



## **Economics of Climate Change in Rwanda**

## Summary and Key Messages

This study has assessed '*the Economics of Climate Change in Rwanda*'. It was funded by DFID and undertaken by the Stockholm Environment Institute (in Oxford) working with local partners. It covers:

1. The impacts and economics costs of climate change;
2. The costs of adaptation; and
3. The potential for low carbon growth.

The study has advanced a number of approaches to investigate these areas, using aggregated analysis (top-down), sector assessment (bottom-up) and case studies. The key messages are presented below.

### **1. The Economic Costs of Climate Change Impacts in Rwanda**

The first key finding is that **existing climate variability has significant economic costs in Rwanda.**

- Periodic floods and droughts (extreme events) already cause major socio-economic impacts and reduce economic growth in Rwanda. Major flood events occurred in 1997, 2006, 2007, 2008, and 2009, where rainfall resulted in infrastructure damage, fatalities and injuries, landslides, loss and damage to agricultural crops, soil erosion and environmental degradation. In some regions of the country there have also been periodic droughts, for example in 1999/2000 and 2005/6.
- The study has undertaken case studies and surveys to investigate recent flood events. A study of the Nyabugogo River Plain found that flood damages occur each rainy season, which lead to direct (damage) and indirect effects, particularly to informal settlements. The second case study in Bahimba Valley reports that the 2005 flood damaged crops, bridges and led to environmental degradation. The final case study, in the Nyabihu Musanze and Rubavu districts, reports that the 2007 floods led to fatalities, agricultural losses, building and infrastructure damage and population displacement.
- The impacts of these events are economically significant. The most severe of the recent events was the 2007 flood. The study has estimated that the direct measurable economic costs of this event were \$4 to \$22 million (equivalent to around 0.1 – 0.6% of GDP) for two districts alone. However, this only includes the direct economic costs of household damage, agricultural losses and fatalities. It does not include the wider economic costs from infrastructure damage (including loss of transport infrastructure), water system damage and contamination, soil erosion and direct and indirect effects to individuals. The total economic costs of the 2007 floods are therefore much larger and would increase further when other national level effects are considered. It is clear that these events have economic costs that would be very significant in terms of national GDP. The continued annual burden of these events leads to reductions in growth over time.
- There are also wider impacts from the current climate. The study has found some indication that recent temperature trends may have shifted the altitudinal pattern of malaria and raised the national burden of malaria in recent decades (increasing preventative and treatment costs). Some of these recent trends (e.g. temperature shifts, climate variability and flood intensity) may reflect an already changing climate. However, any impacts also have to be seen in the context of changing patterns of vulnerability over time.
- The implications of these findings are that Rwanda has a current adaptation deficit, i.e. it is not adequately adapted to existing climate risks.

The second key finding is that **future climate change will lead to additional economic costs.**

- Africa is predicted to have greater impacts than other world regions, because of higher vulnerability and lower adaptive capacity. Impacts could threaten past development gains and constrain future economic progress. Some regions and populations in Rwanda have very high vulnerability.

- The future economic costs of climate change are very uncertain. However, aggregate models indicate that the additional net economic costs (on top of existing climate variability) could be equivalent to a loss of almost 1% of GDP each year<sup>1</sup> by 2030 in Rwanda, though this excludes the future effects of floods and other extremes. This estimate is therefore considered a potential lower bound.
- In the longer-term, after 2050, the economic costs of climate change in Africa are expected to rise, potentially very significantly. However, the aggregate models report that global stabilisation scenarios towards a 2°C target could avoid the most severe social and economic consequences of these longer-term changes. This emphasises the need for global mitigation, as well as local adaptation.
- The study has also undertaken bottom-up assessments of the impacts and economic costs of climate change for a number of sectors, working with climate and socio-economic projections. Rwanda already has a complex existing climate, with wide variations across the country and very strong seasonality, though it is more temperate than much of East Africa. It has two wet seasons, and has strong patterns of climate variability and extremes, not least due to the periodic effects from the El Niño – Southern Oscillation (ENSO) and La Niña, which are associated with extreme rainfall and flooding and droughts (respectively) in the region.
- The study has considered projections of future climate change from a suite of downscaled global models for Rwanda, though geographical dis-aggregation has been limited by data availability. The projections indicate future increases in mean annual temperature (average monthly temperatures) of broadly 1.5 to 3 °C over the range of models by the 2050s (2046 -2065). The changes in precipitation are more uncertain. All the climate models show that rainfall regimes will change and the majority indicate an increase in average annual rainfall (with a central value of typically 10%), particularly in September to November, indicating a potential strengthening of the rains. However, some models project rainfall reductions in some months. The information on extreme events (floods and droughts) is much more variable. While there is some evidence of a recent intensification of these events, the future projections vary widely. Nonetheless, many models indicate an intensification of heavy rainfall in the wet seasons, which is particularly important in relation to a greater flood risk.
- The range of model results highlights the considerable uncertainty in predicting future effects, especially in relation to scenarios of future rainfall, floods and droughts, though also due to future socio-economic conditions and environmental services. Nevertheless, the analysis here does reveal potential areas of concern and helps focus priorities. Furthermore, it is essential to recognise this uncertainty, not to ignore it. There is a need to plan robust strategies to prepare for uncertain futures, rather than using uncertainty as a reason for inaction.
- In the absence of adaptation, the study estimates that there could be a potentially large increase in the health burden of malaria in Rwanda. This arises because a large part of the rural population lives at higher elevations, where the disease is currently restricted by temperature. The study has applied a new malaria risk model, based on altitude, and finds that climate change could increase the rural population at risk for malaria by 150% by the 2050s. The increase in the disease burden is significant and could lead to full economic costs that are over fifty million dollars/year. These effects are raised as a future priority area for consideration (further research and early action, see recommendations). The study also identifies other possible direct and indirect health effects from climate change.
- In the agricultural sector, the net economic effects vary with the range of climate projections and the analytic models used. Under some futures and with certain models, modest impacts on agriculture are predicted in the medium term (with some regions even experiencing increased agricultural yields). However, under other scenarios and other models there are economic costs projected for the sector. A range of additional factors are also important, which are not included in these assessments, including the effects of extreme events, pests and diseases, etc. The range of potential effects and the high importance to the economy and livelihoods mean that this sector is a priority for future consideration (further research and early actions).

---

<sup>1</sup> Central net values (sum of positive and negative) for market and non-market effects. The results exclude future extremes (floods & droughts) and do not capture a large range of potential effects including all ecosystem services.

- Even in the absence of climate change, the economic costs of the periodic floods that affect Rwanda could rise significantly in future years, due to socio-economic change (population and economic growth). The study has assessed these changes and finds that in the absence of adaptation, these drivers could increase the costs of events by a factor of five by 2030, i.e. a periodic large-scale regional event similar to the 2007 flood could have direct economic costs of up to one hundred million dollars (though events of this size are infrequent). A key priority therefore is to increase the resilience of Rwanda to cope with these extreme events. Climate change is likely to further increase the economic costs of these events. Many of the projections indicate a change in heavy precipitation events for Rwanda. A number of models suggest a 10% increase in intensity for 1 in 10 year and 1 in 100 year rainfall events (though other projections indicate increases of 50% for 1 in 10 year events). These increases in intensity would increase the economic costs of periodic flood events significantly, because of the non-linearity in the costs with flood depth and strength. They would also mean a reduction in the return period of larger events, i.e. more significant floods would occur more frequently. Even when annualised, these indicate significant increases in economic costs. The effects on droughts are more uncertain, but the range of model projections does include changes that would exacerbate existing periodic events for some regions of the country.
- The study has investigated additional issues with energy supply and demand. For the energy sector, the relatively high level of hydro generation in the Rwandan electricity mix might increase future vulnerability under a changing climate, though the main trends in the projections indicate the primary concern would be for coping with more extreme events (greater rainfall intensity). It is noted, however, that future land-use patterns will also be important in influencing future hydro potential. Similarly, the trend in average temperatures will increase the number of hotter days and potentially increase the cooling burden in urban areas, important in relation to building comfort levels and equipment. However, analysis across the range of model projections shows effects are likely to be modest even by the 2050s, due to the existing temperate climate.
- Finally the sectoral analysis has considered ecosystem effects. Rwanda has exceptional biodiversity. These ecosystems provide multiple benefits to society, which in turn have economic benefits, though these are rarely captured by markets. These benefits are known as 'ecosystem services' and include provision of food, supporting services, regulatory services including flood protection and recreational and cultural services. The study has mapped the potential ecosystem services in Rwanda and considered (qualitatively) the potential additional pressures from climate change. The study finds that ecosystem services are integral to the Rwandan economy and underpin over 50% of Rwandan GDP, as well as sustaining a very large proportion of the population. There are many stresses on these systems already and climate change will add to these pressures. These potential effects are also highlighted as an early priority area.
- The study has undertaken a number of case studies to provide more detailed local analyses. This has included the consideration of flood events, vulnerable groups and iconic ecosystems.
- Overall, the bottom-up analysis indicates that in the absence of adaptation, the aggregated estimates of economic costs - which occur on top of the existing effects of climate variability - could potentially be very large. Detailed analysis for a single burden (malaria) in a single sector (health) indicates that future economic costs could be over fifty million dollars a year by the 2050s. There are also potential effects on ecosystem services, which whilst difficult to estimate in economic terms, could be just as important. The analysis of future costs of extreme events indicates that large increases in the economic costs of these events will occur over the same period. Finally, there are some possible scenarios of climate change on the agricultural sector which would lead to high economic costs and have very significant effects on rural livelihoods. Overall, the bounded range of economic costs could potentially be very large, as GDP equivalent costs. There is also likely to be a strong distributional pattern of effects, with some sub-regions and some groups affected more than others. Finally, there are also potential regional effects to Rwanda from climate change in other East African countries.

## **2. The Economics of Adaptation in Rwanda**

- Adaptation can reduce the economic costs of climate change but it has a cost. The costs of adaptation are still emerging and as they follow from impacts, these too are uncertain. However, this does not mean that no action should be taken. Instead it requires more robust strategies.
- The study has investigated the top-down aggregated estimates of the costs of adaptation. It has used estimates for Africa/East Africa and scaled these to Rwanda. Four categories of adaptation have been identified. Two of these are development activities and are targeted towards the large economic costs of current climate variability. They are 1) addressing the current adaptation deficit and 2) increasing social protection. The second two are associated with tackling future climate risks and are 3) building adaptive capacity and 4) enhancing climate resilience. The overall costs of adaptation vary according to which of these categories is included.
- The immediate needs (for the year 2012) for building adaptive capacity and addressing early priorities requires a significant scaling up from the current NAPA estimates (\$8 million), estimated at \$ 50 million/year. However, a much higher value of approximately \$ 300 million/year is warranted if the categories of social protection and accelerated development (to address the current adaptation deficit) are included. As highlighted above these categories are associated with current climate variability – such as the existing vulnerability to floods - and are therefore associated with development, rather than with future climate change. However, investment in these areas provides greater resilience for future change and they are essential in reducing future impacts.
- The estimated costs of adaptation will rise in future years. The aggregated estimates provide a possible range, with implications for the source and level of finance required. Estimates of medium-term costs to address future climate change are typically of the order of \$50 – 300 million per year for Rwanda by 2030, focused on enhancing climate resilience. Note that the investment in 2030 builds resilience for future years when potentially more severe climate signals occur. However, higher values (in excess of \$600 million /year) are plausible if continued social protection and accelerated development are included, noting that these are primarily development activities.
- The study has also assessed the costs of adaptation for Rwanda using a sectoral bottom-up approach, to test the estimates above and to give greater insight into sectoral planning.
- The study has advanced a framework to prioritise early adaptation in the sectoral analysis, which considers uncertainty within an economic framework. This identifies early priorities for adaptation of:
  - Building adaptive capacity;
  - Focusing on win-win, no regret or low cost measures (justified in the short-term by current climate conditions or involving minimal cost);
  - Encouraging pilot actions to test promising responses; and
  - Identifying those long-term issues that require early pro-active investigation (though not necessarily firm action).
- A series of ‘adaptation signatures’ have been developed to identify actions in each of these four categories for each sector. The broad outline of steps (as above) is the same in each sector. However, the exact activities vary, hence the use of a ‘signature’ concept that considers options on a case by case basis. These signatures have been to develop indicative adaptation costs for the health, water and agriculture sectors. These have been complemented by case studies which include examples of adaptation projects and costs.
- In the health sector, the potential costs of adaptation to address the potential increasing burden were considered based on treatment and prevention costs. In the water sector, water resource investments were assessed across sectoral activities to identify areas for climate resilient development and adaptation mainstreaming, based on the Rwanda’s NAPA and EDPRS recommendations for integrated water resource management (IWRM), as well as 2009/10 public expenditures and MTEF

projections. In the agricultural sector, estimates are provided to illustrate the scale of effort that may be required and some of the urgent priorities.

- A large number of immediate priorities areas and no regrets options have been identified from these assessments. As examples, they include the strengthening of effective surveillance and prevention programmes for health linked to enhanced meteorological systems and similar strengthening programmes in other areas (e.g. expanded monitoring of key ecosystems). They also include capacity building to strengthen the meteorological analysis and forecasting for seasonal outlooks and forecasting (agriculture) and extreme events (flood risk), with the latter linked to the strengthening and development of early warning and disaster risk reduction, as well as risk mapping and basic screening in planning. Finally, they include pilot actions across all sectors and for promising options (e.g. terracing, malaria prevention) the potential scaling up of sectoral programmes.
- The sectoral assessments and the case studies show relatively high adaptation costs, which confirm the lower end of the adaptation estimates for 2030 above and justify investment needs. They also demonstrate the potentially much larger costs when development-adaptation needs are included. Finally, the studies demonstrate that adaptation has potentially very large benefits in reducing present and future damages.
- However, while adaptation reduces damages, it does not remove the impacts of climate change entirely. Residual impacts in Rwanda, particularly for some regions and groups of society, will need to be considered. They will also be important for recovery after climatic disasters and for future impacts. It is highlighted that the costs of adaptation are only part of the full costs of climate change: both adaptation costs and residual effects are therefore important for international negotiation discussions.
- Finally, while there is a large need for adaptation finance, and entitlement to substantial funds must be assured, accessing these funds will require the development of effective mechanisms and institutions, as well as involvement of the public and private sector, as well as regional (East Africa) responses. There is a need for Rwanda to agree on next steps, the future focus and to build capacity, including national and sectoral planning objectives, enhanced knowledge networks and verifying outcomes of adaptation strategies and actions.

### **3. Low Carbon Growth in Rwanda**

- The analysis has first considered the current emissions in Rwanda. These show that the country currently has relatively low emissions of greenhouse gas emissions (total and per capita). Moreover, Rwanda has already introduced a range of low carbon options across many sectors.
- The study has then considered the potential change in emissions consistent with planned development in the Vision 2020 plan and developed a future emissions profile for Rwanda. This projects that the strong growth planned in the Vision document, as well as other changes from population and urbanisation, will increase future total and per capita GHG emissions significantly, even though Rwanda is initiating policies that are consistent with low carbon development.
- Under the future 'business as usual' development scenario, the study estimates that total emissions of greenhouse gases will double between 2005 and 2020. These future increases are driven by the transport and agriculture sectors, which are likely to become the dominant sources of future emissions. However, even in the electricity sector, which currently has a high share of renewables (hydro), the plans for the development of Lake Kivu would start to increase the absolute emissions from electricity generation in the short-term and potentially increase the carbon intensity of the entire Rwandan generation mix in the medium term.
- The current plans across the economy (or for some sectors, the lack of plans) could 'lock-in' Rwanda into a higher emission pathway. The increases from the transport, agricultural and electricity sectors, and the associated increase in national emissions, would occur at exactly the time when there are likely to be greater economic opportunities for carbon credits and markets, particularly if national level mechanisms emerge. Following these higher carbon pathways will therefore lead to an opportunity

loss for Rwanda. They could also lead to other economic, social and environmental costs: an example would be the congestion, higher fuel costs, greater fuel imports and higher air pollution that would occur if private car use grows rapidly in Kigali.

- The study has therefore investigated low carbon options across the economy, developing a low carbon alternative pathway. This shows that there are a large number of 'no regrets' options, particularly from improvements in transport efficiency, domestic stoves and agriculture, as well as for the electricity sector, which would enhance economic growth, as well as allowing further access to international carbon credits. These options produce significant emission savings and can be realized at negative cost, i.e. the economic benefits outweigh the costs. An example would be with an energy efficiency measure that actually saves the individual or company money (e.g. from reduced fuel costs) when compared to the current baseline. These options also have wider economic benefits from greater energy security and diversity, reducing air pollution and reducing environmental impacts.
- The study has evaluated the emission reduction potential from such options, for a number of potential sectors, and compared this against the 2020 baseline. This finds that large-scale national emission reductions could be achieved under a scenario which would also be economically advantageous.
- The study also highlights the need to widen this analysis and to develop a longer term strategy beyond 2020. This needs to consider how the international action by developed countries to address climate change might affect Rwanda, notably in relation to its planned economic growth in areas such as tourism, exports, etc. as well as considering how best to co-ordinate co-operative regional (East African) responses to enhance potential low carbon opportunities.
- Overall, because of its location, availability of resources, and socio-economic conditions, the study concludes that there are significant economic benefits for Rwanda in following a low carbon development path, as well as large environmental and social benefits. Such a pathway is strongly in Rwanda's self interest, and would also provide potential extra investment from carbon financing. The low carbon path investigated produces very real economic, environmental and social benefits, including ancillary benefits of reduced fuel imports, improved air quality, improved energy security, and reduced pressure on natural resources. Key steps to achieve this, and to enhance climate resilient growth and adaptation, are highlighted below.

