The Republic of Uganda

MINISTRY OF WATER AND ENVIRONMENT

CLIMATE CHANGE DEPARTMENT

Economic Assessment of the Impacts of Climate Change in Uganda

Final Study Report

November 2015

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

- Le Groupe-conseil Baastel sprl, Belgium (lead)
- University of Makerere, Uganda
- Metroeconomica, UK
- Centre for International Development and Training (CIDT), University of Wolverhampton, UK

Main Authors:

- Anil Markandya (Metroeconomica)
- Courtenay Cabot-Venton (Baastel)
- Olivier Beucher (Baastel)

Contact: olivier.beucher@baastel.com

baastel Metroeconomica MAKERERE UNIVERSITY CIDT

ABOUT THE PROJECT

This study was commissioned by the Climate and Development Knowledge Network (CDKN), at the request of the Government of Uganda, and funded jointly by CDKN and the UK Department for International Development (DFID), Uganda office. The work was locally coordinated and owned by the Climate Change Department (CCD) of the Ministry of Water and Environment.

Le Groupe-conseil baastel sprl, generally known as 'Baastel', led the study process from its office in Uganda. The consortium included:

- The Makerere University (Uganda)
- Metroeconomica (UK)
- The University of Wolverhampton Centre for International Development and Training (CIDT) (UK)

The following experts contributed to the study:

- Olivier Beucher, Lucile de Boisson, Jon Garcia, Lisa Kistler, Alain Lafontaine (Baastel)
- Bernard Bashaasha, Shuaib Lwasa, Tom Mwebaze, Isaac Nakendo, Alex Nimusiima, Adam Sebbit (Makerere University)
- Nick Dale, Anil Markandya, Tim Taylor (Metroeconomica)
- Rachel Roland, Dawn Springthorpe (CIDT)
- Joseph Spadaro (Basque Centre for Climate Change – BC3)
- Joel Botai, Wasswa Francis Nsubuga, Hannes Rautenbach (University of Pretoria)
- Peter Droogers (FutureWater)
- Grant Ballard-Tremeer, Morna Isaac (Eco ltd)
- Jacquelin Ligot (Climate and Energy Solutions)
- Stephen Mutimba (Camco Kenya)
- Courtenay Cabot-Venton, Scott Cunliffe, Jillian Dyszynski, Lammeck Kajubi, Council Dickson Langoya, Kennedy Okuda, Albert Rugumayo, Liberal Sekurikoko, Mxolisi Shongwe, Humphrey Wanzira, Kate Zinszer (as independent consultants)
- Claire Monkhouse and Victoria Cox (CDKN)

For further information, contact:

Government of Uganda Climate Change Department: Mr Joseph Epitu josephepitu@gmail.com

CDKN: Claire Monkhouse Claire.m.monkhouse@uk.pwc.com

Baastel: Olivier Beucher olivier.beucher@baastel.com

Full project reports (in particular Climate change scenarios, sectorial studies and case-study reports) and detailed technical annexes to support this document are available on the study webpage on the CCD website: http://www.ccu.go.ug/index.php/projects/cdkn and www.cdkn.org

We acknowledge the valuable contributions of many people and organisations. In particular, we would like to thank the Climate Change Department, Ministry of Water and Environment, as well as all the stakeholders who contributed to this work and gave their time for consultations, meetings, workshops and report reading, from Uganda but also from Rwanda, Kenya and Tanzania. The study process has been highly participatory and this wouldn't have been possible without their contributions.

LIST OF ACRONYMS

Acronym	Definition
AR5	5th Assessment Report
BAU	Business As Usual
CDKN	Climate and Development Knowledge Network
CCD	Climate Change Department
CIDT	Centre for International Development and Training
CSA	Climate Smart Agriculture
DFID	Department for International Development
DJF	December January and February
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GoU	Government of Uganda
IAM	Integrated Assessment Model
IAV	Impacts Adaptation and Vulnerability
IFPRI	International Food Policy Research Institute
IPCC	International Panel for Climate Change
IRR	Internal Rate of Return
JJA	June July and August
KCCA	Kampala City Council Authority
LB	Lower Bound
LPG	Liquefied Petroleum Gas
MAM	March April and May
MCM	Millions of Cubic Meters
MOLG	Ministry of Local Government
MWE	Ministry of Water and Environment
NCE	New Climate Economy
NCCP	National Climate Change Policy
NDP	National Development Plan
NEMA	National Environment Management Authority
NGO	Non-Governmental Organisation
NPL	National Poverty Line
OECD	Organization for Economic Cooperation and Development
PPP	Purchasing Power Parity
R&D	Research and Development
RCP	Representative Concentration Pathway
SON	September October and November
SSP	Shared Socio-Economic Pathways
UB	Upper Bound
UBOS	Uganda Bureau of Statistics
WEAP	Water Evaluation and Planning

TABLE OF CONTENTS

KEY MESSAGES

- *Development prospects will only be reached if climate impacts are mitigated.*

Development prospects for Uganda foresee an average annual growth rate around 7-8% over the next 25 years and a drop in poverty levels. These prospects depend, however, on a lot of factors working in favour of implementation of sustainable development policies. Current research indicates that the adoption, through the UNFCCC negotiations, of a high ambition climate change scenario, combined with the right policies to achieve low carbon growth, is likely to support the achievement of such development.

There is a link between the impacts of climate change and future growth prospects in the country. In the absence of adaptation actions, climate factors could compromise the Uganda Vision 2040 targets. The impacts of climate change will constrain growth in Uganda. Fortunately, these impacts can be mitigated via adaptation, which can de-couple growth from climate impacts.

In addition, economic growth is a key factor in ensuring that climate impacts are manageable relative to the resources available to tackle them. While damages caused by climate change increase with economic growth, so do the resources available to deal with them, and on balance the costs of adaptation fall as a percent of GDP, as GDP increases

- *Climate change damage estimates in the agriculture, water, infrastructure and energy sectors collectively amount to 2-4% of GDP between 2010 and 2050.*

Climate change is predicted to have a significant impact on Uganda. The national-level studies show that if no adaptive action is taken, annual costs could be in the range of US$3.2 - 5.9 billion within a decade, with the biggest impacts being on water, followed by energy, agriculture, and infrastructure. Over the 40 years from 2010-2050, the costs of inaction are estimated at between US$273 - 437 billion. . Even if there were no further increases in climate impacts, the cost of inaction would rise over time because of an increase in population. Poor and vulnerable groups are mostly likely to be impacted through damages to their assets, livelihoods and their food security. While the range in potential impact is quite large, the magnitude of the figures on the cost of inaction merit immediate action to mitigate these impacts.

The economic impacts of climate change are closely interconnected with economic growth. If we assume a growth path close to the Uganda Vision 2040, the economy will expand enormously by 2050 – to about 20 times its size in 2010. Under this scenario, the damages also increase at a similar rate and the estimates amount to approximately 2-4% of cumulated GDP over the period. If the economy does not see this level of growth, damages will be slightly less, but as a percentage of GDP they will still rise.

- *The cost of adaptation is high, but the cost of inaction is 24-46 times greater.*

Total spending on adaptation is estimated in 5 year intervals, from 2015 to 2030, based on Uganda's existing Costed Implementation Strategy and selected adaptation options from this study. During the next five years (short term) the cost is estimated at about US$406 million. On an annual basis this amounts to about 5% of net official assistance received by the country and 3.2% of total government revenues (excluding grants). In future the adaptation budgets rise significantly: to US$644 million for 2021-2025 and US$596 million for 2026-2030, and it is likely that, as a share of government revenues in those years, the demands for adaptation will rise.

However, the cost of inaction is much greater, estimated at around US$3.1-5.9 billion a year by 2025, a range that is around 24-46 times greater than the proposed adaptation budget. These costs combine current climate variability and future climate change, and therefore some of these costs will occur regardless of the expected climate impacts.

o *Uganda is ready to take immediate actions, and must do so.*

Many of the study's recommended actions make sense in terms of managing the current sectoral problems that the country faces, for example declining agricultural yields or water shortages for hydro-power plants. With climate change, the incentive to implement adaptation actions simply becomes stronger and more urgent. Further to this, many of the recommended actions are likely to be 'no regrets'- i.e. they will bring about gains regardless of whether climate change happens or not. Many of the actions also have potential co-benefits, for example reducing use of biomass for energy has carbon benefits and also potential biodiversity, health, and water management benefits.

The study makes a number of national-level recommendations for immediate action, including:

- Prioritizing the Government's Costed Implementation Strategy as a matter of urgency.
- Mainstreaming climate change into sector development plans, including translation of key priorities into sector annual plans and budgets. In many cases, the sector analysis on the impacts of climate change justifies and reinforces the need for urgent action on many of the measures that are already contained in the Costed Implementation Strategy.
- Mainstreaming adaptation priorities into District Development Plans that will rise out of the National Development Plan II.
- Ensuring that implementation of all action is monitored and enforced.

In addition, there is a general recommendation that applies across the board, regarding the need for further research to inform policy, planning and action on climate change in Uganda, in particular on issues such as:

- More precise estimates of impacts of climate change on yields of export crops by region, especially coffee.
- Impacts of climate change on livestock and on which breeds are most adaptive to these changes.
- Better estimates of likely changes in yields by crop and region.
- More detailed estimates of the impact of climate change on water resources. This will require more refined hydrological modelling than has been carried out so far. The work conducted by BRLi/Expertise France in the Mpanga river catchment is an excellent example of this kind of study.
- Quantitative estimates of reductions in water use through various efficiency measures. Local research centres may be best suited to carry out such work.
- Quantitative estimates of the benefits of conservation and protection of watersheds, water catchment areas, river banks and water bodies.
- Determine more accurately the impact of climate change on hydro power.
- The scope for substituting other fuels for domestic biomass will require detailed investigation on the costs and scope for distribution within the country.
- Better data on assets at risk from extreme events is required to plan for infrastructure protection.

The study also makes recommendations in relation to the sectoral and detailed case studies, as presented in this report.

Executive Summary

o *Background*

This report on *The Economic Assessment of the Impacts of Climate Change* provides information about the current "adaptation deficit" present in Uganda and the negative consequences and costs that climate variability already has on the Ugandan economy, and is expected to have under future climate change scenarios. Economic assessments of the impacts of climate change were conducted at the national level for five sectors (agriculture and livestock, energy, water, human settlements, and transport infrastructure), and detailed case studies were carried out in five local level locations: Kampala (focusing on infrastructure), Kabale & Tororo (health), Karamoja (agriculture and livestock), Mount Elgon (coffee), and Mpanga river catchment (water and electricity). The national-level assessment was carried out under two of the latest Representative Concentration Pathways (RCPs) developed as part of the Fifth Assessment Report (AR5) under the Intergovernmental Panel on Climate Change (IPCC).

The overall aim is to provide policy makers and international development partners in Uganda with the evidence base on the economic impacts of climate change in order to mobilise increased investment for adaptation in climate-sensitive sectors. The study also aims to increase the capacity of government officials to use the evidence on the economic impacts of climate change in development and investment planning.

o *Climate Projections*

The analysis started by carrying out a set of climate projections based on RCP scenarios RCP4.5 and RCP8.5. RCPs are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC. 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[1]. The national temperature and precipitation projections for Uganda are given in this report; the table below summarises the main results at national level.

Table ES1: Temperature and rainfall projections under RCP 4.5 and RCP 8.5 for Uganda.

Parameter	RCP 4.5	RCP 8.5
Annual temperature changes from the median	In +50 years to present: +1.5°C to +2°C in most continental parts of Uganda In +80 years from present: +2°C to +2.5°C in most of Uganda.	In +50 years to present: +2°C to +3°C in most continental parts of Uganda In +80 years from present: +4°C to +5°C 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.

The study investigated extreme events (droughts and floods) but did not provide a clear projection for these owing to the limitations of the climate modelling data. Nevertheless there are some data on areas facing higher risks of these events. The study estimated the coefficient of variation in inter-annual rainfall for Uganda and found a range from 13 to 29%. Areas where value is greater than 20% are more likely to experience more frequent and severe droughts or floods. Such high variations in inter-annual rainfall were found in locations in

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

the south and north-east of Uganda, while the lowest variations were in the south-west and north-west of Uganda.

o *Development prospects for Uganda*

The National Vision document (Uganda Vision 2040 [2]) provides development paths and strategies to operationalize Uganda's Vision statement which is "A Transformed Ugandan Society from a Peasant to a Modern and Prosperous Country within 30 years". It aims at transforming Uganda into competitive upper middle income country over this time period. The Vision foresees a consistent annual growth rate of 8.2% in per capita Purchasing Power Parity (PPP) GDP from 2010 to 2040, reaching US$4,300 in 2030 and US$9,500 in 2040. The latest per capita GDP figure is US$1,630 in PPP (2013). The Vision constitutes an ambitious programme foreseeing poverty in terms of the *National Poverty Line* (NPL) falling from 25% in 2009 (the latest figure available) to 5% in 2040 and the economy becoming much less agriculture based, with the share of that sector falling from 22% in 2010 to 10% in 2040. At the same time industry would grow from 26% to 31% and services from 51% to 58%. Other projections for the country carried out by the international climate community and institutions such as the World Bank are a little less optimistic, but generally express a similar view of the future prospects for the country.

These changes and the associated growth in GDP would be achieved through an increase in investment, from 24% of GDP at present to 30%, and major programmes of investment in transport, energy, water and urban infrastructure. The urban population would increase from 13% currently to 60% by the end of the period, and total population from 35 million to 60 million according to latest projections. Energy sources would change such that dependence on fuel wood and traditional biomass is replaced by electricity and gas, with much of the former coming from new hydro plants as well as nuclear and some domestic gas generation.

These prospects depend, however, on a lot of factors working in favour of implementation of sustainable development policies, one being a world in which there is an international agreement to implement a high ambition climate scenario. Such an agreement would spur the kind of development that is envisaged in the Vision2040 document, with major urban infrastructure investments in compact energy efficient developments, a transport system that is both efficient and low carbon, and an energy system that develops the low carbon indigenous resources to the extent feasible. A high ambition scenario will provide greater emphasis within that to renewables and non-fossil sources.

Furthermore, external finance to support such a pathway will be enhanced if the international agreement includes significant funds to support mitigation through low carbon development programmes in countries like Uganda, and finance to support adaptation. Uganda's Costed Implementation Strategy, which includes climate adaptation actions, has a total estimated cost of US$2.9 billion covering the next 15 years, and implementation will be contingent on such funds being available, in addition to funds from domestic sources.

It is not possible to be certain that a positive future for Uganda naturally goes with a high ambition scenario. Current research indicates, however, that a high ambition scenario **combined with the right policies to achieve low carbon growth** is indeed likely to result in such development. This has been convincingly demonstrated in the recent report by the Global Commission on the Economy and Climate[3], which shows that a package of measures including: reduced fossil fuel subsidies, the pricing of carbon throughout the economy, innovative finance for low carbon investments, increased subsidies for research and development in low carbon energy, and policies to ensure compact city development, will result in sustained green growth of the kind that

[2] Uganda Vision2040. (Undated). National Planning Authority. Government of Uganda.
[3] NCE (2014) *Better Growth, Better Climate. The New Climate Economy Report*. Washington, DC: The New Climate Economy, The Global Commission on the Economy and Climate.

is characterised by the global forward looking sustainable scenario (SSP1)[4]. At the same time the report argues, as have a number of others, that RCP8.5 will result in lower growth and greater inequality in the medium to long term.

o *Links between Development and Climate Impacts*

A higher rate of growth in real incomes results in a greater reduction of poverty. The less poverty there is in a country the smaller is the number of people vulnerable to climate related events such as floods and landslides. The affected groups have the capacity and resources to construct more durable structures and take measures to protect property and human lives. Furthermore, governments have access to a larger tax base from which they can finance expenditures that fall under the category of public goods and that would not be undertaken by private citizens. Examples are drainage systems in cities and dikes to prevent rivers from overflowing.

At the same time it is true that higher growth in an economy will lead to more assets that need protection and therefore a higher adaptation budget. The analysis carried out here shows, however, that as a percentage of GDP, adaptation costs are lower when growth is higher. Thus the higher costs of adaptation under faster growth are fully offset by the higher level of GDP.

There is also a link between the impacts of climate change and future growth prospects in the country. Key among these is the effect of climate on Ugandan export crops of coffee, cotton and tea. The Agriculture Sector Report produced as part of this study notes that climate-induced yield losses for coffee could be in the order of 50-75% by 2050 and progressively lower in the intervening years. These would represent a major impact on the economy, which is currently deriving 18% of its export earnings from coffee. Similar impacts are predicted for tea and cotton. Export earnings are a major source of growth for a country, as they allow for the import of capital goods that support growth across many sectors and create opportunities for employment in related industries. Thus **in the absence of adaptation actions, climate factors could compromise the Uganda Vision2040 target of 8% annual growth.** The research carried out in this study indicates, however, that there may be prospects for preventing some of these losses **and provides good examples of how adaptation, although requiring some upfront costs, does contribute to the country's economy**.

Economic prospects for growth could also be affected by water deficits resulting from the current climate variability as well as climate change, if they are not addressed through adaptation measures. The Water Sector Report produced as part of this study estimates major shortages in supply relative to demand, for agriculture and industry. These will act as a constraint on growth in the affected sectors. In addition, extreme events such as droughts have caused losses to agriculture in the recent past in the range of 1-7% of GDP. If these become more frequent, as is likely, economic output in key sectors will be reduced, having knock-on effects in other sectors. Such impacts can be reduced to a significant extent by adaptation measures that use water more efficiently and improve water storage and distribution efficiency.

Likewise with infrastructure, extreme events are already impacting transport infrastructure and mobility in the country. If outlays to adapt the system to such events are not made, losses in infrastructure functions will negatively affect economic growth. With respect to the energy sector, the country also faces twin deficits in traditional biomass and in electricity. Both deficits will increase over time unless they are addressed, and their size will increase as a result of climate change. Without action, economic sectors that depend on energy will be

[4] SSP1 is one of five scenarios developed by the international development and climate change community and is called the sustainability scenario. It is characterised by: reduced inequalities globally and within countries as low income countries develop at a rapid rate and a high level of education is achieved globally. The low global population growth is associated with a consumption oriented towards low energy intensity goods and low animal product consumption. This is partly enabled by a fast paced and environmentally friendly technological development. Reduced fossil fuel dependency and rapid clean energy technological development is concurrent with high level of environmental awareness. Environmental governance is successful at achieving global and implemented agreements. The Millennium Development Goals are achieved within the next decade or two.

held back and their growth will be compromised. Vision2040 requires energy supplies to increase to match the expected increase in output.

These links between climate impacts and economic growth are very real and are present now. Economic development is already constrained by the adaptation deficit to existing climate variability, and this is only likely to become worse with expected future climate change. Action is urgently needed.

o *Costs of Inaction*

National Estimates

Estimates were made of the costs of inaction under climate variability and change for agriculture, water, total infrastructure (which combines both transport infrastructure and human settlements) and energy. It has to be borne in mind that they are approximate and probably an underestimate given data limitations. Nevertheless they provide an order of magnitude of the true costs. Over the 40 year period 2010-2050 these damages amount to somewhere between US$273 and US$437 billion for these sectors alone if no action is taken. It is also important to note the estimates include the costs of both current climate variability as well as climate change.

Table ES2 provides a summary of the costs of inaction to climate variability and change over the period 2010-2050 for Uganda, for the agriculture, water, energy and infrastructure sectors.

Table ES2. Summary of costs of inaction to climate variability and change 2010-2050 for Uganda Annual Costs (US$Mn.)

	2025		2050		Total 2010-2050	
	LB	UB	LB	UB	LB	UB
Agriculture	293	513	1,401	2,458	22,200	38,300
Water	2,437	4,499	5,538	10,225	120,356	222,225
Energy	338	338	10,443	10,443	123,600	123,600
Infrastructure (*)	94	505	581	3,857	6,478	52,747
Total Costs to Uganda	3,162	5,855	17,963	26,983	272,634	436,872
As percent of PPPGDP	3.01	5.57	2.31	3.48	2.80	4.49

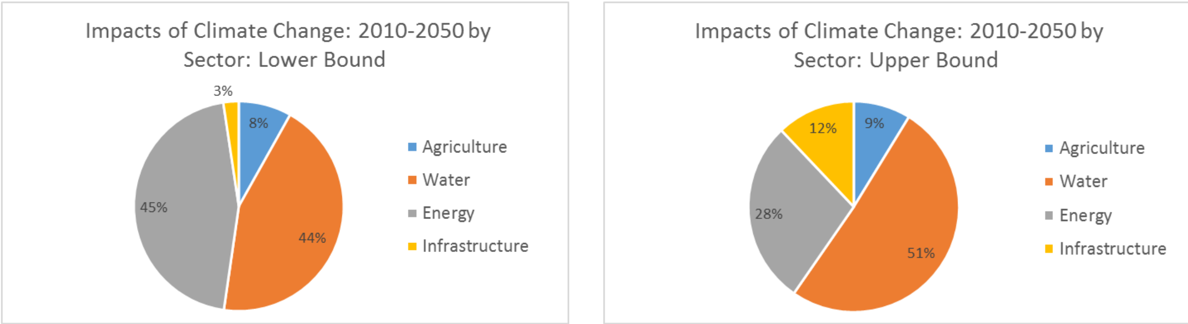
Notes:
LB/UB: Lower/Upper bound estimates obtained from projections under SSP1/RCP4.5 and SSP5/RCP8.5 scenarios respectively.

Damages to infrastructure are expected values based on expected frequency of extreme events.
GDP projections are based on SSP1, which has annual growth rates for Uganda from 2010-2050 of 7.8% per annum

* loss in the capacity of infrastructure to withstand climate change

As illustrated in Figure ES1 below, with the lower-bound estimates of the range of scenarios studied, damages in the energy and water sectors are dominant, with energy accounting for 45% and water for 44%. They are followed by agriculture at 8% and infrastructure at 3%. With the higher-bound estimates water is dominant accounting for half of all damages, followed by energy at 28%, infrastructure at 12% and agriculture at 9%. However, these percentages need to be interpreted with care, as some sectors costs may be under represented due to data limitations. For example in agriculture the costs of floods and droughts are not fully incorporated in the totals.

Figure ES1. Share of the cost of inaction for the four sectors studied – lower and upper bound provided by the different climate and economic scenarios considered



As discussed above the impacts of climate change over such a long period depend in part on the growth of the economy. If we assume a growth path close to the Uganda Vision2040, the economy will expand enormously by 2050, to about 20 times its size in 2010. Hence the large cumulated damage estimates amount to approximately 2 to 4% of cumulated GDP over the period. On the other hand if the economy does not grow at this pace, damages will be slightly less, but as percentage of GDP they will rise. Hence **economic growth is a key factor in ensuring that climate impacts are manageable relative to the resources available to tackle them**.

The other important point to note about the costs of inaction is that they include the effects of current variability as well as future change. Indeed a detailed analysis shows a major part of the problem is from the current variability in climate and lack of infrastructure to ensure a balance between the available supply of natural resources and the demand for them in the face of this variability. This fact gives urgency to the need for action to address the gap.

Sectoral estimates

Key messages from the sectoral studies conducted at the national scale are presented below.

Agriculture:

Overall losses for food crops by 2050 are not likely to be more than US$1.5 billion and could well be less. Under the assumed growth in the economy this would be less than 0.2% of GDP in that year.

Estimated impacts on livestock production are quite small in all cases (1 or 2%). However, this modelling is only for yield and area whereas the key impacts on livestock may come from other climate change factors, in particular droughts, floods and diseases.

Agricultural exports are a key area of concern. Significant impacts on the Arabica coffee growing area to 2050 are predicted due to climate change. An illustrative estimate of the value of losses due to a 50% reduction in production of Arabica and Robusta coffee combined, would be about US$1,235 million in 2050. Estimates of impacts on tea growing areas also indicate significant losses of value and some potential losses of cotton production are projected. Taken together these results indicate the potential for Uganda agricultural export production and value to be strongly affected by climate change in the period up to 2050 in the absence of adaptation actions. The costs are US$134-196 million by 2025 andUS$641-938 million by 2050.

It is widely accepted that extreme weather events have been increasing and becoming more severe in recent years. To give an indication of the order of magnitude of recent losses, the damage figure of US$47 million to crops (NEMA, 2008) is equal to about 3% of the value of all cash and food crops in that year. Other extreme events have resulted in even bigger losses, possibly as much as 30% of the sector's normal output.

For some agricultural products the threat from droughts and floods appears to be more important than the threat from decreased yields It is already present and needs urgent action, making it a priority in terms of adaptation. It should also be stressed that current and future increased risks from flooding and droughts are in areas of existing poverty and therefore these events have serious consequences for local economies and food security. The Karamoja case study demonstrates that quite clearly.

Water: **Total water demand is expected to increase** from 408 million cubic meters a year (MCM/y) in 2010 to 3,963 MCM/y in 2050. Based on the assumption that no additional investments in the water sector would take place, other than those already planned for in current investment plans, total unmet demand will then rise from 3.7 MCM/y to 1,651 MCM/y in this period under climate change. **In most months water shortages will be enormous**.

Converting this into monetary terms, **the expected cost in 2050 is anticipated to be on the order of US$5.5 billion**. This is a conservative estimate and the figure could be as much as ten times higher if income effects on willingness to pay are taken into account**. About three-quarters of the costs arise from a shortage of water for irrigation**. The next most important in value is livestock, followed by domestic and industry.

The largest overall economic losses are anticipated to be in the Lake Victoria, Albert Nile and Lake Kyoga watersheds. These values underline the need for further investment in the water supply infrastructure in Uganda: **with or without climate change the economic losses are of a significant magnitude**.

As far as extreme events are concerned, the study found that each drought event represents an average annual damage in the last decade of US$237 million.

Infrastructure: There are two impacts from climate change on infrastructure: one is through lost resilience of buildings, road etc. to increased temperature and precipitation; and the other is through damage caused by extreme events.

On the first, **the major costs arise from losses of resilience to residential buildings**, followed by public buildings and non-residential buildings. Together these account for 96% of the costs of lost resilience. Taking the adaptation costs as lower bounds of damages we get estimates of US$60-76 million in 2025, rising to US$347-621 million in 2050.

Damages caused by extreme events include 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$34-214 million by 2025 and to US$234-809 million by 2050. Note, however, that as a percentage of projected GDP the damages do not increase. Assuming a doubling of frequency of extreme events every 25 years would result in damages of around US$68-429 million by 2025 and US$938-3,236 million by 2050. The figures are average or expected damages; a particular event could have higher or lower costs and indeed a similar one to that which occurred in 2007 would result in significantly higher costs in the future. The range of costs associated with these is very wide, and depends on how much value is attached to a loss of life. In total these costs are between 0.3 and 3.8 times those from lost resilience.

Energy: In the case of energy **the main costs arise from unmet biomass demand**, which is expected to grow significantly even without climate change (with no climate change, deficit of biomass is estimated at 1,710 million tonnes over the period 2010-2050). Total costs from 2010 to 2050 from this unmet demand amount to US$123.6 billion. Climate change could also decrease biomass availability by 5 - 10% between 2020 and 2050, which would increase the costs of inaction from US$123.6 billion to between US$130 and US$136 billion (not shown in Table ES2).

In addition, there is **a possibility that hydropower potential will decrease** due to a reduction in precipitation. If there is a decline, it is estimated to be around 26% by 2050. Under that scenario, the analysis shows that the government's current expansion programme is sufficient to cover the hydropower deficit, as long as the other components of the programme are implemented according to the proposed schedule.

It is important to remember, however, that this is a very ambitious and resource intensive programme. The estimated additional capital investment in hydro, nuclear and other generation from now to 2050 is around US$83 billion. **The country will need to invest around one billion dollars in power, or around US$200 million per year**, equal to about 1% of its GDP, in the first five years. In future years the amounts increase very sharply.

Case study estimates

The case studies also provide some supporting evidence on the costs of inaction. The figures provided are for illustrative purposes only, and have not been included in the national cost estimates.

Table ES3: Summary of costs of inaction to climate variability and change in selected case studies

Case study	Illustrative costs of inaction
Urban development and infrastructure: Kampala	• Damages arising from floods are estimated at between US$3.7 - 17.6 million by 2025 and between US$33.2 - 101.7 million by 2050. • Costs to climate-proof infrastructure are estimated at between US$560 - 600 million for the period 2015-2030, rising to between US$3,259 - 3,699 million over the 2015-2050.
Agriculture: Karamoja	• For Oryeotyene Northward village in Abim district (representing an agricultural zone) projections of losses of crop value from future climate events up to 2050 (based on the estimated losses from recent events in this study) produced total losses of potential crop production of about 9% (for a less severe scenario) and 18% (a more severe scenario). • For Nakayot village in Napak district (representing an agro-pastoralist zone) similar projections for losses in crop production to 2050 produced estimates of about 15% in a less severe scenario and 32% in a severe scenario. • For Lopedot Village in Amudat district (representing a Pastoral Zone) estimated losses in crop production value to 2050 are about 19 to 28% for the different scenarios.
Agriculture: Mt. Elgon (coffee)	• Under 'Business as Usual' (i.e. no adaptation measures) and present climate variability, the Internal Rate of Return (IRR) for coffee cultivation on a 15 year cycle is around 16%, when you include losses from drought and excessive rain. • Under future predicted climate changes, this return is expected to decline to around 9% in the next 15 years cycle (2015-2030) and fall further to 5% in the second cycle (2030-2045). • Under 'Climate Smart Agriculture' the IRRs are higher, but there is still expected to be a decline from the current climate variability rate of 25% to a rate of 22% with projected climate change.
Water and energy: Mpanga	• Annual average economic losses from sectors other than energy (i.e. mining, industry, livestock and, to a lesser extent irrigation for agriculture) in this area amount to between US$45,400 to US$78,900 by 2035. These costs may rise to US$188,000 if the income elasticity of willingness to pay and future increases in income following the scenarios of GDP and population are taken into account.

	• The largest economic costs, however, will fall on the energy sector. Transferring costs of lost load from a study in Kenya, adjusting for income differences and inflation, we find annual costs by 2030 to 2035 may be as high as US$25 million to US$98 million.
Health: Tororo and Kabale	• In Tororo in Eastern Uganda, where malaria is endemic (widespread), the cost of malaria may rise from a range of US$8.7 - 221 million in 2010 to a range of US$20.1 - 560.5 million in 2050. • In Kabale in South-western Uganda, where the disease is more epidemic (sporadic) in nature, malaria is expected to increase in cost from between US$0.7 - 15.8million in 2010 to between US$1.55 - 41.7million in 2050.

Overall Costs, Uncertainties and Their Implications for Development

The overall picture from this analysis points to the significant costs of not taking action on climate variability and future climate change in Uganda. The national-level studies show **annual costs that could be in the range of US$3.2 billion to US$5.9 billion within a decade**, with the biggest impacts being on water, followed by energy, agriculture, and infrastructure. The range of estimates is wide for two main reasons. First, there are uncertainties in the physical climatic impacts and, second, there are uncertainties in the values we attach to those impacts. In the case of energy and agriculture, the greater uncertainties are on the physical impacts of climate change, whereas in the case of infrastructure they are more on the valuation of the consequences of climate change. For water both factors play a similar role.

As already noted, these costs combine the effects of current variability and future climate change. **Even if there were no further increases in temperature or precipitation or frequency of extreme events, the costs of inaction would rise over time because of an increase in population (expected to grow by more than 2% p.a. over the next 40 years) and GDP (expected to grow at around 7 to 8% p.a. over the same period).** There is of course an additional potential effect from climate change to be added in: An increase in the frequency and intensity of extreme events would be significant for agriculture and water and could be significant for infrastructure. Although we judge this to be likely, the models are unable to provide a quantitative estimate of such increases.

Some critics argue that the uncertainties on costs are so large it is not possible to take them seriously. We would not support such a conclusion. While the figures presented cannot be precise, they all point to a range of costs that more than merits action. Even at the lower end they indicate potential impacts on vulnerable members of society and on the growth of the economy that cannot be ignored. While some better information will be forthcoming on climate change in the coming years (including in Uganda), there is enough evidence available now to justify action in a number of areas. These are reviewed in the next section.

0 *Adaptation Options*

Adaptation offers the prospects of a considerable reduction in the economic and social costs of climate change. What's more, many adaptation options include 'co-benefits' –benefits over and above the benefit of improving resilience to climate change.

The study has looked at the short, medium, and long term adaptation options at the national level for agriculture, water, infrastructure and energy.

The adaptation policies as supported by the evidence involve a combination of (i) physical investments, (ii) training and capacity building, and (iii) reforms in the laws, regulations, and fiscal instruments that relate to the different sectors. These three sets of measures are complementary; investments to adapt to climate risks need the capacity to implement them effectively and often they need the right incentives for different agents to make the best use of them. At the same time, there are areas where reform takes mostly a non-physical investment form. Examples are actions to use water and energy more efficiently or to respond to information about an impending flood or drought. Urgent reforms needed in Uganda include for example: Information to farmers about climate-smart agriculture and climate resilient land management practices; incentives for and information on benefits of water harvesting and methods of conservation; standards for energy efficiency in buildings though codes; and amendment of regulations with respect to design of public buildings and roads, among others.

For agriculture some of these are a continuation of what is already ongoing as part of the Government's Agriculture Sector Development Strategy and Investment Plan[5], providing extension services and conveying information on weather and market conditions to farmers in a timely manner. Weather-related information is clearly a critical factor. These programmes will also provide benefits in the medium to long term, when other factors that start in the short term will play a bigger role as important adaptation actions in the face of climate change, such as farm diversification, post-harvest handling and storage. The same applies to case-specific climate smart agriculture programmes, which can be implemented to reverse the loss of yields in a cost effective way, and Arabica coffee is an example. Finally, improved water storage is critical to address drought events. It needs to be started immediately and continue over the medium to long term, as it will become even more important over time. This can be done in a relatively cost effective manner.

