to be stepped up in the future as population growth and an increase in the stock of infrastructure take place. A cost benefit assessment of individual programmes is needed to justify and prioritise (rank) them. While this can only be done at the local or regional level, one can make a preliminary assessment of the amount by which the programme items described in Table 14 would need to reduce damages to generate a given rate of return of (we have chosen) 10 percent, assuming that expected damages will follow the path given in Tables 9 and 10. In doing this we assume:

i. The expenditures in Table 14 are incurred evenly over the 5 year period 2015-2019.
ii. They start to impact on the costs of extreme events following on from 2020 to 2030.
iii. Disaster relief is not included in the reduced damages as its costs are included in Table 14.

Table 14: Disaster Risk Management Adaptation Costs to 2030

Proposed adaptation action	Priority &Timing	Amount (US$)
Develop and implement a climate change–induced disaster risk management strategy	High Priority. Short term action	305,995
Create an appropriate legal and regulatory framework for disaster management	Priority. Medium term action	174,854
Promote vulnerability risk mapping (including the social and economic impacts of climate change) of the whole country and all sectors		510,511
Improve early-warning systems and preparedness to avoid or minimize the adverse impacts of climate change	Very High Priority Immediate action	1,012,261
Strengthen climate change–induced disaster management institutions at the national and local levels to reduce causality and ensure preparedness	Priority. Medium term action	3,933,341
Provide basic needs to victims of climate change–induced disasters in the form of financial assistance or donations of food, goods and services as the need arises		No Cost Provided
Encourage the formation of resident associations that can respond to emergencies, and involve them in key decision making to reduce risks.		809,481
Strengthen the National Emergency Coordination and Operations Centre and establish a national contingency fund	High Priority. Short term action	2,898,793
Promote the development of innovative insurance schemes to insure households, institutions and businesses against the destruction caused by extreme weather events and disasters	Priority. Medium term action	2,498,839
Total		**12,144,075**

The analysis shows that **with a 7 percent reduction in expected damages, the programme in the Costed Implementation Strategy to deal with floods would generate a rate of return of 10 percent.** This is under the most conservative assumptions: a VSL at the lower bound of the estimated range, and correspondingly the same for injuries, damages to infrastructure and affected persons. If we take the upper bound of the range the programme would have to make a very small reduction in expected damages (1.2 percent) to achieve a 10 percent rate of return. The results quoted refer to the SSP1 scenario. There is very little change if we work with the SSP5 scenario. Finally note that no increase in frequency due to climate change has been assumed in making these calculations.

These findings of course are not surprising. Expected damages in 2020 from disasters are estimated to be from $23 million as a lower bound. Moreover they are estimated to rise with time. **A programme that reduces these figures for a period of 10 years (to 2030) and costs only $12 million will have a very high net benefit**. Of course the case for the projects is not proven and more work is needed to link the programmes to reductions in damages but there is some evidence to support them.

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