## **Recommendations**

The study has outlined a number of recommendations and future priorities.

- Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. Such a follow-on phase might include a broader (and for key priorities, a deeper) analysis by sector, particularly for health burdens, agriculture, water/flood risks and ecosystem services. This would need to be accompanied by a more systematic adaptation assessment, with estimates of costs, focused on short- and medium priorities at a sectoral (and cross-sectoral) level. On the low carbon side, it would be useful to undertake a more comprehensive analysis of potential opportunities, with marginal abatement cost curves and consideration of priorities across all sectors. This would provide both adaptation and low carbon costs in detail, and as part of an investment and financial flow analysis (by sector), it would establish the potential additional funding needs above the current development baseline. This would provide a firm basis for increased future funding. Taken together, this follow-on analysis could form the basis of a new strategy.
- There are a number of urgent priorities for building adaptive capacity in Rwanda that should be fast-tracked, notably in relation to meteorological and hydrological data collection, monitoring and forecasting (as these underpin future prediction and analysis), early warning systems, as well as information provision, monitoring (indicators) networks and focal points. The early priorities also include increasing the knowledge base, education and training and strengthening existing programmes.

- There is also a need to build future climate change risk screening into development and planning, at a sectoral and regional level. Information on climate, resources and adaptation strategies and options should be mainstreamed into all sectoral plans.
  - To enable this, the study recommends that a national knowledge management system be developed; with easy access by all stakeholders to compile more detailed databases of potential climate risks across all areas of the economy.
- Access to substantial adaptation funds must be assured. However, mechanisms and institutions for effective use must be developed to allow Rwanda to access these funds. This requires early and concerted action to build capacity across stakeholders and with the affected communities themselves. This is an early priority.
  - To achieve this, some form of national adaptation authority should be set up to assess the potential for climate resilient growth across all areas of the economy and to mainstream adaptation into government departments and with Rwanda's development partners. There is also a need to encourage the linkage between national adaptation and low carbon action (the latter including the designated national authority).
- There are many benefits if Rwanda switches to a lower carbon pathway. However, this will not happen on its own and steps are needed to realise these benefits and to maximise the potential flow of carbon credits under existing and future mechanisms.
  - Low carbon plans should extend beyond the power generation sector. This will necessitate a greater focus on transport and agriculture.
  - There is a particular need to consider areas of development that might 'lock-in' Rwanda into higher emissions pathways, notably in the energy, transport and urban environment. It would be useful to specifically address these threats and to identify alternatives through the existing sector planning and review process.
  - All future development and planning, including low carbon investment, should consider future climate change, which necessitates climate risk screening in future low carbon plans across all sectors. Potential linkages between adaptation and low carbon development (especially in finance) should be explored.
- The planned revision of the EDPRS should examine the potential effects of climate change and the potential for adaptation and low carbon growth. There is also a need to build on existing government and donor coordination structure (such as the various Sector Working Groups including Environment, Infrastructure, Agriculture and Health). In the longer-term, there is a need to develop a new strategic vision for Rwanda that addresses these areas, for example, with the revision of the Vision 2020 document, including both domestic and international aspects.
- The steps above would provide national action on a low-carbon, climate resilience investment plan and would establish Rwanda as an international leader, with the 'first mover advantage' in negotiations and securing finance.
- Finally, the potential for a more radical policy shift is also highlighted as an option for Rwanda. Because of the level of current development and the importance of near-term decisions in determining the long-term economic and social structure of the country, it might be possible to truly promote a visionary approach to low carbon development and climate resilient growth within the context of environmental sustainability and economic growth, i.e. to set a new model for Africa. This would position Rwanda internationally along a very progressive vision, consistent with the recent Presidential statements on climate change and adoption of green technology.
- Key priorities for adaptation and low carbon growth are outlined below.



Adaptation Strategies	Priority Actions
<b>Immediate needs &amp; capacity building</b>	<ul style="list-style-type: none"> <li>• Expanded research assessment into effects, adaptation and economics. Early capacity building, e.g. meteorological data/systems and early warning systems</li> <li>• Develop national climate change strategy including knowledge management and screening of sectoral and regional plans for climate risks and adaptation opportunities. Include in EDPRS revision. Build into long-term vision (e.g. next Vision 2020)</li> <li>• Prepare plans for a national adaptation authority to improve sectoral coordination, link to international finance, and support private sector. Enhance links between adaptation and low carbon.</li> </ul>
<b>Climate resilience</b>	<ul style="list-style-type: none"> <li>• Develop climate resilience strategies for immediate concerns (e.g. cross sectoral meteorological systems, information and forecasting, health and malaria monitoring and actions, flood risk screening)</li> <li>• Develop prototypes of sectoral actions (pilots) and pathways for scaling up to cover all vulnerable regions and populations</li> </ul>
<b>Social protection</b>	<ul style="list-style-type: none"> <li>• Protect vulnerable livelihoods and strengthen existing social protection programmes, expanding the coverage to consider climate change.</li> </ul>
<b>Accelerated development</b>	<ul style="list-style-type: none"> <li>• Adapt existing development projects to include 'no regret' measures to reduce climate risks and opportunities to develop adaptive capacity</li> <li>• Scale up successful prototypes to sectoral development plans</li> </ul>

Mitigation Strategies	Recommended Actions
<b>Low-Carbon Growth (LCG)</b>	<ul style="list-style-type: none"> <li>• Full analysis of low carbon options, costs and potential for prioritisation and development of strategy for mechanisms.</li> <li>• Develop national strategies to mainstream LCG in planning, including a revised EDPRS and possibly new Vision.</li> <li>• Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM)</li> <li>• Prioritize agriculture, transport and electricity generation low carbon measures, considering short-term opportunities but also longer-term areas where potential 'lock-in' and identify alternatives. Improve sectoral co-ordination.</li> <li>• Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use</li> </ul>
<b>Climate resilience &amp; co-benefits</b>	<ul style="list-style-type: none"> <li>• Climate risk screening of low carbon growth pathways</li> <li>• Consider opportunities to achieve robust development, e.g. in planning hydropower (large reservoirs, small in-stream turbines), biofuels, on-farm carbon management (e.g. zero grazing, woodlots)</li> </ul>

# Table of Contents

1. INTRODUCTION.....	1
BACKGROUND, AIMS AND OBJECTIVES.....	1
METHODS.....	2
STUDY TEAM, LOCAL GOVERNANCE AND PARTNERSHIPS.....	3
REPORT OUTLINE .....	3
2. IMPACTS AND ECONOMIC COSTS OF CLIMATE CHANGE IN RWANDA .....	4
CLIMATE PROJECTIONS FOR RWANDA .....	4
SOCIO-ECONOMIC PROJECTIONS.....	6
2.1. AGGREGATE ECONOMIC ESTIMATES OF CLIMATE CHANGE IN RWANDA .....	7
2.2. NATIONAL BOTTOM-UP SECTORAL ASSESSMENTS AND CASE STUDIES.....	9
HEALTH .....	10
WATER AND INFRASTRUCTURE.....	12
ENERGY .....	19
AGRICULTURE.....	20
BIODIVERSITY AND ECOSYSTEM SERVICES.....	24
SYNTHESIS AND RECOMMENDATIONS.....	27
3. ADAPTATION COSTS AND BENEFITS IN RWANDA.....	29
3.1. AGGREGATE ESTIMATES OF ADAPTATION COSTS FOR RWANDA.....	30
3.2. NATIONAL SECTORAL ASSESSMENTS AND CASE STUDIES.....	32
HEALTH .....	35
WATER AND INFRASTRUCTURE.....	36
WATER SUPPLY .....	39
ENERGY .....	44
AGRICULTURE.....	44
BIODIVERSITY AND ECOSYSTEM SERVICES.....	48
SYNTHESIS AND RECOMMENDATIONS.....	51
4. LOW CARBON GROWTH IN RWANDA .....	54
ELECTRICITY.....	56
TRANSPORT.....	58
AGRICULTURE AND OTHER SECTORS.....	60
INVESTIGATING THE COSTS AND WIDER CO-BENEFITS OF POTENTIAL OPTIONS.....	63
REGIONAL AND INTERNATIONAL ASPECTS .....	65
RECOMMENDATIONS.....	65
5. PROJECT DESCRIPTION AND PROJECT TEAM .....	68

Final Version (4): Incorporating final comments from the steering group.

# 1. Introduction

The '*Economics of Climate Change in Rwanda*', funded by DFID and undertaken by the Stockholm Environment Institute (led by the Oxford Office, in conjunction with the SEI office in Nairobi) together with local partners, has assessed the impacts and economics costs of climate change, the costs and benefits of adaptation and pathways of low carbon growth for Rwanda<sup>2</sup>.

This summary is provided as an initial guide for developing policy in Rwanda and with its development partners. The impacts and economics of climate adaptation and low carbon futures in developing countries are uncertain and often contentious: experts are still developing methodologies and political negotiations are still being progressed.

## ***Background, Aims and Objectives***

To better understand the economic impacts of climate change in Rwanda, the UK (DFID) Government donors have funded a study by the Stockholm Environment Institute (SEI), Oxford office, to assess the economic impacts of climate change in Rwanda and two other East African countries. The key aims of the study were:

- To assess the impacts and economic costs of climate change for Rwanda, considering key sectors of the economy and non-market sectors such as health and ecosystems;
- To analyse the costs and benefits of adapting to these effects over different timescales;
- To assess the potential for low carbon growth, including development benefits and finance opportunities;
- To build national capacity and take advantage of local knowledge;
- To use the results to enhance the evidence base to inform and guide the Government's negotiation position for COP 15, as part of a regional approach to negotiations and promoting dialogue on shared challenges;
- To inform decision-making at domestic, regional and international level on the economics of climate change in Rwanda, and the region as a whole; and
- To highlight areas where further work is required to understand impacts and policy responses to climate change.

The study also had a focus to help stimulate government, private sector and civil society debate and actions on the development and implementation of policies to adapt to and mitigate climate change.

---

<sup>2</sup> The study is part of a larger East Africa regional study, which includes detailed country assessments for Burundi and Kenya. The DFID/DANDIA project has also benefited from related economics of climate change projects being coordinated by the Stockholm Environment Institute in Oxford, including the AdaptCost project (funded by UNEP) which is assessing adaptation costs at the African scale and the EC ClimateCost project.

## Methods

The study had a number of different objectives, each aimed towards different potential stakeholders. The information needed to meet the objectives above included aggregated information on the economic costs of climate change, the costs and benefits of adaptation, and the economic costs and benefits of a low carbon growth pathway, but at the same time, data and information to help inform on national, regional and even local priorities. Tackling all of these aims in a single study was challenging, but to address this, the study adopted a multi-level approach, using different aggregation levels to iteratively build-up several lines of evidence on impacts and adaptation.

Three aggregation levels and suites of methods were used. The first was a top-down aggregated economic analysis. The second was a sectoral economic impact assessment at national level using more bottom-up assessments. The third was a series of sub-national-local case studies on vulnerability and adaptation (adaptation 'signatures') to provide local context and inform decision making. These local studies allow consideration of livelihoods, development and poverty alleviation, which would be missed by a high level economic assessment. A schematic of the method is shown below.

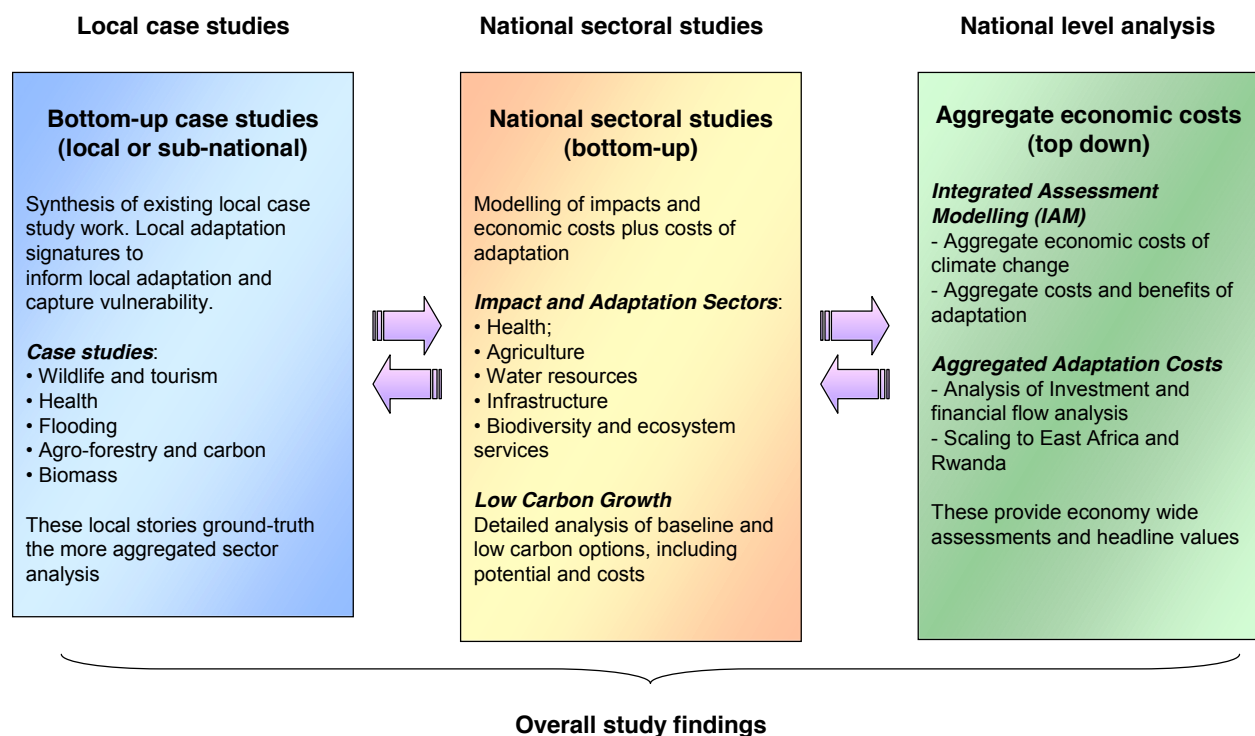


Figure 1. Overview of the lines of evidence.

***The combined evidence across the framework provides information on the economic costs of climate change and the costs and benefits of adaptation, to help inform national priority setting and as input to international negotiations.***

The advantage of this approach is it combines different methods ranging from high-level economic assessment models down to local-level vulnerability studies. This builds up a comprehensive evidence-base for policy makers, and allows the study to cross-reference model-derived aggregations with national and sectoral economics studies and local experiences. It has also allowed the team to compare different

aggregation levels. A key focus has been the use of complimentary information from the different approaches for iterative analyses, where information from one method informs another.

For the national level analysis case studies, there is a very large range of effects that could be assessed. The study has considered the potential effects, building on the existing literature, then analysed the main risks in each sector. Given the timing and resources available, the study has also worked with existing models and information where possible, using both international and local expertise. The analysis has covered many of the key priority impacts. However, the many lines of evidence make harmonisation of data and results more challenging. This study should therefore only be viewed as an initial analysis.

The methods for economic assessment, especially for adaptation, are still evolving. There are very few detailed assessments that have attempted such analysis at the national scale in any regions and there are few studies on Africa. The study has therefore included methods from more formal cost-benefit analysis and more ad hoc approaches as used in the NAPAs. This reflects the fact that any one approach will not be able to cover all the various objectives outlined above, and allows investigation of what works well for different levels and sectors. The lessons that these different approaches provide will be key to future research and the design of subsequent studies. The other challenge for adaptation, and perhaps the most difficult, has been to separate out adaptation to the current climate (often termed the adaptation deficit) from adaptation to future climate change. This is an issue of attribution, but it is key to parts of the current negotiations underway internationally. This is considered further in the adaptation section.

### ***Study team, Local Governance and Partnerships***

The team assembled for the study included a number of international experts on impacts, adaptation and economics. It also worked in partnership with teams in-country. A full team description is included at the end of the document. The study has emphasised national ownership through the inclusion of national bodies, and by working through (and with) a National Advisory Committee to the study. The study was presented at a number of events in Rwanda including during an initial inception phase (late 2009), at the study launch event in March, in presentation of interim results at the Kigali Finance for Development conference and the East African negotiators meeting, as well as an official study launch on November 25, 2009. This consultative approach ensured that stakeholders were identified, consulted and informed, which helped to build national capacity and took advantage of local knowledge. The study also contributed to two week-long workshops to build capacity in Africa, including Rwandan participants.

### ***Report outline***

This report is set out as follows.

Chapter 2 presents the analysis of the possible impacts and economic costs of climate change in Rwanda. It first presents a top-down aggregated assessment using economic models. It then presents a sector by sector analysis including analysis and case studies.