This last factor is linked to the water sector, where water harvesting and water conservation are already important and cost-effective measures. In addition, priority is given to early-warning systems for floods and droughts. In the medium to long term a key action, started now, will be to develop Integrated Water Resource Management Systems for the 8 basins of the country, which will better protect catchments against degradation; and seek international cooperation over bodies such as Lake Victoria, which is already being impacted by changes in climate. The cost benefit analysis realized at the national level demonstrate that the benefits of action to adapt in the water sector are very high and further investments than the ones currently planned in Uganda may well be justified.

As far as energy is concerned, the focus is on measures to reduce biomass demand by increasing efficiency of its use; and to increase efficiency in the use of electricity, where there is already a deficit. These actions are already active but need to be strengthened in response to climate change. Likewise a program that needs to be activated now and continued in the medium term is the promotion of renewable energy sources other than hydropower, which could be negatively affected by climatic factors. This last aspect, however is uncertain and needs to be followed closely over the coming years so generation expansion plans can be adjusted appropriately. There will also be a need to explore alternatives to biomass other than electricity and this should be a matter of priority.

Lastly, for infrastructure one priority is to ensure that land use plans, building codes and codes for design of transport systems reflect the need to make them more climate-resilient. These are measures that can be implemented in the short term. The other is to strengthen systems for flood control and disaster management, including early warning, so the consequences of such events are reduced significantly. These will be enacted gradually over the next 15 years. In terms of the cost of extreme weather events to infrastructure, the study concludes that if the government can reduce damages by even a small amount (i.e. around 7%) it will, under the most conservative assumptions, generate a rate of return of at least 10 per cent.

o *Financial and Policy Implications of Adaptation*

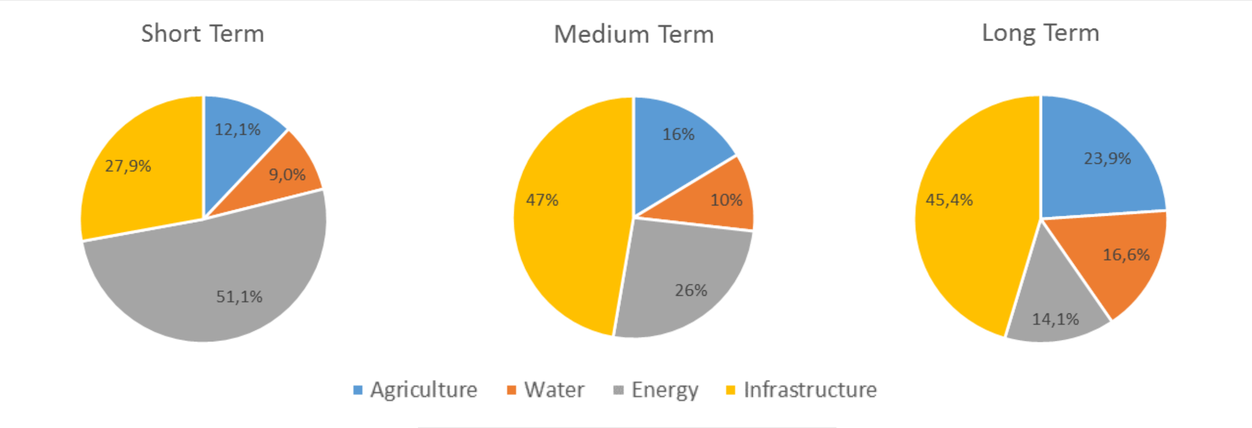
Total spending need on adaptation is estimated in 5-year intervals, from 2015 to 2030. It draws largely on the Costed Adaptation Strategy of the National Climate Change Policy, modified in some areas by estimates made in this study. During the next 5 years (short term) the cost is estimated at about US$406 million. On an annual

[5] See MAAIF, 2010. A*griculture Sector, Development Strategy and Investment Plan: 2010/11-2014/15*, Kampala, MAIF.

basis this amounts to US$81 million, which is about 5% of net official assistance received by the country and 3% of total government revenues (excluding grants). In the future the amounts needed for adaptation measures rise significantly: to US$644 million for 2021-2025 and US$596 million for 2026-2030. We cannot predict net official assistance or government revenues that far ahead but it is likely that, as a share of each of these the demands for adaptation will rise.

As illustrated in Figure ES2 below, over the next 5 years the largest share of adaptation costs by sector is for adaptation in energy and energy utilisation (nearly half), followed by infrastructure (28%), agriculture (12 %) and water (9%). In the medium term (2021-2025) the structure is more evenly spread; energy is still the largest but now accounts for around a quarter, and water and infrastructure each account for 16% and 18% respectively. Agriculture still remains at 12%. Finally, in the long term (2026-2030), infrastructure dominates at 45%, agriculture is next at 24%, followed by water at 17% and energy at 14%. Taking the undiscounted costs over the whole period, infrastructure is the highest component at 43%, energy is next at 28%, agriculture at 18% and water at 12%.[6]

Figure ES2. Share of adaptation costs by sector



In term of source of funding, our analysis suggests that international development partners and government is expected to be dominant in all cases. For agriculture, the private sector will have a role in supporting insurance against crop failure, and Non-governmental organizations (NGOs) could be important in supporting conservation agriculture and promotion of sustainable rangeland practices. For water it is difficult to see a major role for the private sector and the programme will have to rely on government and international development partners support. NGOs may play a useful role in promoting Integrated Water Resource Management at the local level. For energy, the private sector will have a key role in the development of renewables and in promoting energy efficiency. NGOs could also contribute in these policy areas. For some measures, such as setting and enforcing energy codes, the government has the overall responsibility, but for others such as water catchment protection and power sector design and management, international development partners support will be needed. Finally, for infrastructure investment in climate-proofing, efforts for private buildings will fall on the private sector, as can some of the costs of climate proofing transport infrastructure. Setting the land use plans and codes for new construction and designing and implementing more effective drainage systems and other measures to reduce damage from extreme events will fall on the governments, with some international development partners support.

[6] The undiscounted costs allows us to compare outlays in different time periods relative to each other and to the other components of government expenditure and income. This would not be possible if we reported future costs in a discounted fashion.

Complementarity of Adaptation Investment and Policy Reforms

The items in the adaptation program detailed above cover both physical investments as well as policy reforms. Both involve some financial resources, and the two are complementary in the sense that without the policy reforms many of the physical investments will not achieve the goals and without the physical investments the policy reforms will not succeed. Cases of investments that need matching policy reforms include, but are not limited to:

- Investment in irrigated agriculture will need reforms in the pricing of water and in rules for the allocation of water.
- Promotion of improved post-harvest handling, storage, and value-addition will need reforms in the way such services are provided and charged for and in access to credit by farmers.
- Improved schemes to get information to farmers will need reforms in how such information is stored and transmitted.
- Encouragement of water storage and harvesting may require reforms in the access of credit to households for such devices.
- Promotion of renewable energy sources will require reforms in the pricing of energy from such sources and in energy policy.
- Promotion of energy-efficient appliances will benefit from subsidy programmes to support the purchase or leasing of such equipment.
- Building codes that incorporate climate resilience requirements will need reforms in the methods for ensuring compliance.
- Effective selection of projects to protect against damage from extreme events will require reforms in the use of benefit-cost analysis, to include non-monetary costs.

In the cases above, reforms in pricing and access to credit will not be effective unless the resources are there to make the investments. In addition, measures such as innovative insurance schemes will need to be backed up by investment programmes that reduce systemic risk to economic agents and that cannot be addressed through insurance markets.

o *Policy Recommendations*

The Government of Uganda should urgently prioritize action on climate change, building on work that is already ongoing. The recommendations below arise from this study.

1) Prioritize the Costed Implementation Strategy as a matter of urgency. The research conducted for this assignment consistently highlighted that the NCCP Costed Implementation Strategy is focused on a strong set of measures appropriate to dealing with anticipated climate changes. Further, many of the activities are anticipated to yield greater benefits than costs, and hence are justified on economic grounds. Mainstreaming of adaptation priorities into district costed implementation strategies will be critical.

2) Mainstream climate change into sector development plans, including translation of key priorities into sector annual plans and budgets. This is a process that is already taking place via the CCD, and should be prioritized to mainstream the findings from the various studies that have been conducted in Uganda into the sector development plans, including annual plans and budgets, under the umbrella of NDPII.

3) Mainstream adaptation priorities into the District Development Plans that will rise out of the National Development Plan II. In addition to mainstreaming climate change into sector policies, it is critical that appropriate adaptation action be taken at the district level. To achieve this, 5-year district development plans will need to mainstream adaptation priorities, and progress should be monitored by the CCD through their annual reports. The Ministry of Local Government (MOLG) will be a key agency to support and audit local governments for budget and planning purposes. The CCD should assist the MOLG to ensure that climate change is mainstreamed into local government policies and plans. Specifically, the MOLG assessment manual is used to identify whether proposed budgets comply with national priorities and standards, and climate change considerations should be mainstreamed into this tool.

4) Ensure that implementation of all action is monitored and enforced. Monitoring is key to ensure that actions are undertaken in a timely manner. Implementation of these plans should be monitored using the planned NCCP Performance Measurement and Reporting process. A clear set of performance targets that are time bound, and assigned to specific agencies, should be developed to facilitate monitoring. Enforcement of existing activities such as protection of watersheds, land use planning, and building codes should be prioritized.

Sector specific recommendations are detailed in the full report. These reinforce and build on the recommended actions already contained in the Costed Implementation Strategy and should continue to be developed and refined for specific sectors and regions.

o *Limits of the study*

The economic assessment of the impacts of climate change involves critical decisions regarding a number of issues for which guidelines for good practices are useful and should be followed whenever possible. There are many choices to make (for example, the extent of climate change to be considered, which sectors and types of costs should be included, and how to treat the (autonomous) adaptation, among others), and there is no consensus on which is the right method in many cases. Further, there are many gaps in the data available to feed into modelling, and as such certain assumptions are made. While some of the issues are associated with technical elements, others are due to human judgement (ethical aspects), and do not have correct nor incorrect answers.

As a consequence, it is important to consider the limitations of this study, and the areas where further evidence and analysis is required. **Adaptation planning and investment can only be properly done if there is sufficient evidence available in the country - and at the local/ regional level where necessary.** However, this study has illustrated that there is a strong economic and social case for adaptation now in many instances, and that the case is only expected to be strengthened with predicted climate change in Uganda. In such cases, imperfect data should not delay action.

1. INTRODUCTION AND METHODS

This study was commissioned by the Climate and Development Knowledge Network (CDKN), at the request of the Government of Uganda, and funded jointly by CDKN and the UK Department for International Development (DFID), Uganda office. Its overall aim is to provide policy makers and international development partners in Uganda with the evidence base on the economic impacts of climate change in order to promote increased investment for adaptation in climate-sensitive sectors. The *Economic Assessment of the Impacts of Climate Change* provides information about the current "adaptation deficit"[7] present in Uganda and the extent of the negative consequences that climate variability has on the Ugandan economy. Five sectors (agriculture and livestock; energy; water; human settlements; transport infrastructure) were analysed at the national level, and five case-studies were implemented at the local level, in different regions of Uganda.

As a first step, the team generated updated climate change scenarios for Uganda under two realistic and possible greenhouse gas concentration pathways. The national level assessment of the possible impacts of climate change was then carried out under two of the latest possible Representative Concentration Pathways (RCPs) developed as part of the Fifth Assessment Report (AR5) under the Intergovernmental Panel on Climate Change (IPCC). Economic assessments of the impacts of climate change were conducted at the national level as well as in a more detailed way through case studies for five locations, namely Kampala (focusing on infrastructure), Kabale & Tororo (health), Karamoja (agriculture and livestock), Mount Elgon (coffee), and the Mpanga river catchment (water and electricity). The team then analysed – in a participatory manner - the policy implications of the results of the economic assessment.

1.1. Context and objectives

Uganda's 2010–2015 five-year National Development Plan (NDP) already recognises that addressing the challenges of climate change is crucial to enhancing sustainable economic and social development. Most of the key economic sectors are affected by climate change and government has recognised the significance of climate change and its effect on the national economy. Uganda has made significant progress toward mainstreaming climate change into national development planning, in particular with the formulation of its National Climate Change Policy (NCCP), which aims at guiding all climate change activities and interventions in the country, and its Costed Implementation Strategy. A summary of the policy context around climate change in Uganda is provided in Annex 1.

To support the Government of Uganda (GoU) in implementing the NCCP, the *Economic Assessment of the Impacts of Climate Change* provides information about the current "adaptation deficit" present in Uganda and the extent of the negative consequences that climate variability has on the Ugandan economy. More specifically, the study considers the specific projected costs of climate change to key sectors of the economy in both the medium and long term in order to strengthen the evidence base for climate compatible development planning, both at the national and the local level through a number of case-studies.

This study was commissioned by the Climate and Development Knowledge Network (CDKN), at the request of the Government of Uganda, and funded jointly by CDKN and the UK Department for International Development (DFID), Uganda office. The overall aim is to provide policy makers and international development partners in Uganda with the evidence base on the economic impacts of climate change in order to mobilise

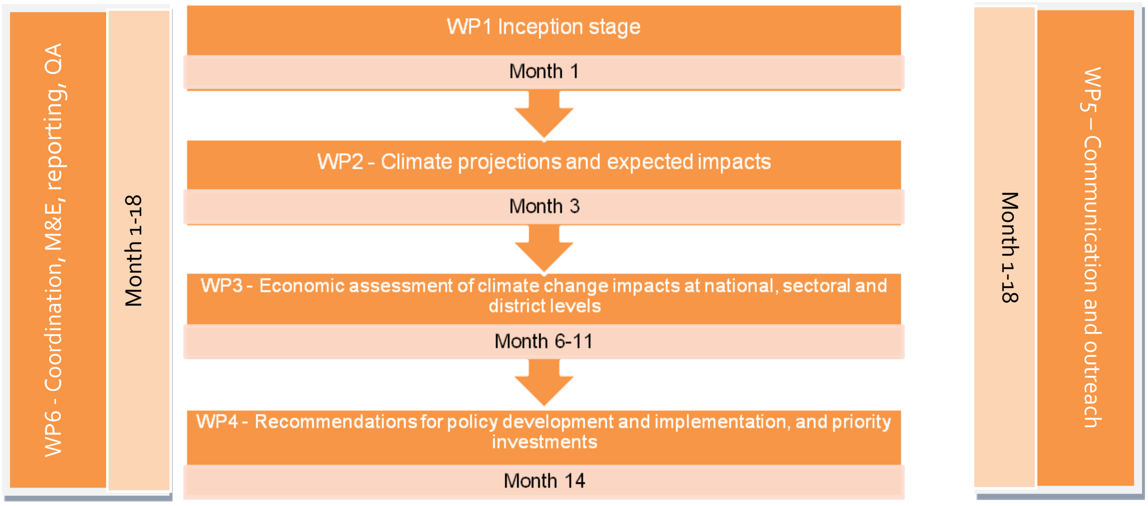
[7] An adaptation deficit is said to exist when the level of adaptation to current climate variability is insufficient.

increased investment for adaptation in climate-sensitive sectors. The study also aims to increase the capacity of Government officials to use the evidence on the economic impacts of climate change in development and investment planning. It provides the economic case for prioritised interventions and investments by the Government of Uganda in climate-resilient development, and contributes to access climate and development finance.

1.2. Organisation and methods

The study process was divided into six distinct, inter-related work packages (WPs) that fed into each other to produce the study deliverables, as shown in Figure 1below:

Figure 1: Project Structure



The analysis has been carried out at the case study/local level, the sector level and the macro/national level. In this assessment the main effort has been at the sector level, but the analysis is supported by evidence from local case studies where possible. A macro-level assessment has been made in terms of developing projections for Gross Domestic Product (GDP) and economic output to 2050 and reporting damages as a percentage of GDP for the selected sectors. The assessment at this level also looks at the links between economic growth in the country on the one hand and the climate scenarios that emerge globally on the other.

The objectives of the analysis conducted at the **sectoral level** are to: (a) estimate the damages caused by climate change in economic and social terms; and (b) identify the adaptation options and rank them in terms of priority and timing.

The **case-studies** consist of economic assessments of the impacts of climate change at the local level (district or even village level), targeted on key sectors in those locations. The objective is to *provide examples* of what the cost of climate change at the local level *could* be, and suggest policy actions regarding available adaptation options. The case-studies provide some valuable evidence to back up the national assessments and provide the opportunity to look at context specific issues.

The **national level assessment** of the possible impacts of climate change has been carried out under two of the latest possible Representative Concentration Pathways (RCPs) developed as part of the Fifth Assessment Report (AR5) under the Intergovernmental Panel on Climate Change (IPCC [8]). The RCPs were used in

[8] Meinshausen, M., S. J. Smith, K. V. Calvin, J. S. Daniel, M. L. T. Kainuma, J.-F. Lamarque, K. Matsumoto, S. A. Montzka, S. C. B. Raper, K. Riahi, A. M. Thomson, G. J. M. Velders and D. van Vuuren (2011). "The RCP Greenhouse Gas Concentrations and their Extension from 1765 to 2300." Climatic Change (Special Issue), DOI: 10.1007/s10584-011-0156-z, freely available online (PDF) (HTML).

conjunction with local and global socioeconomic scenarios, drawing on existing national and sectoral projections as well as the IPCC socioeconomic scenarios (called Shared Socioeconomic Pathway - SSPs), which are included in the RCPs. At the sectoral level the basic components of the methodology consisted of the following steps:

- Step 1: Construct the baseline for the sector, projecting the changes in key inputs and outputs of goods and services from the sector to 2050. This is referred to as "Business as Usual".
- Step 2: Estimate the damages/benefits to the sector outputs from current climate variability and future climate change.
- Step 3: Evaluate the key adaptation options or strategies from the literature (in particular the NCCP) and stakeholder consultations and look at what impact these will have on the damages caused by climate change.
- Step 4: Collect the results of the adaptation assessments and propose a ranking of adaptation options in the short-medium-long term with supporting evidence on their benefits and costs.

In order to assess the impacts of climate change, updated climate change scenarios, downscaled[9] to the Uganda territory, were necessary. The University of Pretoria in South Africa generated regional-scale historic and future climate change projections of annual, seasonal and monthly rainfall and near-surface (2m above the Earth's surface) temperatures in Uganda under two realistic and possible greenhouse gas concentration pathways: (1) a moderate concentration pathway (RCP 4.5), and (2) a more extreme concentration pathway (RCP 8.5). The data was then complemented by a number of statistically downscaled scenarios at station points and in specific regions of Uganda where the study implemented case-studies.

As was highlighted during the Regional Lessons Learned workshop that was organised in April 2014, and which gathered stakeholders from Rwanda, Tanzania and Kenya where similar economic assessments have been conducted in the past, strong buy-in from local stakeholders and policy makers of the results of the economic assessment and their policy implications is essential. Hence the study scope and choice of issues to be covered was based on stakeholder involvement, as was the choice of adaptation measures to be evaluated, the latter drawing heavily on the *Costed Implementation Strategy* of the NCCP.

1.3. Study scope

The choice of sectors to be covered was agreed during the inception workshop. Five sectors were selected and approved by the Climate Change Department (CCD): agriculture and livestock; energy; water; human settlements; transport infrastructure. For methodological reasons, the latter two sectors were ultimately merged into one single 'infrastructure' study.

The choice of case-studies was also been made on the basis of a list of agreed selection criteria and proposals from different stakeholders and international development partners. Criteria included the agro-ecological zones, the history of climate impacts, livelihood patterns, the presence and availability of data, the situation as regards previous or future development and climate change interventions, and accessibility. The selection also considered geographical diversity and the covering of different sectors of the national-level assessment. The case-studies implemented are:

Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. The pathways are used for climate modelling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come.

[9] By "downscaled" we mean that projections at the global scale form the IPCC have been used to produce projections at the national and local scale (50*50km grid points on the Uganda territory).

- **Infrastructure**: Economic assessment of the impacts of climate change in the Kampala urban area, in close collaboration with the Kampala City Council Authority (KCCA)
- **Export/agriculture sector**: Economic assessment of the impacts of climate change on the coffee sector in Bududa district in the region of Mt. Elgon;
- **Agriculture**: Economic assessment of the impacts of climate change in three villages of the Karamoja region (agricultural sector) chosen from three different agro-ecological
- **Health sector**: Economic assessment of the impacts of climate change on malaria prevalence in the districts of Tororo and Kabale;
- **Water and hydropower sectors**: Economic assessment of the impacts of climate change in the Mpanga river catchment.

Briefing notes of those case-studies are in Annex 5.

The main reports generated by the study over its 18 months duration, in particular the sector reports and the case-study reports, are available on the CCD website at: http://www.ccu.go.ug/index.php/projects/cdkn and are also available from www.cdkn.org

1.4. Limits of the study

As part of this study process, Garcia, J. and Markandya, A. (2014) prepared a review of methodologies used worldwide for the economic assessment of the impacts of climate change. The review notes that **the economic assessment of the impacts of climate change involves critical decisions regarding a number of issues for which guidelines for good practices are useful and should be followed whenever possible**. Although there has been significant progress in the field, there is still considerable work to be done on covering certain issues and using a wider set of methodologies.

Indeed, assessing the cost of the impacts of climate change is far from straightforward. There are many choices to make, and there is no consensus on which is the right method in many cases. While some of the issues are associated with technical elements, others are due to human judgement (ethical aspects), which do not have correct nor incorrect answers. The review enumerates six sets of choices, which relate to:

1. The extent of climate change to be considered.
2. How we model the effects of a given level of climate change in a country or region. Not only is there uncertainty about future climate, particularly for extreme events, but it is also present in relation to how society and systems will change over time and how climate change will affect it. Uncertainties about these aspects can dominate the climatic changes in terms of what the future impacts society will face and what will be its capacity to deal with them. Researchers use a range of models and produce different scenarios to represent this uncertainty, but this does not completely resolve the problem
3. Which sectors and types of costs should be considered?
4. The issues of space and timing.
5. How to treat distributional issues within a particular generation.
6. How to treat the (autonomous) adaptation that will take place in response to climate impacts.

Finally, researchers have to decide how to incorporate into the models the unavoidable existing uncertainties.

It is important to note that the preceding issues refer to the assessment of the costs of impacts of climate change as well as to some extent to the costs of adaptation measures. In addition, however, the latter also raise additional issues:

- Scope of analysis: researchers have to decide which measures are taken as a baseline (that is, which measures would be implemented in the absence of climate change), and consequently which are to be considered additional on account of climate change. This is far from straightforward given the complex relation between development policies and climate change adaptation policies.
- Objective of adaptation and balance between adaptation and residual damage: studies may indeed potentially consider different objectives for the level of adaptation to aim for.

In terms of data, perhaps the most important missing element is with respect to the frequency and intensity of extreme events. The climate projections do not offer direct guidance on this, although they do indicate that the distribution of rainfall will shift to reflect an increase in the frequency of high rainfall days, implying an increase in flood events, as well as an increase in low rainfall days and drought events. Further work is needed to relate such events to the expected distribution so that it can be used for the evaluation of adaptation options that seek to reduce damages from such events. In the meantime, we have carried out the analysis under two assumptions: one that the frequency remains the same and the other that it increases in line with recent increased frequency of such events. But the latter is an *ad hoc* assumption that should be validated or improved upon.

Other areas where information is needed can be divided into the physical and the economic. On the physical side there are still major uncertainties on the impacts of climate change in terms of changes in yields of key crops, on changes in water availability by basin and on flow rates in the rivers where hydropower dams are located. To be sure these uncertainties cannot be eliminated but they can be reduced and the data be made more spatially explicit. On the economic side information on likely responses of agents to different measures need to be gathered (e.g. water and energy efficiency measures), as well as on the assets at risk from extreme events. With the additional data a more accurate estimate of the benefits and costs of adaptation measures can be conducted.

As a consequence, it is important to consider the limitations of this study, and the areas where further evidence and analysis is required. **Adaptation planning and investment can only be properly done if there is sufficient evidence available in the country - and at the local/ regional level where necessary.** However, this study has illustrated that there is a strong economic and social case for adaptation now in many instances, and that the case is only expected to be strengthened with predicted climate change in Uganda. In such cases, imperfect data should not delay action.

2. CLIMATE AND DEVELOPMENT SCENARIOS FOR UGANDA

The climate projections are based on two Representative Concentration Pathway (RCP) scenarios, namely RCP4.5, which is an optimistic scenario and RCP8.5, which is more a “business as usual” scenario in terms of CO2 emissions. Overall, the decrease in rainfall in most of Uganda (-5 to -30mm per month), combined with a significantly wetter December-January-February (DJF) season, will result in significantly drier conditions for the rest of the year (longer wet season that extends from September-October-November (SON) towards December-January-February (DJF). This is combined with significant temperature increases, especially during the March-April-May (MAM) and June-July-August (JJA) seasons; overall, those changes will require a number of adaptation strategies that have been be studied in the Economic Assessment. In addition, A significant drop of total rainfall over Lake Victoria (-20% from present), combined with about 1°C temperature increase will impact the lake water level. Specificities of some of the regions where case-studies have been conducted, have also been duly considered. The study also investigated extreme events (droughts and floods) but did not provide a clear projection for these due to data limitations.

Development prospects for Uganda (Vision 2040 and SSP scenarios) expect an important growth in GDP per capita by 2030, which would be multiplied by 2 or 3 when compared to current (2015) levels. Poverty would fall dramatically and the economy would become much more industry and service based. The urban population is expected to increase from 13% now to 60% over the same period. SSP1 or Uganda Vision 2040 scenarios are more likely to occur with a high ambition international climate agreement during the UNFCCC negotiations in Paris, December 2015.

Growth is a key part of adaptation to climate change (less poverty, higher capacity to construct durable infrastructure, larger tax base for the government). But climate change does impact on growth: for Sub-Saharan Africa, a one degree increase in temperature leads to a decrease of 1.8% in GDP growth with a high statistical significance (Dell, 2012). Impacts such as a decrease in export crops revenues, water deficits, increased flooding and damages to transport infrastructures, and energy deficits will constrain growth in Uganda. Fortunately these impacts can be mitigated via adaptation, which can de-couple growth from climate impacts.

We carried out a set of climate projections based on RCP scenarios RCP4.5 and RCP8.5. Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the Intergovernmental Panel on Climate Change (IPCC) for its fifth Assessment Report (AR5) in 2014. 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[10].

2.1. Main results from the climate downscaling

Rainfall and near-surface temperatures are the two main parameters required by economic models for establishing economic scenarios, since it is these two variables that affect society the most. The main results obtained at the national scale are presented below. Additional downscaled scenarios were produced in each of the case-study locations, using grid-point data generated at the national level (see Annex 3). For more information, the reader can refer to (i) the report *Regional-scale Climate Change Projections of Annual, Seasonal*

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

*and Monthly Near-Surface Temperatures and Rainfall in Uganda (*Rautenbach (2014)), and (ii) the five case-study reports.

2.1.1. Observations: current climate

- Observed annual rainfall totals for Uganda vary from 500 mm to 2800 mm, with an average of 1180 mm.
- Observed seasonal rainfall totals for Uganda are characterised by a bimodal cycle (two rainy seasons) in the south with higher rainfall during the rainy seasons MAM (March-April-May) and SON (September-October-November). In the north, a unimodal cycle (one rainy season) becomes more obvious with a longer single rainy season that extends across the seasons MAM, JJA (June-July-August) and SON, while the DJF (December-January-February) season is drier. The far north-east of Uganda receives little rain during all months of the year.
- Observed averages in annual near-surface temperatures for Uganda are around 21°C. Monthly temperatures range from a minimum of 15°C in July, to a maximum of 30°C in February. The highest temperatures are observed in the north, especially in the north-east, while lower temperatures occur in the south. The JJA season is the coolest, while DJF and MAM are the warmest.

2.1.2. Projections: moderate climate change (RCP4.5)

- Projected annual rainfall totals are expected to differ little from what is presently experienced, with projected changes within a range of less than plus or minus 10% from present. However, less rainfall is expected to occur over most of Uganda, with slightly wetter conditions over the west and north-west. Rainfall totals might drop significantly over Lake Victoria (-20% from present). What is significant on a seasonal time scale is the projected increase in seasonal rainfall for the DJF season (up to 100% from present), which is indicative of a longer wet season that extends from SON towards DJF.
- Projected near-surface temperatures are in the order of +2°C in 50 years from present, and in the order of +2.5°C in 80 years from present. Temperatures are expected to rise more during the MAM and JJA seasons in comparison to the DJF and MAM seasons. A lower temperature increase of about 1°C is expected for Lake Victoria.

2.1.3. Projections: more extreme climate change (RCP8.5)

- Projected annual rainfall total changes are very similar to that of the RCP4.5 projections, and therefore still close to what is currently observed. On a seasonal time scale the MAM and JJA seasons might expect slightly less rainfall, while the percentage increase in DJF rainfall, as in the RCP4.5 projections, is again very significant. A similar drop (-20%) over Lake Victoria is projected.
- Projected near-surface temperatures are in the order of +3°C in 50 years from present, and in the order of +5°C in 80 years from present. Seasonal temperatures are expected to increase between +2°C and +3°C for DJF, MAM and JJA in 50 years from present, with a slightly lower increase for SON. In 80 years from present, temperatures might rise as much as +5.5°C during the JJA season (currently the coolest season), while increases of between +4°C and +5°C are expected for the seasons DJF, MAM and SON. Smaller changes are expected over Lake Victoria.

Table 1 gives a summary of those results.

Table 1. Temperature and Rainfall projections under RCP 4.5 and RCP 8.5 for Uganda.

Parameter	RCP 4.5	RCP 8.5
Annual temperature changes from the median	In +50 years to present: +1.5°C to +2°C in most continental parts of Uganda In +80 years from present: +2°C to +2.5°C in most of Uganda.	In +50 years to present: +2°C to +3°C in most continental parts of Uganda In +80 years from present: +4°C to +5°C 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.

2.1.4. Implications for the economic assessment

The above-summarized expected changes in near surface temperature and rainfalls fed into the economic model and the sectorial analysis conducted under WP3 of the Economic Assessment. In particular, the main features that should have an impact on the economy are the following:

- The decrease in rainfall in most of Uganda, combined with a significantly wetter DJF season, will result in significantly drier conditions for the rest of the year (longer wet season that extends from SON towards DJF);
- This is combined with significant temperature increases, especially during the MAM and JJA seasons; overall, those changes will require a number of adaptation strategies that have been studied in the Economic Assessment.
- A significant drop of total rainfall over Lake Victoria (-20% from present), combined with about 1°C temperature increase will impact the lake water level.
- Specificities of some of the regions where case-studies have been conducted (e.g. in the Mount Elgon area and the western districts of the country, where more rainfall is expected), have also been duly considered.

2.1.5. Extreme events

The study investigated extreme events (droughts and floods) but did not provide a clear projection for these, as this is a very speculative exercise given the data available. Nevertheless there is some data on areas facing higher risks of these events. The climate study calculated the coefficient of variation in inter-annual rainfall on a spatial scale for Uganda and found a range from 13 to 29%. Areas where value is greater than 20% are more likely to experience more frequent and severe droughts or floods. Such high variations in inter-annual rainfall were found in locations in the south and north-east of Uganda, while the lowest variations were in the south-west and north-west of Uganda. The report concluded that stations where rainfall had varied more over the past 30 years than the 30 years before that, were at risk of experiencing more droughts in the future. A map of these areas is available in Rautenbach (2014).

Available estimates of economic damages occurring in recent years are very site specific and there are no quantitative projections for extreme event occurrence under different climate change scenarios. The analysis does conclude, however, that these risks are likely to increase in the future in large parts of Uganda.

Maps of the Annual mean near-surface temperature change and total rainfall change from the median projected over 50-years and 80-years from present, under both the RCP 4.5 and the RCP 8.5 concentration scenarios, are presented in Figure 2 and Figure 3.

Figure 2. Annual mean near-surface (2m) temperature (°C) change and total rainfall (mm/month) change from the median projected over 50-years (average 2046-2065) and 80-years (average 2075-2095) from present (average 1985-2005) under the RCP 4.5 concentration scenario.