Chapter 3 presents the analysis of the costs of adaptation in Rwanda. It first presents a top-down aggregated assessment based on the emerging estimates for Africa. It then presents a sector by sector analysis including case studies which address the potential economic costs identified in the analysis in part 1.

Chapter 4 presents the analysis of low carbon growth for Rwanda.

More detailed technical annexes support all of these areas. They are available on the project website: <http://rwanda.cceconomics.org/>

## 2. Impacts and Economic Costs of Climate Change in Rwanda

The impacts and economic costs of current climate variability and events in Rwanda are already very significant, not least due to high population pressure. The country has high land use pressures and is exposed to a risk of high degradation of lands and erosion due to floods and rains, as well as desertification trends and droughts in some regions of the East and South-East. These extreme events have dramatic impacts on infrastructure, the built environment and the economy, cutting across key sectors including agriculture, tourism, infrastructure and health.

Rwanda is also likely to be affected significantly by future climate change. Results from several lines of evidence indicate major reasons for concern. Climate change will have significant impacts and economic costs, though there may also be benefits in some sectors and regions.

### ***Climate Projections for Rwanda***

Rwanda has a complex existing climate, with wide variations across the country and with very strong seasonality. It is primarily a mountainous country, with average altitude of 900 m in south-west, 1500 to 2000 m in the south and the centre of the country, 1800 to 3000 m in the highlands of the north and the west and 3000 to 4500 m in the regions of Congo-Nile Crest and the chain of volcanoes. The equatorial climate is modified by this widely varying altitude across the country. It leads to a more temperate climate than much of the rest of East Africa. Average annual temperature in Rwanda range between 16°C and 20°C though they are much lower than this in the higher mountains.

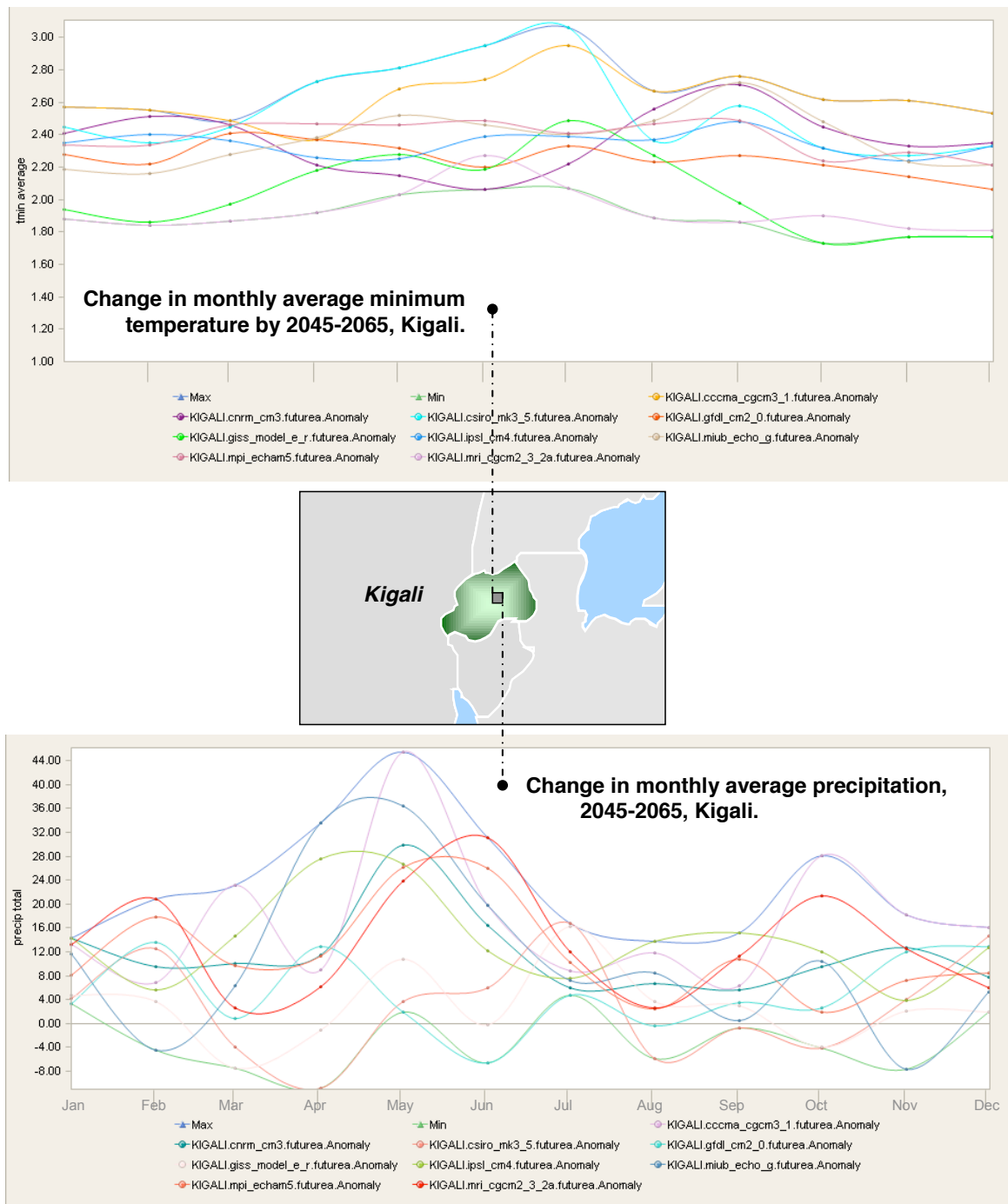
The country has a particularly variable and complex pattern of rainfall, within tens of kilometres. Average rainfall is around 1,250 mm per annum. In broad terms, the annual cycle is bimodal, with two wet seasons: the long rains from mid-September to mid-December and from March to May. The two wet seasons arise from the Inter-Tropical Convergence Zone (ITCZ) moving northwards and retreating southwards respectively. Overall, there are significant inter-annual and spatial variation in the strength and timing of these rains.

There are complex patterns of climate variability, which are due to many factors, notably the El Niño – Southern Oscillation (ENSO) events though also sea surface temperatures in the Indian and Atlantic Oceans. El Niño is associated with anomalously wet conditions during the short rains and some El Niño events, such as 1997, with extreme flooding. La Niña conditions are associated with unusually dry conditions such as during the year 2000 drought.

Given the high complexity and heterogeneity, projections of future climate change are very uncertain at the global scale. Even with regional downscaling techniques, it is very challenging to make predictions of climate futures with the present state of knowledge. For Rwanda, this is hampered by the lack of long-term statistical meteorological data. The study has compared a range of climate projections for Rwanda and investigated available meteorological trends. This involved collaboration with regional partners and experts, as well as using downscaled international data sets from the climate change explorer (CCE) (see box) which compares the projections from nine global circulation models (GCM). The broad trends are summarised below. Unfortunately, due to the lack of historic records, there is only sufficient data in the CCE database for one downscaled station in Rwanda, for Kigali airport. Rwanda has a long series of climatological data “1961-1989 or 1990 (for almost 150 stations) and Kigali Airport for 1961 -2009 period. It has not been possible to use this wider data set within this study, due to the condition of the data and availability, though it would be possible to generate data using correlation with Kigali Airport. This would be an extremely useful step to provide a better pattern of country variations.

## weADAPT Climate Change Explorer

The Climate Systems Analysis Group (CSAG) ([www.csag.uct.ac.za](http://www.csag.uct.ac.za)), based at the University of Cape Town, operates an empirical downscaled model for Africa and provides meteorological station level responses to global climate forcings for a growing number of stations across the African continent. The data are shown below for change in average monthly rainfall and minimum temperature.



**Figure 2.** Projected changes in average monthly precipitation and minimum temperature anomalies across nine GCM models for period 2046-2065 (A2 scenario), statistically downscaled to Kigali. Climate Change Explorer tool, Climate Systems Analysis Group and SEI, 2009.

Analysis of historical temperatures at Kigali indicates that minimum temperatures have been rising faster than maximum temperatures, but with a general overall rise in temperature particularly since 1992. All of the climate model scenarios show future increases in mean annual temperature in future years. The CCE data, based on downscaled data for Kigali's airport station, reports an increase of average maximum monthly temperatures of around 1.5 to 2.7 °C (for a business as usual, no mitigation, scenario) over the range of models by the 2050s (2046 -2065), with greatest warming from July to September. The trend in monthly average minimum temperatures (shown in the box) project a rise of between 1.7 to 2.8 °C for 2046-2065, with the most warming occurring in June to August.

Changes in precipitation are more uncertain. Although the intensity, frequency and spatial distribution of precipitation are unknown, all the climate model scenarios show that average rainfall regimes will change, ranging from positive and negative anomalies across the models. The majority of the projections indicate that average annual rainfall will actually increase, particularly in some seasons, indicating a potential strengthening of the rains which is important in relation to flood risk. However, some models show reductions in rainfall in some months (see box). A shift in the timing of seasons is already being reported in certain regions and this could have a significant impact on agriculture. The range of model results highlights the considerable uncertainty in predicting future changes and the need to consider a robust approach to adaptation decision making to deal with uncertain future climate scenarios.

The information on extreme events (floods and droughts) is much more variable. There is some evidence that the recent intensification of these events since the 1980s is due to the intensity of the El Niño and La Niña phenomena. There may be some intensification of heavy rainfall in the wet seasons, which is particularly important in relation to a greater flood risk and city drainage. Whilst periodic droughts are likely to continue, associated with the current ENSO and affecting some parts of the country, there is wide model variation in terms of the potential change in the frequency, intensity or duration – though some indicate that East Africa may experience more extreme drought events in the future.

### ***Socio-economic projections***

The analysis of the effects of climate change also requires projections of socio-economic information over the same period as the climate projections. These allow specific consideration of Rwanda's current situation and the planned development and economic growth. Rwanda has an estimated population of over 9 million inhabitants, a surface area of 26,338 km<sup>2</sup> and is the most densely populated country in Africa, with about 397 inhabitants/km<sup>2</sup>.

The study has built up a future baseline for the country, to allow consideration of the potential effects of socio-economic change and development in Rwanda. This is important because the future economic costs of climate change are strongly influenced by socio-economic change, due to population growth, increased wealth, land-use change, etc. Indeed, there would still be changes in economic costs in the future, even if there was no future climate change, or expressed in another way, it is inappropriate to assume that climate change will take place in a world similar to today. Previous studies show that these future socio-economic changes are often as important as climate change in future economic costs. The climate scenarios and projections above need to be seen in the context of a future socio-economic conditions, resource management and vulnerability. In many cases, the pattern of future socio-economic scenarios will actually affect future vulnerability: and some choices will affect future effects of climate change in positive or negative ways. These effects need to be considered when designing future policy interventions.



***The projections of future climate change in Rwanda are uncertain. There is a wide range of future change possible, even for future temperature rise. Higher uncertainty is associated with changes in rainfall and there are only emerging indications of the possible changes in extreme events (floods). These future projections need to be seen in the context of future socio-economic conditions, themselves with many possible pathways.***

***Nonetheless, the climate is changing already and the most striking conclusion is that the climate of 2030 (and beyond) is very unlikely to be the same as at present.***

***It is essential to recognise this uncertainty, not to ignore it. There is a need to plan robust strategies to prepare for uncertain futures and not to use uncertainty as a reason for inaction.***

The study has therefore assessed future climate change – and low carbon potential – against a baseline of expected growth and development consistent with Vision 2020 goals, i.e. rapid economic growth towards middle-income country status. This will be built on a development away from subsistence agriculture towards a knowledge-based economy through development of the private sector, high value agriculture, services and industry. These efforts will require adequate infrastructure, energy, water and land resources in the context of high levels of population growth, urbanisation and economic growth. While the study has not undertaken a full uncertainty analysis on these projections, some sensitivity analysis has been included to investigate how alternative futures might influence the study results.

## **2.1. Aggregate Economic Estimates of Climate Change in Rwanda**

The study has used top down economic modelling to estimate the aggregate effects of climate change in Rwanda. It has used a number of the global economic integrated assessment models (IAMs) which provide highly aggregated information on potential economic costs using a framework that links emissions, climate change and impacts on the economy, though this level of aggregation requires assumptions and simplifications. The study has worked with two of the leading global IAMs; the FUND and PAGE models.

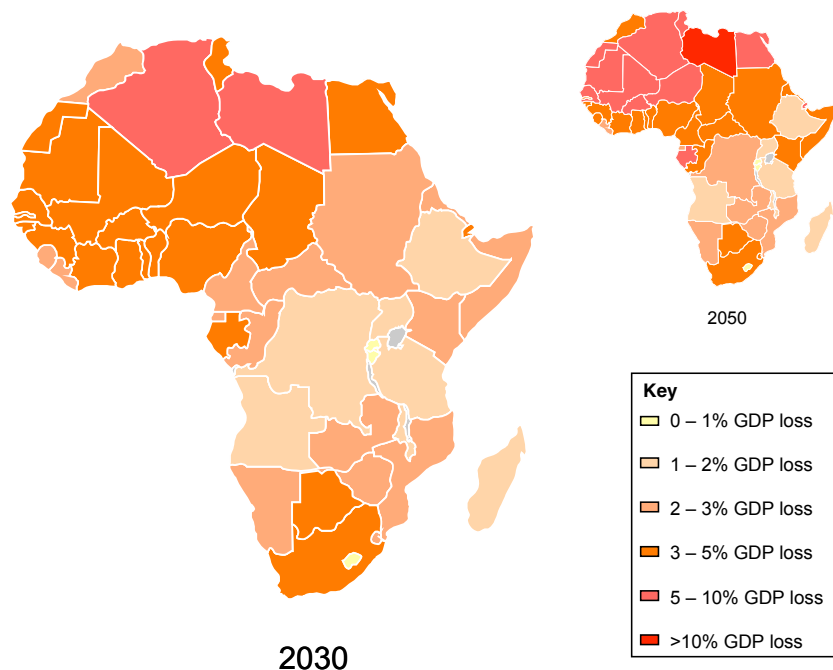
The analysis has been undertaken at the continent wide level, with some dis-aggregation at country level. The first finding from these model runs is that the relative economic costs (as a % of GDP) from climate change in Africa are likely to be higher than in other world regions. Africa is particularly at risk (vulnerable), due to the large number of areas prone to existing floods and droughts, the number of regions that are already close to tolerance limits in terms of heat or water availability, and low adaptive capacity.

The FUND model runs (see figure) estimate that climate change could lead to annual economic costs of (market exchange rates) by 2030, equivalent to just under 1 % of GDP<sup>3</sup> each year in Rwanda (central value, including market and non-market sectors, aggregating positive and negative effects), which would equate to annual (central) costs of \$40 million/year. This is lower than in many other African countries, due to the higher elevation and high relative rainfall levels in Rwanda. Nonetheless, the compound effect

---

<sup>3</sup> Note that some of the costs counted as climate impacts are not part of GDP— thus the comparison is only a relative indication across countries and not a direct measure of the effect on the economy. For instance, soil erosion is not counted in GDP, although the loss of soil due to intense storms would be a climate impact.

of these economic costs each year would be significant over time. Moreover, this model excludes future flood events, which are of particular concern for Rwanda.



**Figure 3. Annual Economic Costs from Climate Change as a Fraction of GDP in Africa.**

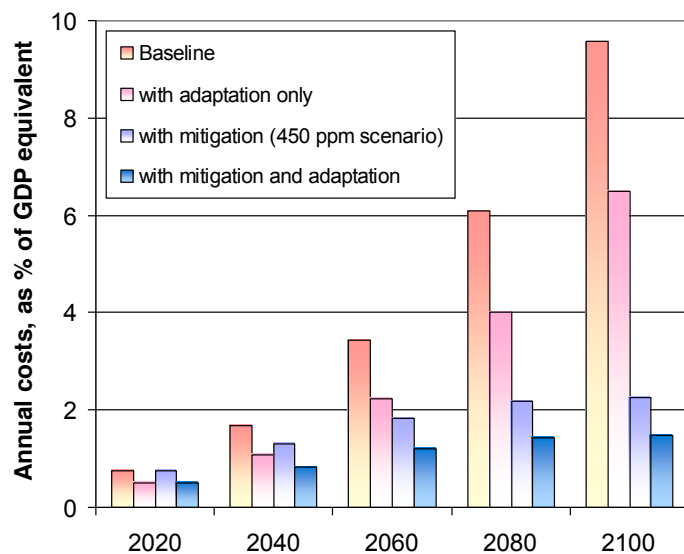
Source FUND national model

A second series of runs with another model, PAGE, has investigated the aggregated costs of climate change in Africa for different scenarios, and aggregated costs and benefits of adaptation.

The model shows that in the absence of global mitigation, economic costs from climate change in Africa could be extremely large. The central values from the model are shown in the figure. Moreover, there will be high economic costs even with adaptation.

An additional run has been undertaken with a stabilisation scenario, with a central expectation of achieving a 2°C target. This reduces the future economic costs, particularly in later years, avoiding more severe potential economic costs. With adaptation, the residual impacts are manageable.

This emphasises the need for global mitigation, as well as local adaptation. Note that adaptation needs are similar in early years in both scenarios, due to the change already locked into the system.



**Figure 4. Annual Mean Economic Costs from Climate Change as a Fraction of GDP in Africa.**

With mitigation and adaptation. (Source PAGE model)

These estimates are indicative only. They provide some insights on signs, orders of magnitude, and patterns of effects. The results are dependant on a variety of factors including the assumed growth

trajectory, population assumptions on impacts and economic costs and they combine positive and negative effects. Finally, the models reflect only a partial coverage of the effects of climate change and exclude several effects that would be potentially important for East Africa (including flooding and droughts, cross-sectoral links and socially contingent effects, and the cumulative effects on adaptive capacity).

***While there is high uncertainty, the integrated assessment models indicate that the additional economic costs of climate change could be equivalent to almost 1% of GDP each year by 2030 for Rwanda (central values), noting that this excludes any changes in extreme events.***

## 2.2. National bottom-up sectoral assessments and case studies

The study has also undertaken bottom-up analysis at national level. These assessments have, where possible, considered potential impacts and economic costs for a range of sectors and regions. This national level modelling has been complemented with local case studies. Overall results are reported by sector. Further details are provided in the sectoral technical annexes, available on the project web-site.

To capture climate change uncertainty, the study analyzed a range of future scenario projections using downscaled outputs from ten GCM models, rather than considering single future projections, in addition to historic climate trend analysis.

Given the potentially wide range of possible effects, across and within sectors, from climate change, the study has focused on a number of priority sectors. The choice of priorities was aligned to those identified in the NAPA and the 1st National Communication. The NAPA identified high vulnerabilities to climate change of the population and sectors of agriculture, water resources and energy due to mutual influences and cumulative impacts of:

- High degradation of arable land due to erosion, following torrential regime of rains in Northern regions (Gisenyi, Ruhengeri and Byumba), Centre/West (Gitarama, Kibuye, Gikongoro) and floods in their downhill slope;
- Desertification trend in agro-bioclimate regions of the East and South-East;
- The lowering of level of lakes and water flows due to pluviometric (rainfall) deficit and prolonged droughts; and
- Degradation of forests.

These translate into a high degree of vulnerability for the majority of Rwandans whose livelihoods are dependent on rain-fed agriculture and ecosystem services. Effects of climate change are likely to be more pronounced in Rwanda due to the combination of high vulnerability and low adaptive capacity.

A number of additional categories of potential impact were added following an initial literature review by the study. The first involved widening the consideration of floods to infrastructure. The second included a consideration of the urban built environment and energy (supply and demand). The final area considered a much wider consideration of ecosystem services including wildlife tourism assets.

The bottom-up analysis is presented by sector below.

## Health

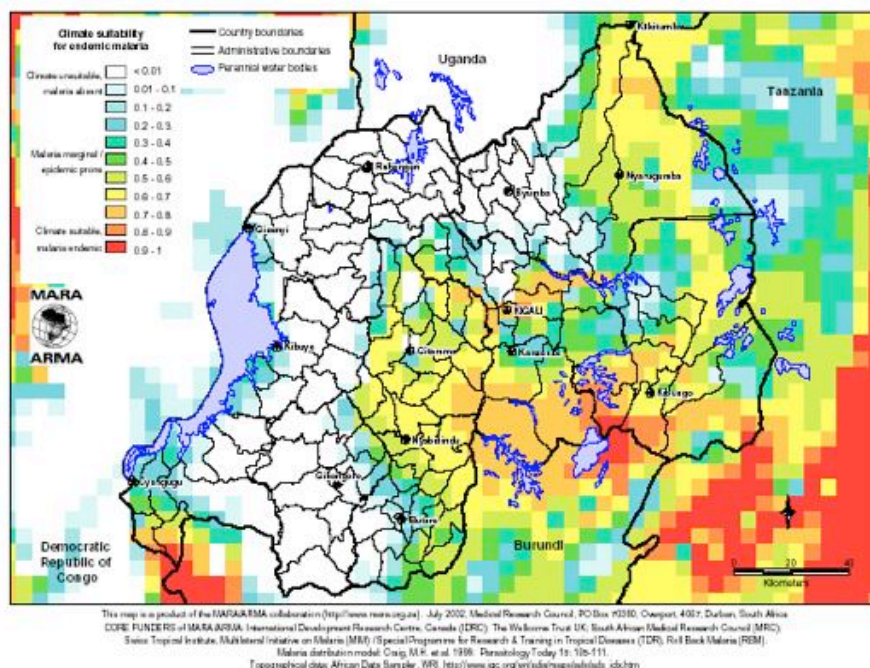
### Background

Climate change is likely to affect human health, either directly such as with the effects flood injury, or indirectly, for example, through the changes in the transmission of vector-borne diseases or through secondary effects following flood events. There are also a wider set of indirect impacts from climate change on health, which are linked to other sectors (e.g. water quality, food security, etc). All these health effects will have economic consequences, through the direct medical costs, health protection costs, lost time at work, and welfare changes.

Previous work has identified a potentially wide range of health effects from climate change in East Africa and Rwanda. This includes the potential shift or increase in incidence of malaria, diarrhoea, schistosomiasis and the potential for heat related mortality and morbidity. It also includes the increased incidence of deaths/injuries/disease linked to flooding and the indirect effects caused by displacement, disease outbreaks, etc. There are other indirect effects associated with changes in the risk of under-nourishment and malnutrition, and wider effects between economic and development levels and health.

### Analysis and Results

The study<sup>4</sup> has focused on one of the major future risks, malaria. A full technical report is available on the health study at the web-site (<http://rwanda.cceconomics.org/>). This section summarises this work. The current burden of climate-sensitive disease is high in Rwanda. The main potential impact identified in most assessments is malaria, which is one of the most physically and economically debilitating diseases in the region. It is one of the leading causes of morbidity and mortality in Rwanda, and the reason for 40% of all health centre visits. With its extensive highlands the country is particularly sensitive to changes in climate where the disease is, at present, restricted by temperature.



**Figure 5. Distribution of Endemic Malaria.**

Source: MARA/ARMA

<sup>4</sup> Undertaken by London School of Hygiene and Tropical Medicine: Menno Bouma and Sari Kovats, plus Alistair Hunt, Metroeconomica, in partnership with GGISNUR (Rwanda). We would also like to thank the Rwandan Ministry of Health and TRAC Plus Malaria Unit

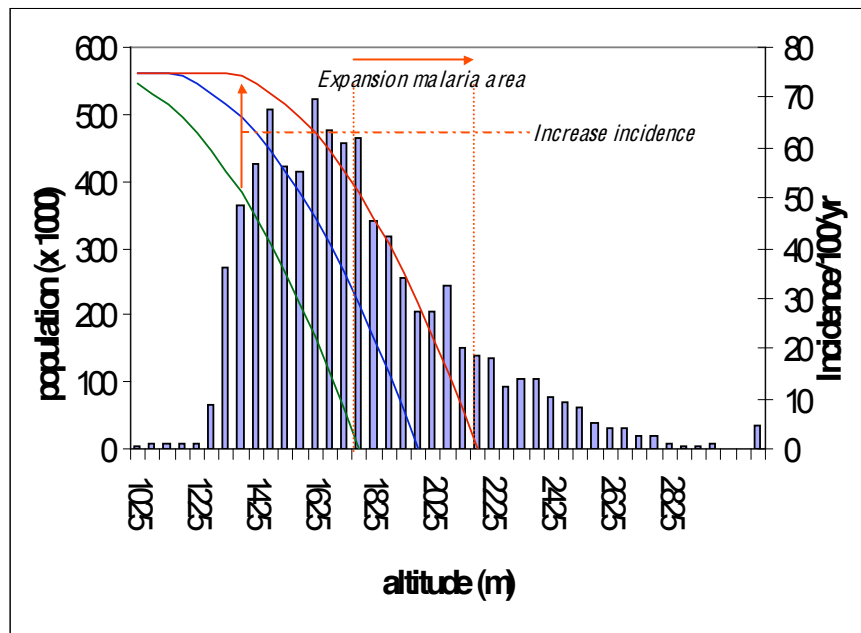
Climate change dependent shifts in altitude related malaria, and the distribution of the population in the highlands, allows for an assessment of the impact on malaria's clinical and economic malaria burden.

Rwanda is particularly sensitive to future changes in climate because a large part of the population lives at higher elevations, where the disease is, at present, restricted by temperature. The greatest burden of climate-sensitive diseases falls upon the poorest and most vulnerable.

A new malaria risk model was applied based on altitude, tailored to assess, on a national and intermediate/long time scale, the impact of climate change on malaria. The model uses the product of incidence times population size to estimate an absolute amount of malaria in Rwanda. Taking the sum for all altitudes provides a measure for expected changes in malaria, taking into account the altitudinal distribution of the population in the country.

The expected changes in temperature from climate change have been directly be translated into changes in malaria exposure, and applied to the rural population size known for each 50 meter stratum in the country. The figure shows the overall analysis and the malaria lapse rate (in green) against rural population (blue bars). The change from the 1980s (green) to present (blue line) can be compared against future projected increase in temperature (red line).

In the 2050s, as a result of climate warming (2.2°C, the central projection), the population at risk for malaria in rural areas over 1000 meter (99% of the population) is predicted to increase by 153%. Approximately half of this predicted increase in mean temperatures has already occurred since the 1980s, and is likely to have raised the national burden of malaria in recent decades.



**Figure 6. Malaria risk model in Rwanda.**

Note: rural population distribution with altitude, Rwanda (blue bars). Estimated incidence (per 100 per year) in the 1980s (green line), present (blue line) and 2050s (red line).

The shift of malaria to higher altitudes exposes new populations to malaria transmission. On a short temporal scale and for relative short time series, gradual climate change is difficult to disentangle from the

interannual variability and so not easily observed. However in medium and long time scales the uphill shifting trend of malaria, without adaptation, is likely.

Potential increases in rainfall for some scenarios (14.7%), and rainy days (11.3%) would be spatially more heterogeneous, and less robust than those for temperature, and might increase the estimates based solely on temperature based in this study<sup>5</sup>.

The absolute malaria burden resulting from climate change and the associated economic costs will depend on more accurate estimates of the present burden and the increase of the rural population (at present estimated at 2.75% per year). In practice future burdens will be strongly influenced by a variety of factors including future socio-economic development and income levels.

Other determinants of the current and future malaria burden not addressed in this study include: changes in land use, socio-economic development, control efforts, changes in efficacy and affordability of antimalarials and insecticides, possible developments in developing an effective and affordable vaccine, and the prevalence of co-infections such as HIV/AIDS. At current population levels, the most conservative assessment taking only temperature changes into account suggests that, annually, a central projection of an extra 2.52 million people will be affected in the 2050s as compared to the 1980s, in absence of adaptation (and assuming no rural population growth from 2009<sup>6</sup>). Excess mortality is estimated to be in the order of 7,300 people per year, of which 6,350 are below the age of 15. Additional hospitalizations (about 20,000 per year for infants) will stretch existing facilities. In areas where malaria becomes newly established, and where populations will become prone to epidemics, extensive mortality in the economic active age group can be expected. On the medium time scales considered in this study, the epidemic belt will extend to regions with a complete lack of herd immunity, with serious clinical and economical consequences for morbidity and mortality. On a long time scale, the epidemic burden will stabilize when malaria becomes more endemic, and if warming is not halted, will gradually decline and disappear. In the process, the relative protection of the highland population against malaria will be lost as the endemic potential spreads, and will saddle the country with a permanent economic burden.

The additional burden of endemic and epidemic malaria in 2050s are estimated to be (for population levels of 2009) between \$ 61 million to 77 million annually (central estimate). These figures include direct costs (out of pocket expenses, e.g. for medication), indirect costs (loss of earning), disutility costs, (e.g. other costs, discomfort pain and inconvenience), costs for hospitalisation (< 5 yr), and the economic value of Life Years Lost (based on the minimum wage). These estimates do not take the potential rainfall related increases into account. The estimation of the malaria's economic burden resulting from climate change is sensitive to adult mortality resulting from epidemics. Contrary to the declining "epidemic costs", the "endemic costs" are long-term, and will continue to rise (e.g. Annual DALYs lost in the population over 14 yrs associated with increases endemic malaria reaches 20,000 In the 2050s). Apart from limiting the impact of epidemic malaria, a permanently higher health budget will be required to mitigate endemic malaria on higher altitudes. These measures will require a considerable investment in diagnostic, treatment, preventative and control measures.

## ***Water and Infrastructure***

### ***Background***

Water is a critical sector and climate change affects the whole water cycle and water ecosystems. Changes in precipitation, evapo-transpiration, river flow and groundwater systems affect water availability and the function and operation of existing water infrastructure (including hydropower, navigation, irrigation

---

<sup>5</sup> Note that the actual changes are complex to predict. An increase in patchiness—episodes of intense rain followed by intense heat might actually reduce the micro-habitat for mosquitoes as the breeding grounds are first destroyed by the runoff and then dry up within a day with the heat before the full breeding cycle is completed.

<sup>6</sup> Future population projections are available for Rwanda. However, the method here only considers the rural population, thus urbanization rates would also be needed. Because of the extra uncertainty in trying to predict the net effects, the study applied to the current population only.



systems, drinking water supply and waste water treatment). Water is also essential in energy supply, agriculture, tourism, industry, etc. across the Rwandan economy. Ancillary stresses of land-use change and erosion, pollution and sedimentation exacerbate vulnerability to current and future climate risks.

For East Africa and for Rwanda, water is also associated with climatic variability and extremes. The East Africa region is subject to periodic extremes with serious floods or prolonged drought, associated primarily with El Niño – Southern Oscillation (ENSO) events. These events lead to large economic costs associated with damage / losses and historically have also had high social impacts, associated with famine. The El Niño is associated with wet conditions during the short rains and some El Niño events, such as 1997 and more recently 2007, with extreme flooding. La Niña conditions are associated with unusually dry conditions such as during the drought in the year 2000.

The eastern and southeast regions are more affected by prolonged droughts while the northern and western regions experience abundant rainfall that at times causes erosion, flooding and landslides

These episodic events can be traced back over the last 100 years – they are associated with the current climate and present needs to adapt to climatic risks, that is, they are not directly attributable to future climate change. However, there are some indications that climate change may have led to an intensification of some of these events over recent decades. The rising consequences of historical events are determined as much by historical socio-economic change, i.e. the changes in land use and land cover that have occurred with population, socio-economic growth, land-use patterns in Rwanda, as the historical climate change.

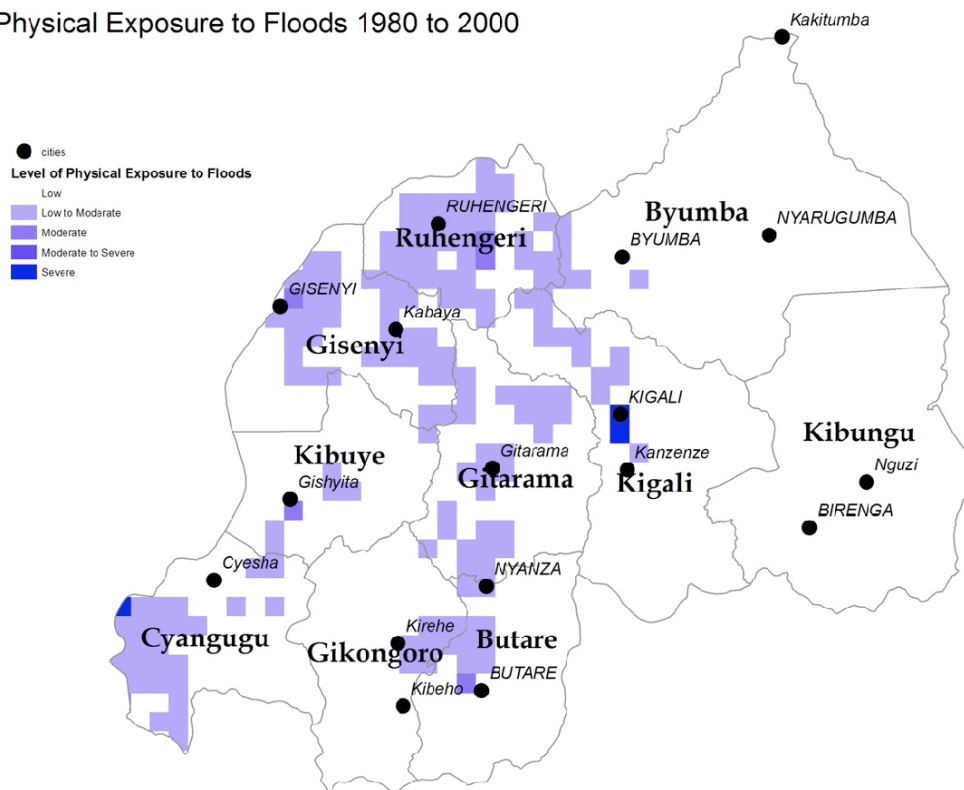
#### Analysis

The study has investigated the economic costs of these historic events. The study has looked at the international information on the number of deaths, number of people impacted and direct financial losses and then estimated the total economic costs of the events. An example with the 2007 floods is presented below. It is estimated that even a sub-set of the impacts of this event had a cost equivalent to around 0.6% of GDP. This only includes the direct economic costs of household damage, agricultural losses and fatalities. It does not include the wider economic costs of infrastructure damage (including damage to the transport sector), water system damage and contamination, soil erosion and direct and indirect effects to individuals. It is anticipated that the total economic costs of the 2007 floods would be many times higher than the value above, potentially at a level equal to several percent of GDP equivalent.