RCP 4.5: Annual temperature change (°C) relative to 1985-2005 **RCP 4.5: Annual rainfall change (mm/month)** relative to 1985-2005

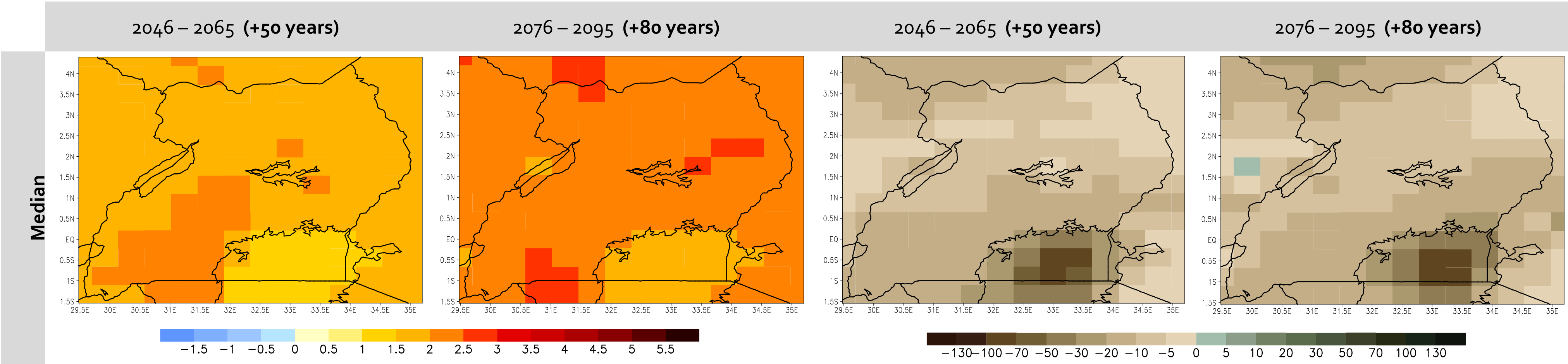
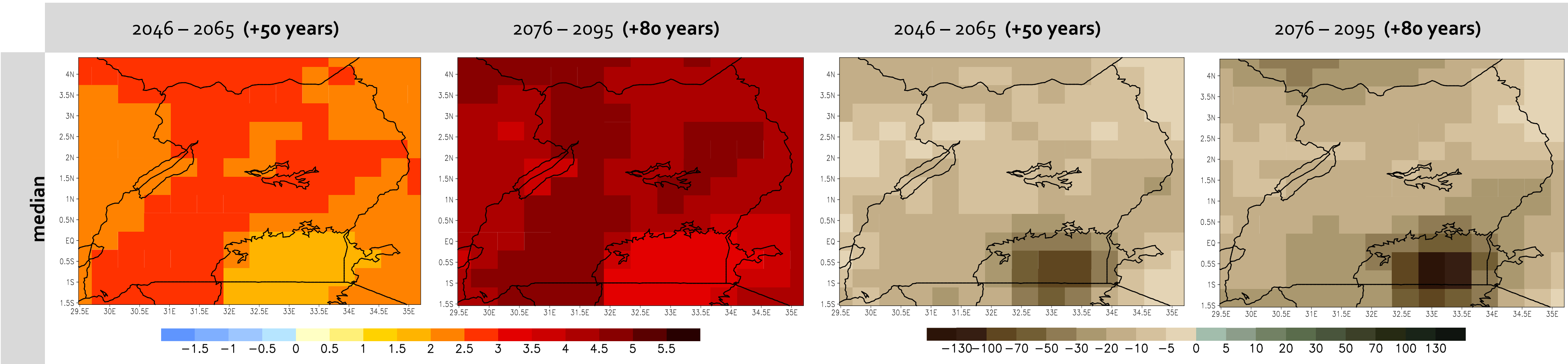


Figure 3. Annual mean near-surface (2m) temperature (°C) change and total rainfall (mm/month) change from the median projected over 50-years (average 2046-2065) and 80-years (average 2075-2095) from present (average 1985-2005) under the RCP 8.5 concentration scenario.

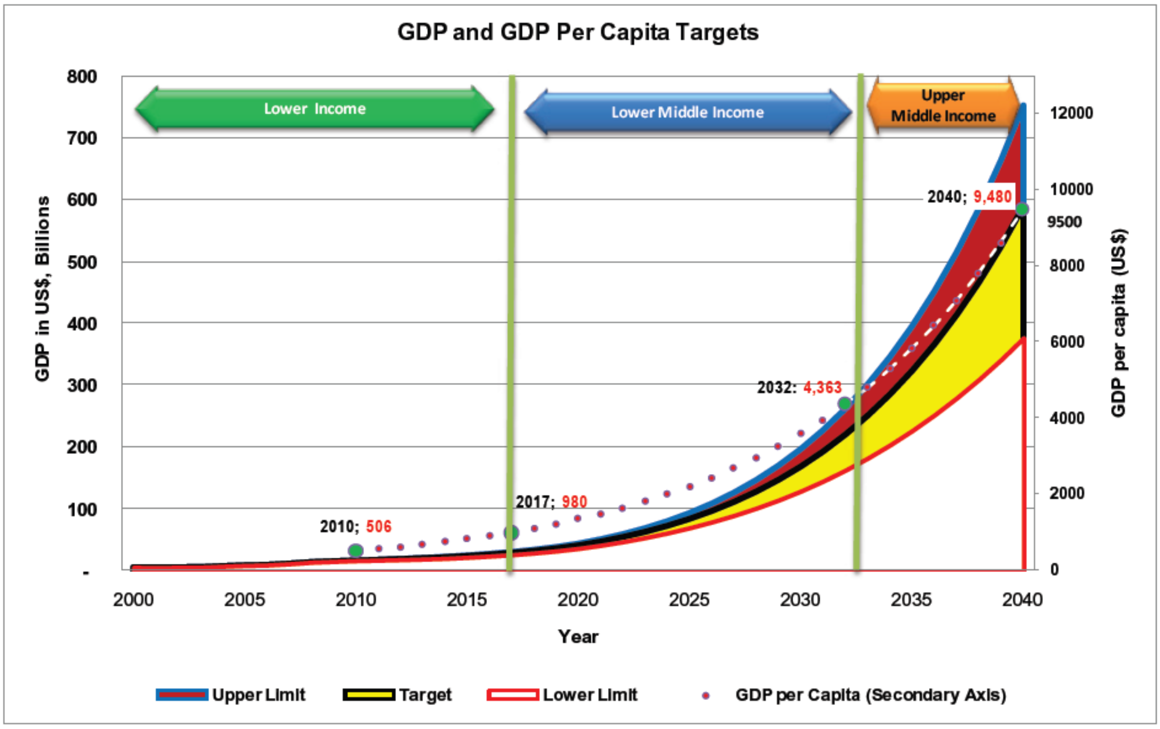
RCP 8.5: Annual temperature change (°C) relative to 1985-2005 **RCP 8.5: Annual rainfall change (mm/month)** relative to 1985-2005



2.2. What are the development prospects for Uganda?

The National Vision document (Uganda Vision 2040[11]) foresees a consistent annual growth rate of 8.2% in per capita Purchasing Power Parity (PPP) GDP from now to 2040, reaching US$4,300 in 2030 and US$9,500 in 2040[12]. The latest per capita GDP figure is US$1,630 in PPP dollars for 2013.

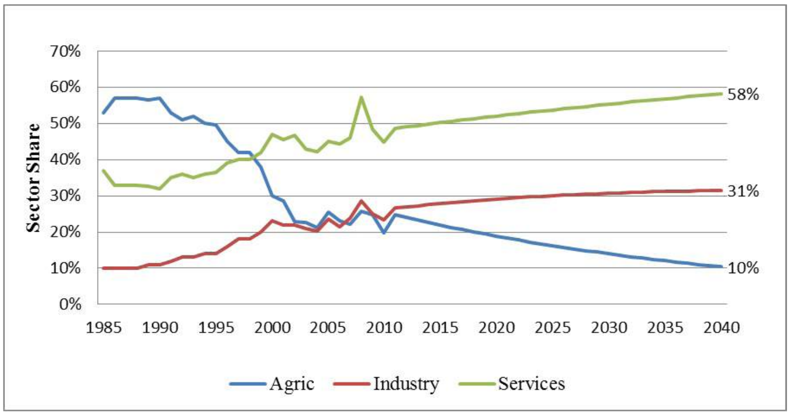
Figure 4. The Growth Path to the Upper Middle Income Status by 2040



Source: Uganda Vision 2040, from NPA estimates

The Vision constitutes an ambitious programme foreseeing poverty in terms of the National Poverty Line (NPL) falling from 25% in 2009 (the latest figure available) to 5% in 2040 and the economy becoming much less agriculture based, with the share of that sector falling from 22% in 2010 to 10% in 2040. At the same time industry would grow from 26% to 31% and services from 51% to 58%, as show in Figure 5.

Figure 5. Sector Shares of GDP (Actual and Forecasts)



[11] Uganda Vision2040. (2010). National Planning Authority. Government of Uganda.

[12] These figures are in PPP$ at 2011 prices.

Source: Uganda Vision 2040,

These changes and the associated growth in GDP would be achieved through an increase in investment, from 24% of GDP at present to 30%, and major programmes of investment in transport, energy and water and urban infrastructure. The urban population would increase from 13% currently to 60% by the end of the period, and total population from 35 million to 60 million according to latest projections. Energy sources would change to such an extent that dependence on fuel wood and traditional biomass is replaced by electricity and gas, with much of the former coming from new hydro plants as well as nuclear and some domestic gas generation.

All of this depends on a lot of factors working in favour of implementation of sustainable development policies, one being a world in which there is an international agreement to implement a high ambition climate scenario. This will provide a spur to the kind of development that is envisaged in the Vision2040 document, with major urban infrastructure investments in compact energy efficient developments, a transport system that is both efficient and low carbon, and an energy system that develops the low carbon indigenous resources to the extent feasible. The Vision2040 document has a Business as Usual that is a combination of hydropower, geothermal, nuclear, solar, biomass and thermal power. A high ambition scenario will provide greater emphasis within that to renewables and non-fossil sources. Furthermore, external finance to support such a pathway will be enhanced if the international agreement includes significant funds to support mitigation through low carbon development and adaptation programmes in countries like Uganda.

The Uganda Vision2040 can be compared with the Shared Socio-economic Pathways (SSPs) produced by the climate change research community and major international financial institutions such as the OECD[13]. There are five such scenarios and for each projections have been made of per capita GDP, population and urban share of population for all countries including Uganda. A useful perspective can be gained by looking at three of them:

- SSP1, which is characterized as a 'sustainability' scenario with poor countries like Uganda growing rapidly and closing the gap with the richer countries in living standards, while the world as a whole pursues environmentally friendly development
- SSP3, which is referred to as a 'fragmentation' scenario in which the world is fragmented into marginalised and poor regions, countries struggling to maintain their living standards and pockets of moderate wealth. There is little progress towards achieving the Millennium Development Goals, lower energy and material intensity consumption and lower fossil fuel dependency.
- SSP5, which is referred to as a 'conventional development scenario' where conventional development (economic growth and pursuit of self-interest in a liberalised world) is perceived as the solution to social and economic challenges. As a result, fossil fuel dependency deepens and mitigation challenges are high.

The prospects for Uganda vary considerably according to which scenario is realised. According to OECD projections, by 2030 GDP per capita in Uganda is expected to rise to US$3,839 under SSP1, to US$2,818 under SSP3 and US$4,204 under SSP5 (all in 2011 Purchasing Power Parity (PPP) US Dollars). This range is a little lower than Vision2040's aim of attaining US$4,383 by 2030. Perhaps more important is the observation that the projection under a climate friendly scenario is very similar to that of a conventional development scenario, but much higher than one where there is fragmentation in the world economic structure. The climate friendly SSP1 has GDP per capita only 9% lower than the conventional development SSP5[14]. On the other hand, the fragmented scenario has GDP per capita nearly one-third lower. In such a case Uganda would make much less progress on the Sustainable Development Goals especially on poverty reduction. The reduction in poverty as a result of a one% increase in per capita GDP (the elasticity of poverty with respect to income growth) is

[13] Researchers from the Integrated Assessment Modelling (IAM) and Impacts, Adaptation and Vulnerability (IAV) communities developed the SSP storylines/narratives (O'Neill et al, 2012).

[14] This comparison fails to take account of the fact that a sustainable scenario is more environmentally friendly and has lower environmental damages, which are not accounted for in the GDP. Were they to be included the comparison may even favour SSP1 over SSP5.

estimated at around 0.34 between 1999 and 2013[15] If this elasticity were to hold between 2015 and 2030 then under SSP1 poverty would decline from 38% currently to 22%, but under SSP3 it would only decline to 30%.

There is some evidence to support the view that SSP1 is more likely to be realised in a world in which there is a high ambition international climate agreement than one in which action on climate change is weak and uncoordinated (Ansuategi et al., 2015). The rationale behind this pairing is that a high ambition agreement goes hand-in-hand with robust, climate compatible decisions and national policies and therefore a more sustainable and equitable socio-economic pathway that realises RCP4.5. Conversely, a low ambition agreement provides less impetus for climate compatible development policies and consequently is more likely to lead to RCP8.5 and to a less sustainable socio-economic pathway and worsening global inequality.

It is of course not possible to be certain that SSP1 naturally goes together with a scenario involving less climate change such as RCP4.5, or that SSP3 will be the result of a climate policy that follows RCP8.5. For both a high and low ambition climate agreement, there is a continuum of possible outcomes in terms of the regional and national responses to the agreement and the specific social, economic and climate-related policies that are put in place. Current research indicates, however, that a high ambition scenario **combined with the right policies to achieve low carbon growth** is indeed likely to result in SSP1 and RCP4.5 being realised. This has been convincingly demonstrated in the recent report by the Global Commission on the Economy and Climate (NCE, 2014), which shows that a package of measures including: reduced fossil fuel subsidies, the pricing of carbon throughout the economy, innovative finance for low carbon investments, increased subsidies for research and development in low carbon energy, and policies to ensure compact city development, will result in sustained green growth of the kind that is characterised by SSP1. At the same time the report argues, as have a number of others, that RCP8.5 will result in lower growth and greater inequality in the medium to long term.

Another important benefit from a high ambition scenario for Uganda would be a greater likelihood that its Costed Implementation Strategy for Adaptation will attract finance. The programme has a total estimated cost of US$2.9 billion covering the next 15 years but implementation will be contingent on funds being available from domestic and international sources, and the latter are more likely to be sufficient under a high ambition agreement.

2.3. Links between Development and Climate Impacts

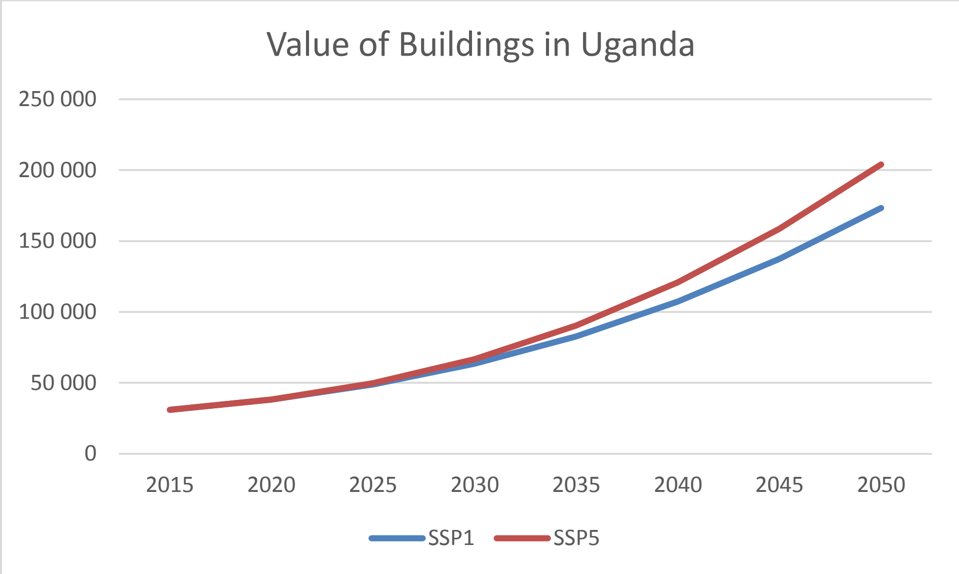
The discussion in the previous section is of great importance in understanding that an important determinant of adaptation to climate change in a country is its level of development. A higher rate of growth in real incomes generally results in a greater reduction of poverty. The less poverty there is in a country the fewer, other things being equal, is the number of people vulnerable to climate related events such as floods and landslides. Those affected by such events have the capacity and resources to construct more durable structures and take measures to protect property and human lives. Furthermore governments have access to a larger tax base from which they can finance expenditures that fall under the category of public goods and that would not be undertaken by private citizens. Examples are drainage systems in cities, dikes to prevent rivers from overflowing etc.

At the same time it is true that higher growth in an economy will lead to more assets that need protection and therefore a higher adaptation budget. This can be seen in the sector study for infrastructure where we consider two SSP scenarios: SSP1, which represents a growth in GDP of 8.1% annually and SSP5, which represents a

[15] Uganda had 37.8% of the population below the poverty line of $1.25 per day in 2013. This figure had declined from 59.4% in 1999, as a result of an increase in real per capita income, which went from $686 to $1,413 over the same period, giving an elasticity of 0.34.

growth of 8.9% over the same period. As a result the value of assets is higher for the latter than for the former as can be seen in Figure 6.

Figure 6. Value of buildings under different growth scenarios (US$, 000)



Source: Derived from the Infrastructure Sector Report.

In terms of costs of adaptation, the amount required will be greater when GDP growth is higher. To stay with the same example, the infrastructure sector report estimates total adaptation costs for the building and transport infrastructure of Uganda to be US$4.6 billion for the period 2015 to 2050 under SSP1 and RCP4.5. If the country has faster growth and SSP5 is realized the total cost rises to US$5.6 billion for the same period (all costs are undiscounted). As a percentage of GDP, however, the adaptation costs are not higher under SSP5 than they are under SSP1: in fact they are slightly lower by the end of the period. In 2050 the adaptation costs for infrastructure amount to 7.8% under SSP1 and to 7.5% under SSP5. It appears therefore that the higher costs of adaptation under faster growth are fully offset by the higher level of GDP.

There is also a link between the impacts of climate change and future growth prospects in the country. Key among these is the effect of climate on export crops of coffee, cotton and tea. As was noted in the Agriculture Sector Report, climate-induced yield losses for coffee production could be on the order of 50-75% by 2050 and progressively less in the intervening years. These would represent a major impact on the economy, which is currently deriving 18% of its export earnings from coffee. Estimates of impacts on tea growing areas indicate significant losses. Estimates consider a 50% fall in production by 2050 as plausible. Finally the latest research shows some potential losses of cotton production due to yield impacts in the range of 60-77% of the no climate change scenario by 2050. Export earnings are a major source of growth for a country, as they allow for the import of capital goods that support growth across many sectors and create opportunities for employment in related industries. Thus in the absence of adaptation actions climate factors could compromise the Uganda Vision2040 target of 8% annual growth.

The research carried out in this study indicates, however, that there may be prospects for preventing some of these losses. A detailed investigation of the Mt Elgon area (see Case Study below) suggests for example that investment in Climate Smart Agriculture (CSA) for Arabica coffee can pay off in higher yields, part of which may be lost to climate factors but which still leave output at higher levels than current production. More work is needed to see the prospects for CSA more widely in Uganda, covering more regions as well as the export crops of tea and cotton, but **this is a good example of how adaptation, although requiring some upfront costs, does contribute to the country's economy**.

Economic prospects for growth could also be affected by water deficits resulting from the current climate variability as well as climate change if they are not addressed through adaptation measures. The Water Sector Report estimates major shortages in supply relative to demand, for agriculture and industry. These will act as a constraint on growth in the affected sectors. In addition extreme events such as droughts have caused losses to agriculture in the recent past in the range of 1-7% of GDP. If these become more frequent, as is likely, economic output in key sectors will be reduced, having knock-on effects in other sectors. Such impacts can be reduced to a significant extent by adaptation measures that use water more efficiently and improve water storage and distribution efficiency.

In terms of infrastructure (buildings and transport), the study has shown that significant expenditure will be needed to make the systems resilient to changes in temperature and extreme events. If these outlays are not made losses in infrastructure functions will impact on economic growth. Already Ugandans experience delays in travel when there are heavy rainfalls and local flooding. These impact on the economic productivity of the sectors in which they work and reduce overall GDP relative to its potential. This will get worse as the economy expands and as the opportunity cost of delays and breakdowns increases. Adaptation requires making the systems more climate resilient, something that is a priority right now and will become more so over the coming decades

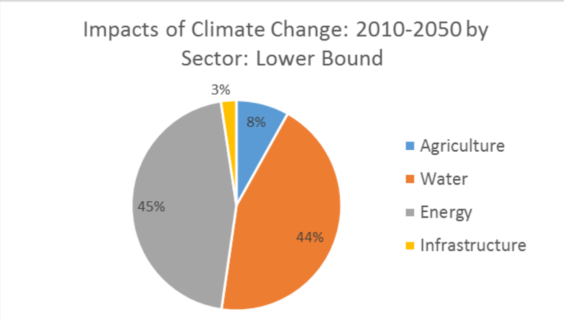
On energy, the country also faces twin deficits: in traditional biomass and in electricity. Both deficits will increase over time unless they are addressed and their size will get larger as a result of climate change. Without action economic sectors that depend on energy will be held back and their growth will be compromised. The Vision2040 absolutely needs energy supplies to increase to match the expected increase in output.

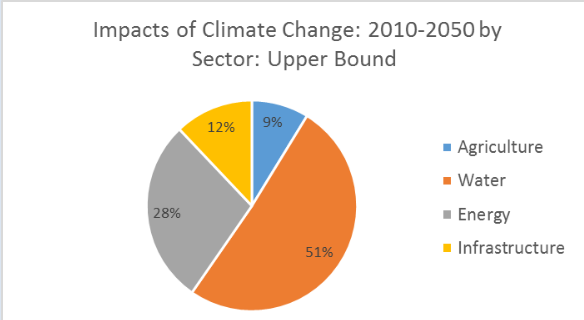
These links between climate impacts and economic growth are very real and are present now. Economic development is already constrained by the adaptation deficit to existing climate variability, and this will only become worse with future climate change. Action is urgently needed.

3. COSTS OF INACTION

Estimates were made of the costs of inaction under climate variability and change for agriculture, water, infrastructure and energy. It has to be borne in mind that they are approximate and probably an underestimate given the limited data. Nevertheless they provide an order of magnitude of the true costs. Over the 40 year period 2010-2050 these damages amount to somewhere between US$273 and US$437 billion for these sectors alone if no action is taken. Figure 7 shows the share of damages by sector for the lower and upper bound estimates. In the lower-bound estimates energy and water are dominant, with energy accounting for 45% and water for 44%. They are followed by agriculture at 8% and infrastructure at 3%[16].

Figure 7. Costs of inaction by sector –lower and upper bound provided by the different climate and economic scenarios considered





Note: LB/UB: Lower/Upper bound estimates obtained from projections under SSP1/RCP4.5 and SSP5/RCP8.5 scenarios respectively

With the upper-bound estimates water is dominant accounting for half of all damages, followed by energy, at 28%, infrastructure at 12% and agriculture at 9%. With the higher bound estimates of damages, the share of infrastructure rises reflecting the greater variance in the estimated damages for these two sectors.

The impacts of climate change for such a long period depend in part on the growth in the economy. If we assume a growth path as defined by SSP1, which is close to the Uganda Vision2040, the economy will expand enormously by 2050 – to about 20 times its size in 2010. Hence the large cumulated damage estimates amount to approximately 2 to 4% of cumulated GDP over the period. On the other hand if the economy does not see this level of growth, damages will be slightly less but as a percentage of GDP they will rise. Hence economic growth is a key factor in ensuring that climate impacts are manageable relative to the resources available to tackle them.

The other important point to note about these costs of inaction is that they include the effects of current variability as well as future change. Indeed a detailed analysis shows a major part of the problem is from the current variability in climate and lack of infrastructure to ensure a balance between the available supply of natural resources and the demand for them in the face of this variability. This fact gives urgency to the need for action.

3.1. Costs of inaction at the sector level

Figure 8 and Table 2 below provide a summary of the costs of inaction to climate variability and change over the period 2010-2050 for Uganda, for the agriculture, water, energy and infrastructure sectors.

[16] These percentages need to be interpreted with care, as some sectors costs may be under represented due to a lack of information. For example in agriculture the costs of floods and droughts are not fully incorporated in the totals.

Figure 8. Annual cost of inaction to climate variability and change per sector by 2025 and 2050 (US$Mn.)

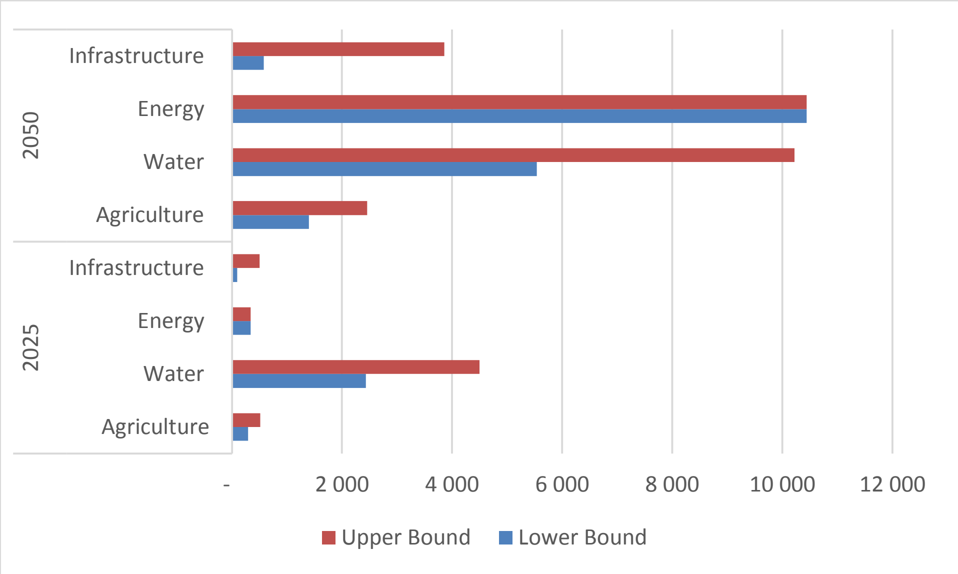


Table 2. Summary of costs of inaction to climate variability and change 2010-2050 for Uganda Annual Costs (US$Mn.)

	2025		2050		Total 2010-2050	
	LB	UB	LB	UB	LB	UB
Agriculture						
Food Crops	157	313	750	1,500	12,000	23,000
Livestock	2	4	10	20	200	300
Export Crops	134	196	641	938	10,000	15,000
Total	**293**	**513**	**1,401**	**2,458**	**22,200**	**38,300**
Water						
Domestic	273	504	638	1,177	13,657	25,216
Irrigation	1,545	2,852	4,081	7,535	82,003	151,411
Industry	146	270	195	360	5,851	10,803
Livestock	473	873	624	1,153	18,845	34,795
Total	**2,437**	**4,499**	**5,538**	**10,225**	**120,356**	**222,225**
Energy						
Biomass Unmet Demand	338	338	10,443	10,443	123,600	123,600
Total	**338**	**338**	**10,443**	**10,443**	**123,600**	**123,600**
Infrastructure (*)						
Extreme Event Damage to Infrastructure & Humans	34	429	234	3,236	3,610	48,369
Lost resilience	60	76	347	621	2,868	4,378
Total	**94**	**505**	**581**	**3,857**	**6,478**	**52,747**
Total Costs to Uganda	**3,162**	**5,855**	**17,963**	**26,983**	**272,634**	**436,672**
As percent of PPPGDP	**3.01**	**5.57**	**2.31**	**3.48**	**2.80**	**4.49**

Notes: These costs of inaction include the effects of current variability as well as future change

Damages to infrastructure are expected values based on expected frequency of extreme events.
GDP projections are based on SSP1, which has annual growth rates for Uganda from 2010-2050 of 7.8% per annum

* loss in the capacity of infrastructure to withstand climate change

3.1.1. Agriculture

Table 2 summarises the costs for agriculture, giving figures for 2025, 2050 and for the whole period 2010-2050. The largest impact is on food crops, followed closely by the export crops of coffee, tea and cotton. The range of estimates is more varied for food crops, with the upper bound losses proportionally greater than the other agricultural products. Livestock losses are small but that may reflect lack of knowledge about how the sector is affected by climate. While losses as a percentage of GDP are not large, they are significant relative to the size of the sector. Given the vulnerability of the rural population the implications of the losses for poverty and wellbeing are high.

In the absence of additional measures to adapt to climate change there will be significant consequences on food crops and livestock, on export crops, and on both of these sectors from extreme events.

Food crops: Climate impacts on regular farming are hard to predict. The very sophisticated models used for this purpose show wide divergence on what will happen to the output of 11 staples that have been modelled (cassava, groundnuts, maize, millet, pigeon peas, potatoes, rice, sorghum, soybean, sugar cane and sweet potato). Most of them indicate some decline up to 2050 but some even point to a possible increase. The largest falls are predicted for cassava, potato and sweet potato, which could decline by as much as 40% by 2050. In most cases, however, the decline in yields is less than 10%. Under the scenarios considered overall losses for food crops by 2050 are not likely to be more than US$1.5 billion per year and could well be less than that. In the summary table at the end of this section we have considered damages at that level and half that level by 2050, with proportion changes in the intervening years[17]. It is important to note, furthermore, that these national figures mask important local differences in yields and value of production. In the regional analysis the largest impacts on production and total value are shown in the East and North for all crops.

Livestock products: Climate impacts on production are quite small in all cases (1 or 2% by the end of the period) based on the International Food Policy Research Institute (IFPRI) modelling. However, this modelling is only for yield and area whereas the key impacts on livestock will come from other climate factors, in particular droughts, floods and diseases. We have used this range to estimate possible losses for the sector to 2050.

Agricultural exports are a key area of concern**.** Significant impacts on the Arabica coffee growing area to 2050 are predicted due to climate change. These will have major implications for production and export value particularly in the Eastern region. There are also significant impacts predicted in the Robusta coffee growing regions elsewhere although the research is much less developed than for Arabica coffee. Climate induced yield losses for coffee could be in the order of 50-75% by 2050, as a result of a combination of yield reductions and (more importantly) loss of areas where coffee can be grown. These would represent a major impact on the economy, which is currently deriving 18% of its export earnings from coffee. Estimates of impacts on tea growing areas also indicate significant losses. Estimates consider a 50% fall in production by 2050 as plausible. Finally the IFPRI modelling shows some potential losses of cotton production due to yield impacts in the range of 60-77% of the no climate change scenario by 2050. Taken together these results indicate the potential for Ugandan agricultural export production and value to be strongly hit by climate change in the period to 2050 and beyond in the absence of adaptation actions. We have used these ranges to estimate losses in production by 2050, with proportional losses in the intervening years. The costs, given in Table 2 are US$134-196 million by 2025 andUS$641-938 million by 2050.

Extreme events: It is widely accepted that extreme weather events have been increasing and have been more severe in recent years. Analysis by Rautenbach (2014) concludes that these risks are likely to increase in the future in large parts of Uganda. To give an indication of the order of magnitude of recent losses, the damage figure of US$47 million to crops (NEMA, 2008) is equal to about 3 per cent[18] of the value of all cash and food

[17] In the sector modelling it is assumed productivity growth will take place in the agriculture sector at 2.4% per annum to 2030 and at 1.9% thereafter.
[18] Calculation based on GDP data for the agricultural sector in 2008 in UBOS (2013).

crops in that year. Other extreme events have resulted in even bigger losses, possibly as much as 30% of the sector's normal output.

It appears therefore that the threat from droughts and floods is more important than the threat from decreased yields. It is already present and needs urgent action, making it a priority in terms of adaptation. It should also be stressed that current and future increased risks from flooding and droughts are in areas of existing poverty and therefore these events have serious consequences for local economies and food security. The Karamoja case study demonstrates that quite clearly.

3.1.2. Water

Table 2 gives the breakdown of costs by sub-sector within the water sector. About three-quarters of the costs arise from a shortage of water for irrigation. The next most important in value is livestock, followed by domestic and industry.

An estimate has been made of water demand by sector (agriculture, households and industry) in each of the eight watersheds in the country in 2030 and 2050. This is compared with the supply likely to be available. From the two an estimate is arrived at of the unmet demand, now and in the future under given climate scenarios. This unmet demand (part of which arises from climatic factors and part from socioeconomic changes) is then valued in monetary terms. In addition to looking at changes in average conditions, the report also analyses the situation in the case of a drought and how that would translate into losses in the future.

Total demand is expected to increase from 408 million cubic meters a year (MCM/y) in 2010 to 3,963 MCM/y in 2050. Total unmet demand (assuming that no additional investments in the water sector would take place, other than those already planned for in current investment plans) will then rise from 3.7 MCM/y to 1,651 MCM/y in this period. In most months water shortages will be enormous.

The unmet demand has been valued in monetary terms based on methods that are widely used in this field. The expected cost in 2050 is anticipated to be of the order of US$5.5 billion as a lower bound and could be as much as ten times higher if income effects on willingness to pay are taken into account. Domestic consumption is likely to be impacted in three watersheds: Lake Victoria, Aswa and Kidepo. The largest overall economic losses are anticipated to be in the Lake Victoria, Albert Nile and Lake Kyoga watersheds. These values underline the need for further investment in the water supply infrastructure in Uganda. With or without climate change the economic losses are of a significant magnitude.

In addition to unmet demand under average conditions the report has also looked at droughts. Past extreme events of water shortage have had major impacts, with two droughts in the past decade (in 2005-6 and 2010-11) resulting in losses of US$250 million and US$1,174 million respectively. Each drought occurs about every 3 years representing an average annual damage per drought event in the last decade of US$237 million. Future droughts can be expected to have similar costs but with greater frequency, possibly every three years.

The report has looked at the costs of proposed priority interventions documented in the Government of Uganda's national Climate Change Policy Costed Adaptation Strategy document and compared them to the potential benefits in terms of reducing unmet demand or in reducing losses from droughts. Three programmes, which account for 92% of the Government's strategy were examined: Programme A focuses on improvements in water use efficiency, Programme B addresses water supply issues for agriculture and industry and Programme C sets up an Integrated Water Resources Management system that would help reduce losses from droughts and floods. In each case the model calculates the minimum reduction in damages required for the project to generate a 10% rate of return. The results indicate that even with a very small impact on unmet demand, all three programmes would generate this return. **The implications of such a preliminary analysis are that the benefits of action to adapt in the water sector are very high and further investments may well be justified**.