In 1997, serious floods linked with El-Nino episode of 1997/98 destroyed a large number of agricultural plantations and ecosystems occupying shallows and swamps of Nyabarongo and Akanyaru river basins.

The NAPA outlines the high degradation of arable land due to erosion, following torrential rains in Northern regions (Gisenyi, Ruhengeri and Byumba), Centre/West (Gitarama, Kibuye, Gikongoro) and floods in their downhill slope. It also identifies the negative effects of landslides and landslips in the North (Gakenke, Cyeru, Rulindo, Butaro, and Kinyihira) and the West (Nyamasheke, Karongi and Ngororero) of the country in 2001/2002.

## Physical Exposure to Floods 1980 to 2000



**Figure 7. Location and Exposure to floods in Rwanda**

From 1999 to 2000, a prolonged drought seriously affected Bugesera, Umutara and Mayaga regions and there were similar drought effects in 2005/6.

Predicting the potential future economic costs of any changes from these events from climate change is extremely challenging, not least because the future projections are so uncertain.

Predicting the potential future economic costs of events similar to (or more severe) than these from climate change is extremely challenging, not least because the future projections are so uncertain. Recent projections from climate models suggest that in the coming decades, climate change will intensify the hydrological cycle and increase the magnitude and frequency of intense precipitation events. Flood events can affect infrastructure, through inundation leading to disruption, loss of operations and flood damage such as the washing away of infrastructure (including rain induced land-slides). The impact is particularly severe in terms of health, livelihoods and fatalities when critical infrastructure such as water treatment plants, roads and power sources are affected.

The potential impacts of such future events are also determined by socio-economic trends. A significant part of the recent trend of increased flood impacts can be attributed to the increase in population, including urbanisation, and increased value of assets in flood-prone areas. Other factors include changes in the terrestrial system, such as deforestation and loss of natural floodplain storage, as well as to changes in climate. Similarly, the trend in future impacts will also be determined by these socio-economic drivers as much as by any changes in future climate.



## The Economic Costs of the 2007 flood

There was a recent significant rainfall event in September 2007, which led to fatalities, property loss and displacement in two districts of Rwanda: Nyabihu and Rubavu. Based on a review of EM-DAT (lower estimate) versus aid agency reports (UNDP/IFRC) and news articles (higher estimate), the study has estimated the direct effects of the event.

For valuation, the analysis uses market prices to value the loss of crops/yields, the economic costs of fatality and Rwanda - specific data on house construction costs.



**Figure 8.** Floods 2007 in Bigogwe, northern Rwanda (Rose Mukankomeje, REMA).

Sector	Physical Impacts	Estimated economic cost (2007\$mn)
Health (mortality)	18-20 deaths	1.67 to 18.8 (depending on valuation estimates used)
Property	342-706 houses destroyed 678 houses damaged 2188 to 2369 individuals displaced	0.50 to 0.85 (replacement) 0.16 (displacement)
Infrastructure	Damage to roads, bridges, other	Not estimated
Agriculture	2500 hectares flooded	1.72
Water	Water system damage, contamination	Not estimated
Other	Education - loss of school materials	Not estimated
<b>TOTAL</b>		<b>\$ 4.1 to 21.5 million</b>

It should be noted that this is only a very limited selection of the impacts – and an even smaller proportion of full economic costs. There are likely significant indirect health effects of the floods and no costs of the replacement of infrastructure are shown in the estimates. However, even with these omissions, the losses are estimated at \$4 to \$21.5 million. This is equivalent to economic costs that are equivalent (noting it includes market and non-market effects) of around 0.6% of GDP in 2007. When the full effects of the events are included, the total economic cost would be likely to be significantly higher.

***Existing climate variability has significant economic costs in Rwanda. The periodic droughts experienced lead to large economic costs, for individual events and as reductions in growth over time. It is clear that Rwanda is not adequately adapted to deal with existing climate risks***

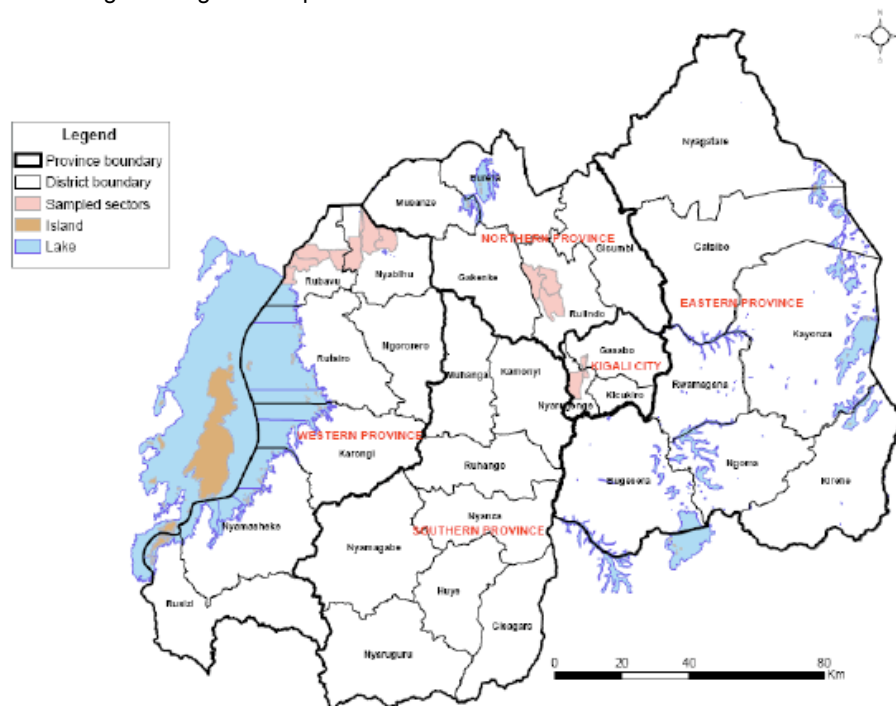
Further case study work has been undertaken on the historic costs of floods. The full case study '*Physical and Economic Flood Impacts and Adaptation Costs in Rwanda*'<sup>7</sup> is available on the study web-site (<http://rwanda.cceconomics.org/>).

To highlight the potential future costs of climate change, it is possible to adopt a "historical analogue" approach to value the impacts of different climate related events. However, these effects will occur under different socio-economic conditions from those experienced in the historic weather events above.

<sup>7</sup> Undertaken by local partners GGISNUR: Jean Pierre Bizimana and Theodomir Mugiraneza, with Contributors: Dr Jean Nduwamungu, Dr Emmanuel Twarabamenye, Mis. Marie Christine D. Simbizi, Mr Edward K. Mwesigye

## Case Study 1: Analysis, Field Work and Surveys of Recent Flood Effects in Rwanda

The study has undertaken new work to try and assess the economic costs of floods in Rwanda. Flood events which resulted in significant damages include 1988, 1997, 2006, 2007, 2008, and 2009 where rainfall resulted in landslides, houses destruction and high damages to crops.



**Figure 9.** Sampled sectors for the case study

Source: GGISNUR Case Study:

Field work was conducted in three areas at sector level namely Rubavu District, Rulindo District and Kigali City. Data collected were related to various floods effects on buildings, transport infrastructures (especially roads) livestock, human being lives and physical environment. Techniques used for gathering needed data and information included checklist, interviews and direct observation. Additional data were gathered through library resources, archived pictures and pictures taken during field work. Given that data and information collected were based on multiple sources of evidence, analysis was guided by triangulation technique.

The three case studies revealed that floods are differently affecting the country due to the climate signal, the in situ topographic characteristics and land use. Practice. For instance, the Nyabugogo River Plain, located in a narrow valley within Kigali City, faces flood risks each rain season, especially from March to May. Food damages are considerable mainly because of informal settlements erected in flood-prone areas. As a result of the 2002 flood, the road connecting Kigali City to Southern Province was impassable and residential and commercial constructions were destroyed and inundated. Likewise, the 2006 flood resulted in the destruction of 40 houses, two fatalities and flooding of shops in Kiruhura Market and nearby factories. Due to inundation since 2003, Kigali City Council decided, in 2006 to relocate the market to the new site. Various strategies were also adopted by the population to cope with flood risk including construction of temporary ditches, water diversion away from houses, sandbags placements, etc. Because of limited capacity of urban planning authorities to control urban development in flood zone and limited coping capacity of local residents to mitigate the floods, the vulnerability to flooding is increasing.

The second case study was Bahimba Valley located in Rulindo District. Areas around the valley are affected by floods. For instance, the 2005 flood destroyed field crops, bridges, caused environmental degradation and road degradation. It also destroyed two commercial buildings, whilst 11 others were critically damaged.

The third case study was Nyabihu Musanze and Rubavu districts. Sectors located on the down stream of Gishwati forest were recently affected by flooding. In Nyabihu and Musanze districts, the 2007 flood killed 20 people; while 4 000 others were displaced. In addition, 706 houses were destroyed and many hectares of crops were damaged. In 2009, heavy rains destroyed 208 houses and 635 hectares of crops.



**Figure 10.** Flooded settlements in Nyabihu District, Jenda Sector in September 2007

While it is impossible to consider all factors that will affect the future economic costs of severe events in detail, it is possible to highlight the major issues qualitatively and then to assign some quantitative weights to assess the likely influence of major determinants such as population size and the level of GDP. The study has considered the potential changes in Rwanda in terms of major damage categories of property, displacement, forestry, transport, utilities, emergency costs, health, agriculture and industrial production. This does not consider any adaptation option, or change in planning policy or construction.

The results indicate very large increases in future potential costs of such flood events, driven strongly by socio-economic trends (population and GDP per capita growth), which alone could account for a 5 fold increase in their economic costs. Even without climate change, addressing flood risks is a priority for Rwanda.

The study has also considered the potential increase in events (number or intensity) under a projection of climate change. The model projections (see earlier sections) indicate a potential increase in rainfall is possible with some potential for heavy precipitation events, which would be associated with flooding. As well as the outputs from the models outlined earlier, the study has considered the results reported in the IPCC AR4 and recent comparison of results from Shongwe et al (2009<sup>8</sup>). This study forecasts an increased intensity of extreme rainfall events in much of East Africa, based on a variety of model projections.

Over the western parts of this region, which includes Rwanda, mean precipitation is projected to increase potentially by more than 10% (by 2100), with similar % changes in the 10-year wettest seasons and events, implying that floods could become more intense (though the degree of change varies widely across the model projections, with some models indicating up to a 50% increase in the highest rainfall events over the long-term). As outlined above, flood events have major effects on key infrastructure. The projected increase in intensity resulting from climate change would also be likely to increase the relative economic costs of periodic flood events, because damages generally rise (non-linearly) with greater flood depth and strength. Even when the effects of these periodic events are annualised, they will lead to additional economic costs. The need to increase resilience to floods is therefore a priority.

While many of the models predict increases in rainfall on average as a result of climate change, droughts are also likely to continue, although it is unclear whether the intensity of these events will change. Some of the projections indicated low-rainfall extremes (potentially associated with droughts) could actually become less severe in Rwanda.

---

<sup>8</sup> Shongwe, M.E., van Oldenborgh and van Aalst (2009). Submitted to Journal of Climate. Projected changes in mean and extreme precipitation in Africa under global warming, Part II: East Africa. Nairobi, Kenya, 56 pp.

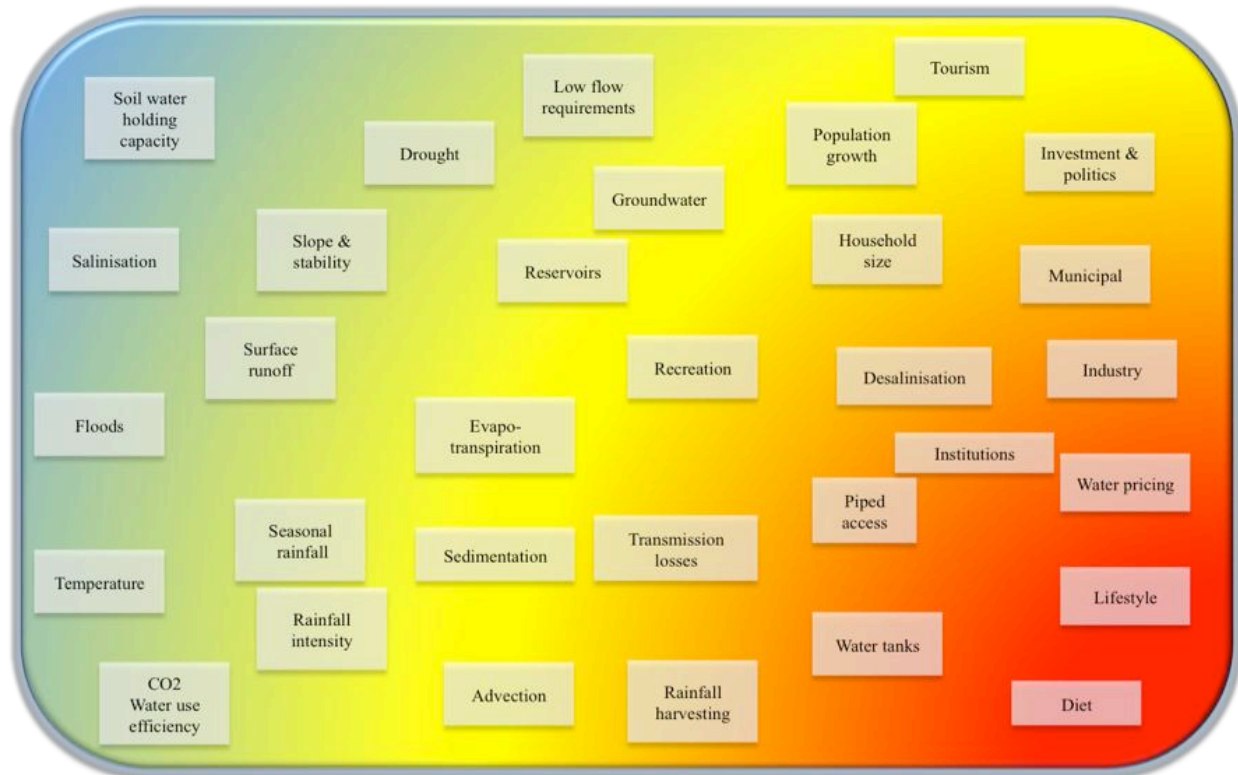
## Water resources

Rwanda's is characterized by a dense network of lakes, rivers, and wetlands. Indeed, water is a valuable natural resource. Approximately 210,000 ha, 8% of the entire country, are under water; lakes occupy about 128,000 ha, rivers about 7,260 ha, and water in wetlands and valleys about 77,000 ha.

The country is divided into two major drainage basins, the Nile to the east and the Congo to the west. The Congo basin covers 33% of Rwanda and handles 10 percent of all national waters. The Nile basin covers 67% and delivers 90 % of the national waters. The forested area of Nyungwe National Park is Rwanda's major watershed for both the Nile and the Congo basins. The waters of the Nile basin flow out through the Akagera river system, which contributes 8 to 10% to the Nile drainage system (USAID 2008).

The network includes numerous lakes: In the Congo basin Kivu is the only lake. However, the Nile basin has six groups of lakes, namely: the lakes of the north, lakes Bulera and Ruhondo and other small lakes; the lakes of the centre: Muhazi; the lakes of Bugesera: Rweru, Cyohoha (south and north), Kidogo, Gashanga, Rumira, Kilimbi, Gaharwa; the lakes of Gisaka: Mugesera, Birira and Sake; the lakes of the Nasho basin: Mpanga, Cyambwe and Nash; and the lakes of the Akagera National Park: Ihema, Kivumba, Hago, Mihindi, Rwanyakizinga

Despite Rwanda's abundant natural water resources endowment, underdeveloped access has resulted in some areas of water scarcity. Total annual renewable water resources are estimated to be 6.3 km<sup>3</sup>/year, with agriculture, domestic and industry as the dominant users. The effects of climate on water supply and demand is not limited to the impacts of rainfall on hydrological systems. Climatic, social, economic and management factors are in play, from the very local balance of water used by plants in an atmosphere with higher carbon dioxide concentrations to the shifting demands for water from the tourist industry (see figure below). There is also the issue of hydro discussed in the next section.



**Figure 11. Range of factors affecting vulnerability, impacts and adaptation to climate change in the water sector.** The factors are roughly arranged from supply to demand (left to right) and from local/micro to regional/macro scale (bottom to top).

## **Energy**

### **Background**

Climate change is expected to have a direct effect on both energy supply and demand, as well as on energy related infrastructure. It is therefore a key sector and links with the low carbon analysis outlined later in the report. The energy sector is affected by the potential changes in extreme events, discussed above, but also from slow onset climate change, in relation to energy demand and higher average temperatures. Previous studies have shown that in other regions, the changes to the energy sector are amongst the most economically important and they emerge as a key driver in the overall FUND model results shown above.