3.1.3. Energy

Energy use in Uganda is dominated by traditional biomass, with electricity and other fuels playing a very small role. The current balance between supply and demand for biomass, however, is very fragile and predictions from the modelling are that if no action is taken there will be a huge deficit of biomass (1,710 million tonnes over the period 2010-2050). The cost of the unmet demand for biomass over this period amounts to US$123 billion with no climate effects. In this Base Case inaction scenario the National Power Sector Generation Expansion Plan, does, however, meet demand for electricity if the plan it is realised in a timely manner. The main dependence for future electricity in this case is for hydropower, with large new hydro plants coming on stream in 2018 and 2019 (Isimba and Karuma respectively), and then in 2024 (Ayago).

From the above we conclude that a Business as Usual scenario for growth, while electricity demand can be met, the demand for biomass is not sustainable and a solution is needed to address the predicted deficit.

A number of alternatives are considered to fill this gap even with no climate change impacts. One would be to increase biomass efficiency and make available an alternative fuel to households who cannot be connected to the grid.

These problems are exacerbated by climate change in two ways. First there is a potential decline in biomass and second a decline in electricity generation owing to a fall in precipitation. Climate change effects on biomass are both direct and indirect. The direct effects occur both through periods of prolonged droughts and prolonged rains as well as through temperature and moisture changes, which affect growth for some species. Indirect impacts include those via crop failures, and problems of transportation. Crop failure as a result of climate variability results in shortages of agro-wastes. Infrastructure damage (of roads and bridges) can also affect access to biomass. For example during the rainy season, charcoal availability is limited due to the difficulties of transporting charcoal to and from remote areas. When the rains get prolonged (above normal rainfall) the charcoal scarcity can lead to price hikes as was witnessed in the 2002 charcoal crisis. A plausible range of decline in biomass owing to these effects is 5-10% by 2050. This increases the costs of inaction from US$123.6 billion (See Table 2) to between US$130 and US$136 billion.

The effects of climate change on hydropower capacity are considered under two variants: one in which capacity declines linearly between 2025 and 2050 so that it is 26% lower by the latter date; and the other in which capacity increases linearly so that it is 15% higher in 2050 relative to 2025. The decline of 26% is based on the climate projections generated as part of this study combined with hydrological modelling using the WEAP[19] model. The increase is based on the results of an alternative model (Hamududu et al., 2009).

In the case of a possible decline of 26% by 2050 the analysis shows that the government's current expansion programme for the power sector is sufficient to cover the hydropower deficit, as long as the other components of the programme are implemented according to the proposed schedule. It is important to remember, however, that this is a very ambitious programme, which will demand large financial resources as well as highly skilled manpower that is able to operate a much more sophisticated electricity system than the one that Uganda has at present. The estimated additional capital investment in hydro, nuclear and other generation from now to 2050 is around US$83 billion. According to these plans, in the period 2015-2020 the country will need to invest around one billion dollars in the electricity system, or around US$200 million per year, a sum which is equal to about 1% of national GDP. In future years the amounts increase very sharply.

3.1.4. Infrastructure

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

[19] Water Evaluation And Planning System– www.weap21.org

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, or that the costs of adaptation are a lower bound to the costs of inaction. This is a common assumption in the adaptation literature and has been used in all the previous assessment of the impacts of climate change on infrastructure. Taking the adaptation costs as lower bounds of damages we get estimates given in Table 2 of US$60-76 million in 2025, rising to US$347-621 million in 2050. These figures are lower than the government estimates for infrastructure protection against climate change.

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, specific to extreme events. 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$34-214 million by 2025 and to US$234-809 million by 2050. Note, however, that as a percentage 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$68-429 million by 2025 and US$938-3,236 million by 2050. See Table 2. The figures are average or expected damages; a particular event could have higher or lower costs and indeed a similar one to that which occurred in 2007 would result in significantly higher costs in the future.

3.2. Costs of inaction from the case studies

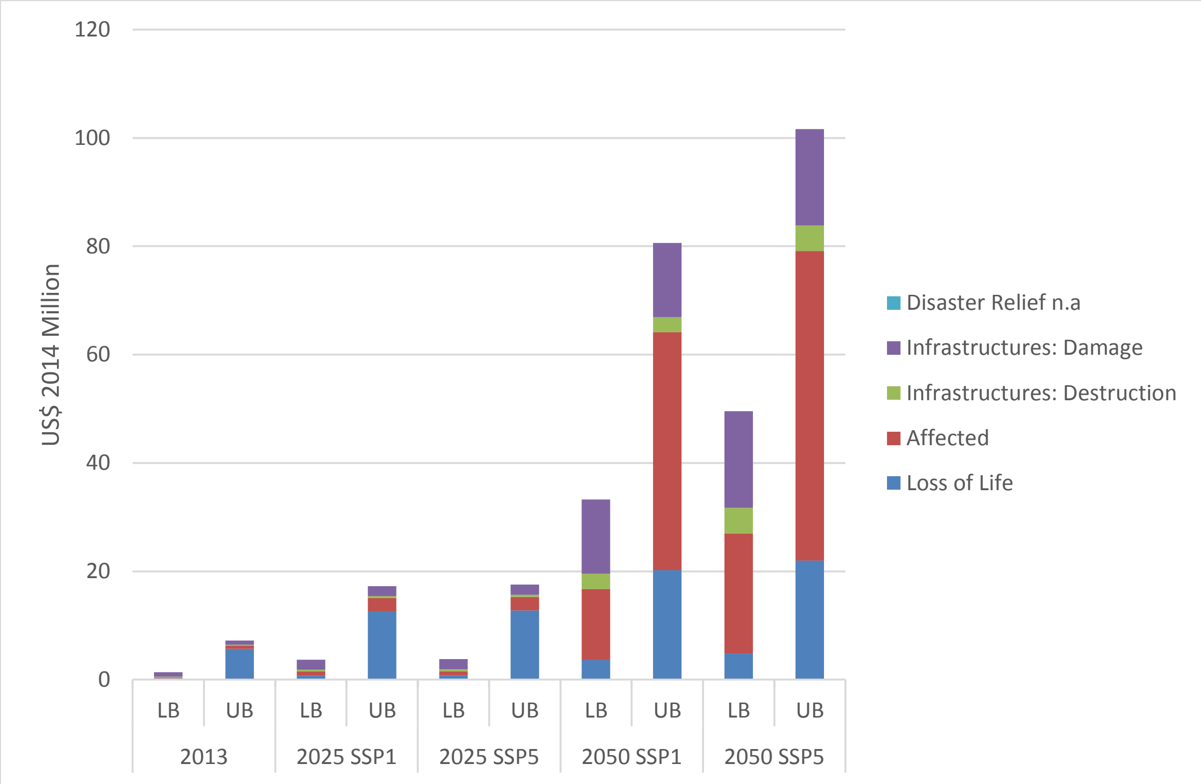
3.2.1. Urban Development and infrastructure: Kampala

Kampala 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 (double that in the Greater Metropolitan Area) and it accounts for about half the GDP of the country. Projections are for the population to grow to some 5 million by 2020, and to 10 million within a generation. It could even exceed 15 million and approach 20 million by 2040 if immigration into the city accelerates in accordance with one scenario.

The estimates of climate impacts for the city concentrated on those arising from floods and from the need to increase resilience of the infrastructure as a result of higher temperatures and changes in precipitation in the future. As far as floods are concerned, Kampala experienced about 11 such events from 1993 to 2014, resulting in 38 deaths, 67,713 people affected, 123 homes destroyed and around 21,000 homes damaged[20]. In order to value these damages for the future we worked on an 'expected annual event' basis. Damage estimates from the above events were converted to an annual average and these were then valued assuming no change in frequency or intensity. On that basis expected damages are estimated 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, as illustrated below.

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

Figure 9 - Expected Annual damages from Floods and Related Events in Kampala with No Change in Frequency US$2014 Million



Note LB/UB: Lower/Upper bound estimates obtained from projections under SSP1/RCP4.5 and SSP5/RCP8.5 scenarios respectively..

The increase is the result of a growing population and assets that are appreciating in value over time. Damages arise from loss of life, injury to persons and their property and cost of disaster relief. There is not much difference between the RCP scenarios, as there is no assumed change in extreme events by scenario. It is possible that the frequency of flood events would increase in the future. If this doubles by 2050 and increases linearly between 2013 and 2050, damages in 2025 would range from US$5.6 million to US$26.3 million and in 2050 from US$66.5 million to US$203.3 million.

As in the national level assessment, the costs of measures to increase the resilience of infrastructure in Kampala are considered as a lower bound for the damages that would be caused to infrastructure if such measures were not introduced. The infrastructure consists of residential buildings, public buildings, private sector offices and factories; and roads, bridges and other major physical structures. The costs arise from the higher cost of new construction to make it more climate resilient, as well as costs of climate proofing existing infrastructure and the higher maintenance costs.

Costs to climate proof infrastructure are significant: they are between US$560 million and US$600 million for the period 2015-2030, and reach between US$3.3 billion and US$3.7billionover the 2015-2050 period. The costs increase with time, to a large extent due to population and economic growth. 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 city GDP the costs increase from 0.03-0.04% in 2015 to around 0.1% in 2050. In per capita terms costs increase from US$2-3 in 2015 to US$27-34 in 2050.

Furthermore 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$3.3 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.

Buildings account for most of the costs. Transport only accounts for a very small amount due to the fact that precipitation is not expected to increase much according to the climate projections and transport infrastructure is mostly affected by an increase in rainfall. The climate scenarios show a decline in precipitation over the period. As this component has more effect on transport, the costs for that sector are reduced.

Within buildings, the most affected sector is residential, which accounts for around 72% of all costs.. Next are non-residential private buildings, which account for 23%, and then public infrastructure with 2%, which though a small share of the total is nevertheless a major part of the public sector's budget (based on current budget levels).

3.2.2. Agriculture: Karamoja

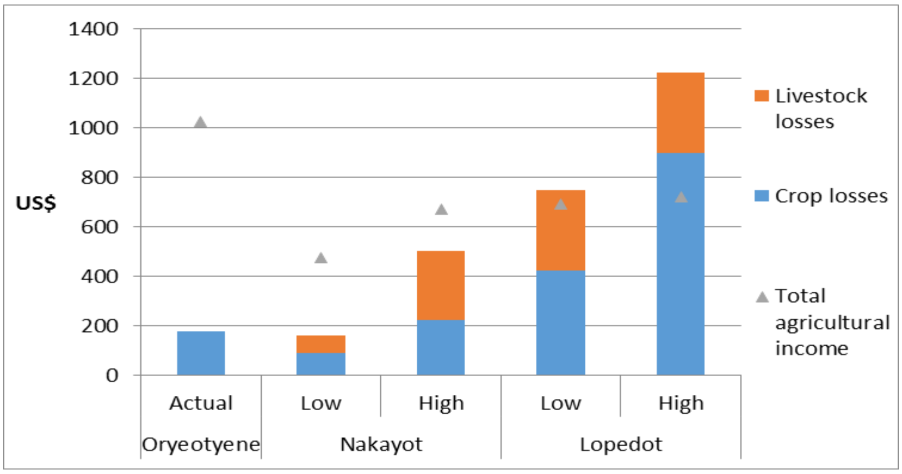
The Karamoja region was chosen as a case study because it faces a number of development challenges in the light of historical marginalization, local and cross-border conflicts and lack of capacity development and investment. Insecurity has hindered economic development in recent decades but peace building programs implemented in the last few years have resulted in a considerably improved situation with the prospect of making the transition from emergency support to longer-term development.

This case study looked at the impact of climate change in three locations in the Karamoja region. The study collected field data via questionnaire and semi structured interviews of local officials and a sample of village households in the villages of: (i) Oryeotyene North Ward Village in Abim district (representing an agricultural zone), (ii) Nakayot Village in Napak district (representing an agro-pastoralist zone) and (iii) Lopedot Village in Amudat district (representing a Pastoral Zone).

The data collected showed the communities in these villages to be absolutely and relatively poor and to face significant fluctuations in their incomes as a result of droughts and floods. In Oryeotyene North Ward village agricultural income per household (including the value of produce not sold) amounted to US$890 per year, equal to around US$0.58 per adult equivalent per day. In Nakayot the corresponding adult equivalent figure was US$0.45 and in Amudat it was US$1.11.[21]

These are estimates for a year in which there was no special extreme event. In Oryeotyene North Ward losses were estimated at about 21% of expected crop production (for the drought in 2009), 11% of expected production (for drought of 2013) and 13.7 per cent of expected production (for floods of 2007). This compares to estimated losses in Nakayot of about 55 to 62% of a normal year's value for the 2014 drought and 23 to 33% for the 2013 drought. The 2014 severe drought in Lopedot is estimated to have reduced crop production value in the village by around 85% compared to the value in 2012.

Figure 10: Estimated average losses per household from the droughts of 2014 (US$) (low-high ranges)



NOTE: A low to high range is not given for Oryeotyene due to much more reliable loss values in the survey than the other two villages

[21] Based on taking the average household size of 7 and applying a coefficient of 0.7 for the 2nd adult member of a household and 0.5 for each child. These equivalency scales set out by OECD are used in calculating incomes for poverty estimation purposes. Conversions to US dollars use purchasing power parity exchange rates.

The study also estimated future impacts from climate change, allowing for some improvements in productivity. For Oryeotyene Northward projections of losses of crop value from future climate events up to 2050 (based on the estimated losses from recent events in this study) produced total losses of potential crop production of about 9% (for a less severe scenario) and 18% (a more severe scenario). For Nakayot similar projections for losses in crop production value to 2050 produced estimates of about 15% in a less severe scenario and 32% in a severe scenario. Similarly the speculative estimates for Lopedot produced losses in crop production value to 2050 of about 19 to 28% for the different scenarios. Thus the prospects in the case of inaction are not encouraging for this region as a whole.

3.2.3. Agriculture: Mt. Elgon

The Mount Elgon region is one of the most vulnerable in Uganda to climate variability. Excessive heat and droughts, excessive rain leading to flooding and landslides, and hailstones have affected it severely over the last 20 years. The impacts of these on people's lives and livelihoods have been very significant.

This case study reviewed the evolving situation for agriculture in the Bududa district, located in Eastern Uganda, in the Mount Elgon region, focussing on Arabica coffee, which is important in terms of rural livelihoods andcontributes 43% of Uganda's total direct coffee export earnings. Bududa, is typical of agro ecological zones in the region. It accounts for of 274 square kilometres of the territory and is located at an average of 1,800m above sea level on the slopes of Mount Elgon.

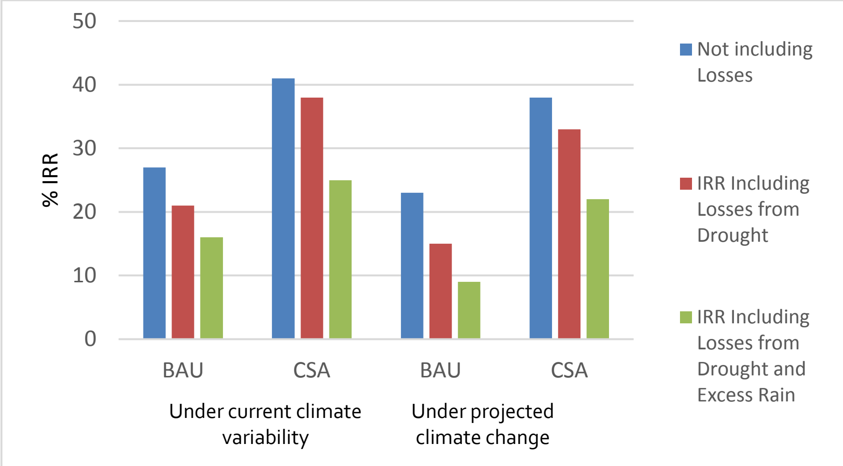
The study found that most households in the district are subsistence farmers and there is little income derived from non-farming sources. Around half of all household income comes from coffee, with the rest derived from bananas, a range of vegetables, some livestock, bees and fishponds. The population of the region has been growing fast: it is more than 80% bigger now than it was at the start of the 1990s. At the same time poverty is widespread: in 2007 around one-third of households were judged to be below the national poverty line.

As far a coffee is concerned the yields and quality of the crop have been declining, in part owing to poor management practices and in part because of an increase in the frequency of droughts, landslides and floods. Changing weather patterns have been observed in the district and the region more generally. Particularly long dry spells and excessive heat were recorded in Bududa in 1997, 2009 and 2014. These caused losses in the range of 10 to 75% in the lower elevations and around 50% at higher elevations based on the data collected in the field. There has also been an increase in the frequency of excessive rainfall and landslides both of which have resulted in significant losses of crops.

The analysis of climate change for this district concentrated on the returns to coffee growing. A comparison was made between the returns under 'Business as Usual' agricultural practices for coffee with the present climate variability and with climate change, based on the data collected in the field. With the present variability the Internal Rate of Return (IRR) for coffee cultivation on a 15 year cycle is around 16%, when you include losses from drought and excessive rain. Under future predicted climate changes, this return is expected to decline to around 9% in the next 15 years cycle (2015-2030) and fall further to 5% in the second cycle (2030-2045). This is illustrated in

Figure 11 below. Taking account of the losses due to such droughts and excessive rain such a return would not render coffee cultivation profitable under present practices. If climate smart agriculture is adopted the IRR would increase to 25% under current climate variability. Although this would decline to 22% with projected climate changes impacts, this would still be higher than current practices.

Figure 11. Returns to coffee growing in the Bududa District (IRR%) under current climate variability and projected climate change, Business As Usual (BAU) and Climate Smart Agriculture scenarios (CSA[22])

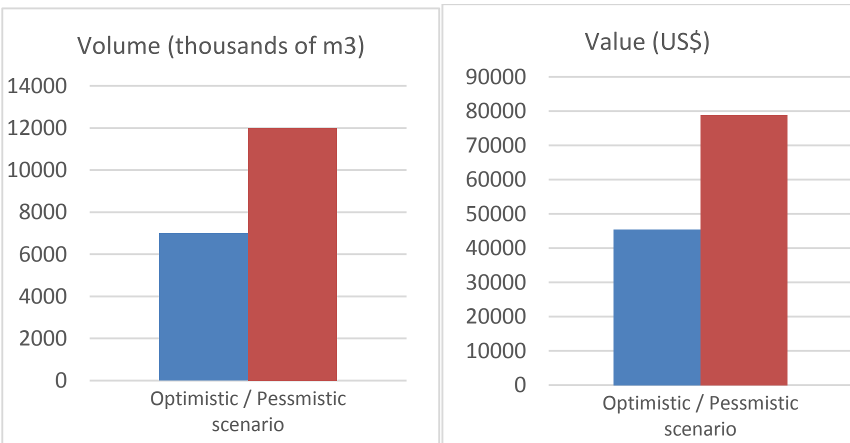


3.2.4. Water and Energy: Mpanga

This case study explores the conflict between the energy and water supply for the use of river water for hydroelectricity generation and supplying the needs of multiple users. The Mpanga basin was selected because it faces a number of challenges, including pressures on both the quantity and quality of water in the river basin. There is an existing hydroelectric plant which has suffered significant outages in the recent past. There is also likely to be increases in demand for water supply for agricultural, industrial as well as domestic purposes.

The impacts of climate change in the Mpanga River Basin are expected to be a decrease in rainfall and a significant increase in temperature. The most significant impacts on water supply are likely to fall in the Rushango area of the catchment. Annual average economic losses from sectors other than energy (i.e. mining, industry, livestock and, to a lesser extent irrigation for agriculture) in this area amount to between US$45,400 to US$78,900 by 2035. These costs may rise to US$188,000 if the income elasticity of willingness to pay and future increases in income following the scenarios of GDP and population are taken into account.

Figure 12. Unmet demand estimated in volume and value in Rushango – average year with 2035 demand, current prices, no discounting



Note: The rationale for not discounting in this figure is that it reflects the value as it might be in 2035. It is a value of an impact in 2035 (in current prices).

[22] In this study we use a restrictive definition of CSA, including those few activities that farmers in Bududa consider critical in order to adapt coffee cultivation to climate change in their geographical location. In particular, on the basis of the consultations conducted, we considered planting of shade trees, mulching and trench construction.

The largest economic costs, however, will fall on the energy sector. Transferring costs of lost load from a study in Kenya, adjusting for income differences and inflation, we find annual costs by 2030 to 2035 may be as high as US$25 million to US$98 million.

3.2.5. Health: Tororo and Kabale

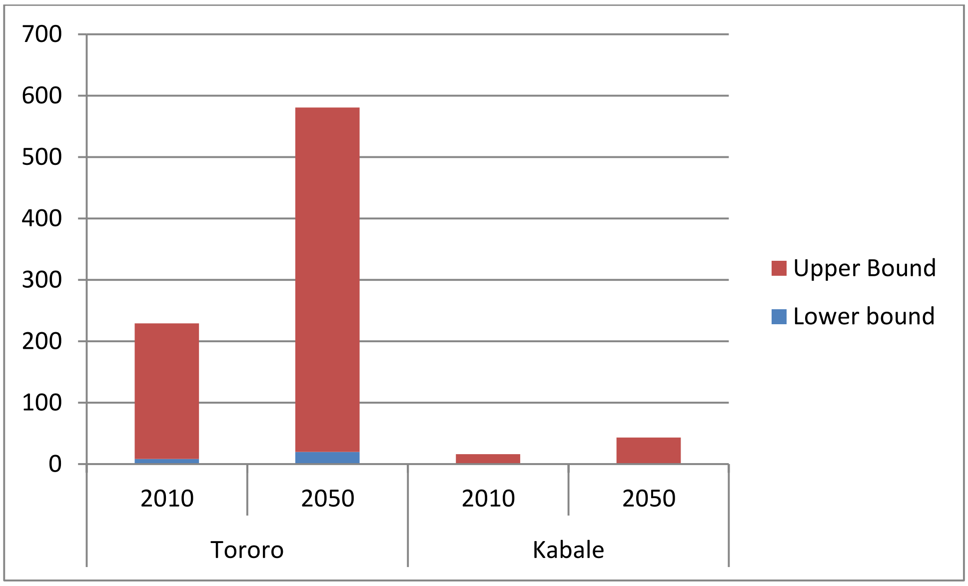
This study looked in depth at the potential impact of malaria in two districts; Tororo in Eastern Uganda where malaria is endemic (widespread) with 82 cases per week in a population of 475,000; and Kabale in South-western Uganda where the disease is more epidemic (sporadic) in nature, with an average of 75 cases per week in a population of 495,000.

Climate projections indicate that temperatures will increase in Tororo by around 1.5 to 3.5°C by 2095 under RCP scenarios 4.5 and 8.5 respectively. The projections for Kabale are for higher increases in temperature: around 3 - 4.5°C by 2095 under RCP scenarios 4.5 and 8.5. In neither district is there any prediction of an increase in average annual rainfall, although there is indication of more days with a small amount of rainfall and less days with heavy rainfall. These changes are likely to create a favourable environment for mosquito breeding, especially in Kabale, which is a high altitude area, more than 2000m above sea level. The evidence base on the linkage between temperature and malaria is limited, but indicates that an increase in temperature is likely to result in an increase in the number of cases of malaria. Only one study dealing with this linkage is from Uganda and is not statistically strong. Other studies from South Africa and Ethiopia point to a similar relation but with different quantitative estimates.

The study quantified the possible increases in cases in 2025 and 2050, building on the existing evidence. This requires projections of population, which are based on the new IPCC shared socio-economic pathways for Uganda downscaled to these districts. The combination of the climate projections with the socio-economic scenarios and malaria modelling results indicates that there will be an increase in cases of malaria due to climate change but also a large increase (if not a greater one) due to the fact that there are more people exposed. In Tororo the population effect will be to increase cases by 5,417 to 5,503 per year in 2025, whereas the climate effect will be to increase them by between 65 and 853, depending on the climate scenario. In Kabale the population effect by 2025 is only about 1,568 to 1,593 more cases, while between 56 and 320 more cases will arise because of the climate effect.

The economic costs of these additional cases has been estimated using data on the costs of treatment, loss of earnings and productivity, and the value attached to the loss of a life. In Tororo, the cost of malaria may rise from a range of US$8.7 million to US$221 million in 2010 to a range of US$20.1 million to US$560.5 million in 2050. In Kabale, malaria is expected to increase in cost from between US$0.7 million to US$15.8million in 2010 to between US$1.55 million to US$41.7million in 2050. Clearly, the costs are expected to increase significantly, even if the width of the ranges provided highlight the considerable uncertainty in the impact, in part because of the issues involved in monetary valuation of mortality and in part because of the variation in climate and socioeconomic scenarios.

Figure 13. Cost of malaria in Tororo and Kabale under climate change in 2010 and in 2050, in million US$



Note: lower and upper bound are results obtained under different scenarios. There is a lower bound for Kabale but it is so small that it is off the scale

3.3. Overall costs, uncertainties and implications for costs of different scenarios for development

The analysis shows that there are likely to be significant costs for Uganda if there is no adaptation to expected climate change. The national level studies show annual costs that could be in the range of US$3.2 billion to US$5.9 billion within a decade, with the biggest impacts being on water, followed by energy, agriculture and infrastructure. The range of estimates is wide for two main reasons. First there are uncertainties in the physical climatic impacts and second there are uncertainties in the values we attach to those impacts. In the case of energy and agriculture the greater uncertainties are on the physical impacts of climate change while in the case of infrastructure they are more on the valuation of the consequences of climate change. For water both factors play a similar role.

As we have already noted these costs combine the effects of current variability and future climate change. Even if there were no further increases in temperature or precipitation or frequency of extreme events the costs of inaction would rise over time because of an increase in population (expected to grow at over 2% p.a. over the next 40 years) and GDP (expected to grow at around 7% p.a. over the same period). The additional effect of climate change is significant for agriculture and water and could be significant for infrastructure if extreme events increase in frequency and intensity. Although we judge this is likely, the models are unable to provide a quantitative estimate of such increases.

The impact of growth on the estimated damage comes about in two ways. On the one hand it increases the asset base that can be damaged, but on the other it also increases the resources available to deal with the damages. The share of GDP that the costs of inaction represents does not go up noticeably over time if GDP growth is maintained at around 7%. That share is estimated at around 3-4% in 2025 and at 4-5% in 2050. Indeed estimates show that damages from climate variability now are probably higher than 3-4%, which gives action an urgency.

Some critics argue that the uncertainties on costs are so large it is not possible to take them seriously. We would not support that conclusion. The figures presented here are not exact, but they indicate a range of costs that merits immediate attention. Even at the lower end they indicate potential impacts on vulnerable members of society that cannot be ignored. While better information may be forthcoming on climate change in the coming years, there is enough available now to justify action in a number of areas. These are reviewed in the next section.

We have also commented in Section 2.3 on how climate change could affect growth in the country. Loss of export earnings from crops like coffee, tea etc. would slow down growth by both contracting an important employment sector and imposing a constraint on the external account that would limit potential imports of capital. Water deficits could act as a brake on development by limiting agricultural growth and increasing the costs of energy as hydropower potential is reduced. Likewise energy shortages for households and industry will make it more difficult or more costly to expand output. Lastly, extreme events that cause infrastructure damages also impact on the productivity of businesses and cause delays in the movement of people and goods across the country.

The view that increasing extreme events have an impact in reducing growth is supported by a recent study at the global level (Hsiang and Jina, 2014). Although not specifically focussed on Uganda, and looking at cyclones across the world from 1950 to 2008, the authors find that income losses arise from a small but persistent suppression of annual growth rates spread across the fifteen years following a disaster, generating large and significant cumulative effects: a 90thpercentile event reduces per capita incomes by 7.4% two decades later, effectively undoing 3.7 years of average development.

4. ADAPTATION OPTIONS

Adaptation offers the prospect of a considerable reduction in the costs of climate change What's more, many adaptation options include 'co-benefits' –benefits over and above the benefit of improving resilience to climate change.

The study has looked at the short, medium, and long term adaptation options at the national level for agriculture, water, infrastructure and energy. The short term is taken as 1-5 years, (2015-2020); the medium term as 6-10 years (2021-2025), and long term as 11-15 years (2026-2030)

In the short-term for agriculture some of these are a continuation of what is already ongoing as part of the Sustainable Agriculture Programme, providing extension services and conveying information on weather and market conditions to farmers in a timely manner. Weather-related information is clearly a critical factor. These programmes will also provide benefits in the medium to long term, when other factors that start in the short term will play a bigger role as important adaptation actions in the face of climate change, such as farm diversification, post-harvest handling and storage. The same applies to case-specific climate smart agriculture programmes, which can be implemented to reverse the loss of yields in a cost effective way, and Arabica coffee is an example. Finally, improved water storage is critical to address drought events. It needs to be started immediately and continued over the medium to long term as it will become even more important over time. This can be done in a relatively cost effective manner.

This last factor is linked to the water sector, where water harvesting and water conservation are already important and cost-effective measures. In addition, priority is given to early-warning systems for floods and droughts. In the medium to long term a key action, started now, will be to develop Integrated Water Resource Management Systems for the 8 basins of the country, which will better protect catchments against degradation; and seeking international cooperation over bodies such as Lake Victoria, which is already being impacted by changes in climate.

As far as energy is concerned, the focus is on measures to reduce biomass demand by increasing efficiency of its use; to increase efficiency in the use of electricity, where there is already a deficit. These actions are already active but need to be strengthened in response to climate change. Likewise a program that needs to be activated now and continued in the medium term is the promotion of renewable energy sources other than hydropower, which could be negatively affected by climatic factors. This last aspect, however is uncertain and needs to be followed closely over the coming years so generation expansion plans can be adjusted appropriately. There will also be a need to explore alternatives to biomass other than electricity and this should be a matter of priority.

Lastly, for infrastructure one priority is to ensure that land use plans, building codes and codes for design of transport systems reflect the need to make them more climate-resilient. These are measures that can be implemented in the short term. The other is to strengthen systems for flood control and disaster management, including early warning, so the consequences of such events are reduced significantly. These will be enacted gradually over the coming 15 years.

Tables 3 to 6 provide qualitative information on the likely benefits and costs of a number of short term priorities, either identified as *Strategic interventions* in the NCCP Costed Implementation Strategy or proposed in the sectoral case-studies. Some of these are costed in the next section.

4.1. Agriculture

In the short term for agriculture, some of the policies and measures that can be effective are a continuation of what is already ongoing as part of the Government's Agriculture Sector Development Strategy and Investment Plan[23], providing extension services and conveying information on weather and market conditions to farmers

[23] See MAAIF, 2010. *Agriculture Sector, Development Strategy and Investment Plan: 2010/11-2014/15*, Kampala, MAIF.

in a timely manner. Weather-related information is clearly a critical factor. In addition the programme emphasises the role of diversification, post-harvest handling, and storage as important adaptation actions in the face of climate change. In some cases specific climate smart agriculture programmes can be implemented to reverse the loss of yields in a cost effective way, and Arabica coffee is an example. Finally improved water storage is critical to address drought events and will become more so over time. Such storage can be done in a relatively cost effective manner.

Table 3. Short Term Priorities for Adaptation in Agriculture

Short term priorities	Impact	Likely Benefits and Costs as per the analysis conducted
Support community-based adaptation strategies through expanded extension services and improved systems for conveying timely climate information to rural populations for enhanced climate resilience of agricultural systems	Improved autonomous adaptation in the face of climate variability and change (i.e. spontaneous actions taken by farmers and communities given the changes they observe).	Benefits of better information to farmers are found to be very high in many studies. At least 10% of losses could be avoided by proper use of weather and climate information. It is imperative to tailor information to farmers needs and ensure those in the agriculture sector who depend most on the information receive it in time.
Promote agricultural diversification, improved post-harvest handling, storage and value addition in order to mitigate rising climate related losses and improve food security and household incomes.	Stabilisation of incomes under climate variability and change.	Benefits of diversification are well documented. As long as programmes use resources carefully and efficiently the potential is there for a high benefit to cost ratio.
Develop innovative insurance schemes (low-premium micro-insurance policies) and low-interest credit facilities to insure farmers against crop failure and livestock loss due to droughts, pests, floods and other weather-related events.	Access to insurance avoids farmers adopting: low return/ low-risk practices, low application of inputs like fertilizer, lower adoption of new technologies and investments	The evidence indicates that insurance schemes can have significant benefits if adopted. The problem is affordability for many poor farmers. If the programme can provide subsidies on a sustainable basis it should yield high benefits relative to costs. (Haggar & Schepp, 2012).
Promote and encourage climate smart agriculture (CSA) and ecologically compatible cropping systems to increase resilience to the impacts of climate change.	Less impacts on ecosystems and increased resilience to climate variability	Benefits of crop diversification have been estimated as significant. Case study in the Mt Elgon Region shows significant benefits if CSA is adopted in the coffee sector.
Promote sustainable management of rangelands and pastures through integrated rangeland management.	Benefits are improved livestock productivity irrespective of climate change. Climate benefits will be related to management under extreme conditions	Benefits relative to costs with respect to climate have been little studied but case study in Karamoja region showed cost per household of proposed programmes to be low. It would take a very small increase in output to justify such an outlay in benefit cost terms.
Improve water availability in drought prone areas through water storage at the household or village levels.	Stabilisation of incomes and reduced dependence on government aid.	The Karamoja study indicated that in a drought year farmers are losing 50-75% of their crops. If the system could prevent 60-65% of the loss resulting from the drought the investment would be socially beneficial. This needs to be

		confirmed but it is very likely that with some configuration of water storage facilities a saving of that amount could be made.