The study has investigated the effects of climate change on the energy resources (supply side) for Rwanda. The study has also investigated the potential changes in energy demand from higher average temperatures.

The electricity generation sector has been considered in more detail in the low carbon growth study (see later section and more detailed annex). The generation mix in Rwanda has a high proportion of hydro power, and in recent years, poorly protected watershed areas and erratic rains have affected Rwanda's hydroelectric power generation resulting in an additional economic cost of 65, 000 US\$ a day<sup>9</sup> for additional diesel generation. However, these issues appear to have arisen from a combination of issues relating to land-use practice and generation management, rather than directly due to shifts in climate.

For the energy sector, the relatively high level of hydro generation in the Rwandan electricity mix might increase future vulnerability to a changing climate. However, most models predict modest increases in average rainfall, though average temperature, evaporation/evapo-transpiration and run-off are also important in generation. More detailed regional assessment has been undertaken in other studies as part of the Nile Basin Initiative, as part of a regional hydro study<sup>10</sup>. This considered Rusumo Falls on the Kagera river (Burundi/Rwanda/Tanzania) and Ruzizi III on the Ruzizi river (Rwanda/DRC). The study also looked at run-off and storage-yield. Overall, the study predicts that average runoff, and thus generation, would increase in these regions, based on average model results and that there was a low risk of negative effects (though possibly some issues with variability, especially for smaller reservoirs). A greater concern may arise from the potential for more extreme events, particularly greater rainfall intensity, which would necessitate some planning for greater flood control for future projects. Future socio-economic changes such as land-use patterns and water resources use will also be important.

Outside temperature affects heating and cooling requirements which in turn affects energy demand with demand increasing with both colder temperatures (heating in homes, offices and factories) and with higher temperatures (cooling and air conditioning). The average temperature increases associated with climate change will, in general terms, decrease the demand for heating in colder months and regions (a benefit), but increase the demand for cooling in hotter months and regions (an impact but also an adaptation), though the scale of these effects is strongly determined by the climatic zone and socio-economic conditions. On top of the pattern of average warmer temperatures, the models also project increases in the number of heat extremes (heat-waves).

### **Analysis**

Space cooling is already a major source of energy demand in tropical and subtropical cities, even for middle income countries. Cooling demand is strongly linked to income, and this becomes important in relation to the Vision baseline and growth rates, increasing the costs of electricity and also increasing GHG emissions when this demand is met through fossil generation (a notable link between adaptation

---

<sup>9</sup> By 2006, Rwanda was spending about 65,000 USD a day for diesel to power electric generators as a result of decline in water levels in Rugezi wetland, see <http://www.lse.ac.uk/collections/africaClimateChangeForum/pdf/Dr%20Rose%20Mukankomeje.pdf>

<sup>10</sup> Strategic/sectoral, social and environmental assessment of power development options in the Nile Equatorial Lakes region. Supplemental analysis – Climate change and potential impacts on hydro generation. Interim report - Climate change and impacts on runoff. August 16, 2006. SNC-Lavalin International Inc. Stratus Consulting Inc.



and low carbon growth). There can also be an issue with cooling for IT – important given Rwanda’s aspiration to be a major IT hub and a service based economy.

The net changes in energy demand will vary with location across Rwanda. These effects are likely to be particularly important at the city scale, due to the concentration of population and industry, and because of the urban heat island effect. They will also involve differences in primary energy between heating (biomass and some fossil heating) versus cooling (electricity). Note that for the more vulnerable, lower income groups, there will not be access to cooling options, and thus they have a much greater risk to higher temperatures, both in relation to the potential health impacts of extreme events (and health risks) but also in terms of lower productivity.

The study has assessed the potential cooling burden from climate change. This uses the metric of Cooling Degree Days (CDD), which provide an indication of the number of days when cooling might be required, based around thresholds of temperature, and the total cooling demand across the year for these days. Note that they give an indication of burden, rather than necessarily economic costs (it depends whether this cooling demand is supplied).

There is no officially designated base temperature for CDD. The study has used 22°C on the basis of building management practice and values used in other studies.

The study has estimated the projected future days when average daily temperature is above the base temperature of 22°C, the temperature difference is calculated, and this is then summed for all such days in a given year. The analysis of the baseline period shows effectively no cooling demand. Under model-simulated baseline conditions, there are between 150 and 320 CDD in Kigali.

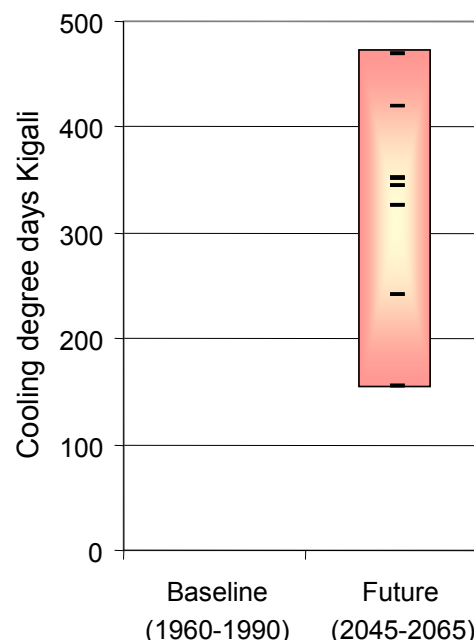
While the increase is dramatic, because it is from such a low baseline, the absolute levels are modest compared to other neighbouring countries. This does not appear to be a major priority burden. However, it could be an issue for peak temperatures at certain times of year.

## Agriculture

### Background

Agriculture is still a mainstay of the Rwandan economy. Much of the Rwandan population is still rural and agriculture sustains much of the population. Agriculture contributes about 39% of GDP in current prices (as of 2005), employs about 88 percent of the economically active population (much of it employed only seasonally), and is the main earner of foreign exchange, supplying up to 80% of export<sup>11</sup>. While the importance of this sector to the economy is declining as a proportion of GDP, it is, and will continue to be, extremely important.

For the majority of the poor in Rwanda, agriculture is a main livelihood strategy. The population living below poverty line is estimated at 60%, of which 66% live in rural areas and around 43% of the population is in a situation of extreme poverty. A very high percentage of the population is engaged in subsistence



**Figure 12.** Cooling degree days (Kigali). The lines show the individual model projections and the bar shows the full range.

<sup>11</sup> Republic of Rwanda (2009). Ministry of Agriculture and Animal Resources. Strategic Plan for the Transformation of Agriculture in Rwanda – Phase II. (PSTA II) Final Report. February 2009

farming. The dominant farm type is smallholder. Additionally, livestock production is central to livelihoods and food security. As elsewhere, farmers are increasingly called upon to provide services beyond growing crops. Protection of watersheds, control of soil erosion, maintenance of wetlands, protection of natural forests and biodiversity, supporting natural wildlife are all common development objectives that entail some contribution from agriculture. Pilot schemes on payment for ecological services and community carbon sequestration have shown considerable promise.

As highlighted above, weather-related hazards already present a serious threat to agriculture. Floods are a particular hazard for the agricultural sector and as outlined above.

It is possible that these events will be exacerbated by a mix of climate and socio-economic change. However, the prediction of these effects is challenging.

From recent survey data, the populations with the greatest risk of being affected by climate change are the food insecure and otherwise highly vulnerable groups (e.g. disease burdened). Areas where access to food is most problematic include the Eastern Curve, Bugesera, Southern Plateau and Lake Shore areas where over 45% of the households have weak access to food.

Similar trends are found in the former provinces of Kigali Ngali, Butare, Kibuye and Kibungo. These trends correlate with regional rainfall deficits and frequent droughts. Of the food insecure, 58% reported having experienced drought, compared with 38% of the food-secure.

Production impacts from ENSO related drought events in 1997 and 2000 show significant losses in maize, bean (see right) and animal production, particularly in Eastern and Southeastern regions. Additionally, these drought events are also favourable conditions for pests such as caterpillars found on sweet potato and predators found on beans.

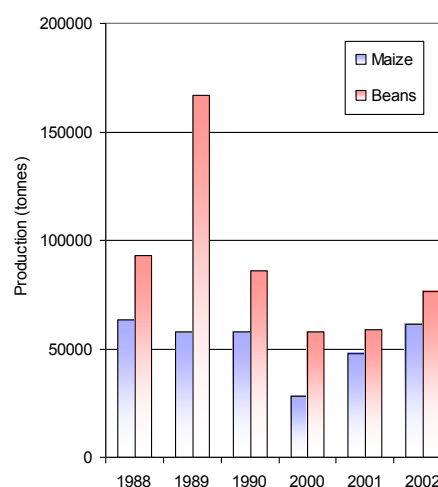
During the 2000 drought, the Ruhengeri and Kigali-Ngali provinces (particularly the Bugesera region) saw dramatic reductions in maize of 203% and 192% from 1990 levels. Bean production losses were significant in the Kigali-Ngali and Gitarama provinces with 247% and 192% reductions from 1990.

The 1997 La Nina drought events also resulted in livestock losses in cattle, goats, pigs and poultry in the above regions, particularly the Umatara Province. Estimated costs of cattle losses were Rwf 20 billion (Uwizeyimana, 2004).

There is also an issues of high soil erosion risk for land in Rwanda, because smallholders cultivate steep slopes to bring land under cultivation that is not suited to this purpose. Previous studies<sup>12</sup> have estimated that soil erosion results in a loss of 1.4 million tons of soil per year, equivalent to an economic loss due equivalent to US \$ 34,320,000, or almost 2% of GDP.



**Figure 13.** Flooded Plot in Gishwati watershed (2007, Western Province), Mukankomeje, 2009.



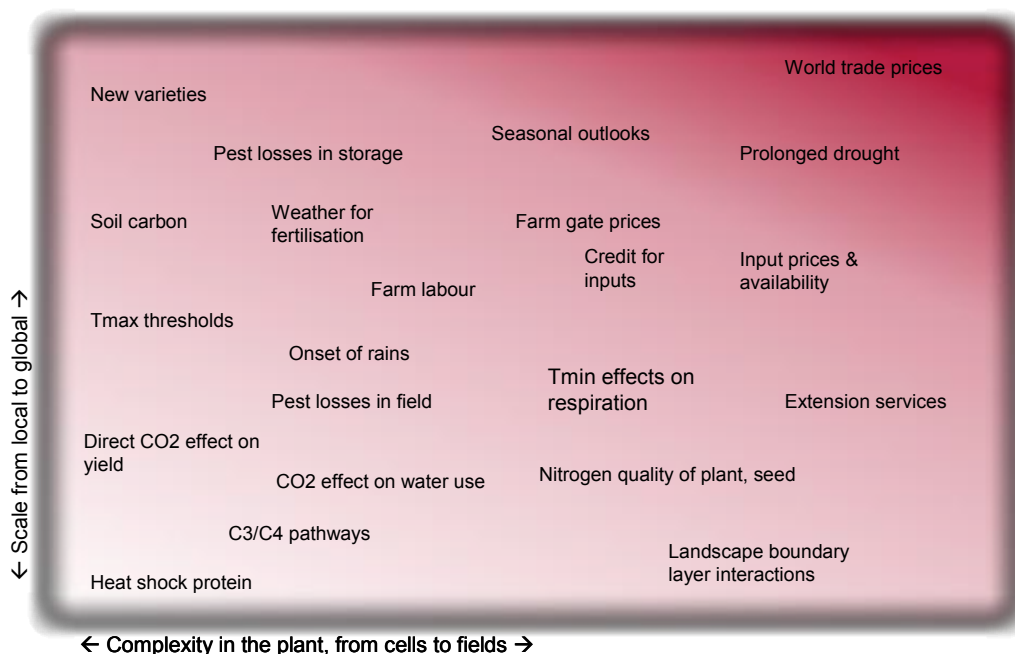
**Figure 14.** Production of Maize and Beans. Adapted from Uwizeyimana, 2004. Production shown for Ruhengeri, Kibungo, Gisenyi, Kigali-Ngali, Butare

<sup>12</sup> ROR (2006). Economic Analysis of Natural Resources Management in Rwanda. Republic of Rwanda (ROR), Kigali.

### Analysis

While this presents a picture of the existing sensitivity of the sector to current climate variability, the study has focused on the additional challenge posed by climate change. Agriculture is a climate sensitive sector and will be affected by climate change, potentially both positively and negatively. Temperature and other climatic changes will affect yield and growing season and there is also a potentially direct (positive) CO<sub>2</sub> fertilisation effect. Given much of Rwandan agriculture is currently rain-fed, there are also potentially wide ranging effects from the possible changes in precipitation. Moreover, there are a number of complex interactions with other factors such as extreme events (floods and droughts), soil degradation and erosion, pests and diseases, and with other key sectors such as water availability for irrigation, land competition which will affect the sector. Any responses will be differentiated between parts of the country. They are also very influenced by responses and agricultural management practices (autonomous reactions) such as Rwanda's Crop Intensification Program (CIP) to increase yields through increased inputs and improved varieties (MINIAGRI, 2009)<sup>13</sup>. The net effects of socio-economic and climatic impacts make it difficult to predict with accuracy the impact of climate change on agriculture.

Indeed, the impact of future climate change will be an outcome of the interplay of biophysical, socio-economic and decision-choice factors. The 'cloud' diagram below suggests some of the factors involved in the future effects of climate and socio-economic change for agriculture. In the bottom left hand part of the diagram are those issues which are local in nature, both geographically and at the individual plant level. Along the horizontal axis are factors that move from individual plant to entire crop level. Along the vertical axis are the factors involved in moving from local farm level issues through to global issues. The top right hand area of the diagram are therefore associated with higher order global effects, i.e. world trade prices.



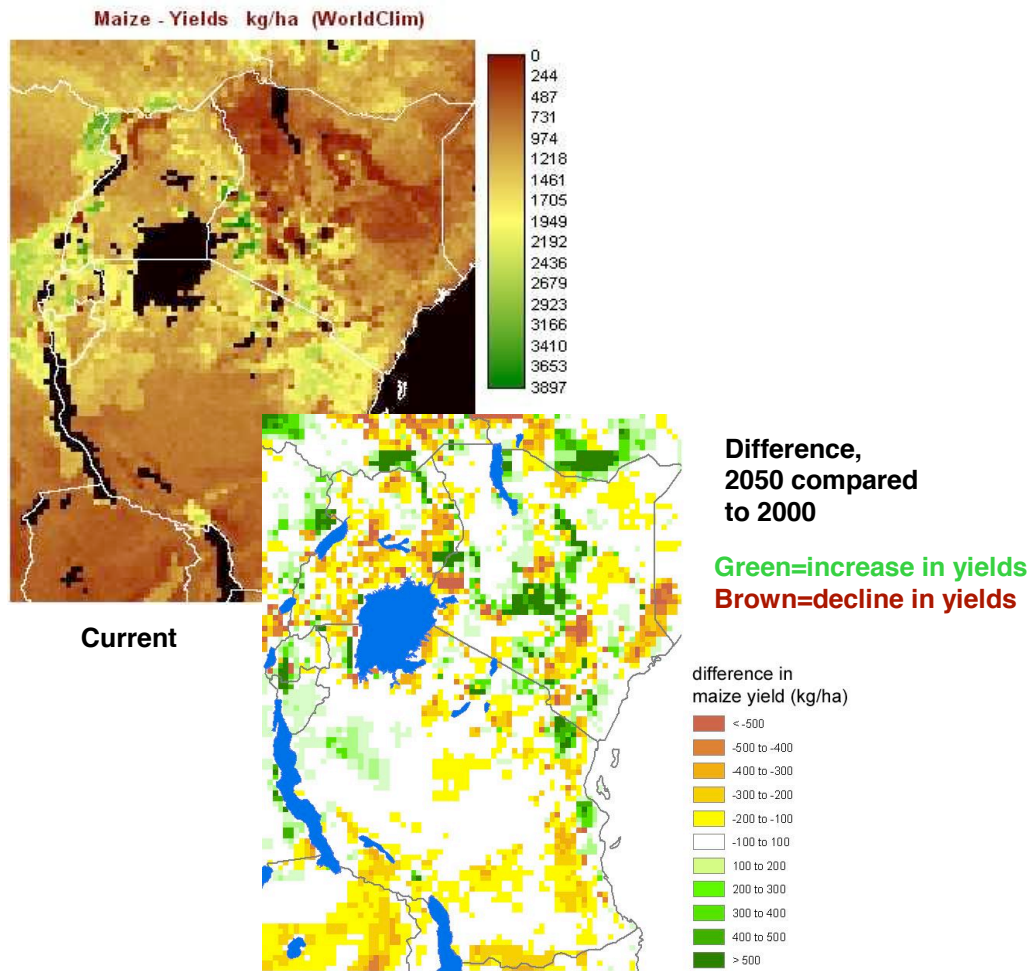
**Figure 15. Range of factors affecting agricultural vulnerability, impacts and adaptation to climate change**

Some previous studies by study team partners have assessed the potential changes for agriculture in Rwanda and East Africa. This includes alternative approaches based on different methodologies. Some of the outputs from these assessments are presented below.