4.2. Water sector

In the water sector water harvesting and water conservation are important and cost effective measures. In addition, priority is given to early warning systems for floods and droughts, and to developing Integrated Water Resource Management Systems for the 8 basins of the country. These systems will involve better protection of catchments against degradation and seeking international cooperation over bodies such as Lake Victoria that is already being impacted by climate change. The short term priorities are broadly in three areas. One is to reduce wasteful use of water resources; the second is to ensure water supply to key sectors, especially agriculture; and the third is to manage water resource systems in such a way that floods are prevented and existing resources conserved to meet a fluctuating natural supply situation. Table 4 reflects these priorities, indicating where major gains in benefits can be obtained from the proposed programmes.

Table 4. Short Term Priorities for Adaptation in the Water Sector

Short term priorities	Impact	Likely Benefits versus costs
Strengthen water resource monitoring networks and flood warning systems	Reduction in losses from flood events and learning for future management	Previous studies show warning systems have a very high benefit to cost ratio.
Promote and encourage water harvesting and efficient water utilization among individuals, households, institutions.	Reducing water deficit for households has huge direct benefits to them and makes more available for agriculture and industry	The analysis shows that even if this program achieves a 0.5% improvement in efficiency it will generate a 10% return
Ensure availability of water for production in water dependent sectors in order to increase their resilience to climate change impacts	In the case of agriculture it will prevent fluctuations in incomes during droughts (see agriculture priorities)	Reduced unmet demand in agriculture, livestock and industry. Analysis shows that even with a 0.4% increase in supply the programme has a return of 10%. The Mpanga case study shows that even with quite small reduction in energy losses as a result of better water regulation, the benefits exceed the modest costs of the programme of UD$1.4 mn.
Promote Integrated Water Resources Management (including underground water resources), including contingency planning for extreme events such as floods and drought.	Ensures better preparation in the case of droughts and floods, thus reducing damages to agriculture and infrastructure.	Reduced damages from future droughts of around 4-5% are sufficient to generate a return of 10% from this component. The Mpanga case study estimated costs of water catchment protection at US$4.2 million and showed that plausible benefits in the form of increased hydropower in the range of 8-33% would be enough to justify the costs.
Ensure that guidelines for infrastructure/ hydraulic works (i.e., water for production, piped	Investments made now will be designed to withstand	Benefits hard to quantify but experience shows it can be costly to

water supply schemes and conditional grants guidelines for support to point sources protection) include climate change effects	climate effects (e.g. higher levels of water discharge)	ignore such factors when designing hydraulic systems with long lifetimes.
Improve and strengthen trans-boundary cooperation regarding water resources management	Lack of cooperation can result in overuse of water resources, which could become more scarce with climate change	Hard to quantify in general, the benefits can be very high in individual cases and costs are not especially high.
Support institutional and human capacity building in water resource use, development and management	Better management of the resource	Costs of such programmes are small relative to benefits when they are well designed.

4.3. Energy sector

In the energy sector, the focus is on measures to reduce biomass demand by: increasing efficiency of its use; substituting biomass use with other fuels; increasing efficiency in the use of electricity as well as its supply; and promoting the use of renewable sources other than hydro (which could be negatively affected by climatic factors).

In terms of reducing biomass demand the options evaluated included a major increase in the use of LPG or other fuels, as well as electricity for households that currently rely on biomass. A switch to LPG is one option but it would entail a large programme to import the fuel (the total amount needed over the next four decades is around US$1.7 billion, or US$42 million per annum). Another alternative is to eliminate the deficit through the use of imported biomass – equal to about 86 million tons in the next 40 years, or around 2.2 million tons per year. These options need further investigation but a preliminary analysis indicates that **the benefits of developing an alternative fuel program** (in terms of reducing the unmet demand) **are well in excess of costs and should constitute a priority area of intervention.**

Meanwhile the most important overall objective in the short term is to make more efficient use of biomass in the traditional energy sector, and three of the short term priorities focus on that. The second objective is to promote renewable energy and other energy sources so that households can switch out of traditional biomass and to more sustainable and clean sources. The third objective is to increase efficiency in the modern energy sector, particularly in the use of fossil fuels. The fourth objective is to ensure the best use of hydropower in the country by careful management of the water resources. This last aspect, however, is uncertain and needs to be followed closely over the coming years so hydro generation expansion plans can be adjusted appropriately. There will also be a need to explore alternatives to biomass other than electricity, and this should be a short term priority.

Table 5. Short Term Priorities for Adaptation in the Energy Sector

Short term priorities	Impact	Likely Benefits versus costs
Promote and participate in water resource regulation so as to ensure	Better management and protection of	Not evaluated quantitatively but we note current power shortages indicate the

the availability of water for hydropower production	water resources for hydropower	seriousness of the problem and proposed costs are not high. The estimated cost of this priority for the Mpanga river catchment is US$1.5 million. With a 5% discount rate, the reduction in energy losses needed for benefits to exceed costs is only between 0.92 and 3.61%.
Promote energy-efficient firewood cook stoves, solar and liquefied petroleum gas (LPG) cookers	Reduced demand for biomass	Efficiency increases in use of wood fuel are critical even without climate change and more so with it. If well implemented benefits will be very high relative to costs but problems arise with take up rates.
Promote the development of energy conservation and efficiency projects in all sectors; for example, to promote the use of stabilised bricks and efficient brick kilns in the building sector		Efficiency increases in use of wood fuel are critical even without climate change and more so with it. If well implemented benefits will be very high relative to costs.
Promote efficient firewood/charcoal stoves and solar and LPG cookers, and address the high upfront costs of acquiring these technologies through household subsidies or tax waivers		Measure is critical to reducing the use of biomass. Success depends on high take up rates under modest subsidy payments.
Conduct research to determine the potential impacts of climate change elements on the country's power supply chain	Makes planning for future energy supply more effective	Although costly this is a key requirement, given the lack of knowledge and the importance of information on likely future impacts on supply of energy
Enforce building codes to reduce energy consumption	Reduced consumption of energy	In other countries enforcement of building codes is a cost effective way to reduce energy use if implementation can be assured.
Promote the use of energy-efficient technologies such as compact fluorescent and other high energy lamps	Reduced consumption of energy	Benefits of adoption are high relative to costs but the challenge is take up. Some programs have had little impact and others involving subsidies have not been cost-effective. Care needs to be taken in selecting the right promotional measures.
Explore alternative sources of energy to domestic biomass	Close deficit in unmet biomass demand	Alternatives could be combination of imported wood, LPG and kerosene.

4.4. Infrastructure

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 urgently needs to be addressed today. Infrastructure comprises residential buildings, non-residential private buildings, public infrastructure (including schools, hospitals, ports, airports, government offices) and roads, railways and bridges.

For infrastructure one priority is to ensure that building codes and codes for design of transport systems reflect the need to make them more climate resilient. The other is to strengthen systems for flood control and disaster management, including early warning, so the consequences of such events are reduced significantly. The list includes a number of priority areas. The first is to start the programme of making existing and new transport infrastructure more climate resilient. This involves changes in government codes and regulations and, most importantly, measures to ensure compliance with them. Related to that is the need to make risk assessments prior to undertaking new infrastructure projects, for which the existing guidelines need to be modified to provide more detailed climate related assessment procedures. The second is to ensure better water catchment protection, so that transport systems do not suffer from flooding every time there is high rainfall. Linked to that is the need for flood control programmes in major urban areas, including better drainage, more effective warning systems and a contingency fund to take care of emergency needs following an extreme event.

Table 6. Short Term Priorities for Adaptation in Infrastructure

<table>
<tr><th>Short term priorities</th><th>Impact</th><th>Likely Benefits versus costs</th></tr>
<tr><td>Building codes need to be amended now and enacted over the next 15 years to implement climate-proofing measures</td><td rowspan="2">Avoided damages to infrastructure from increases in temperature and rainfall</td><td rowspan="2">The analysis assumes that the damages avoided are less than the costs of the measures</td></tr>
<tr><td>Government regulations to be amended now and enacted over next 15 years with respect to design of public buildings and roads</td></tr>
<tr><td>Integrate climate change into the existing infrastructure risk assessment guidelines and methodology</td><td rowspan="2">This will complement the enactment of the building codes and government regulations for infrastructure design.</td><td rowspan="2">Urgent need to develop capacity and implement methodology and monitoring of compliance.</td></tr>
<tr><td>Establish and enforce climate change–resilient standards for transport and infrastructure planning and development through monitoring and reporting systems</td></tr>
<tr><td>Promote and encourage water catchment protection in transport infrastructure development and maintenance</td><td>Reductions in future costs from flooding of transport network</td><td>Involves designing measures to support catchment protection. Critical action with high benefits relative to costs. The Kampala case study shows benefits of flood control in three catchments of the city (Lubigi, Nakivubo and Nalukologo) under climate change to be in excess of costs and a fourth catchment (Kinawataka) where further investigation is needed.</td></tr>
</table>

Climate-proof existing and future infrastructure by conducting geotechnical site investigations (GSIs) to determine whether areas are appropriate or inappropriate for infrastructural development	Avoided costs from development in locations likely to be impacted by climate change	Not evaluated in this study but is clearly an important component of site selection investigations, which should include climate considerations.
Develop and implement a climate change–induced disaster risk management strategy and prepare a risk mapping	Reductions in resulting damages from extreme events	The analysis shows that with a 7% reduction in expected damages the programme in the Costed Implementation Strategy to deal with floods would generate a rate of return of 10 %. This is under the most conservative assumptions.
Improve early-warning systems and preparedness to avoid or minimize the adverse impacts of climate change		
Strengthen the National Emergency Coordination and Operations Centre and establish a national contingency fund		
Flood control programmes for 4 catchments in Kampala: Nakivubo, Kinawataka –phase 1 and 2-, Lubigi and Nalukologo	Reductions in flood damages	As mentioned above, our analysis shows the net benefits are enough to meet a 10% rate of return for all programmes except Kinawataka 1, where more information is needed.

5. Financial and Policy Implications of Adaptation

Total spending need on adaptation is estimated in 5 years intervals, from 2015 to 2030. It draws largely on the Costed Adaptation Strategy of the National Climate Change Policy, modified in some areas by estimates made in this study. In the next five years (short term), the cost is estimated at about US$406 million. On an annual basis this amounts to US$81 million, which is about 5% of net official assistance received by the country and 3.2% of total government revenues (excluding grants). In the future the adaptation budgets rise significantly: to US$644 million for 2021-2025 (US$129 million a year) and US$596 million for 2026-2030 (US$119 million a year). It is likely that, as a share of each of these the demands for adaptation will rise. If one compares these expenditures with the costs of inaction, however, the latter are much higher. In Table 2 they are estimated at around US$3.1-5.9 billion a year by 2025, a range that is around 24-46 times greater than the proposed adaptation budget.

Over the next five years, the largest share by sector is for adaptation in energy and energy utilisation (nearly half), followed by infrastructure (28%), agriculture (12%) and water (9%). In the medium term (2021-2025), the costs are more evenly spread; energy is still the largest at around a quarter, and water and infrastructure each account for 16% and 18% respectively. Agriculture still remains at 12%. Finally in the long term (2026-2030), infrastructure dominates at 45%, agriculture is next at 24%, followed by water at 17% and energy at 14%, and water at 12%. Taking the undiscounted costs over the whole period infrastructure is the highest component at 43%, energy is next at 28%, agriculture at 18% and water at 12%.

In term of source of funding, international development partners and government are dominant in all cases. For agriculture, the private sector will have a role in supporting insurance against crop failure and NGOs could be important in supporting conservation agriculture and in the promotion of sustainable rangeland practices. For water, it is difficult to see a major role for the private sector so the programme will likely have to rely on government and international development partners' support. NGOs may play a useful role in promoting Integrated Water Resource Management at the local level. For energy, the private sector will have a key role in the development of renewables and in promoting energy efficiency. NGOs could also contribute in these policy areas. For some measures such as setting and enforcing energy codes, the government has a key responsibility but for others, such as water catchment protection and power sector design and management, international development partners support will be needed. Finally for infrastructure, investment in climate proofing private buildings will fall on the private sector, as can some of the costs of climate proofing transport infrastructure. Setting the land use plans and the codes for new construction and designing and implementing more effective drainage systems and other measures to reduce damage from extreme events will fall on the governments, with some international development partners support.

5.1. Costs of adaptation options

The costs of adaptation of the strategic interventions identified in the Costed Implementation Strategy of the government, by sector, are summarised in Table 7. and Figure 14. Table 7. breaks down the costs over time in three time periods: short term (1-5 years, 2015-2020), medium term (6-10 years, 2021-2025), and long term (11-15 years, 2026-2030). These are the same periods covered in the Costed Implementation Strategy and the measures selected are broadly the same as in that document but there are some differences. First, items where we could not identify the benefits quantitatively or qualitatively in the analysis were excluded from the list. Second, where the analysis provided more accurate information on costs, these were used. This applied, for example, to infrastructure, where we give a further breakdown of the costs of climate proofing buildings and transport and report some different figures. While this study collected additional data on costs of adaptation in the case studies, this has not been used in the table, as it was not possible to scale it up to the macro level.

As in the Costed Implementation Strategy document, we provide an indication of the possible sources of finance, listed in order of importance. The following observations follow from the data:

i. Total spending needed in the next five years is estimated at about US$406 million. On an annual basis this amounts to US$81 million, which is about 5% of net official assistance received by the country in 2013 and 3.2% of total government revenues (excluding grants) in 2012 (latest years available). In the future the adaptation budgets rise significantly: to US$644 million for 2021-2025 and US$596 million for 2026-2030. We cannot predict net official assistance or government revenues that far ahead but it is likely that, as a share of each of these the demands for adaptation will rise.

ii. Over the next five years the largest share (nearly half) is for energy and energy utilisation, followed by infrastructure (28%), agriculture (12%) and water (9%). In the medium term (2021-2025) the structure is more evenly spread; energy is still the largest and accounts for around a quarter, and water and infrastructure each account for 16% and 18% respectively. Agriculture still remains at 12%. Finally in the long term (2026-2030), infrastructure dominates at 45%, agriculture is next at 24%, followed by water at 17% and energy at 14%. Taking the undiscounted costs over the whole period infrastructure is the highest component at 43%, energy is next at 28%, agriculture at 18% and water at 12%.

iii. In terms of the source of funding Table 8 shows international development partners and government as dominant in all cases. For agriculture the private sector will have a role in supporting insurance against crop failure and NGOs could be important in supporting conservation agriculture, promotion of sustainable rangeland practices. They may also make a contribution in a number of other areas. For water it is difficult to see a major role for the private sector and the programme will have to rely on government and international development partners support. NGOs may play a useful role in promoting Integrated Water Resource Management at the local level. For energy the private sector will have a key role in the development of renewables and in promoting energy efficiency. NGOs could also contribute in these policy areas. For some measures such as setting and enforcing energy codes the government alone is responsible but for others such as water catchment protection and power sector design and management international development partners support will be needed. Finally for infrastructure investment in climate proofing private buildings will fall on the private sector, as can some of the costs of climate proofing transport infrastructure. Setting the codes for new construction and designing and implementing more effective drainage systems and other measures to reduce damage from extreme events will fall on the governments, with some international development partners support.

iv. It is difficult to separate out the relative role of government and international development partners in many of the components of the proposed programme. This is a matter for detailed evaluation that was outside the scope of this study. We have indicated, using our best judgement, the order of importance in the table by the order in which sources are listed but this is only a rough guide. One should note, however, that even where international development partners support plays a lead role, some burden will fall on government expenditures.

Table 7. Costs of adaptation options to 2050 (adapted from the Government's Costed Adaptation Strategy)

Sector and Strategic interventions	Amount (US$Mn.)				Source of Funding
	Short	Medium	Long	Total	
Agriculture					
Promote and encourage highly adaptive and productive crop varieties and cultivars in drought-prone, flood-prone and rain-fed crop farming systems	9.1	7.1	11.8	28.0	International development partners and Government
Promote and encourage highly adaptive and productive livestock breeds	15.3	7.1	10.5	32.9	International development partners and Government
Promote and encourage conservation agriculture and ecologically compatible cropping systems to increase resilience to the impacts of climate change.	6.1	2.9	3.9	12.9	International development partners. NGO. Government
Promote sustainable management of rangelands and pastures through integrated rangeland management	0.0	8.8	13.2	22.0	International development partners. NGO. Government
Promote irrigated agriculture by encouraging irrigation systems that use water sustainably	0.0	21.7	32.9	54.6	International development partners and Government
Promote and encourage agricultural diversification. improved post-harvest handling. Storage and value addition to mitigate rising climate related losses and to improve food security and household incomes.	13.8	5.9	9.9	29.6	Government and International development partners
Support community-based adaptation strategies through expanded extension services and improved systems for conveying timely climate information to rural populations for enhanced climate resilience of agricultural systems	4.6	2.9	3.9	11.4	Government and International development partners
Develop innovative insurance schemes (low-premium micro-insurance policies) and low-interest credit facilities to insure farmers against crop failure and livestock loss due to droughts. pests. floods and other weather-related events	0	49	56.4	105.4	Private Sector. International development partners and Government
Total	**48.9**	**105.4**	**142.5**	**296.8**	
Water					
Promote and encourage water harvesting and efficient water utilization among individuals. households. institutions and sectors	1.2	4.2	6.1	11.5	Government. NGOs

Sector and Strategic interventions	Amount (US$Mn.)				Source of Funding
	Short	Medium	Long	Total	
Ensure availability of water for production in water dependent sectors in order to increase their resilience to climate change impacts	15.4	26.7	27.3	69.4	International development partners. Government
Promote Integrated Water Resources Management (including underground water resources). including contingency planning for extreme events such as floods and drought.	13.9	30.5	61.5	105.9	Government. International development partners. NGO
Ensure that all guidelines for infrastructure/ hydraulic works mainstream climate change	3.1	0	0	3.1	Government
Support institutional and human capacity building in water resource use. development and management	1.5	2.7	0	4.2	Government. International development partners
Strengthen water resource monitoring networks and flood warning systems	1.5	3.1	4.1	8.7	Government. International development partners
Total	**36.6**	**67.2**	**99.0**	**202.8**	
Energy					
Promote and participate in water resource regulation so as to ensure the availability of water for hydropower production	45.8	8.2	0.0	54.0	Government
Promote and participate in water catchment protection as part of hydroelectric power infrastructure development	0.0	27.4	32.9	60.3	Government . International development partners
Diversify sources by promoting the use of alternative renewable energy (solar. biomass. mini-hydro. geothermal and wind) less sensitive to climate change	0.0	41.1	0.0	41.1	Government. Private Sector. International development partners. NGO
Promote energy-efficient firewood cook stoves. solar and LPG cookers	114.5	13.7	0.0	128.2	Government. International development partners. NGO. Private Sector.

Sector and Strategic interventions	Amount (US$Mn.)				Source of Funding
	Short	Medium	Long	Total	
Conduct research to determine the potential impacts of climate change elements on the country's power supply chain	0.0	41.1	24.7	65.8	Government. International development partners
Promote the development of energy conservation and efficiency projects; e.g. the use of stabilised bricks and efficient brick kilns in the building sector	0.0	12.2	17.4	29.6	Government.Private Sector. International development partners. NGO
Enforce building codes to reduce energy consumption	43.3	20.2	8.3	71.8	Government
Promote the use of energy-efficient technologies such as compact fluorescent and other high energy lamps	0.0	1.2	0.6	1.8	Government. Private Sector
Promote efficient firewood/charcoal stoves and solar and LPG cookers. and address the high upfront costs of acquiring these technologies through household subsidies or tax waivers	3.5	1.8	0.00	5.3	Government. Private Sector
Total	**207.1**	**166.9**	**83.9**	**457.9**	
Infrastructure					
Building codes enacted and implemented for private sector buildings	33.0	49.5	82.5	165.0	Private Sector and Government
Building codes enacted and implemented for public sector buildings	9.7	14.6	24.3	48.5	Government
Additional costs for climate proofing paved roads & railroads	3.9	19.7	30.5	54.0	Government. International development partners. Private Sector
Integrate climate change into the existing infrastructure risk assessment guidelines and methodology	14.1	0.0	0.0	14.1	Government. International development partners
Promote and encourage water catchment protection in transport infrastructure development and maintenance	35.2	72.4	84.2	191.8	Government. International development partners
Conduct geotechnical site investigations (GSIs) to determine whether areas are appropriate for infrastructural development	14.1	144.8	44.9	203.8	International development partners. government

Sector and Strategic interventions	Amount (US$Mn.)				Source of Funding
	Short	Medium	Long	Total	
Develop and implement a climate change–induced disaster risk management strategy	0.3	0.0	0.0	0.3	Government. International development partners
Create an appropriate legal and regulatory framework for disaster management	0.2	0.0	0.0	0.2	Government. International development partners
Promote vulnerability risk mapping (including the social and economic impacts of climate change) of the whole country and all sectors	0.6	0.0	0.0	0.6	Government. International development partners
Strengthen climate change–induced disaster management institutions at the national and local levels to reduce causality and ensure preparedness	0.0	1.1	2.9	4.0	Government
Encourage the formation of resident associations that can respond to emergencies. and involve them in key decision making to reduce risks.	0.2	0.6	0.0	0.8	Government. NGOs
Strengthen the National Emergency Coordination and Operations Centre and establish a National Contingency Fund	1.7	0.00	1.2	2.9	Government. International development partners
Promote the development of innovative insurance schemes to insure households. institutions and businesses against the destruction caused by extreme weather events and disasters	0.0	2.1	0.4	2.5	Government. Private Sector
Total	**113.0**	**304.7**	**270.9**	**688.7**	
GRAND TOTAL	**405.6**	**644.2**	**596.3**	**1,646.2**	

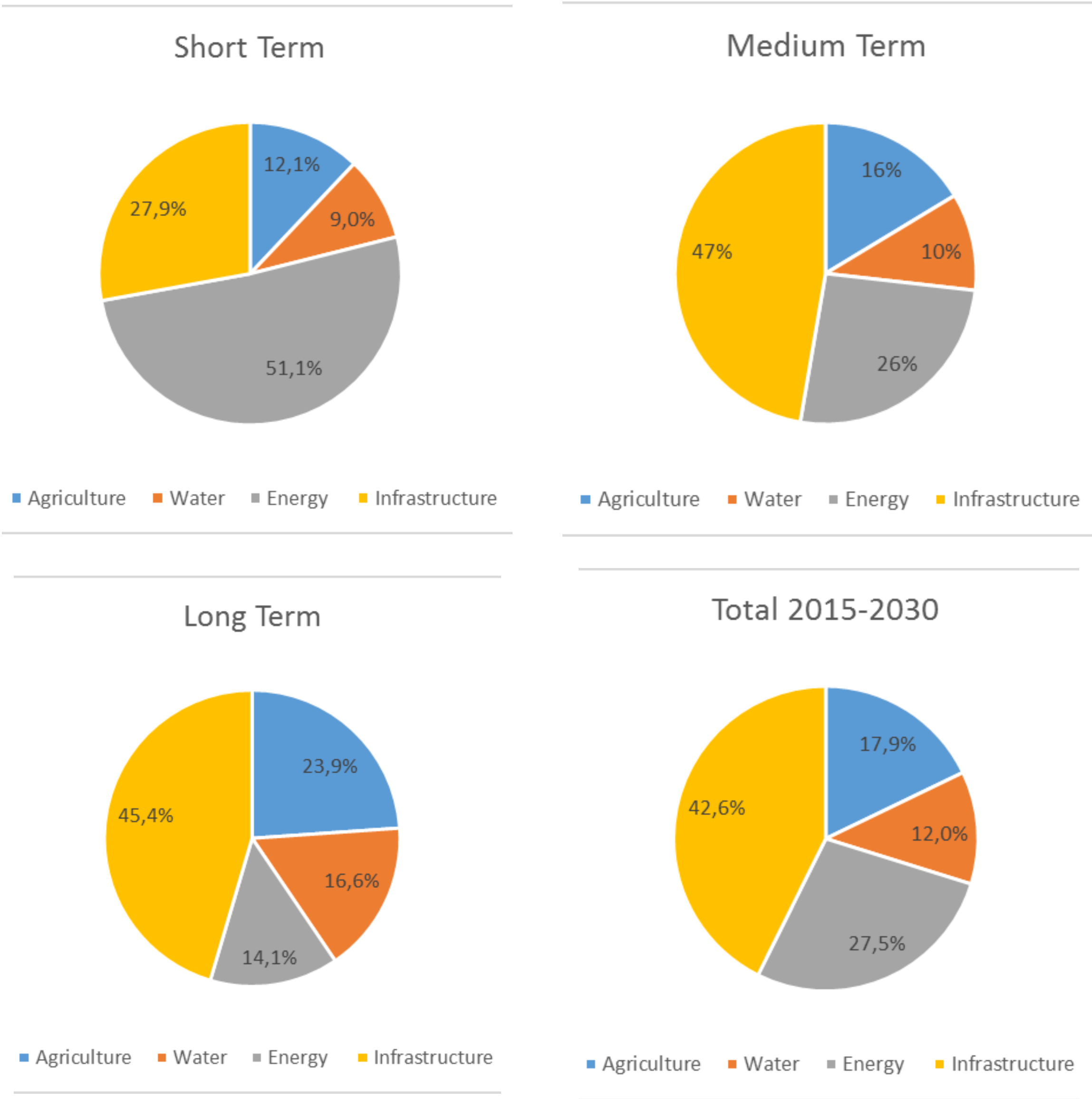
5.2 Complementarity of adaptation investment and policy reforms

The items in the adaptation programme listed in section 4 cover both physical investments as well as policy reforms. Both involve some financial resources and the two are complementary in the sense that without the policy reforms many of the physical investments will not achieve the goals and without the physical investments the policy reforms will not succeed. Cases of investments that need matching policy reforms include, but are not limited to:

- Investment in irrigated agriculture will need reforms in the pricing of water and in rules for the allocation of water.
- Promotion of improved post-harvest handling, storage and value-addition will need reforms in the way such services are provided and charged for and access to credit by farmers.
- Improved schemes to get information to farmers will need reforms in how such information is stored and transmitted.
- Encouragement of water storage and harvesting may require reforms in the access of credit to households for such devices.
- Protection of water catchments may require setting-up of Payment for Environmental Services (PES) schemes.
- Promotion of renewable energy sources will require reforms in the pricing of energy from such sources and in energy policy.
- Promotion of energy efficient appliances will benefit from subsidy programmes to support the purchase or leasing of such equipment as well as the introduction of standards.
- Building codes that incorporate climate resilience requirements will need reforms in the methods for ensuring compliance.
- Effective selection of projects to protect against damage from extreme events will require reforms in the use of benefit cost analysis, to include non-monetary costs.

In the above cases reforms in pricing and access to credit will not be effective unless the resources are there to make the investments. In addition, measures such as innovative insurance schemes will need to be backed up by investment programmes that reduce systemic risk to economic agents, in particular those that cannot be addressed through insurance markets.

Figure 14. Shares of adaptation costs by sector: 2015-2030



6. Policy Recommendations

The Government of Uganda should urgently prioritize action on climate change, building on work that is ongoing. The recommendations below arise from this study.

1) Prioritize the Costed Implementation Strategy as a matter of urgency. The research conducted for this assignment consistently highlighted that the NCCP Costed Implementation Strategy is focused on a strong set of measures appropriate to dealing with anticipated climate changes. Further, many of the activities are anticipated to yield greater benefits than costs, and hence are justified on economic grounds. Mainstreaming of adaptation priorities into district costed implementation strategies will be critical.

2) Mainstream climate change into sector development plans, including translation of key priorities into sector annual plans and budgets. This is a process that is already taking place via the CCD, and should be prioritized to mainstream the findings from the various studies that have been conducted in Uganda into the sector development plans, including annual plans and budgets, under the umbrella of NDPII.

3) Mainstream adaptation priorities into the District Development Plans that will rise out of the National Development Plan II. In addition to mainstreaming climate change into sector policies, it is critical that appropriate adaptation action be taken at the district level. To achieve this, 5-year district development plans will need to mainstream adaptation priorities, and progress should be monitored by the CCD through their annual reports. The Ministry of Local Government (MOLG) will be a key agency to support and audit local governments for budget and planning purposes. The CCD should assist the MOLG to ensure that climate change is mainstreamed into local government policies and plans. Specifically, the MOLG assessment manual is used to identify whether proposed budgets comply with national priorities and standards, and climate change considerations should be mainstreamed into this tool.

4) Ensure that implementation of all action is monitored and enforced. Monitoring is key to ensure that actions are undertaken in a timely manner. Implementation of these plans should be monitored using the planned NCCP Performance Measurement and Reporting process. A clear set of performance targets that are time bound, and assigned to specific agencies, should be developed to facilitate monitoring. Enforcement of existing activities such as protection of watersheds, land use planning, and building codes should be prioritized.

Sector specific recommendations are detailed in the full report. These reinforce and build on the recommended actions already contained in the Costed Implementation Strategy and should continue to be developed and refined for specific sectors and regions.

As highlighted previously, ***the cost of inaction is estimated to be 24-46 times the cost of adaptation and therefore investment in adaptation should be prioritized now.*** This section outlines the policy implications and recommendations for action on adaptation.

6.1. General Policy Recommendations

Numerous consultation meetings were held with government and other relevant stakeholders in Uganda throughout this research, including several consultations specifically around policy implications. Throughout consultation for this assignment, government counterparts have consistently highlighted the following points as important for uptake of findings into policy and planning:

- **It is critical that the findings of this study are integrated into the NDP2 process.** Consultation findings were clear that the NDP2, and the resulting implementation plans to be developed as a result of NDP2, are the key entry point for ensuring uptake of climate change across the different sectors.

Ensuring good dissemination of findings across line ministries and building their capacity to actually use them in NDP2 implementation through targeted support actions could contribute to this process.

- **Mainstreaming should also happen within the specific sector based policies and plans.** However, many of these policies are just finalizing their review process, and hence it was reiterated that the most effective recommendation for climate mainstreaming in the immediate term was through the NDP2 process, especially as the outcomes of this process will then influence all of the sector development plans.
- **Ownership over this process is critical at a local level.** All implementation will happen at the local level – therefore it is critical that districts develop their own costed adaptation strategies based on their local context/climate impacts, but within the broad envelope of resources that the central government has identified. This is a point that is highlighted in related studies; for example the USAID Vulnerability Assessments[24] highlight how generic recommendations at a national level are important, but specific local level costed adaptation strategies are necessary. It was also highlighted that it is very important that the local government counterparts have ownership/leadership over this process, so that they can design strategies that are feasible and context specific.

Within this context, the following recommendations are made:

6.1.1. Prioritize the Costed Implementation Strategy as a matter of urgency

The research conducted for this assignment consistently highlighted that the NCCP Costed Implementation Strategy is focused on a strong set of measures appropriate to dealing with anticipated climate changes. Further, many of the activities are anticipated to yield greater benefits than costs, and hence are justified on economic grounds.

As a minimum, adaptation options that fit with the following criteria are highly likely to be cost efficient and should be implemented as a matter of priority:

- No regrets measures – these are measures that will bring about net benefits regardless of climate change, and therefore should be implemented. Broadly speaking, many of the measures listed in Tables 3-6 can be classified as "no regrets". For example, measures to promote sustainable agriculture, encourage efficient water use, diversification to clean energy sources, and promotion of fuel efficient stoves are all good examples of no regrets adaptation measures. Further work is required to analyse the net benefits of a range of options for specific hotspot sectors/regions.
- Soft measures – adaptation measures are often divided into soft measures (such as capacity building or training) and hard measures (such as infrastructure). Soft adaptation measures are typically lower cost and are often no regrets. However, it should be noted that capacity building needs to be invested in over time, it is not a 'one off' activity, and it needs to be considered 'who' needs to have capacity built, and for what purposes.
- Low carbon development options – these options were frequently raised in consultation as a key priority for government, and can bring benefits both in terms of adaptation as well as mitigating future carbon emissions, at the same time as supporting Uganda's development goals, thus bringing a win-win scenario to the Government of Uganda.

[24] USAID (2013). "Uganda Climate Change Vulnerability Assessment Report".

6.1.2. Mainstream climate change into sector development plans, including translation of key priorities into sector annual plans and budgets

This is a process that is already taking place via the CCD, and should be prioritized. Decades of development spending can be wiped out by climate change; this can be avoided by ensuring that all sector development plans are climate-risk sensitive.

The CCD's mainstreaming guidelines, which outline key evaluation criteria for selecting adaptation options, are summarized in Box 1. Much of this work has been done at a national level – climate change impact assessments, identification of a suite of adaptation measures, and a Costed Implementation Strategy at the national level have all been developed. Further, much of the work contained in this study feeds into these outcomes. The next step is very clearly to mainstream the findings from the various studies that have been conducted in Uganda into the sector development plans, including annual plans and budgets, under the umbrella of NDPII.

Box 1. Mainstreaming Steps (as per the CCD's mainstreaming guidelines)

Step 1: Conduct Climate Change Impact and Vulnerability Assessment
Step 2: Identify and analyze adaptation and mitigation options
Step 3: Identify and cost programmes and actions for Climate Change interventions
Step 4: Design and implement a plan for mainstreaming Climate Change in the different sectors
Step 5: Monitor the CCMA Implementation Process
Step 6: Evaluate performance and review the Adaptation and Mitigation Process

6.1.3. Mainstream adaptation priorities into the District Development Plans that will rise out of the National Development Plan II.

District costed implementation strategies will be critical for ensuring action on the ground that is context specific and has buy-in from local level actors. Therefore mainstreaming of adaptation priorities into district development plans will be critical. In order to achieve this, 5-year district development plans will need to mainstream adaptation priorities, and progress should be monitored by the CCD via their annual reports. This recommendation is very much in line with the existing costed implementation strategy: "It should be noted up front that a significant share of these estimated financial resource needs will be required and channelled at the local level, where a majority of the priority actions under this strategy will materialize, following the adopted policy principle of community-based actions to address climate change and its impacts."

Typically, the first step for doing this is to identify, at a national level, hotspot sectors and regions that will be most affected by climate change. The case studies included in this study are a first step in this regard, alongside the work of FAO, USAID and others. The second step would be to analyse climate change impacts on these sectors/districts, to the greatest extent possible. This information could then be used to convene a series of stakeholder consultations, where participants can help to build a full list of potential adaptation options, and then prioritize these options based on factors such as cost, timeframe, urgency, etc. This information could underpin the development of district-level action plans, containing priority adaptation options.

The CCD's mainstreaming guidelines should underpin the analysis leading to the mainstreaming into the 5 year district development plan for adaptation actions (see Table 9 in Annex 1).

Further, the Ministry of Local Government (MOLG) will be a key agency to support and audit local governments for budget and planning purposes. The CCD should assist the MOLG to ensure that climate change is mainstreamed into local government policies and plans. Specifically the MOLG assessment manual is used to identify whether proposed budgets comply with national priorities and standards, and climate change considerations should be mainstreamed into this tool.

6.1.4. Ensure that implementation of all action is monitored and enforced

Monitoring is key to ensure that actions are undertaken in a timely manner. Implementation of these plans should be monitored using the planned NCCP Performance Measurement and Reporting process. A clear set of performance targets that are time bound, and assigned to specific agencies, should be developed to facilitate monitoring. Capacity building at both the central and district levels will greatly help government agencies to undertake and monitor implementation effectively.

Furthermore, enforcement of these actions will be critical. Specific examples were raised throughout the study where enforcement is very much needed and could be a no regrets measure to enforce activities that are already enshrined in regulation. Examples include:

- Enforce existing laws on protection of watersheds
- Enforce existing laws on land use planning
- Implement and enforce measures for water resource regulation and water catchment protection.
- Strengthen and enforce building codes, to reduce energy consumption, to ensure climate smart building and transport infrastructure,

6.2. Sector and Case Study Policy Recommendations

Specific recommendations for each sector and case study were developed, and discussed with national and local stakeholders at a final policy workshop in Kampala (May, 2015; see Annex 4). The long list of recommendations is presented in Table 8. These are not exhaustive, and many require further assessment. It is important to note that all of these recommendations must sit within the context of the overarching recommendation to use the available evidence to mainstream adaptation action into the 5-year district plans, annual plans, and budgets. This is critical because there is no one-size-fits-all approach to adaptation for Uganda and each of these recommendations needs to be reviewed within the local context. They should also be considered in the context of the study limitations outlined in section [1.4].

In many cases, the analysis on the impacts of climate change justifies and reinforces the need for urgent action on many of the measures, some of them being already contained in the Costed Implementation Strategy as well as those that have been added as a part of this study.

Table 8. Sector and Case Study Policy Recommendations

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
Agriculture	Support community-based adaptation strategies through expanded extension services and improved systems for conveying timely climate information to rural populations for enhanced climate resilience of agricultural systems Promote agricultural diversification, improved post-harvest handling, storage and value addition in order to mitigate rising climate related losses and improve food security and household incomes. Develop innovative insurance schemes (low-premium micro-insurance policies) and low-interest credit facilities to insure farmers against crop failure and livestock loss due to droughts, pests, floods and other weather-related events Promote and encourage climate smart agriculture (CSA) and ecologically compatible cropping systems to increase resilience to the impacts of climate change. Promote sustainable management of rangelands and pastures through integrated rangeland management. Improve water availability in drought prone areas through water storage at the household or village levels.	1. **Implement measures to address losses from droughts and floods in the immediate term.** MWE should lead on improvements in water availability in drought prone areas, and water storage and watershed management in flood prone areas. 2. **Design measures to be fit for purpose.** This is particularly relevant for the insurance and irrigation sectors. While most of the agricultural measures in the costed implementation strategy typically yield benefits higher than costs, irrigation and insurance are both often highlighted in the literature as being very dependent on good design that is fit-for-purpose to deliver benefits. Therefore further feasibility and design studies should be done as part of the district adaptation strategies. Although action on insurance is scheduled for the medium term it would be desirable to initiate discussions with insurance providers now, so that the relevant data can be collected. 3. **Liaise with the financial sector on provision of micro-credit** to support diversification and improvements in post-harvest handling, storage and value addition as well as for the adoption of CSA. 4. **Implement adaptation measures for the coffee sector.** See recommendations listed below from the Mount Elgon case study. 5. **Start an evaluation for CSA for other export crops** with a view to initiating the programmes by the medium term at the latest. 6. **Initiate additional research**. This research could involve agricultural research centres such as IFPRI and IITA working closely with local research facilities on crops and livestock. Research needs include: • More precise estimates of impacts of climate change on yields of export crops by region. • Impacts of climate change on livestock and on which breeds are most adaptive to these changes. • Better estimates of likely changes in yields by crop and region.
Water	Strengthen water resource monitoring networks and flood warning systems Promote and encourage water harvesting and efficient water utilization among individuals, households, institutions.	1. **Reduce water deficits by basin in the most effective way possible.** This will require coordination between the Ministry of Agriculture as well as energy and the municipalities responsible for water supply to households and industry. 2. **Prioritize the following actions in the immediate term.** These activities make up 92% of the Costed Implementation Strategy for water, and are demonstrated to be far more cost effective than inaction:

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
	Ensure availability of water for production in water dependent sectors in order to increase their resilience to climate change impacts Promote Integrated Water Resources Management (including underground water resources), including contingency planning for extreme events such as floods and drought. Ensure that guidelines for infrastructure/ hydraulic works (i.e., water for production, piped water supply schemes and conditional grants guidelines for support to point sources protection) include climate change effects Improve and strengthen trans-boundary cooperation regarding water resources management Support institutional and human capacity building in water resource use, development and management	• Improvements in water use efficiency ; • Activities that address water supply issues for agriculture and industry; and • Establishment of an Integrated Water Resources Management system that would help reduce losses from droughts and floods. 3. **The CCD should liaise with financial institutions** to support the programme for encouraging water harvesting and efficient water utilisation among households and farmers; 4. **Design and implement contingency plans to deal with floods and droughts** in coordination with local governments and Ministry of Works. 5. **Undertake further work to cost the following components of the Costed Implementation Strategy, namely Component 3: "Promote and strengthen the conservation and protection against degradation of watersheds, water catchment areas, river banks and water bodies" and Component 6: "Improve and strengthen trans-boundary cooperation regarding water resources management".** 6. **Other activities that should be given high priority include the following:** climate change mainstreaming guidelines for infrastructure / hydraulic works; support to institutional and human capacity building in water resource use, development and management; and strengthening water resource monitoring networks and flood warning systems. For example, guidelines for integrating climate change effects to infrastructure/hydraulic works and establishing a monitoring scheme to ensure they are implemented should be coordinated with the Ministry of Works. 7. **Initiate additional research**: • Estimates of the exact impact of climate change on water resources are somewhat scarce. We have used the best available from Water2Invest and the National Water Resources but these can be improved. This will require more refined hydrological modelling than has been carried out so far, with specialised research institutes working in this area. The work conducted by BRLi/Expertise France in the Mpanga river catchment is an excellent example of this kind of study. The University of Wageningen in the Netherlands has capacity for such modelling as have some other centres. • Quantitative estimates of reductions in water use through various efficiency measures. Local research centres may be best suited to carry out such work.

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
		• Quantitative estimates of the benefits of conservation and protection of watersheds, water catchment areas, river banks and water bodies.
Energy	Promote and participate in water resource regulation so as to ensure the availability of water for hydropower production Diversify energy sources by promoting the use of alternative renewable energy sources (such as solar, biomass, mini-hydro, geothermal and wind) that are less sensitive to climate change Promote energy-efficient firewood cook stoves, solar and liquefied petroleum gas (LPG) cookers Promote the development of energy conservation and efficiency projects in all sectors; for example, to promote the use of stabilised bricks and efficient brick kilns in the building sector Promote efficient firewood/charcoal stoves and solar and LPG cookers, and address the high upfront costs of acquiring these technologies through household subsidies or tax waivers Conduct research to determine the potential impacts of climate change elements on the country's power supply chain Enforce building codes to reduce energy consumption Promote the use of energy-efficient technologies such as compact fluorescent and other high energy lamps	1. **Implement measures to reduce biomass demand and manage biomass supply effectively and urgently** (including items 4, 6 and 9 in the costed implementation strategy). Review alternative sources of energy to make up for the deficit in biomass that is predicted. Draw up a plan for distribution of such energy and mobilise resources to implement the most cost effective option. 2. **Conduct a feasibility study for alternative fuel options, costs and benefits.** 3. **Expand the government's energy programme to increase electricity connections and to extend the supply network for some alternative fuel to biomass.** 4. **Ensure design of such programmes provides support to the poorest to access alternative fuels.** This is reflected in item 9 of the costed implementation strategy but may need increased resources. 5. **Implement energy efficiency measures as a matter of priority.** The components of the costed implementation strategy that deal with energy efficiency (items 4,6,7,8,9) are likely to be cost effective, no regrets measures that also help to build low carbon development. 6. Integrate climate proofing measures/standards into building codes to reduce energy consumption and set up a monitoring scheme to ensure they are implemented. 7. **Improve biomass productivity** – there are a number of no regrets actions that can help to address the biomass deficit. These will need to be evaluated within the local context, but could be usefully added into any local/regional adaptation plans, and could include measures such as forestry practices, afforestation/reforestation, utilize waste material and maximize efficiency of the land. 8. **Implement measures for water resource regulation and water catchment protection urgently.** Items 1 and 2 in the costed implementation strategy address these problems and need to be initiated now, with a long term view to protecting hydropower potential. These are no regrets measures. 9. CCD to liaise with MWE on plans to use water for energy under reduced flow regimes both when drought conditions prevail now and in the future when flow rates may decline. 10. **Initiate additional research**:

<table>
<tr><th>Sector</th><th>Key Actions from the Costed Implementation Strategy</th><th>Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research</th></tr>
<tr><td></td><td>Explore alternative sources of energy to domestic biomass</td><td>• Conduct research to determine more accurately the impact of climate change on hydro power. This is covered by Item 5 in the costed implementation strategy, and needs to be implemented urgently as the impacts of climate change on hydro are uncertain and could be critical for Uganda's energy supply.
• More sophisticated modelling of water flows in river systems under climate change is needed. Specialised centres can provide such services.

11. In addition the scope for substituting other fuels for domestic biomass will require detailed investigation on the costs and scope for distribution within the country and local consultancy services should be able to provide that.</td></tr>
<tr><td>Infrastructure</td><td>Building codes need to be amended now and enacted over the next 15 years to implement climate-proofing measures

Government regulations to be amended now and enacted over next 15 years with respect to design of public buildings and roads

Integrate climate change into the existing infrastructure risk assessment guidelines and methodology

Establish and enforce climate change–resilient standards for transport and infrastructure planning and development through monitoring and reporting systems

Promote and encourage water catchment protection in transport infrastructure development and maintenance

Climate-proof existing and future infrastructure by conducting geotechnical site investigations (GSIs) to determine whether areas are appropriate or inappropriate for infrastructural development</td><td>1. The following high priority actions for adaptation in infrastructure must precede any new investment, and will require that the Ministry of Works liaise with MWE, Ministry of Lands, Housing and Urban Development and Ministry of Transport to set up the codes for making buildings and transport systems resilient to climate change.
• Develop appropriate land use plans;
• Climate proof public buildings;
• Develop standards for private buildings;
• Develop standards for transport and infrastructure planning; and
• Integrate climate change-resilient standards into existing infrastructure construction codes and risk assessment guidelines.

2. Prioritize measures to reduce the risk of extreme events to infrastructure, including:
• improved early-warning systems and preparedness systems;
• development and implementation of a climate change–induced disaster risk management strategy; and
• strengthening of the National Emergency Coordination and Operations Centre and establishment of a national contingency fund.

3. Develop a priority ranking for actions to improve drainage in urban areas and across the road network to prevent flooding.

4. Initiate additional research:</td></tr>
</table>

<table>
<tr><th>Sector</th><th>Key Actions from the Costed Implementation Strategy</th><th>Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research</th></tr>
<tr><td></td><td></td><td>Better data on assets at risk from extreme events is required and could be collected by local research centres and consultancy firms.</td></tr>
<tr><td>Kampala</td><td>KDPD 2012; Kampala's Low Carbon Development and Climate Resilient (LCDCR) Strategy</td><td>1. Policies, plans and regulations must be designed to mainstream climate change adaptation and cautiously consider the results of this study. Specifically:
Plans developed under the KPDP (2012) must be revised in 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 are of particular priority.
It is urgent that building codes are revised vis-à-vis climate projections, promoting bio-climatic designs and the use of appropriate materials.
2. Mainstream adaptation into Kampala's Low Carbon Development and Climate Resilient (LCDCR) Strategy. 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. The LCDCR strategy should also guide public investment and incentivize significant and appropriate private investment towards adaptation.

3. Strengthen the application and enforcement of tools, such as Environmental Impact Assessments, especially regarding the protection of wetlands.

4. Political incentives must be revised, to prioritize public interests over private gains.

5. Kampala should urgently 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.

6. 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</td></tr>
</table>

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
		increasing their participation and leverage in citywide processes of urban planning, management and investment". 7. **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. • Conduct further research on the impacts of climate change on health, water supply or ecosystems degradation • Shortlist other adaptation options related to the improvement of physical infrastructure and conduct a CBA, including different areas of the city and more geographical detail. • Evaluate the costs and benefits of socio-institutional and ecosystem-based adaptation options. 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. 8. **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. 9. **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.

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
Malaria in Tororo and Kabale		1. **There is need for cross-collaboration bringing together different ministries** to ensure the health co-benefits of actions to adapt to climate change are maximized and maladaptation is avoided. For example, appropriate drainage systems need to be included in new road construction schemes to reduce the potential breeding grounds for mosquitos 2. **Conducting more research on the linkage between climate-change and malaria**. Better weather data, alongside malaria surveillance data, may enable a clear understanding of the climate related risks for malaria and potentially lead to improved early warning for malaria risk. 3. **Implementing education and awareness campaigns** to strengthen dissemination of information about malaria risk and the appropriate use of bednets, particularly in areas where malaria may newly appear or is expected to significantly increase in prevalence. In areas where malaria is prevalent, prioritize urgently the dissemination of LLINs, IRS, clearing of breeding sites, and proper treatment. 4. **Identifying appropriate contexts for longer term measures**, which may include mainstreaming of health co-benefits of adaptation into infrastructure development and wider development policies, including: • Revise planning regimes to ensure proper drainage, control construction and prevent encroachment on wetlands in particular. • Implement measures to ensure that farming practices take account of malaria risk, e.g. planting crops away from houses.
Coffee in Mount Elgon		**1. Conduct further research and analysis** in order to identify: (i) The impact of climate variability on coffee yields in the Mt Elgon region, and other coffee growing regions in Uganda. (ii) The cost and benefits of different approaches to CSA in the coffee sector, in particular to identify 'low regret' options and options where there are co-benefits. (iii) The economic viability of coffee growing under BAU and CSA in different regions in Uganda, in order to focus investment on regions where there is a stronger economic case for coffee cultivation in the long term.

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
		(iv) Barriers and enablers that effect the adoption of CSA practices by farmers, in order to identify what wrap-around support might be needed, and subsequent to this an analysis of how support may be best delivered. (v) The costs and benefits of alternative livelihoods in Bududa, including cultivation of other crops and non-farming activities, versus coffee cultivation. **2.** Use the evidence from the above to inform the design of a **CSA programme for coffee, including practical measures as well as institutional support, and help to identify what additional complementary strategies might be needed.** Critically, the development of such a programme should also involve the private sector, and an analysis of the market and value chain for coffee, to enable improved commercialisation. **3.** Given the high level of investment that is potentially required, it is recommended that **any CSA programme is first piloted** in order to establish whether expectations around costs, benefits, and yields, etc, are borne out in reality in Uganda.
Karamoja Agriculture		**High priority activities include:** 1. Capacity building for livelihoods programming and agriculture. 2. Crop diversification is considered a very high priority and likely to achieve a positive return. 3. Improvement of water availability 4. Pasture for animals **Medium term activities include:** 5. Household income diversification 6. Rehabilitating degraded land **Activities that require further investigation, but which were listed by stakeholders as important include:** 7. Improvement of crop storage; resettlement planning; flood control and improvement of transportation.

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
Water and hydropower in Mpanga		1. **Policies that could help better balance demands should be implemented as a matter of priority,** including better catchment management and interaction of stakeholders in decision making processes. This relates to the NCCP Costed Implementation Strategy adaptation option: "**Promote and participate in water resource regulation between users so as to ensure the availability of** water for hydropower production". **There is clear need for integrated river basin management in the catchment**. An assessment of existing policies suggests that even if only changes to the average level of water available for energy is considered the policies would only have to marginally reduce the lost load for the benefits to exceed the costs. Other unquantified near term benefits may include improved ecosystem services from the river. This could be done through the promotion of water catchment protection as part of hydroelectric power infrastructure development, through soil conservation practices such as agroforestry for example, as suggested in the NCCP Costed Implementation Strategy. 2. **Opportunities should be identified for cross-sectoral adaptation measures**. Actions to reduce biomass demand, for instance, will improve the quality of water in the river and measures to reduce energy consumption would reduce the losses due to climate change in the energy sector in the Mpanga River Basin. Hence the recommendation to diversify energy sources by promoting the use of alternative renewable energy sources (such as solar, geothermal and wind) that are less sensitive to climate change. Such cross-sectoral impacts may lead to the need for more complex analysis of strategies – simple sectoral analysis may miss key impacts on other sectors and opportunities for win-win solutions. 3. **Sufficient funding should be allocated for employing Community Development Officers to enforce existing laws.** 4. **Further research is required for:** a. **Improved data availability on river flows to facilitate better policy making** b. **Improved forecasting on weather and water supply shortages.** This will require significant investment in data collection and in analysis, and also education about weather forecasts for communities. Forecasts for water supply shortage are in their relative infancy internationally – and the background data would need to be significantly improved in Uganda before this could be realised.

Sector	Key Actions from the Costed Implementation Strategy	Specific Recommendations Arising from the Economic Assessment of the Impacts of Climate Change Research
		c. **Determine the potential impacts of climate change elements on the country's power supply chain and act on findings**

REFERENCES

Ansuategi. A. Greño. P. Houlden. V. Markandya. A. Onofri. L. Tsarouchi G. and Walmsley. N. (2015). Impact of climate change on the achievement of the post-2015 development goals. CDKN Report.

Garcia, J. and Markandya, A. (2014): *The economic assessment of the impacts of climate change. A review of methodologies.* Baastel, Metroeconomica, December 2014.

Haggar,J. & Schepp, K (2012) *Coffee and Climate Change: Impacts and options for adaption in Brazil, Guatemala, Tanzania and Vietnam,* NRI Working Paper Series: Climate Change, Agriculture and Natural Resources, No. 4, February 2012

Hsiang SM and Jina AS (2014). The Causal Effect of Environmental Catastrophe on Long-Run Economic Growth: Evidence from 6.700 Cyclones NBER Working Paper No. 20352

MWE (2013) National Water Resources Assessment 2013. Directorate of Water Resources Management, Ministry of Water and Environment

NCE (2014). Global Commission on the Economy and Climate. The New Climate Economy Report: Better Growth. Better Climate.

NEMA (2008) *Uganda National Environment Report of 2008*, National Environment Management Authority

O'Neill *et al*., (2012). Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research. National Center for Atmospheric Research (NCAR), Boulder, CO November 2-4, 2011. Meeting Report Final Version, March 12, 2012.

Rautenbach. H. (2014) *Regional-scale Climate Change Projections of Annual. Seasonal and Monthly Near-Surface Temperatures and Rainfall in Uganda*. Report for Climate Change Unit. Ministry of Water and Environment. Uganda Climate & Development Knowledge Network (CDKN).

Uganda Vision2040. (Undated). National Planning Authority. Government of Uganda.

Reference to previous reports from the study include:

- The Economic Assessment of the impacts of climate change in the agriculture, energy, infrastructure and water sectors (4 sector reports)
- The five case-study reports

All the reports are available on CCD and CDKN websites: www.cdkn.org and http://ccd.go.ug/index.php/projects/cdkn

ANNEX 1: EXISTING POLICY CONTEXT ON CLIMATE CHANGE

National Policy on Climate Change

The national policy and regulatory framework on climate change is premised on the Uganda Constitution of 1995 as amended in 2005, which states that, "Every Ugandan has a right to a clean and healthy environment."[25] Objective X111 of the constitution of Uganda advocates for the management of the environment for sustainable development. It provides that every citizen is expected to protect the environment, natural resources including land, water, wetlands and fauna and flora and prevent damage of natural resources from pollution and other causes.

Uganda's 2010–2015 five-year **National Development Plan (NDP)** already recognises that addressing the challenges of climate change is crucial to enhancing sustainable economic and social development. Most of the key economic sectors—such as forestry, energy and agriculture—will be affected by climate change and the importance of climate change and its effect on the national economy has been recognized.

"The Uganda National Development Plan (NDP) 2010/11–2014/15 serves as the single most powerful guide for investment planning, budget allocation and social interventions in the country. All government programmes are linked to the NDP within the existing policy, legal, planning, monitoring and reporting systems. The NDP mainstreams climate change into the development plans, policies and budgets of all sectors." (Government of Uganda climate change strategy). The 2nd National Development Plan is in the process of being finalized by the Government, and will be the key overarching document for mainstreaming climate change policy.

Uganda has made significant progress toward mainstreaming climate change into national development planning, in particular with the formulation of its **National Climate Change Policy** (NCCP). This Policy aims at guiding all climate change activities and interventions in the country. It provides direction for the key sectors that will be affected by the impacts of climate change, to facilitate adaptation and strengthen coordinated efforts amongst sectors towards building an overarching national development process that is more resilient. Table 10 sets out the adaptation priorities identified in NCCP.

An institutional framework has been established, with the creation of the **Climate Change Department (CCD)** under the Ministry of Water and Environment (MWE), which will be in charge of the overall implementation of the Policy. The policy is also meant to provide a framework for ensuring coordinated action, with adequate attention paid to capacity requirements and the development of the financial mechanisms and tools required to respond to the climate change challenge along these policy directions at the national level.

Table 9. Adaptation policy priorities identified in the NCCP for key sectors

Key sector	Policy priorities identified
Agriculture and Livestock	To promote climate change adaptation strategies that enhance resilient, productive and sustainable agricultural systems To promote value addition and improve food storage and management systems in order to ensure food security at all times, as a factor of resilience
Water	To support on-going efforts to ensure that climate change concerns are integrated into national efforts for sustainable and long-term conservation, access and effective utilisation and management of water resources
Fisheries and Aquaculture	To strengthen efforts to promote integrated fisheries resource management and improve aquaculture in order to ensure sustainable fisheries production
Transport and Works	To develop and ensure integrated planning and management of transport and other physical infrastructure that build on insights from climate predictions

[25] . The Constitution of the Republic of Uganda

Forestry	To ensure the sustainable management of forestry resources so that they can continue to provide global services, including mitigating climate change, while supporting the sustainable development needs of communities and the country
Wetlands	To promote long-term wetland conservation and restoration of degraded wetlands so that they can continue to provide global services, including mitigating climate change, while supporting the sustainable development needs of communities and the country
Biodiversity and Ecosystem Services	To effectively address the challenges posed by climate change impacts on biodiversity and ecosystems, so as to ensure ecosystem health and provision of ecosystem services that are crucial to sustainable and resilient development
Health	To strengthen adaptive mechanisms and enhance early-warning systems and adequate preparedness for climate change–related diseases
Energy	To promote sustainable energy access and utilisation as a means of sustainable development in the face of uncertainties related to climate change
Wildlife and Tourism	To ensure the conservation of wildlife resources and plan for improved resilience of tourism resources and infrastructure to climate change
Human Settlements and Social Infrastructure	To promote the urban planning and development of human settlements that are resilient and robust enough to withstand climate change–related risks and hazards
Disaster Risk Management	To ensure disaster mitigation and adequate preparedness for climate change–induced risks, hazards and disasters

The NCCP is complemented by the **Uganda National Climate Change Draft Costed Implementation Strategy.** The Costed Implementation Strategy is built on the results of extensive consultations held with key sector ministries and stakeholders that will be involved in its implementation. The strategy offers a way towards operationalising the NCCP. It is essentially aimed at the following inter-related objectives, as outlined in the policy:

- To provide for a more detailed action plan/road map for the implementation of the National Climate Change Policy
- To provide phased indicative climate change programmes for the priority areas under the policy
- To highlight the roles and responsibilities of the various stakeholders in the implementation of these programming priorities
- To provide indicative costing for these programmes
- To indicate in a more detailed manner potential sources of funding and financial tools to be tapped for the implementation of the policy, and to act as a tool to leverage such funding
- To provide a solid basis for the monitoring and evaluation of the policy implementation process
- To provide examples of prototype infrastructure designs for key sectors to be impacted by climate change, such as transport and works

Nationally, there are two strategic processes that are ongoing – the National Adaptation Plan Road Map that was submitted to the UNFCCC in May 2015, and Uganda's Intended Nationally Determined Contribution (INDC) to the UNFCCC that was submitted in October 2015. This report, and the recommendations contained herein, will need to be a part of these processes.

The **National Adaptation Plan Road Map** sets out key steps that need to be taken, indicative activities, lead institutions, as well as a timeframe. Key steps include:

- Lay the groundwork and address gaps – including stocktaking, addressing capacity gaps, and assessing climate needs and vulnerabilities.
- Preparatory elements – analysing climate change scenarios, assessing vulnerabilities and identifying adaptation options, reviewing and appraising adaptation options, compiling national adaptation plans, and integrating adaptation into national and subnational development, and sectoral planning.
- Implementation strategies- prioritizing climate adaptation in national planning, developing a long term national adaptation implementation strategy, enhancing capacity, and prioritizing coordination.

- Reporting, monitoring and review – monitoring and reviewing the NAP process, iteratively updating national adaptation plans, outreach on the NAP process.

Uganda's **Intended Nationally Determined Contribution (INDC)** was submitted to the UNFCCC in preparation for COP 21 in Paris (Dec 2015). The INDC gives priority to reducing vulnerability and addressing the adaptation needs of the country, while at the same time fulfilling the country's obligations to contribute to global emission reductions. The outcomes of Paris will be significant for how Uganda moves forward on climate change adaptation and mitigation, and how actions will be financed.

Ongoing Actions Relating to Climate Change Adaptation

Further to this, there are several ongoing initiatives to mainstream climate change and create district level plans:

- The Climate Change Department is currently working with each ministry to mainstream climate change into sector policies and plans. Guidelines have been created to facilitate this process ("Guidelines for the Integration of Climate Change in Sector Plans and Budgets", June 2014). The CCD has drafted a Performance Measurement Framework that was presented at a national workshop in early 2015 and will be finalized in the next few months.

- The United Nations (UN) Food and Agriculture Organization (FAO) has been developing country specific guidance, intentions and commitments on addressing the issues of climate change within its mandate, specifically as it pertains to agriculture, fisheries and forestry. FAO is also working at the district level to develop priority adaptation actions for agriculture.

- The Government has developed a Climate Change Action Plan for the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), which is in a draft form and is still in the process of approval. A climate change task force has been operationalized, is now constituted and performing its core functions. At the local government level, 19 districts have been working on institutional strengthening in budgeting and planning for climate change adaptation (CCA). Tools developed include:
    - Screening checklist to measure level of integration in the District Development Plans (DDPs)
    - Capacity Assessment tool to measure institutional capacity to implement CCA in the district technical planning committee
    - Training carried out at Local government
    - Using the Ministry of Finance, Planning and Economic Development (MoFPED) Out-put Budgeting Tool to allocate resources for CCA and Local Governments (LGs)
    - Action planning for CCA
    - Developing indicators to track and monitor CCA in DDPs
    - Awareness of the USAID Vulnerability assessment of the agriculture crop sector

- The Directorate of Water Resources Management is working in the four water management zones of Uganda, and has conducted a hydrological study for the Mpanga river catchment to help implement an integrated water management plan. They plan to extend this to other catchments in the country. Some work has also been conducted on irrigation in the country (MWE/Directorate of Water Development), with a number of potential areas for irrigation schemes identified.

ANNEX 2: INFORMATION NEEDS FOR EFFECTIVE ADAPTATION PLANNING

Table 10. Areas where more information is required to implement an effective adaptation roadmap for climate change

Sector	Information Needed	Reason for Importance
Several	Changes in the frequency and intensity of extreme events as a result of climate change. We have assumed either no change or an ad hoc change based on the last few years but better estimates are needed.	They are critical to the evaluation of defense measures.
Agriculture	More precise estimates of impacts of climate change on yields of crops by region.	This will determine where and to what extent policies such as CSA can be effective. The Mt. Elgon case study demonstrated the need for further information to evaluate CSA programmes in the region.
	Impacts of climate change on livestock and on which breeds are most adaptive to these changes.	Design of livestock adaptation programme. This came up clearly in the Karamoja case study
	Better estimates of likely changes in yields by crop and region.	Although many studies have been conducted, their results are not consistent.
Water	Estimates of the exact impact of climate change on water resources are somewhat scarce. We have used the best available from Water2Invest (http://www.futurewater.nl/uk/projects/climate-kic-innovation-project/) and the National Water Resources (MWE, 2013) but these can be improved.	Better estimates of where deficits are likely to be greatest and where actions will be a priority.
	Quantitative estimates of reductions in water use through various efficiency measures (see Table 3).	We have estimated what levels of reduction are needed to achieve a given rate of return and they seem plausible but clearly the case will be stronger with actual estimates. The Mpanga case study was a case in point where we could only estimates breakeven levels of reduction of losses from actions.
	Quantitative estimates of the benefits of conservation and protection of watersheds, water catchment areas, river banks and water bodies.	This is a critical component of the adaptation programme but very little data are available on the impacts.
Energy	Estimates of loss of hydropower capacity over the period 2020-2050.	The literature provides conflicting data, some showing an increase in flow rates and another a decrease. Data by basin on a more accurate basis is required. This is why the findings of the Mpanga case-study are subject to uncertainty both related to the values of water and energy losses, and the cost of adaptation options

	Potential for substituting domestic biomass deficits by other sources, including imported biomass, LPG, kerosene. Costs and prices	6.2.1.1. This is critical for the design of the energy strategy in response to increase demand and falling supply for domestic biomass. 6.2.1.2.
Infrastructure	Better data on assets at risk from extreme events and their value	Data are limited and we had to make many assumptions to evaluate the benefits relative to the costs. These need to be verified. In the Kampala case-study the lack of crucial data on the economic costs of the current and likely future impacts of climate change has however reduced the scope of the economic analysis.
Health	Better evidence on how climate factors impact health	In the Mpanga case-study, the knowledge base is not well developed as to the precise linkage between climate and malaria and the evidence on the valuation of health outcomes in Uganda is still weak.