<sup>13</sup> Note that the CIP has the potential to increase agricultural GHG emissions while increasing yields due to high fertilizer use.



Crop models have been applied to Rwanda, as part of an East African analysis looking at individual crop varieties using impact assessment based approaches. These reveal mixed patterns in the region and strong differences between areas within Rwanda, with some areas showing higher yields or potential for new crop varieties, whilst other showing negative effects (e.g. with studies of maize yields shown above). Other work by Jones and Thornton (2003)<sup>14</sup> report a decrease in maize yields for Rwanda. The simulated reduction (kg/ha) in this study is 7%.for 2055 relative to the projected baseline.



**Figure 16.** Maize yields under current (left) climate conditions and difference in maize yields due to one projection of climate and land-use change (right, the difference from the baseline of 2000 to 2050).

Source: ILRI.

A key conclusion of this analysis is that **given present knowledge, the outcome of future climate change for agriculture in Rwanda remains highly uncertain.**

Warmer conditions in the highlands might benefit crops, with longer seasons and more radiation. The balance of rainfall and evapo-transpiration may well shift. Intense rainfall and in some regions periodic droughts are already features of the Rwanda climate and certain to continue to be significant hazards (even without climate change).

<sup>14</sup> Jones, P.G., Thornton, P.K. (2003). The potential impacts of climate change on maize production in Africa and Latin America in 2055. *Global Environmental Change* 13 (2003) 51–59.

## ***Biodiversity and ecosystem services***

### ***Background***

Rwanda is a country with exceptionally rich biodiversity and ecosystems. It has five distinct ecosystems divided into: cropland and natural vegetation (47 % of total land); scrubland, savannah and grasslands (32 % of total land); forest (12 % of total land); wetlands and water bodies (8 % of total land); and sparse/barren vegetation (1 % of total land) (USAID, 2008<sup>15</sup>).

It also has a number of designated protected areas, notably: Volcanoes National Park, which is a globally important reserve of mountain gorillas; Nyungwe National Park, which has a large number of important (and endemic) plant and bird species; and Akagera National Park. The country also has a total of 480,000 ha of forested land (19.5%) of total land area, mostly within the national parks and the two forest reserves, and a large number of lakes and rivers.

All of these ecosystems provide multiple benefits to society, which in turn have economic benefits, though these are rarely captured by markets. These benefits are known as 'ecosystem services' and can be divided into provisioning (e.g. agriculture, fisheries, timber, water), supporting (soil formation, nutrient recycling), regulating (climate regulation, flood protection, water quality regulation) and cultural services (recreational and tourist, educational and cultural benefits).

### ***Analysis***

Climate change is likely to have major effects on both managed and natural ecosystems and associated ecosystem services. The study has assessed the potential future risks to biodiversity and ecosystem services. A full technical report is available at the web-site (<http://rwanda.cceconomics.org/>). This section summarises this work.

To investigate the issues of ecosystem services, the study has undertaken three steps.

- It has first investigated the value of ecosystem services for human well being and the economy of Rwanda.
- It has then considered the drivers of change that put pressure on these ecosystem services and threaten socio-economic systems,
- Finally, the study has considered the potential effects of climate change on ecosystem services, and the implications for the future assuming different development pathways (including Vision 2020 pathways) for Rwanda.

The first step has been to collate information on the importance of ecosystem services. The population and economy of Rwanda are very dependent on the natural environment and resources and ecosystem services are key to the economy. In addition to the role of agriculture (discussed above):

- The tourism sector is strongly based around wildlife tourism. For the year 2005 the revenue from the Volcano National Park alone is a contribution of about 0.2 percent of GDP (ROR, 2006<sup>16</sup>).
- Biomass energy accounts for the vast majority of the population's domestic energy needs (94%) (using biomass energy in the form of fuel wood, charcoal or agricultural residues for cooking and heating purposes), and energy in small-scale commercial and public sectors.
- Forest plantations provide not only wood resources (79%), but also opportunities for fuel wood harvest (5%), apiculture (beekeeping) (0.4%), and agricultural activities/cattle breeding (2%). The contribution of the forestry sector to the national economy is not well known, although it is conservatively estimated to have stood at 1.3 per cent of total GDP between 2001 and 2006 (ROR 2007).

---

<sup>15</sup> USAID 2000. Rwanda Environmental Threats and Opportunities Assessment. Report for USAID Rwanda, Kigali. Chemonics International Inc. Also available on: [http://www.encapafrika.org/documents/biofor/Rwanda\\_2003.pdf](http://www.encapafrika.org/documents/biofor/Rwanda_2003.pdf)

<sup>16</sup> ROR (2006). Economic Analysis of Natural Resources Management in Rwanda. Republic of Rwanda (ROR), Kigali.

- Hydro production provides around a large proportion of electricity produced (see low carbon growth section).
- Fish protein comprises one per cent of the total protein supply, and the supply of fish and fisheries products was a one kg/person/year (World Resources Institute 2003) and Rwanda's freshwater fish catch in 2000 was 6,726 metric tons, up from 2,350 metric tons in 1990, whilst freshwater aquaculture has also increased to 270 metric tons.

USAID (2008) valued some of these ecosystem services at US\$285 million as below.

**Table 2.** Estimation of the economic value of ecosystem services in Rwanda and beneficiaries

Ecosystem services	Economic Value (\$US/year)	Beneficiaries
Watershed protection	117,757,583	Local communities, OCIR THE, Electrogaz, Regideso/Burundi
Biodiversity protection	2,000,000	Global community
Carbon sequestration and storage	162,080,000	Global community
Recreation and tourism	3,372,313	Global community, ORTPN and tour operators
Total	285,209,896	

Source: (USAID, 2008)

***Ecosystems provide key economic benefits (services) to Rwanda and underpin much of the economy. There are many stresses on these systems already and climate change will add to these pressures.***

The study has next assessed the current vulnerability of these systems from various stressors including natural threats such as erosion, floods, drought, invasive species, diseases and pests and social pressure including population pressure, forced resettlement, overexploitation of biological resources, poaching, human induced fire, conflict and insecurity (see (DFID & MINITERE, 2003<sup>17</sup>; ROR, 2006). Indeed, biodiversity loss in Rwanda is severe. This has been compounded by progressive disappearance of national parks, habitat destruction, growth of cash crops, conflict, encroachment, grazing and unsustainable agricultural practices, as well as forest loss. Riverine resources including fish diversity are also decreasing along with a loss of wetland biodiversity and habitat. Examples of such cases are outlined in the case studies in the annexes, reporting on previous survey work such as the Rugezi wetlands degradation.

Four critically stressed ecosystem services (UNEP and IISD (2005<sup>18</sup>)) have been identified in Rwanda. They are:

- maintenance of biodiversity;
- food provision;
- water supply, purification and regulation;
- energy resources.

<sup>17</sup> DFID and MINITERE. 2003. Overview of Rwanda's Land Policy and Land Law and key challenges for implementation. Briefing Paper. Department of Foreign and International Development (DFID) and Ministry of Lands, Resettlement and Environment (MINITERE), Kigali.

<sup>18</sup> UNEP and IISD 2005. Connecting Poverty and Ecosystem Services: Focus on Rwanda. United Nations Environment Programme (UNEP) and International Institute for Sustainable Development (IISD), Kigali.

The study has also looked at how socio-economic development might affect these ecosystems in the future (even without climate change). The continued importance of the agricultural economy – and the plans in the vision 2020 to progress agricultural production - could result in further pressure on natural resources and ecosystems, including the four critically stressed ecosystem services above. Similarly the population growth forecast for the country is likely to strongly increase pressures, on top of the existing high population density. However, the planned shift toward a service based sector would lessen these pressures.

However, the Government has recognised the role natural resources in economic development and policy is shifting to address degradation. This includes the adoption of a National Environmental Policy followed by the enactment of laws towards protection, conservation and promotion of environment. Baseline information has recently been collated as part of the State of the Environment and Outlook Report (REMA, 2009<sup>19</sup>).

Nonetheless, climate change will act as an additional pressure on these ecosystems services. This is particularly important for many natural or semi-natural systems because of the potential threshold levels and because of the potential for adaptation. To investigate, the study has explored a number of case studies. One of these has been on the Mountain Gorillas, which are an important source of tourist revenues and foreign currency.

Montane habitats are amongst the most vulnerable to climate change because climate change will cause climatic zones (and species) to move. The success of this movement will depend on various factors:

- The availability of suitable space, which is particularly important given land-use pressures,
- The capacity of a species and ecosystems to migrate e.g. migration will be easier for birds than for plants,
- The connectivity within the landscape structure, e.g. the availability of stepping stones and/or habitat networks), and
- The presence of receptor habitats within the new climate range of a species.

For montane species, the most obvious initial response is for lower/higher altitude species to move uphill (to maintain the temperature zone they are acclimatised to). However, there are physical limits for high altitude species, i.e. eventually there is no similar climatic zone to move up. The risk is that for certain montane species, there will be no overlap between their potential future range and their current range, making the threat of extinction more likely.

---

<sup>19</sup> REMA (2009): Rwanda State of Environment and Outlook Report. Rwanda Environment Management Authority. P.O. Box 7436 Kigali, Rwanda.

### Case Study. Mountain Gorillas

Gorilla tourism is Rwanda's third largest revenue earner after tea and coffee production. In 2007, tourism earned over US\$ 42 million for the country, \$7 million of which was for gorilla permits alone.

Gorilla tourism in Rwanda, as well as coffee and tea production, is highly dependent on ecosystem services provided by the afro-montane forest. There are two species of Gorilla, the eastern lowland and the mountain, the latter including populations in the Volcanoes National Park and the Bwindi Impenetrable National Park.



Photo courtesy Rwanda Tourism

The Virungas Volcanoes mountain gorillas live in high-altitude montane forests with a dense herb layer and abundance of fruit, ranging up to 3,400 m in altitude with occasional forays even higher (UNEP/CMS 2008) and the area of habitat these mountain gorillas is approximately 450 km<sup>2</sup>. A census of the Virunga mountain gorilla population carried out in 2003 shows a 17% increase in population size since 1989, with a total number of 380 gorillas. Due to its very small population level and a series of threats to their habitat, mountain gorillas face a high risk of extinction in the wild. The mountain gorilla is listed as Critically Endangered on the IUCN Red List of Endangered Species (IUCN 2008).

The surrounding area is vulnerable due to livelihood pressures, agriculture and forest fragmentation, etc. Climate change will be an additional pressure on top of this. The montane forest system in the Virungas region is isolated from other similar ecosystems by great areas of lowland habitats. Isolation has produced a high level of endemism with a very unique species composition and environment. The current climate of these mountains is much wetter than the surrounding lands, with perhumid (rain every month) conditions and rainfall up to 3,000 mm per year (UNEP/CMS 2008). These conditions make montane forests in the Virungas region the main source for the surrounding population.

At this time, the effects of climate change on montane forests in the region are not fully understood. The predictions outlined earlier from the CCE tool are limited by the number of national stations that can be downscaled and global models are not robust enough to project climate change at the spatial scale of this region. There is likely to be warming, though the level of warming for these specific areas cannot be projected. The forecasts of precipitation for the country as a whole are more uncertain: many models project higher average precipitation and potentially more extreme rainfall.

Since they are confined to a relatively small habitat within a high altitudinal range, changes to the habitat could have severe impacts on the gorilla population. This may arise from direct effects, notably because of the climatic shift in suitable zones for the species themselves but also their forest habitat. There are also potentially indirect effects, the latter arising from effects on surrounding communities, should their livelihoods get affected by climate change. As an example, there might be pressure for both subsistence systems and cash crops (i.e. tea and coffee) that are currently produced on the lower slopes around the montane forests to move upwards to maintain suitable agro-ecological zones.

Further work to explore climate change and ecosystem services is a priority.

### **Synthesis and Recommendations**

The sections above set out an initial analysis of the potential impacts and economic costs of climate change in Rwanda.

The future economic costs of climate change are very uncertain. However, aggregate models indicate that the additional net economic costs (on top of existing climate variability) could be equivalent to a loss of almost 1% of GDP each year by 2030 in Rwanda, though this excludes the future effects of floods and other extremes. This estimate is therefore considered a potential lower bound. In the longer-term, after 2050, the economic costs of climate change are expected to rise, potentially very significantly. However, the aggregate models report that global stabilisation scenarios towards a 2°C target could avoid the most

severe social and economic consequences of these longer-term changes. This emphasises the need for global mitigation, as well as local adaptation.

These findings are strengthened by the bottom-up analysis, which indicates that in the absence of adaptation, the aggregated estimates of economic costs - which occur on top of the existing effects of climate variability - could potentially be very large. Detailed analysis for a single burden (malaria) in a single sector (health) indicates that future economic costs could be over fifty million dollars a year by the 2050s. There are also potential effects on ecosystem services, which whilst difficult to estimate in economic terms, could be just as important. The analysis of future costs of extreme events indicates that large increases in the economic costs of these events will occur over the same period. There are some possible scenarios of climate change on the agricultural sector which would lead to high economic costs and have very significant effects on rural livelihoods.

Finally, the case studies show there is likely to be a strong distributional pattern of effects, with some sub-regions and some groups affected more than others, and highlighting it is the poorest who will be most affected, intensifying inequality. They also highlight the particular effects in some non-market or informal sectors that are not captured by economic metrics, and difficult to assess within formal economic analysis, but are essential to economic growth and prosperity.

Overall, the bounded range of economic costs could potentially be very large, as expressed in equivalent to GDP. There is also likely to be a strong distributional pattern of effects, with some sub-regions and some groups affected more than others.

***The study shows potentially high impacts and economic costs in the absence of adaptation, notably for health, from future floods and for biodiversity and ecosystem services. In other sectors, the pattern is more complex reflecting the range across the climate and socio-economic projections. Nonetheless, there are scenarios with potentially very high impacts and economic costs across all sectors.***

Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. There is also a need to extend the analysis to cover other potential impacts, as the analysis presented here is only a sub-set of potential effects of climate change.

The analysis also shows the need to build future climate change risk screening into all aspects of development and planning at a sectoral and regional level. Information on climate, resources and adaptation strategies and options should be mainstreamed into all sectoral plans. A national knowledge management system should be developed; with easy access by all stakeholders to compile more detailed databases of potential climate risks across all areas of the economy.

Finally, there are also potential effects to Rwanda from climate change impacts that occur in neighbouring countries in East Africa. These regional aspects are important because of Rwanda's landlocked location and dependence on regional infrastructure, whether for access to markets, distribution of goods and resources and power generation as well as issues in relation to regional vulnerability hot-spots and potentially socially contingent effects. There are also trans-boundary issues (e.g. on water basins, ecosystems, etc). These aspects are being considered as part of the regional analysis within the East Africa study.

### 3. Adaptation Costs and Benefits in Rwanda

The study has also considered the costs and benefits of adaptation. The section starts with the existing priorities identified in the Rwandan NAPA.

#### The Rwanda NAPA

The NAPAs (National Adaptation Programmes of Action) recognize the special situation of the Least Developed Countries (LDCs) and provides a process to identify priority activities that respond to their urgent and immediate needs for adaptation to climate change. The NAPAs focus on those areas for which further delay could increase vulnerability or lead to increased costs at a later stage. They are action-oriented, country-driven and flexible and based on national circumstances. The NAPAs include short profiles of projects and/or activities and estimates of 'indicative project costs'.

Rwanda identified six immediate priority areas as part of the NAPA process:

- (1) integrated water resource management,
- (2) setting up an information system for early warning hydrological and agro-meteorological systems and rapid intervention mechanisms,
- (3) promotion of intensive agro-pastoral activities,
- (4) promotion of non-agricultural income generating activities,
- (5) introduction of species resistant to extreme conditions,
- (6) development of alternative sources of energy to firewood.

From these priority options, 7 urgent project profiles have been developed. These projects have direct benefits, cross-cutting impacts, improve the adaptive capacity of the populations and reinforce the resilience of fragile ecosystems. They are reported in the NAPA as:

1. *Land conservation and protection against erosion and floods at the level of Districts of vulnerable regions to climate change;*
2. *Establish the mastering hydro meteorological information and early warning systems to control extreme phenomena due to climate change: - Installation and rehabilitation of hydrological and meteorological stations;*
3. *Development of irrigated areas by gravity water systems from perennial streams and rivers in often vulnerable zones to prolonged droughts;*
4. *Support Districts of vulnerable regions to climate change in planning and implementing measures and techniques related to conservation and water harvesting and intensive agriculture, and promoting existing and new resistant varieties of crops adapted to different bioclimatic soil.*
5. *Increase adaptive capacity of grouped habitat "Imidugudu" located in vulnerable regions to climate change by the improvement of drinking water, sanitation and alternative energy services, and the promotion of non agricultural jobs.*
6. *Increase food and medicine modes of distribution to respond to extreme climate change and sensitize to stocking and conservation of agriculture products;*
7. *Preparation and implementation of woody combustible substitution national strategy to combat the deforestation and erosion as well.*

The estimated total project costs for these projects were \$8.1 million (reported to the UNFCCC)

The NPA also considered *with great importance the aspect of necessary disconnection of energy production of wood as an urgent strategy for Rwanda, which is in the urgent global "national" adaptation efforts to climate change. Also, the stabilization of populations around grouped habitat giving access to basic services and gradual and restabilized reconversion of the population towards agricultural or non agricultural related employment helps to increase the adaptation capacity of the population to climate change, climate variability and extremes.*



However, the priorities outlined in the NAPA only reflects a small part of the adaptation needs for Rwanda. There is urgent and significant investment needed for building capacity for adaptation, piloting early action, and moving to climate resilient growth (including 'climate-proofing' new investment), in line with the economic growth plans outlined in Vision 2020, and taking account of projected population and urbanisation trends. A number of approaches have been used to explore these potential needs, including top-down and bottom-up analysis.