Annex 3: Climate Change Scenarios

- o *National level*

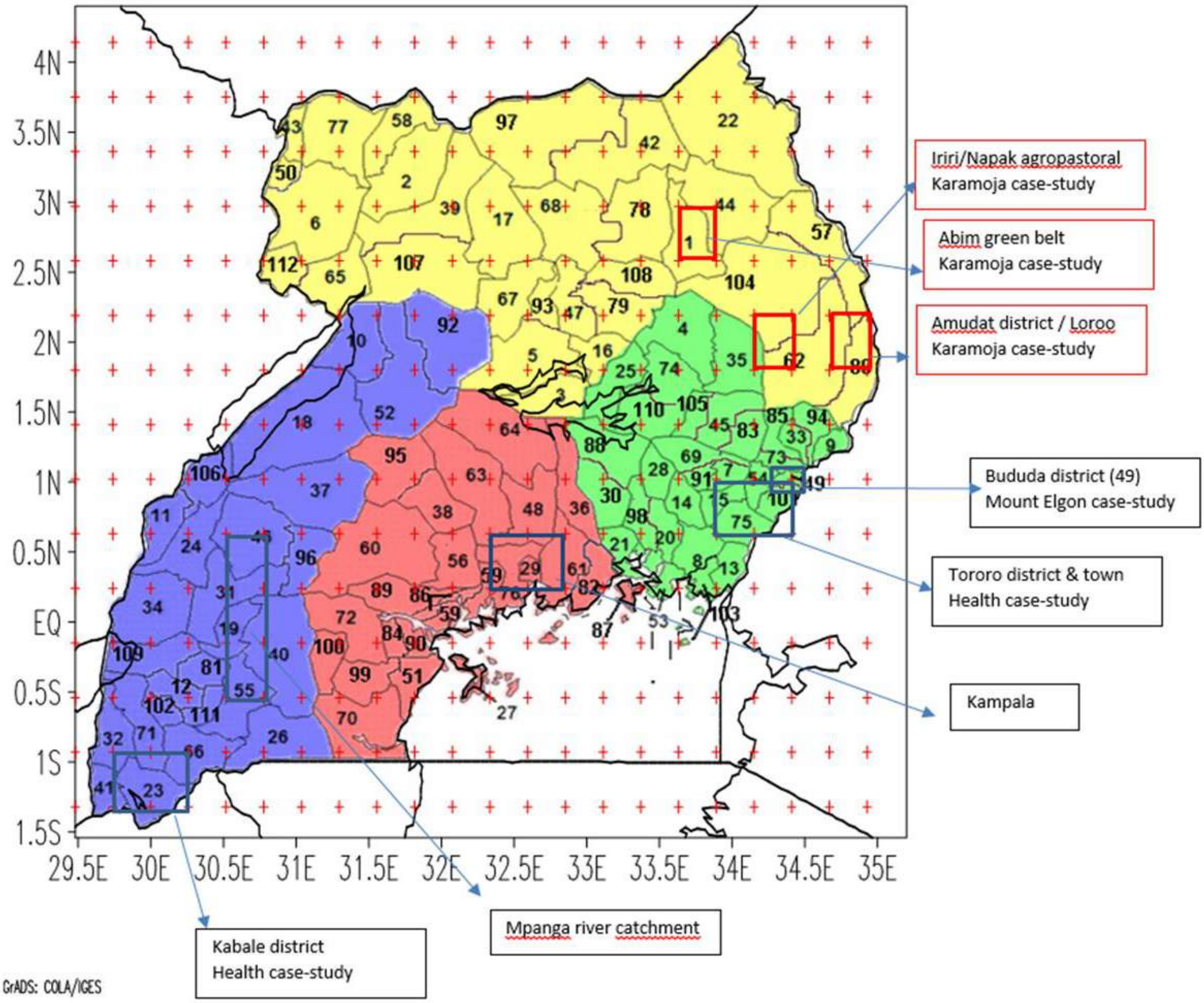
Table 11: Comparison of the results obtained under both the RCP 4.5 and RCP 8.5 concentration pathways

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.
Percentage changes in annual rainfall from the mean	In +50 years from present: not greater than -10% from present and less than +5% from present over the north-west. In + 80 years from present: greater area of positive changes. over the west and north-west; from -5% over the central eastern parts to -20% over the far east. Changes in Lake Victoria and the adjacent land areas are in the order of -20% from present for both +50 and +80 years from present.	In +50 years from present: + 5% from present over the central and western parts of Uganda. In + 80 years from present: up to +20% over the same areas. In both epochs. up to -20% might occur in the east and in the vicinity of Lake Victoria.
Seasonal temperature changes from the median	In +50 years from present: +2.5ºC during the MAM and JJA seasons; +2ºC during DJF and SON. In +80 years from present: +3ºC for MAM and JJA; +2.5ºC in DJF and SON. Victoria Lake temperature increases are in the order of +1ºC for both future time epochs.	In +50 years from present: +2ºC to +3ºC in DJF. MAM and JJA; +2ºC and +2.5ºC SON. In +80 years from present: +4 ºC to 5 ºC in DJF. MAM and SON; as high as +5.5 ºC in JJA. Lake Victoria. again. might experience some smaller changes for both future time epochs.
Seasonal rainfall changes from the median	In +50 years from present: -10mm per month in the north to -20mm per month in the south in MAM; -20mm per month in the central to eastern parts and -5mm per month in the south-west. In DJF. +5mm per month from the central to northern parts; drier in the south (similar to MAM). Noticeable wetter conditions are expected along the eastern. northern and western borders and the adjacent interior (up to +20mm per month). while the south is expected to remain dry. In +80 years from present. very similar changes are projected. although SON might become wetter over most of Uganda (up to +20mm per month).	In +50 years from present: -20mm per month in the north to -50mm per month in the south in MAM. +5mm to +10mm across most of Uganda in DJF. JJA and SON: up to -20mm per month in the centre and north; +30mm per month over Lake Victoria. The opposite is possible for SON (e.g. wetter conditions in the centre and drier in the south) Very similar changes are projected for +80 years from present (Fig. 13). although slightly larger in some areas.
Percentage changes in seasonal rainfall	In +50 years from present: MAM and JJA seasons might be the driest. but with relative small negative percentage changes over most of Uganda (mostly not greater than -20% from present). MAM seems to expect wetter conditions in the west (up to +20% from present)	In +50 years from present: Less than -20% from present in MAM and JJA Rainfall appears to increase significantly during DJF in most parts of Uganda. as also found in the RCP4.5 simulations.

	Significant increase during DJF. especially in the central and northern parts where up to +50% increases were simulated. In +80 years from present. similar percentage changes in seasonal rainfall patterns are projected. However. percentage increases during DJF are greater (even up to +100% from present) with also greater percentages (up to +20% from present) for SON and smaller percentages (down to -30% from present) for JJA. MAM is projected to become slightly drier than in the +50 years from present projection.	In +80 years from present. similar percentage changes in seasonal rainfall patterns are projected: significant percentage increase in DJF (currently a dry season). and drying in JJA (also a dry season

o *Case-study regions*

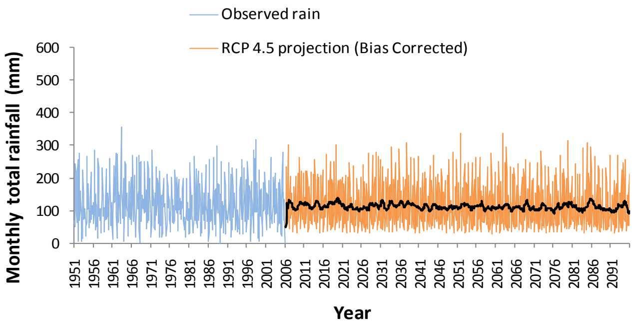
Figure 15: Grid map of climate change downscaled data for Uganda

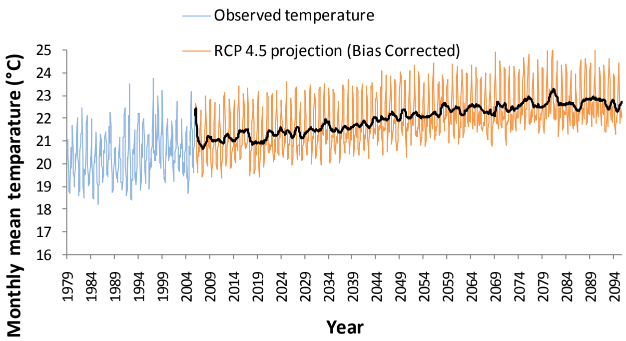


Note: The map shows the case-study districts domains according to CCLM 4.8 RCM grid points across Uganda (red crosses). Spatial averaged values of rainfall and near-surface temperatures calculated across the four grid points on the corners of each domain were regarded as the *dynamical downscaled* climate for the domain.

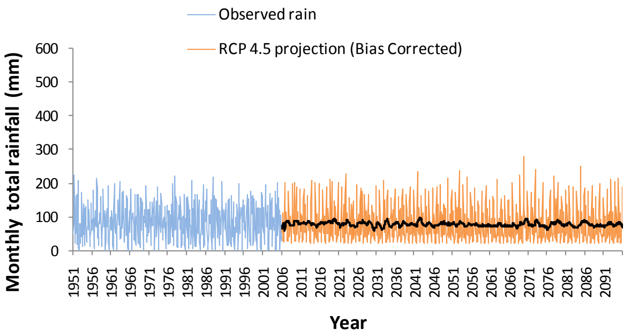
Figure 16. District domain area averaged observed monthly rainfall totals (mm) with bias corrected under conditions of RCP 4.5 (left) and District domain area averaged observed ERA-Interim reanalysis (blue) monthly near-surface temperature averages (°C) with bias corrected under conditions RCP 4.5 (right). The black lines represent 12-month running averages.

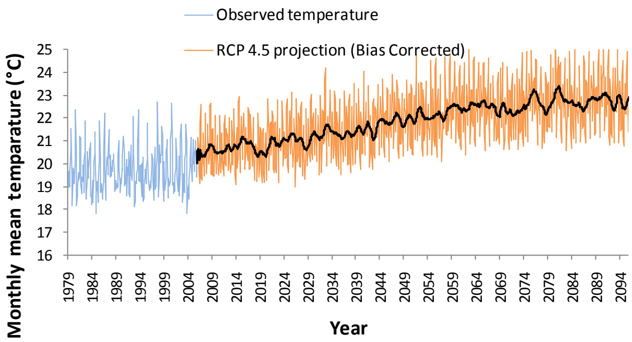
Tororo



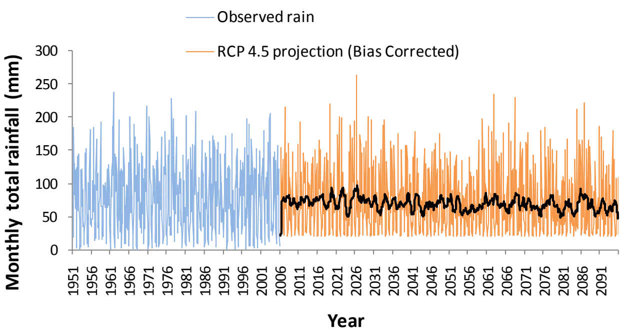


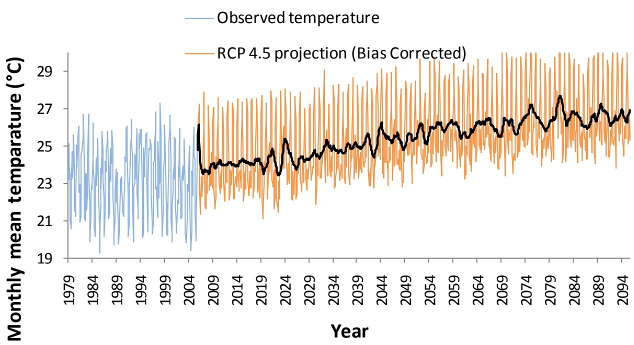
Kabale



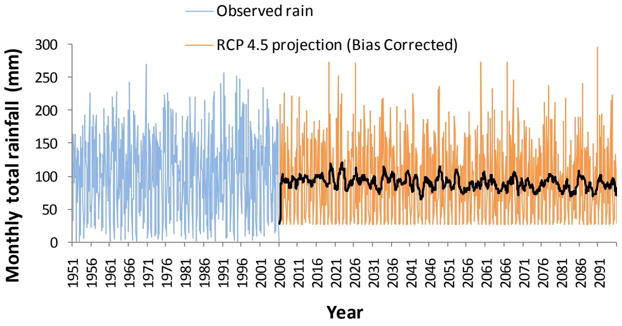


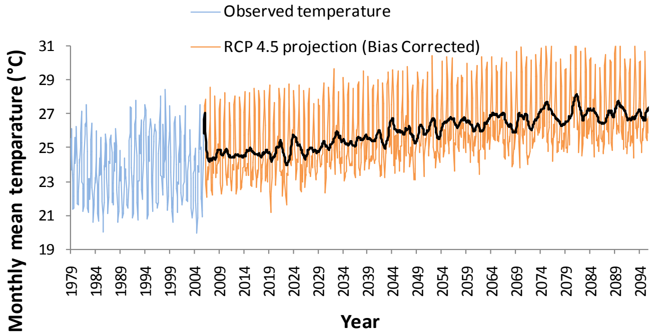
Napak



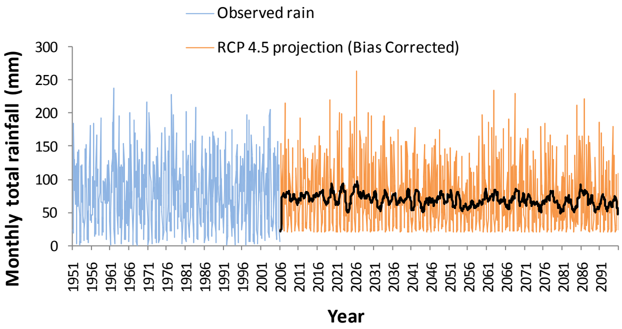


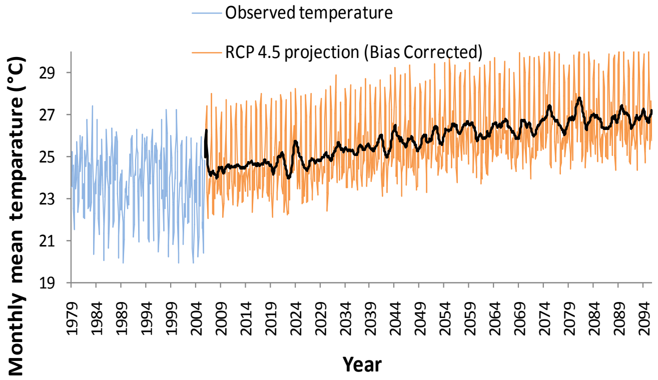
Abim



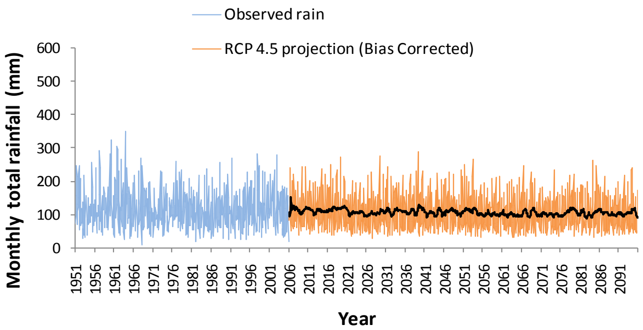


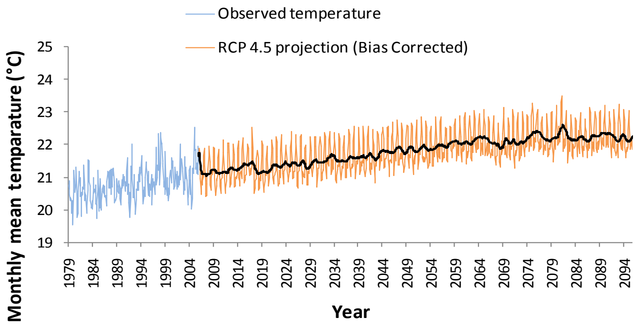
Amudat





Kampala





Annex 4: Initial Feedback from the Final Policy Workshop

The policy recommendations contained in this report were presented at the final policy workshop for this Economics Assessment study in Kampala on May 21, 2015. Both national and local level stakeholders were present at this meeting, and engaged in small groups to discuss priority policy recommendations for the short term, as well as barriers to those priorities being realized. The time was limited, and hence the exercise only gives a snapshot of the types of recommendations that might be incorporated into ongoing processes. The feedback is captured below.

Table 12. Feedback from Final Policy Workshop

Water

1. Enhancement of water storage and water harvesting.
   - Specific measures include: protecting the watershed through tree planting; enforcement of laws on protected watersheds; review of existing laws on the protection of water catchments; conduct draining and desilting in rivers prone to flooding; holistic mainstreaming of environmental protection in water catchment areas.
2. Improvement of water use efficiency.
   - Specific measures include: use of appropriate technologies (such as taps that reduce water consumption), enhancing water use regulations through issuing of permits, promoting best practice in soil and water conservation practices, enhancing rainwater harvesting.
3. Activities that address water supply issues.
   - Specific measures include: construction of large multi-purpose water dams; devolvement of water allocation tools for rational use of water resources especially in areas where there is conflict on water use (this is already enshrined in law regarding drinking water priority), government should encourage water infrastructure investment via Public Private Partnerships (PPP), investment in efficient irrigation technology.

Energy

1. Reduce biomass demand
2. Promote energy efficient technology (e.g. clean stoves, energy saving bulbs)
3. Increase uptake of solar
4. Increase biomass supply by planting appropriate species
5. Encouraging development and uptake of new technologies
6. Increase the tax on charcoal production (mostly affects people in towns)
7. Raise awareness about the cost and benefits of using more energy efficient technology

Infrastructure

1. Review and update standards for design and approval of infrastructure
2. Strengthen land use planning
3. Build capacity in the relevant agencies to enforce the existing laws and regulations

Agriculture

1. Establish early warning systems and improved technologies to provide accurate data that can be used by farmers but also planners and government to mitigate the impacts of climate change.
2. Build capacity for agricultural innovations with central government, local government, private sector, as well as farmers. This should include awareness raising on issues affecting agriculture.
3. Better land use planning.
4. Institutional strengthening of existing regulations. Many regulations are already in place but are not enforced.

5. Promote water and soil conservation practices by increasing the network and capacity of extension workers.

In addition to identifying priority actions, stakeholders also identified barriers to implementation of these actions. Some of the main barriers included:

- **Technology:** Lack of technology; innovative technology is costing and therefore can't reach the poorest (e.g. cookstoves); lack of awareness/capacity around effective use of technology.
- **Land use and ownership:** Land ownership issues due to Uganda's land tenure system, and associated land use policy, especially around wetlands.
- **Policy issues:** Lack of enforcement of policies (for example EIA recommendations are not always implemented, land use/building codes are not enforced); conflicting policies that need to be rationalized (the mainstreaming of climate change might help with this).
- **Finance:** Lack of budget for priority actions.
- **Poor institutional linkages and collaboration;**
- **Lack of political will;**
- **Low capacity:** Human capacity for implementing these measures is low both in terms of numbers of people as well as knowledge, skills and training.

Annex 5: Sectoral and Case-studies Briefing Notes

Economic Assessment of the Impacts of Climate Change in Uganda

National-level assessments

Climate Change and Water

Introduction

Climate change and variability are already affecting the availability of water in Uganda and this is expected to increase over time. The main economic sectors directly affected by water supply and variability are domestic, agriculture and livestock, fisheries, aquaculture, forestry and tourism. Complementary sectors include lake transport and energy production; social sectors that are impacted are health and nutrition and water and sanitation.

As part of the national-level assessment, an estimate has been made of water demand by sector (livestock and agriculture, households and industry) in each of the eight watersheds in the country from 1981-2010. This is compared with the supply likely to be available. From the two an estimate is arrived at of the unmet demand, now and in the future under given climate scenarios. This unmet demand (part of which arises from climatic factors and part from socioeconomic changes) is then valued in monetary terms. In addition to looking at 'normal' conditions in the future the report also analyses the situation in the case of a drought and how that would translate into losses in the future.

Estimated Impacts

Water Demand

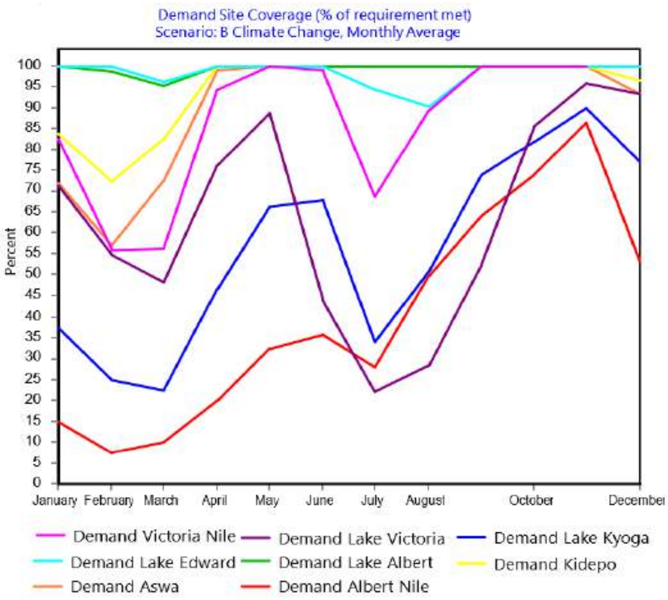
Estimates made show that during the period 1981-2010, average availability of water was sufficient in most months to meet supply although there were some periods when unmet demand reached up to 5% of total demand, which is reasonable but significant.

In the future, under climate change conditions, projections are for a much greater level of demand and some potential reductions in supply. Total demand is expected to increase from 408 million cubic meters a year (MCM/y) in 2010 to 3,963 MCM/y in 2050. Based on the assumption that no additional investments in the water sector would take place, other than those already planned for in current investment plans, **total unmet demand will then rise from 3.7 MCM/y to 1,651 MCM/y in this period under climate change**. In most months water shortages will be enormous.

Value of Unmet Demand

The unmet demand has been valued in monetary terms (using willingness to pay surveys). Overall, the expected cost in 2050 is anticipated to be on the order of US$5.5 billion. This is a conservative estimate and the figure could be as much as ten times higher if income effects on willingness to pay are taken into account.

Figure 17. Unmet demand - monthly average coverage for the period around 2050



The largest overall economic losses are anticipated to be in the Lake Victoria, Albert Nile and Lake Kyoga watersheds. **These values underline the need for further investment in the water supply infrastructure in Uganda**. With or without climate change the economic losses are of a significant magnitude.

In addition to unmet demand under average conditions the report also looked at droughts. Past extreme events of water shortage have had major impacts, with two droughts in the past decade (in 2005-6 and 2010-11) resulting in losses of US$250 million and US$1,174 million respectively. **Each drought lasts about 3 years representing an average annual damage per drought event in the last decade of US$237 million.**

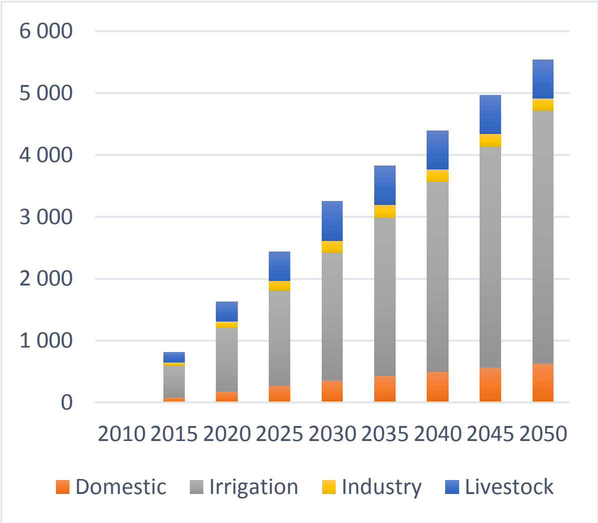
Adaptation Priorities

Adaptation measures include those that improve efficiency on the demand side, those that improve water storage and increase availability on the supply side and those that reduce losses from extreme events.

The report has looked at the costs of proposed priority interventions documented in the Government of Uganda's national Climate Change Policy Costed Adaptation Strategy document[i] and compared them to the potential benefits in terms of reducing unmet demand or in reducing losses from droughts. Three programmes, which account for 92% of the Government's strategy were examined: Programme A focuses on improvements in water use efficiency, Programme B addresses water supply issues for agriculture and industry and Programme C sets up an Integrated Water Resources Management system that would help reduce losses from droughts and floods.

In each case the model calculates the minimum reduction in damages required for the project to generate a 10% rate of return. The results indicate that even with a very small impact on unmet demand, all three programmes would generate this return. **The implications of such a preliminary analysis are that the benefits of action to adapt in the water sector are very high and further investments may well be justified**.

Table 1. Summary of damage and losses by sector 2010:2050 (US$Mn.)



[i] Ministry of Water and Environment, *Uganda National Climate Change Costed Implementation Strategy*, 2012.

Contact: olivier.beucher@baastel.com

Climate Change and Infrastructure

Introduction

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 urgently needs to be addressed today. In this study an estimate is made of:

1) the costs of making the country's infrastructure more resilient in the face of increased climate stress such as increased rainfall and changes in temperature; and
2) the cost of damage to infrastructure from extreme events.

Estimated Impacts

Climate Resilient Infrastructure

Infrastructure comprises residential buildings, non-residential private buildings, public infrastructure (including schools, hospitals, ports, airports, government offices) and roads, railways and bridges. The key findings for the cost of improving the resilience of infrastructure to climate change are the following:

1. **Total costs for ensuring climate resilient infrastructure in Uganda are estimated at US$60-76 million for the year 2025; and US$347-621 million for the year 2050.** New construction accounts for around 76-80% per cent of total costs; the rest is additional maintenance.
2. With the more climate friendly scenario (RCP4.5)**, total costs for the whole period 2010-2050 are around US$2.9 billion** while with a less friendly scenario (RCP 8.5), total costs to 2050 can be as high as **US$4.4 billion.**
3. **The most affected sector is residential buildings, which account for around half of all costs.** Public buildings account for approximately 25% of all costs, and other private non-residential infrastructure account for 17%. In fact, if we take the infrastructure sector as a whole, it is buildings that account for most of the costs (96%). The low cost for transport is mainly the result of projected decline in precipitation: with an increase in precipitation transport costs would play a bigger part as that sector is more affected by an increase in rainfall.

The Government's Costed Implementation Strategy[i], estimates a total cost for transport and works of US$1.05 billion over the next 15 years (i.e. to 2030). This compares with the estimate from this study of US$735-930 million. 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 this study's estimates, giving a total figure of about US$1.1 to US$1.3 billion, which is slightly higher than the Government's estimate.

Extreme Events

The report estimates the cost of extreme events on infrastructure 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. The key findings are as follows:

- If there is no increase in frequency or intensity of extreme events to 2050 then the damages, which are currently between US$20-130 million a year (depending on how you value the loss of life), rise to US$34-214 million by 2025 and to US$234-809 million by 2050.
- **A doubling of frequency of extreme events every 25 years under climate change would result in damages of around US$68-429 million by 2025 and US$938-3,236 million by 2050.** This is equivalent to 0.1-0.4 per cent of GDP in 2050.
- The figures are average of expected damages; an extreme event similar to the El Nino floods in

2007 would represent very significant costs in 2025 and 2050.

Adaptation Priorities

The study concludes that the key adaptation priorities for infrastructure include:

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

All of these actions must precede any new investment in infrastructure. Table 1 lists the items in the Government's Costed Implementation Strategy with a qualitative assessment of their priority.

As far as extreme events are concerned the Government's Costed Implementation Strategy proposes, in addition to the above, a number of actions under risk management that are relevant to protecting infrastructure from extreme events, with a total cost to 2030 of US$12 million. If we compare the cost of the government's projected adaptation program for disaster risk reduction, it is only a fraction of the cost of damages estimated from extreme events. If the government program can reduce damages by even a small amount (i.e. around 7 per cent) they will, under the most conservative assumptions, generate a rate of return of at least 10 per cent.

Table 1. Adaptation Measures for Infrastructure

Item	Amount to 2030	Agency Responsible
Very high priority	**US$Mn.**	
Integrate climate change into the existing infrastructure risk assessment guidelines and methodology	14	Ministry of Water & Envt (MWE)
Establish and enforce climate change–resilient standards for transport and infrastructure planning and development through monitoring and reporting systems	22	Ministries of Works& Transport (MWT) and MWE
Climate proof public buildings	66-91	MWT *
High priority		
Private non-residential buildings	33-46	Private sector*
Residential buildings	148-203	Private sector*
Paved roads	19-20	MWT *
Railroads	30-39	MWT *
Climate-proof existing and future infrastructure by conducting geotechnical site investigations to determine whether areas are appropriate or inappropriate for infrastructural development	204	MWT & MWE
Medium priority		
Promote and encourage water catchment protection in transport infrastructure development and maintenance	192	MWT & MWE

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

---

[i] Ministry of Water and Environment, *Uganda National Climate Change Policy costed Implementation Strategy*, 2012.

Contact: olivier.beucher@baastel.com

Climate Change and Agriculture

Introduction

The agricultural sector is a fundamental part of the Ugandan economy, employing about 66 percent of the working population in 2009/10 and contributing about 22 percent to total GDP in the year 2012 (UBOS, 2013). This brief reports on the findings of a recent study to assess the economic impacts of climate change on agriculture. The report assessed the potential economic impacts of climate change on (i) food crops (ii) livestock and (iii) export crops. It has also made an assessment of the current and future economic impacts of droughts and floods on agriculture in Uganda.

Estimated Impacts

Food Crops

The overall aim of the economic assessment of food crops was to estimate possible future losses of these products and of their economic value, comparing selected climate change scenarios with a no climate change scenario.

Under the scenarios considered overall losses for food crops by 2050 are not likely to be more than US$1.5 billion and could well be less. Under the assumed growth in the economy this would be less than 0.2 percent of GDP in that year.

Other key preliminary findings include:

- Results for production and value changes show great divergence between different climate models, and different regions (with the largest impacts in the East and North for all crops).
- Most of the 11 modelled food crops show reductions in total national production under almost all climate change scenarios to 2050 (e.g. cassava, maize, millet, groundnuts); some cases show both increases and decreases depending on the model (e.g. maize).
- For some crops the impacts on production of climate change in 2050 are quite significant in percentage terms (e.g. cassava, potato and sweet potato show around 40 percent reductions). In most other cases, the percentage reduction is less than 10 percent (e.g. millet, sorghum and pigeon peas).

Livestock

Estimated impacts on livestock production are quite small in all cases (1 or 2 percent). However, this modelling is only for yield and area whereas the key impacts on livestock may come from other climate change factors, in particular droughts, floods and diseases.

Agricultural Exports

Agricultural exports represented about 50 percent of the total export value of Uganda in 2013. Coffee contributes about 18% of total exports. Climate induced yield losses for coffee could be in the order of 50-75% by 2050, as a result of a combination of yield reductions and (more importantly) loss of areas where coffee can be grown. An illustrative estimate of the value of losses due to a 50% reduction in production of Arabica and Robusta coffee combined, would be about US$1,235 million in 2050. The value of losses in a 75% reduction scenario would be about US$1850 in 2050.

Estimates of impacts on tea growing areas also indicate significant losses of value and some potential losses of cotton production are projected.

Taken together these results indicate the potential for Uganda agricultural export production and value to be strongly affected by climate change in the period up to 2050 in the absence of adaptation actions. **Losses due to a 50% reduction in production of coffee and tea combined may cost about US$1,400 million in 2050**.

Extreme Events

For some agricultural products the threat from droughts and floods appears to be more important than the threat from decreased yields.

It is widely accepted that extreme weather events have been increasing and becoming more severe in recent years. To give an indication of the order of magnitude of current losses, these are estimated to be about US$470 million to food crops, cash crops and livestock as a whole, resulting from the 2010-11 drought (OPM (2012)). This equates to about 16 percent of the total value of these items in GDP for 2011. The annual damage figure of US$47 million to crops from the 2008 drought (given in NEMA, 2008) is equal to approximately 3 per cent of the value of all cash and food crops.

Adaptation Priorities

Overall this report concludes the immediate priority in terms of adaptation action is the threat from droughts and floods. It is already present and needs urgent action.

In addition, the Government of Uganda, in its National Climate Change Costed Implementation Strategy, has identified eight areas of adaptation for the agricultural sector, with a proposed budget over the next 15 years of about US$297 million (MWE, 2012). **The proposed strategic interventions deal with current climate variability and can be justified in economic terms on those grounds**. Hence they are part of addressing the adaptation deficit and if implemented effectively, should provide benefits irrespective of future climatic change. The study concludes that:

- Most of those adaptation actions that have medium to long term benefits need to be initiated now because it will take time to test pilot versions and develop programmes that are robust.
- Evidence from the existing literature and from this study suggests that the benefits of many of the proposed measures are potentially high relative to the costs.
- In terms of timing, most of the proposed actions could yield some benefits in the short to medium term, making them more urgent in terms of implementation.

Of course in no case is the evidence from other studies a guarantee that the implementation of the measures in Uganda will be successful and cost effective. The programme needs to be evaluated at the national level on a case by case basis and implementation has to be technically and economically efficient.

A quantitative assessment of those interventions needs a bottom-up analysis of the costs and benefits, which has to work from the local level. Some examples of this will be undertaken in case studies implemented in the Karamoja and Mount Elgon region.

____

Contact: olivier.beucher@baastel.com

Climate Change and Energy

Introduction

This study has analysed the supply and demand for energy in Uganda to 2050, the impact that climate change could have on supply and demand of the sector and possible adaptation measures to deal with any climate change impacts. The analysis has been performed using the LEAP model, which is an energy sector planning model that is widely used for this purpose. The model allows different kinds of energy supply to be evaluated as sources to meet demand by type of energy service in different sectors and for different periods of time. Options are then assessed in terms of costs and the model allows the analyst to choose the least cost combinations subject to whatever constraints are considered appropriate.

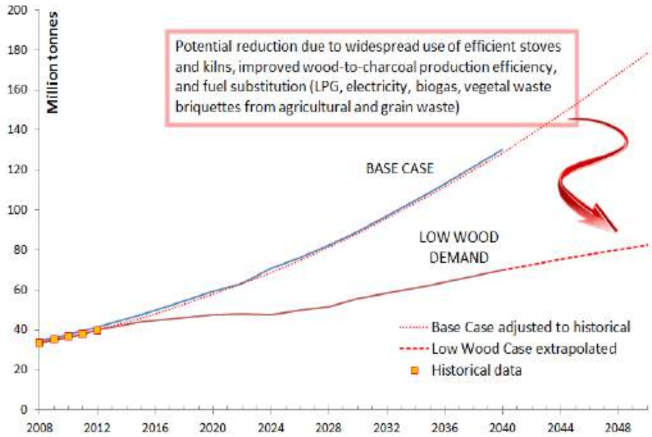
Estimated Impacts

Current Projections

Energy supply in Uganda is dominated by traditional biomass, with electricity and other fuels playing a very small role. The current balance between supply and demand for biomass, however, is very fragile and predictions are that there will be a huge deficit of biomass in the 2020s and beyond.

The report concludes that **a Business as Usual** scenario for **growth in biomass demand is not sustainable and a solution is needed to address the predicted deficit.** Options evaluated include a major increase in the use of LPG as well as electricity for households that currently rely on biomass. This is feasible but will entail a large programme to import wood or LPG or other fuels.

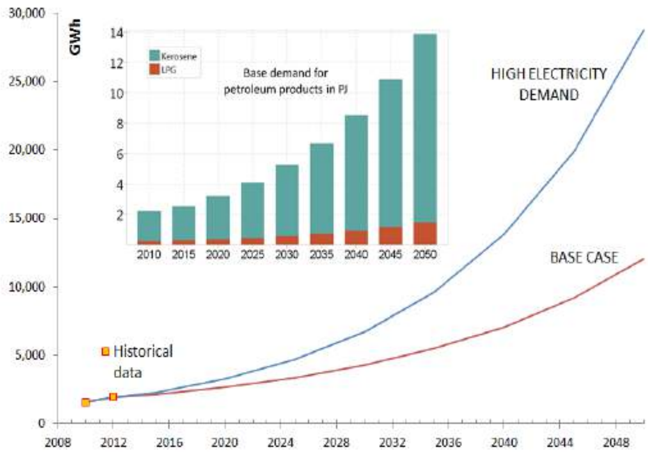
Figure 1: Scenarios of projected annual fuelwood demand in Uganda



In addition, more electricity will have to be generated to fill the gap. With the currently proposed electricity investment programme [26], almost all of the extra demand could be met, but in this scenario there will be a deficit in electricity of around 9 percent of total demand. This deficit could be eliminated if part of the biomass deficit is met through the use of imported biomass – equal to about 86 million tons in the next 40 years, or around 2.2 million tons per year.

These broad conclusions hold under a variety of scenarios, including a higher growth in electricity demand and a reduction in hydropower capacity.

Figure 2: Scenarios of projected demand of electricity and petroleum products in Uganda



[26] Ministry of Energy and Mineral development, *Power Sector Investment Plan*, 2011

Projections under Climate Change

When climate change impacts on the energy sector are evaluated, two things stand out. **The first is that climate change will almost certainly reduce biomass availability**, although it is difficult to quantify by how much. The study estimates that a plausible loss of 5 to 10 percent of domestic wood between 2020 and 2050 would imply the need for additional expenditures of US$0.6-1.3 billion if the gap is filled with imported biomass and between US$5-11 billion if it is filled by LPG.

Secondly, there is a possibility that hydropower potential will decrease due to a reduction **in precipitation**. If there is a decline, it is estimated to be around 26 percent by 2050. Under that scenario, the analysis shows that the government's current expansion programme is sufficient to cover the hydropower deficit, as long as the other components of the programme are implemented according to the proposed schedule.

It is important to remember, however, that this is a very ambitious and resource intensive programme. The estimated additional capital investment in hydro, nuclear and other generation from now to 2050 is around US$83 billion. The country will need to invest around one billion dollars in power, or around US$200 million per year, equal to about one percent of its GDP, in the first five years. In future years the amounts increase very sharply.

Adaptation Priorities

The government of Uganda's Costed Implementation Strategy document [27] reflects a number of the issues discussed above. **The strategy focuses heavily on reducing dependence on biomass and these components should be implemented effectively and urgently**.

The strategy also gives importance to **promoting energy conservation and efficient utilisation of energy to reduce GHG emissions.** The proposed programmes that aim to increase energy efficiency are similar to programmes that have been implemented in many developing countries and these typically show a high level of cost effectiveness. Programming should draw on best practice from other countries, and ensure that standards requiring the adoption of efficient devices, which can be supported by subsidies, are in place.

The strategy does not, however, contain any component encouraging a switch to modern energy of households currently dependent on traditional biomass. LPG is one option and imported biomass or kerosene are other. These alternatives need further investigation but a preliminary analysis indicates that **the benefits of developing an alternative fuel program** (in terms of reducing the unmet demand) **are in excess of costs and should constitute a priority area of intervention.**

Contact: olivier.beucher@baastel.com

[27] Ministry of Water and Environment, *Uganda National Climate Change Policy Costed Implementation Strategy*, 2012.

Economic Assessment of the Impacts of Climate Change in Uganda

Briefing Note: Infrastructure in the Kampala Urban Area

Kampala, the capital of Uganda, concentrates critical economic assets. While there are no robust projections regarding the frequency and intensity of heavy rains, the literature suggests that they have been increasing and will increase with climate change. The costs of inaction are high. Estimates for flooding alone suggest that, if the intensity and frequency of extreme events leading to flooding do not change, current annual damages of between US$1 million and US$7 million in 2013 could rise to between US$33 million and US$102 million by 2050. If the frequency of extreme events doubles by 2050, damages would also double. Adaptation measures can help to mitigate some of this cost; those include (i) revising of policies and plans to account for climate change, (ii) revising building codes to promote bio-climatic designs and avoid building in vulnerable areas, (iii) better use and enforcement of tools such as Environmental Impact Assessment for protection of wetlands, and (iv) strengthening of the evidence base on climate change impacts.

Figure 1: Kampala, Uganda

Introduction

With a little over 1.5 million people in the city itself, and around 3 million people in the Great Kampala Metropolitan Area (GKMA), the capital of Uganda 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. The methodology used in the report combined qualitative and quantitative approaches, and entailed a thorough review of literature and a large number of interviews. The lack of crucial data on the economic costs of the current and likely future impacts of climate change has however reduced the scope of the economic analysis.

Climate Change

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.

Extreme events have already caused significant damages in Kampala. The clearing of vegetation in the hills has increased water runoff, and the encroachment of human settlements onto wetlands has increased exposure to flooding and reduced the capacity of these ecosystems to capture, store and dissipate surface water run-off. Insufficient, poorly designed and poorly maintained urban infrastructure contributes to the high vulnerability of the city to heavy rains.

Vulnerability to drought is also significant. The city has not developed alternative water supply sources to Lake Victoria, and a lack of water for hydro-electricity generation could also have significant impacts in the future.

Economic Impact of Flooding

The study estimates potential damages to humans and physical capital caused by flooding, to 2050, under two scenarios. 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. It is therefore an underestimate. In addition, 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, for example, not included). The table below provides annual damages figures for the two scenarios:

Intensity and frequency of extreme events leading to flooding:	Annual damages in million US$		
	2013	2025	2050
Same as 2013	1-7	4-18	33-101
Doubles by 2050	1-7	5-26	67-203

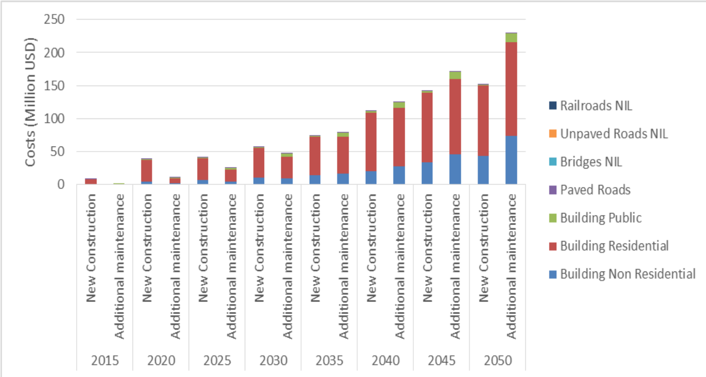
The increase in annual damages is the result of a growing population and assets that are appreciating over time.

Adaptation

The case study estimates the cost of climate proofing new and existing buildings and roads against the projected temperature and precipitation changes to 2050. Given that they consider different climate variables, the estimate of damage cannot be compared to the estimate of adaptation to calculate if adaptation is cost-effective[28]. The estimate of costs of adaptation includes only infrastructure, and excludes other important sectors such as health, water supply or ecosystems degradation. Even with those exclusions, **the estimates of costs are significant, ranging between US$3.3 billion and $3.7 billion between 2015 and 2050:**

- costs are evenly distributed across new construction and maintenance;
- buildings account for 99.8% of the total cost (roads only account for a small fraction);
- private buildings account for 95% of the costs within the building category (the rest are public buildings), residential buildings (as opposed to non-residential) account for 72% of all costs of buildings. The results for the SSP1/RCP4.5 scenario are shown below.

Figure 2: Estimates of Adaptation Costs of Selected Infrastructure Sectors in Kampala



SSP1/RCP4.5 US$2014 Million. Base Case City Growth - NIL indicates no expected cost

The cost of inaction is high and justifies adaptation measures to mitigate some of this cost. Recommended adaptation actions include:

- Plans developed under the Kampala Physical Development Plan (KPDP, 2012) must be revised in light of 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.
- It is urgent that building codes are revised vis-à-vis climate projections, promoting bio-climatic designs and the use of appropriate materials.
- Mainstream adaptation into Kampala's Low Carbon Development and Climate Resilient (LCDCR) Strategy.
- Strengthen the application and enforcement of tools, such as Environmental Impact Assessments, to ensure the protection of wetlands.
- Ensure that all new construction and the modifications of existing buildings is climate resilient.
- Ensure that the opportunities and challenges that informality represent are taken into account
- Improve evidence and research on climate change impacts.
- Ensure that uncertainty is acknowledged and other tools, such as multi-criteria analysis, are used when assessing adaptation strategies.

[28] The estimate of damage considers extreme events leading to flooding; the estimate of adaptation, slow-on-set trends. The types of impacts also differ: the estimate of damage considers deaths, people affected, buildings destructed and buildings damaged; the estimate of adaptation, buildings and roads. A proper cost-benefit analysis was conducted for the improvement of the physical drainage systems of four of the eight catchment areas of the city.

Economic Assessment of the Impacts of Climate Change in Uganda

Briefing Note: Water and energy sector impacts in the Mpanga river catchment

The Mpanga river catchment is suffering increased conflict between the water and energy sectors for the use of the river to serve multiple users. Both water supply and energy production are projected to be negatively impacted by climate change. A vast proportion of the economic costs may fall on the energy sector, estimated at US$25 million to US$98 million annually by 2030 to 2035. Some adaptation options, such as water resource regulation and diversified energy sources, only have to offset between 2.8% to 15% of this loss to be economically justified, and therefore action on adaptation is a high priority.

Figure 1: Mpanga river catchment, Uganda

Introduction

The potential exists for significant conflict between the energy and water supply sectors for the use of river water for hydroelectricity generation and supplying the needs of multiple users. This potential is likely to be exacerbated by socioeconomic development, population growth and climate change, all of which are likely to place significant additional stresses to water systems in Uganda. This study attempts to value the impact of climate change on these two sectors, drawing on the results of an analysis of a range of climate change models (in liaison with a companion study funded by *Expertise France* (BRL ingénierie,2015). Field data was collected via questionnaires and semi structured interviews of local officials and a sample of households in the villages.

The River Mpanga was selected to be the focus of the case study because the river basin faces a number of challenges, including pressures on both the quantity and quality of water in the river as well as socioeconomic development. There is an existing hydroelectric plant which has suffered significant outages in the past 3 years. There are also likely to be increases in demand for water supply for agricultural, industrial as well as domestic purposes.

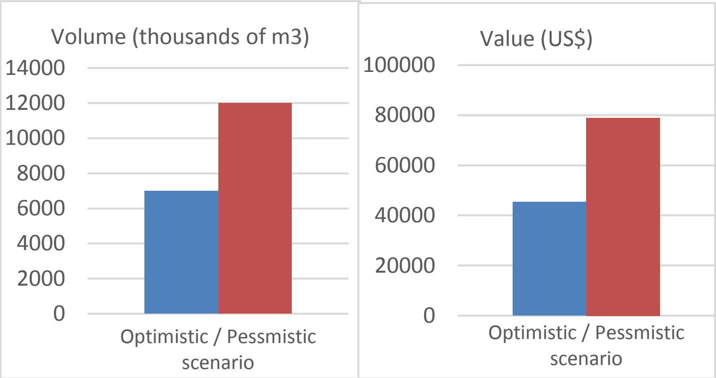
The findings of this study are subject to a number of uncertainties, including model uncertainty, and uncertainty both related to the values of water and energy losses, and the cost of adaptation options.

Climate Change

This study has modelled the impact of climate change in the Mpanga River Basin. The modelling, based on a number of models, shows that rainfall may decrease and that temperature may to rise significantly.

The most significant impacts on water supply are likely to fall in the Rushango area of the catchment due to the water demand in the area and the expected impacts of climate change. Annual average economic losses to the water supply sector in this area may amount to between US$ 45,000 - US$79,000. These costs may more than double (US$188,000) if higher willingness to pay and future scenarios of GDP and population are taken into account. The costs may also increase if industrial demand expands more significantly than expected.

Figure 2. Unmet demand and value in 2035 in Rushango
Average year with 2035 demand, 2015 prices, no discounting*



** The rationale for not discounting in this figure is that it reflects the value as it might be in 2035. It is a value of an impact in 2035 (in current prices).*

Compared to the water sector, the most significant economic costs fall on the energy sector. Transferring economic estimates of the value of lost load from a study in Kenya, adjusting for income differences and inflation, we find annual costs by 2030 to 2035 may be as high as US$25-98 million.

Adaptation

The costs of a number of potential adaptation options were estimated for Mpanga. The percentage of losses that these options would need to offset in order to be economically justified was then estimated. The adaptation costs were based on scaling national level cost estimates from an earlier national sectoral study, which were in turn based on costs developed as part of the National Climate Change Policy - Costed Implementation Strategy of the Government of Uganda, using appropriate multipliers for Mpanga (e.g. proportion of hydro-electricity generation, area or proportion of electricity produced). Cost data is therefore uncertain and further analysis and research is required to develop more robust cost estimates. On the basis of the existing data, actions would only need to offset between 2.8 and 32.8% of estimated losses in order to be justified (10% discount rate).

Ranked from lowest to highest level of impact needed for economic efficiency (i.e. most favourable first), these options are:

1. Promote and participate in water resource regulation between users so as to ensure the availability of water for hydropower production;
2. Conduct further research to determine the potential impacts of climate change elements on the country's power supply chain and act on findings;
3. Diversify energy sources by promoting the use of alternative renewable energy sources (such as solar, biomass, mini-hydro, geothermal and wind) that are less sensitive to climate change; and
4. Promote and participate in water catchment protection as part of hydroelectric power infrastructure development, through soil conservation practices such as agroforestry for example.

Further, it should be noted that these interventions would be likely to have other nearer term benefits – such as enhanced water supply security, ecosystem services, and tourism impacts. The benefits considered here only reflect the average variation and not an extreme event (hence the benefits may be underestimated).

A number of barriers to effective policy on water in particular have been identified, including the need for strong political will and sufficient funding for employing Community Development Officers to enforce existing laws. Enabling factors also include better weather forecasting and early warning systems for water supply shortage and measures to reduce wood fuel demand and avoid deforestation.

There is a clear need for effective integrated river basin management in the Mpanga River Basin to ensure that costs are minimised and that effective adaptation strategies are implemented. Further work is needed to improve the data on river flows to ensure appropriate policy action is taken.

It is also worth noting that national level policy on energy supply will either directly or indirectly impact on the case of the hydroelectric dam in the Mpanga River. Actions to reduce biomass demand, for instance, will improve the quality of water in the river due to reduced soil erosion and measures to reduce energy consumption would reduce demand, and hence the losses due to climate change in the energy sector, in the Mpanga River Basin. Direct measures including actions to promote efficient management of resources – particularly by those sectors with significant consumption – will likely reduce the impact of the lost load.

Economic Assessment of the Impacts of Climate Change in Uganda

Briefing Note: Malaria prevalence in the districts of Tororo and Kabale

Malaria is endemic in 95% of Uganda, and poses significant economic and social costs. In both districts looked at in this study, the costs associated with malaria could more than double by 2050 as a result of both population increase and predicted changes in climate. In Tororo, the **economic cost of malaria due to climate change may rise** from $9-$221 million in 2010 to $20-$561 million in 2050. In Kabale, these costs may increase from between $0.7-$15.8 million in 2010 to between $1.55-$41.7 million in 2050. Efforts need to be increased to reduce this burden – and there are a number of low cost actions that may be taken. Adaptation options such as Long Lasting Insecticide Nets (LLINs), Indoor Residential Spraying (IRS), clearing of breeding sites and proper treatment have been shown to have benefits that far outweigh the costs when they are properly targeted, even without climate change. Additional cost-effective adaptation actions in the immediate term may include information dissemination, particularly to high risk areas, revised planning regimes to help control malaria prevalence, and measures for early warning and action for malaria risk. The spatial differentiation in malaria risk suggests there is no "one size fits all" policy for malaria, and hence there is a need for comprehensive disease vulnerability assessments and action planning across districts.

Figure 1: Tororo and Kabale, Uganda

Introduction

Uganda has one of the highest incidence rates of malaria worldwide. According to a recent USAID study (USAID, 2014), malaria is the leading cause of morbidity and mortality in Uganda. **Climate change is one of the many drivers for malaria, and in the opinion of the study team it is likely to increase the existing burden of malaria in Uganda**, leading to significant costs for society. This study looks in depth at the potential impact of climate change on malaria in the Tororo and Kabale regions. This study attempts to quantify the possible increases in cases of malaria in 2025 and 2050 building on the existing evidence.

There is significant uncertainty in the analysis – the knowledge base is not well developed as to the precise linkage between climate and malaria and the evidence on the valuation of health outcomes in Uganda is still weak. Available quantitative relationships between malaria and climate are coupled with projections of climate and population to estimate future impacts. The evidence base is limited, but does indicate that **with an increase in temperature there is likely to be an increase in the number of cases of malaria**. Only one study dealing with this linkage is from Uganda and is not methodologically strong. Other studies from South Africa and Ethiopia point to a similar relation but with different quantitative estimates. We use the study from Uganda to derive upper and lower bound estimates.

Climate Change

Climate projections indicate that the temperature may rise in Tororo by around 1.5 to 3.5°C by 2095 under Representative Concentration Pathways (RCP) scenarios 4.5 and 8.5 respectively. The projections for Kabale, generally cooler due to altitude (2,000 metres above sea-level), suggest there may be higher increases in temperature by 3.0 to 4.5°C by 2095 under the same scenarios. In neither district is there any prediction of an increase in average annual rainfall, although there is indication of more days with a small amount of rainfall and fewer days with heavy rainfall.

The findings indicate that there may be some increase in cases of malaria due to climate change (in relation to rainfall changes and temperature increase) **but also a larger increase due to the fact that there is likely to be more people exposed** (due to the expected high population growth).

The economic cost of these additional cases, due to both increasing populations and climate change, has been estimated using data on the costs of treatment, time losses and productivity, and the value attached to the loss of a life. The cost of malaria in Tororo could rise from US$8.7-221 million per annum in 2010 to a range of US$20.1-560.5 million per annum in 2050. In Kabale, malaria is expected to increase in cost from between US$0.7-15.8 million per annum in 2010 to between US$1.55-41.7 million per annum in 2050.

Adaptation

There is already an active program to reduce the incidence of malaria and its consequences in Uganda. Stakeholders consider that Long Lasting Insecticide Nets (LLINs), Indoor Residential Spraying (IRS), clearing of breeding sites and treatment are effective short-term actions.

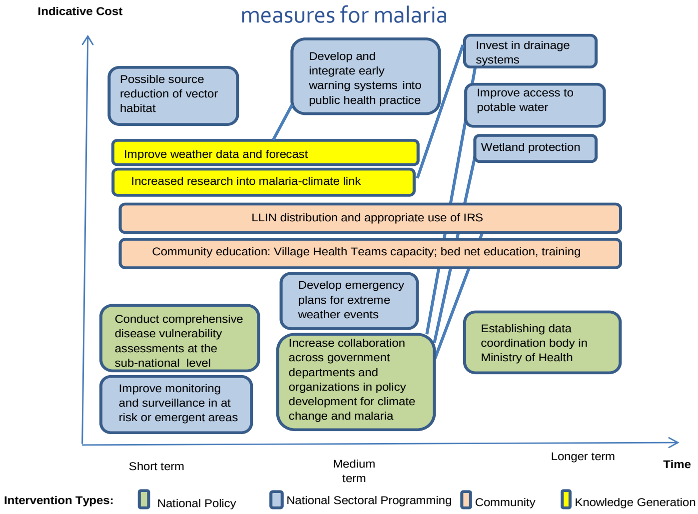
In future, improved agricultural practices such as planting crops away from houses and improved drainage, as well as new drugs, are possible adaptation options. We estimate the current costs and costs in 2050 of three adaptation options: surveillance, LLINs and IRS. In both locations, **the costs of each of the three options may at least double between 2010 and 2050.** Studies indicate that LLINs and IRS have a very high benefit to cost ratio when appropriately targeted. However, our preliminary analysis suggests that **in areas where malaria may be less prevalent, benefits may not always justify costs**, suggesting that a strategy of careful surveillance followed by swift response when outbreaks occur may be most appropriate in areas such as Kabale. Measures may also likely become more cost-effective over time due to socioeconomic and climatic change.

There is a need for cross-collaboration bringing together different ministries to ensure the health co-benefits of actions to adapt to climate change are maximized and maladaptation is avoided. For example, appropriate drainage systems need to be included in new road construction schemes to reduce the potential breeding grounds for mosquitos. Additional actions that need to be advanced in the immediate term, ordered by priority, include:

i. Conducting more research on the climate-malaria linkage, using either existing or new datasets. Better weather data, alongside malaria surveillance data, may enable a better understanding of the climate related risks for malaria and potentially lead to improved early warning for malaria risk.
ii. Strengthening dissemination of information about malaria risk and the appropriate use of bednets, particularly in areas where malaria may newly appear or significantly increase in prevalence due to climatic variation.
iii. Revising planning regimes to ensure proper drainage, control construction and prevent encroachment on wetlands in particular.
iv. Implementing measures to ensure that farming practices take account of malaria risk, e.g. planting crops away from houses.

The spatial differentiation in climate and malaria risk suggests there is **likely no one policy for malaria across the different districts**. **There is a need for investment in comprehensive disease surveillance, vulnerability assessments, and action planning -** taking into account differences in malaria prevalence, climate change projections and socio-economic determinants. Better data is needed to support assessments. Action is also needed to support local adaptive capacity, involving engagement with local stakeholders. Figure 2 gives an overview of potential adaptation measures.

Figure 2: Overview of selection of potential adaptation measures for malaria



Economic Assessment of the Impacts of Climate Change in Uganda

Briefing Note: Arabica Coffee Production in the Mount Elgon Region

The Mount Elgon region, heavily dependent on coffee production, is one of the most vulnerable in Uganda to climate variability. Yields and quality of coffee crops have been declining over the last 30 years, in part owing to poor management practices and in part because of an increase of the frequency of droughts, landslides and floods. Climate change is expected to result in higher temperatures, changes in rainfall and more extreme events, and, as a result, lower coffee yields. An analysis comparing the costs and benefits of coffee farming under "Business as Usual" (BAU) and "Climate Smart Agriculture" (CSA) scenarios was undertaken, in both the current situation and under climate change projections. The analysis demonstrates that there is an economic case for investing in CSA (defined in this study as involving planting of trees, mulching and trench construction), and a complementary programme of institutional support, both now and even more-so under future predicted climatic conditions. It should be stressed, however, that these are preliminary estimates based on limited data and evidence on the effectiveness and impacts of CSA, and in particular a number of assumptions regarding the take up of CSA practices by farmers and the actual improvements in yields that could be achieved. As such the results presented must be treated with caution, and we recommend further work to improve the evidence base.

Figure 1: Bududa district, Uganda

Introduction

In 2010-12 coffee represented around 3% of Uganda's Gross Domestic Product (GDP) and 20-30% of the country's foreign exchange earnings. The coffee sector employed over 3.5 million households in 2011. Arabica coffee production, the focus of this study, contributes 43% of Uganda's total direct coffee export earnings. The case-study has focused on the Bududa district of Mount Elgon, which is typical of agro ecological zones in the region and well covered by coffee cooperatives and private companies.

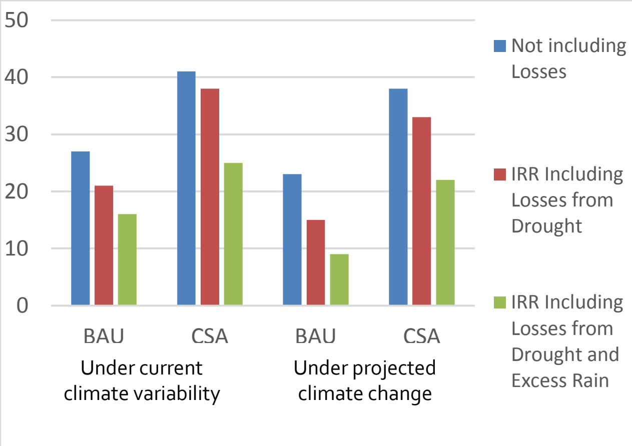
Current conditions

Arabica coffee is very sensitive to weather conditions: optimum mean temperature range is 18-21°C and excessive moisture, heat, or dry conditions directly affect yields. The case study firstly considered the costs and benefits of coffee production under a "Business as Usual" (BAU) scenario and a "Climate Smart Agriculture" (CSA) scenario, considering current climate variability, over a 15 year period, and based on the information collected in the field. The Internal Rate of Return (IRR), which corresponds to the profitability of investments, increases from 27% (BAU) to 41% (CSA), indicating that even under current conditions, investment in climate smart agriculture will deliver greater benefits than costs. The difference in returns between BAU and CSA is similar when losses from drought, and losses from drought and excess rain are incorporated into the model, as we can see in Figure 2.

Climate Change

Climate change projections indicate an increase of temperatures in Mount Elgon, which might negatively affect Arabica coffee production, in particular at lower altitude ranges, and a slight decrease in total annual rainfall. The number of days with moderate to average rain might increase in future, which can have an effect on pests and affect crop growth. Extreme events (excess of rainfall and droughts) are also likely to increase in frequency and intensity. Assuming increases in such events, over a 30 year period, the benefits of CSA over BAU are similarly strong.

Figure 2. Returns to coffee growing in the Bududa District (IRR %) under current climate variability and projected climate change



Adaptation

Seven main types of adaptation options were highlighted as critical by stakeholders in the district, and the study focused on the two that stakeholders considered to be most important: CSA and institutional support measures (or extension services).

The study found that although quite costly, investments in CSA are likely to be justified, as probable benefits outweigh the costs, both under current conditions, and even more so when expected climate impacts are considered. The study indicates that likely investment costs are in the range of US$2.4 million in 2016, rising to US$4.9 million by 2019, over and above the current institutional support programme of Bududa's District Local Government, which has a budget of only around US$ 214,329. The analysis shows investment in these two complementary programmes – CSA and institutional support - would have an internal rate of return of around 36%. If combined with other adaptation approaches, such as complementary policies or providing better climate information, there is, in the view of the study team, potential to sustain coffee cultivation in Bududa, both now and under future predicted climatic conditions.

The study provides an illustration of the potential economic case for investment in CSA for coffee cultivation in the Bududa district. However, there needs to be further consensus before undertaking any major investment programme. It recommends that further research and analysis is conducted in order to identify:

(vi) The impact of climate variability on coffee yields in the Mt Elgon region, and other coffee growing regions in Uganda.

(vii) The cost and benefits of different approaches to CSA in the coffee sector, in particular to identify 'low regret' options and options where there are co-benefits.

(viii) The economic viability of coffee growing under BAU and CSA in different regions in Uganda, in order to focus investment where there is a stronger economic case in the long term.

(ix) Barriers and enablers that effect the adoption of CSA practices by farmers, in order to identify what wrap-around support might be needed, and an analysis of how support may be best delivered.

(x) The costs and benefits of alternative livelihoods in Bududa, including cultivation of other crops and non-farming activities, versus coffee cultivation.

The above actions would help to inform the design of a CSA programme for coffee, including practical measures as well as institutional support, and help to identify what additional complementary strategies might be needed. Critically, the development of such a programme should also involve the private sector, and an analysis of the market and value chain for coffee, to enable improved commercialisation.

Further, given the high level of investment that is potentially required, it is recommended that any CSA programme is first piloted in order to establish whether expectations around costs, benefits, and yields, etc, are borne out in reality in Uganda.

Economic Assessment of the Impacts of Climate Change in Uganda

Briefing Note: Agricultural production in the Karamoja region

This briefing note presents the key messages from the Karamoja case study, which assesses the current and future impacts of climate variability and change in a region that is heavily dependent on agriculture. In many cases recent droughts have resulted in losses of 50 to 100% of total expected production for affected households. Whilst the future impacts of climate change are uncertain, it is estimated that future extreme events could result in losses between 9% and 32% of total production in 2050. Further to this, International Food Policy Research Institute (IFPRI) modelling of percentage impacts on yield from long term rainfall and temperature trends indicates potentially significant impacts on the value of important current crops such as maize (up to 12% reductions) and beans (up to 20%). A number of adaptation strategies are recommended, with a high priority in particular on improving water availability, crop diversification, providing pasture for animals and support to livestock holding and capacity building on climate change and resilience strategies.

Introduction

Insecurity in the Karamoja region has hindered economic development but peace building programmes implemented in the last few years have resulted in a considerably improved current situation with the prospect of making the transition from emergency support to longer-term development. Among current challenges is how best to develop agricultural activities in drought-prone areas with the increased uncertainty of climate change.

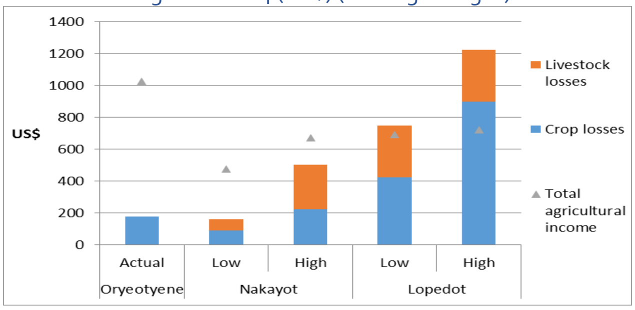
This case study focuses on agricultural production in three specific village locations in the Abim district (Oryeotyene North ward village, Western mixed crop farming - Agricultural zone); the Napak district (Nakayot village, Central sorghum and livestock - Agro-Pastoralist zone); and Amudat district (Lopedot village, South eastern cattle maize - Pastoral zone). The study collected field data via questionnaires and semi structured interviews of local officials and a sample of households in the three villages. It then evaluated a range of current and possible future adaptation options.

Current Impacts

Each of the three villages has had very recent experience of severe drought events and two of the villages have had recent experience of serious flooding. In many cases climate events have resulted in losses of 50 to 100% of total expected production for affected households. Estimates of total impacts on crop production value, and livestock product income, were made for recent severe climate events in each village (Figure 1 gives some examples).

Although it is not valid to make direct comparisons between these loss figures for climate events between crop production and livestock product sales, **the study provides some evidence for the importance of holding livestock to provide greater resilience to climate events**. While livestock production and income may be very badly hit by drought in loss of water supply, losses of pasture and increased disease incidence, the overall impacts are generally not as comprehensive as for crop production.

Figure 1: Estimated average losses per household from the droughts of 2014 (US$) (low-high ranges)



NOTE: A range low to high range is not given for Oryeotyene due to much more reliable loss values in the survey than the other two villages

Climate Change

The study also considers future impacts from climate change although these are only illustrative in the case of extreme climate events projections as detailed changes in frequency and intensity are not available.

For Oryeotyene Northward projections of losses of **crop value** from future climate events (floods/droughts) up to 2050 produced total losses of potential crop production of around 9% (for a less severe scenario) and 18% (a more severe scenario). For Nakayot similar projections produced respective estimates of 15% to 32%, and for Lopedot 19% to 28%.

Illustrative estimates of future impacts from extreme climate events for **livestock value** show total losses up to 2050 of around 11% (less severe scenario) to 16% (more severe scenario) for Lopedot and 12% to 26% (more severe scenario) for Nakayot.

Estimates for overall changes to yields of crops due to climate change up to 2050 were also made for the three locations. These were based on IFPRI modelling[1] of percentage impacts on yield from long term rainfall and temperature trends and are therefore different from the analysis of sudden events presented above. The modelling indicates potentially significant impacts on the **value** of important current crops such as maize (up to 12% reductions) and beans (up to 20% reductions) depending on the climate model used. While these figures are illustrative and based on several key assumptions, they have implications for adaptation in terms of the possible need for crop diversification and other adaptation strategies in the medium and long term.

These findings regarding recent and future losses in crop production due to climate change impacts **highlight the risks to investment in agriculture in the light of plans for expansion of crop production** in the region. The large losses in recently introduced crops in Lopedot indicate the high risks that may be attached to such plans. The conclusions in this localised case study indicate that **there should be more research at the district level to ascertain risks to investment in crops from climate impacts and the level of support that is needed** in livestock production in providing resilience in affected villages.

Adaptation

The gap between living standards in Karamoja and the rest of the country is projected to widen. As a consequence, one can expect significant 'autonomous adaptation' in the region as individuals respond to income and livelihood opportunities in the rest of the country and migrate. Yet this will not be enough to improve livelihoods for the people of these villages, and there is an urgent need to address the local responses to the existing climate variability. The case-study gives an overview of the types of adaptation response that came from the stakeholder consultation with an indicative qualitative assessment of costs and benefits and priorities:

Table 1: Indicative Costs and Benefits of Types of Adaptation Responses

	Type of Response	Costs	Benefits	Policy priority
1	Capacity building on climate change resilience	Moderate	High	High
2	Improvement of crop storage	Medium/High	High	Medium / High
3	Out migration / resettlement	Medium / High	Unclear	To be Determined
4	Crop diversification	Medium/High	Moderate/High	Medium / High
5	Household income diversification	High	High	Medium / High
6	Improving water availability	High	High	Very High
7	Pasture for animals	Moderate	High	High
8	Flood control	High	High	To be Determined
9	Rehabilitating on degraded land	High	High	Medium Term
10	Improvement of transportation	High	High	(Medium / High) Tbd

The analysis carried out indicates improvements in stable income are urgently needed for the people of these villages. At the same time consequences of extreme events need to be mitigated, given the huge losses they cause to the farmers. The evidence indicates that many of these actions are of high value in the current situation and many are urgently needed, especially those addressing extreme events. Climate change will make the need even greater.

[1] The International Food Policy Research Institute (IFPRI) provided the most detailed available modelling results for climate change impacts on agricultural yields per crop