### 3.1. Aggregate Estimates of Adaptation Costs for Rwanda

The top-down analysis has reviewed the existing estimates of adaptation costs for Africa and scaled these to East Africa and Rwanda. A full technical report is available on the adaptation costs at the web-site (<http://rwanda.cceconomics.org/>). This section summarises this work.

**Four categories of adaptation have been identified that relate to the balance between development and climate change.**

Two of these are development activities and are targeted towards the large economic costs of current climate variability (rather than future climate change). However, they are essential requirements in enhancing future resilience. They are:

- 1) Accelerating development to cope with existing impacts, e.g. integrated water management, electricity sector diversity, natural resources and environmental management.
- 2) Increasing social protection, e.g. cash transfers to the most vulnerable following disasters, safety nets for the most vulnerable.

The second two are associated with tackling future climate risks and are

- 3) Building adaptive capacity and institutional strengthening, e.g. developing meteorological forecasting capability, information provision and education.
- 4) Enhancing climate resilience, e.g. infrastructure design, flood protection measures.

The overall costs of adaptation vary according to which of these categories is included. Sources of finance and the balance of public and private costs of adaptation also differ between these four categories.

The study has then looked the potential adaptation costs across these categories for two time periods. The first relates to immediate needs, represented for the year 2012 (i.e., within current operational plans), while the benchmark year for investing in capacity to adapt to future climate change is year 2030 (i.e., towards the medium-term and consistent with many of the global estimates).

The total adaptation costs are strongly influenced by the logic of what is included or excluded as adaptation to climate change.

- The lowest estimates assume that only the 'additional' costs needed to address future climate change should be counted. This includes the need to build capacity and to climate proof future investments.
- Higher estimates are derived when social protection costs are included, though these are directly in response to the existing climate and have a strong overlap with development.
- Even larger costs are possible when some additional funding for the adaptation deficit is included. These are again strongly related to the current climate and are essentially development focused. However, investment in these areas will provide greater resilience to future climate change and the ability to mobilise resources for an uncertain future.



Based on this analysis, the study concluded that a conservative estimate of immediate needs (for 2012) is 280- 400 million / year, though this includes social protection and bringing forward development, and much of this is not directly attributable to climate change (though it is a necessary step to reduce future impacts and increase resilience). These adaptation costs are similar in order of magnitude to recent levels of annual ODA.

The cost of adaptation will increase by 2030. A lower bound for the costs to continue to build capacity and to specifically address future climate change (enhancing resilience) alone is \$50-300 million/year. A plausible upper estimate of the cost is \$620 million /year, though this includes social protection and accelerated development, only part of which is directly attributable to climate change (though it is a necessary step in preventing much larger impacts).

#### **Urgent needs, for 2012:**

- A minimum of \$ 13-21 million / year for immediate priorities and building capacity (plus the 8 million over several years identified in the NAPA).
- Some early enhanced climate resilience (anticipatory adaptation), similar in magnitude to above.
- Social protection, with implied costs of \$120-170 million / year (but related to development).
- A similar or larger cost to above (e.g. \$100-200 million) for accelerated development (overcoming the historic adaptation deficit, again related to development).

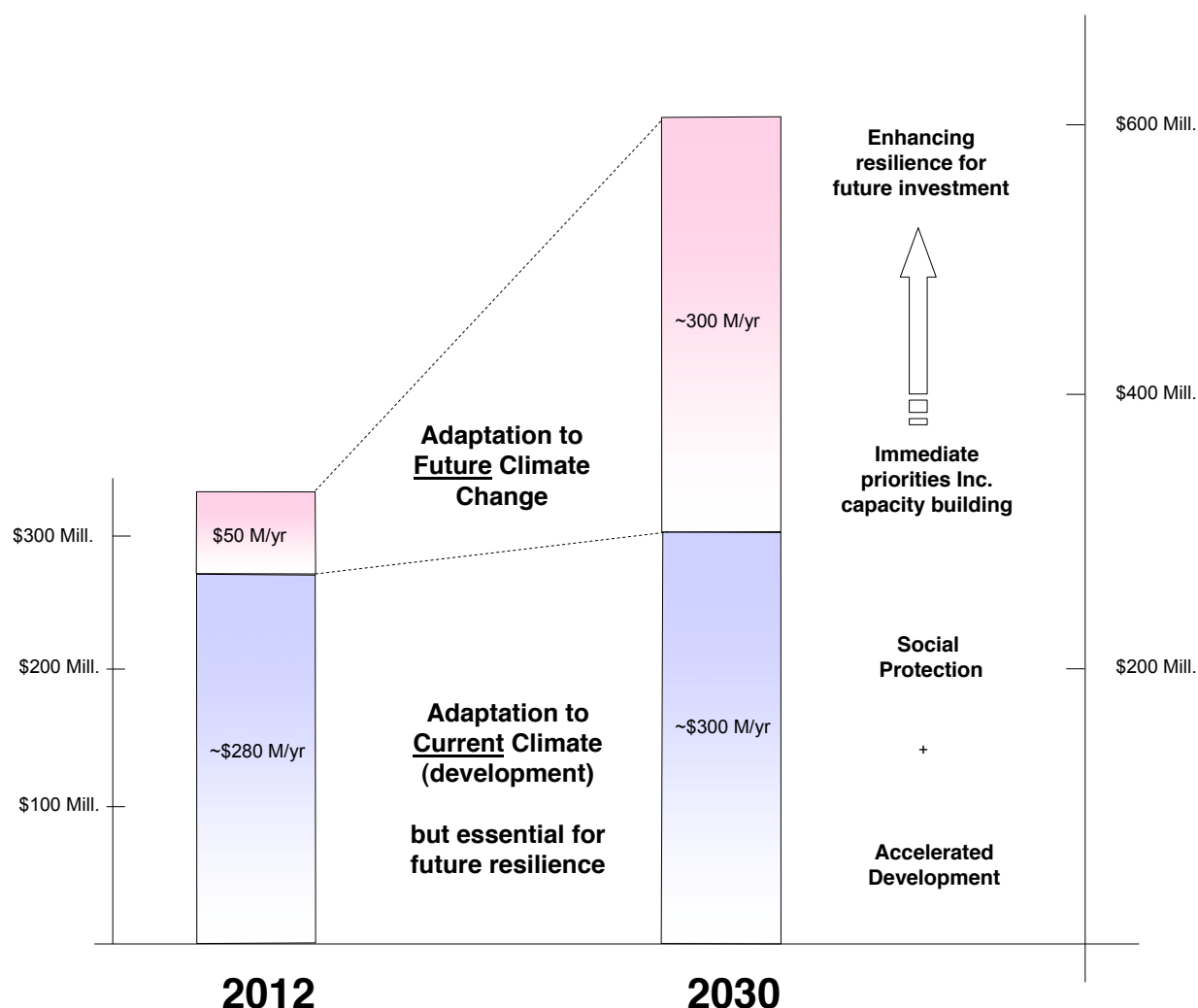
#### **Benchmark costs for 2030:**

- Continued investment in capacity, estimated at \$20–50 million per year.
- A significant rise for enhancing climate resilience in new investment: a minimum of \$33 - \$100 million / year but possibly as high as \$58 - \$280 million / year.
- Further social protection might be the same order of magnitude as above (i.e. \$120-170 million / year).
- Additional accelerated development investment for climate resilience, estimated at \$14 – 124 million / year.

The way that these can potentially add up is shown in the figure below. Those areas in pink – at the top of the diagram – are directly attributable to climate change. Those in purple – at the bottom – are associated with current climate variability (and therefore not attributable to climate change). They are more associated with development and addressing the current adaptation deficit, but they are essential to reduce future impacts of climate change.

***The top-down analysis indicates immediate needs could be around \$ 50 million/year by 2012. However, greater funding is needed to address current climate variability, estimated very approximately at \$ 300 - 400 million / year. While this is development related (not climate change), it will provide greater resilience and reduce future impacts.***

***The cost of adaptation will potentially increase by 2030: a lower bound for the costs to address future climate change alone is approximately \$50 - 300 million/year. A plausible upper estimate of the likely cost is \$ 600 million / year, though this includes development categories of continued social protection and accelerating development***



**Potential Costs of Adaptation to Current and Future Climate in Rwanda \$Million per year**

**Figure 17. Benchmark cost of adaptation in Rwanda**

The study indicates a very significant step-up in funding from the current levels proposed in the NAPA – and the adaptation costs are similar in order of magnitude to current ODA.

### 3.2. National Sectoral Assessments and Case Studies

The study has also undertaken bottom-up sectoral costings of adaptation, one way to test the estimates above and to provide greater insight into sectoral and regional planning.

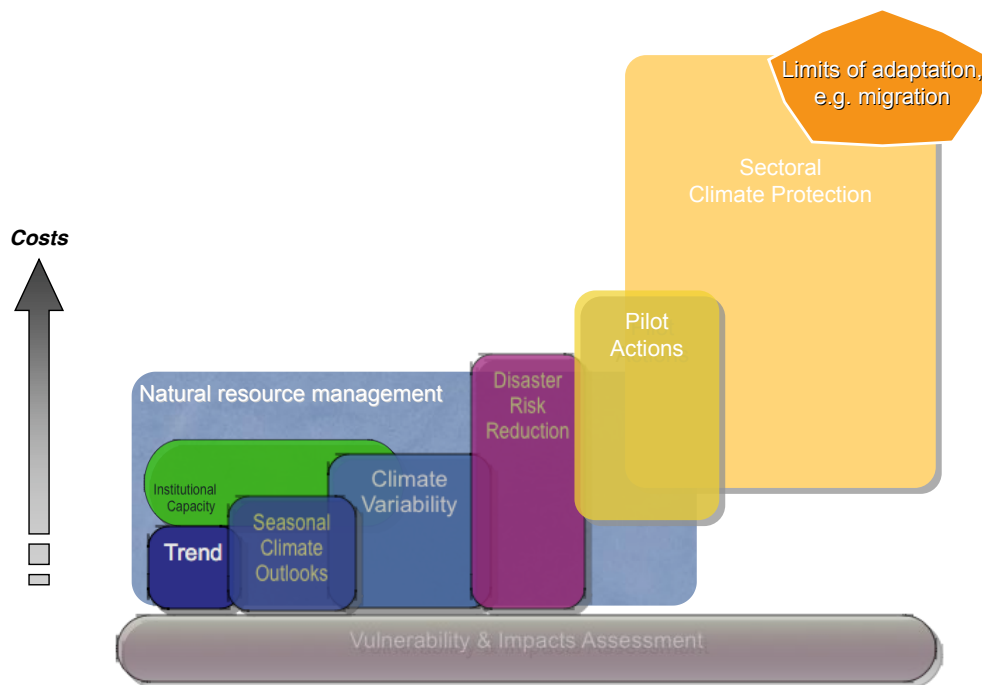
The methods for assessing the costs – and benefits – of adaptation are still evolving. The study has explored a number of approaches, though working around a number of common themes. These are:

- Climate change projections – and impact assessments - are highly uncertain. This is partly because our understanding of climate change and its impacts is incomplete, but also because of future uncertainty on socio-economics and uncertainty in analysis and the influence of assumptions. The current state of knowledge is not good enough to provide central projections or even probabilistic forecasts. It is inappropriate to design adaptation strategy against a single future projection of

modelled climate. Recognizing this leads to a greater focus on decision making under uncertainty, producing adaptation processes and outcomes that are robust against a wide range of future situations. Moreover, given this uncertainty there is value in using a suite of economic tools and methodologies for analysis.

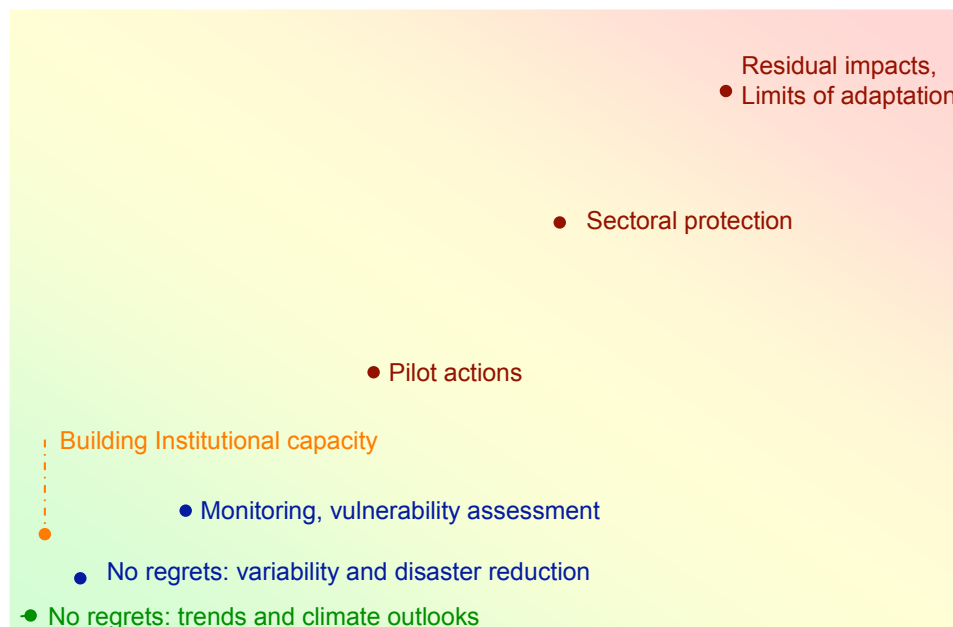
- Adaptation is also a process of social and institutional learning – it is not just a set of outcomes or options to respond to climate projections. Effective adaptation equips people and institutions to cope with a wide range of contingencies. Adaptation can include the need for building capacity and institutional strengthening. It can include a range of measures that have broad multi-sectoral benefits, such as improved climate and weather forecasting, emergency warning and preparedness, awareness and education. It can also include specific adaptation outcomes, including the use of technical (hard) and non-technical (soft) measures.
- There are a number of areas of high vulnerability that are associated with non-market sectors, the informal economy or have strong distributional effects. There is a need to make sure these are not omitted.
- It is important to distinguish action on three time periods. First, the effects of current climate variability and any adaptation deficit, especially in the context of immediate vulnerability must be considered. Second, a focus on a short-term policy window, consistent with the 2030 timescale also must be addressed. Third, the longer term aspects associated with post 2030 analysis must also be identified. This is essential to capture the full climate signals, to consider the long life-span of certain components such as infrastructure and to consider whether short-term actions increase or decrease future resilience or constrain future flexibility.
- The issue of timescales is linked to the economic rationale for action. Not all adaptation decisions need to be taken now. In many cases, it is difficult to plan effective and efficient responses over the long-term for infrastructure, due to the long life-spans involved, the potentially high costs, and the high uncertainty in the climate projections, especially in relation to extremes. This makes the application of formal project appraisal techniques problematic. One way to address this is to look for adaptation in:
  - Building adaptive capacity (e.g. season climate outlooks),
  - Focusing on win-win, no regret or low cost measures which are justified in the short-term by current climate conditions (i.e. addressing current climate resilience and disaster risk reduction), or based on projected climate change, but involving minimal cost, or positive opportunities;
  - Encouraging pilot actions to test promising responses; and
  - Identifying long-term issues including potentially high risks that require early pro-active investigation, even though there might be high uncertainty on specific options. To consider programmes to investigate these and to consider short-term options that allows flexibility for future information to be incorporated.

The study has considered these adaptation responses as a series of steps, together forming an 'adaptation signature'. These identify actions in each of the four strategies by sector. The broad outline of steps is the same in each sector. However, the exact activities vary, hence the use of a 'signature' concept that considers options on a case by case basis. These signatures have been used to develop sector strategies, key actions and indicative adaptation costs. These have been complemented by case studies which include examples of adaptation projects and costs.



**Figure 18. An ensemble of adaptation strategies is required**

The study has considered these signatures in undertaking the adaptation assessment by sector, plotting potential options against this framework, as shown for the broad categories below. Those areas in the green in the bottom left are early priorities (adaptive capacity and no regrets). Those in the yellow reflect pilot actions that need testing before full sectoral implementation. The move towards full sectoral programmes – and perhaps more extreme responses to the limits of adaptation are shown in the red areas towards the top right of the diagram.



**Figure 19. Examples of adaptation strategies**

The study has considered these issues in undertaking the adaptation assessment by sector.

## **Health**

There are adaptation strategies formulated that can be implemented, most of which are likely to build on well-established public health approaches. They include:

- Strengthening of effective surveillance and prevention programmes
- Sharing lessons learned across countries and sectors
- Introducing new prevention measures or increasing existing measures
- Development of new policies to address new threats

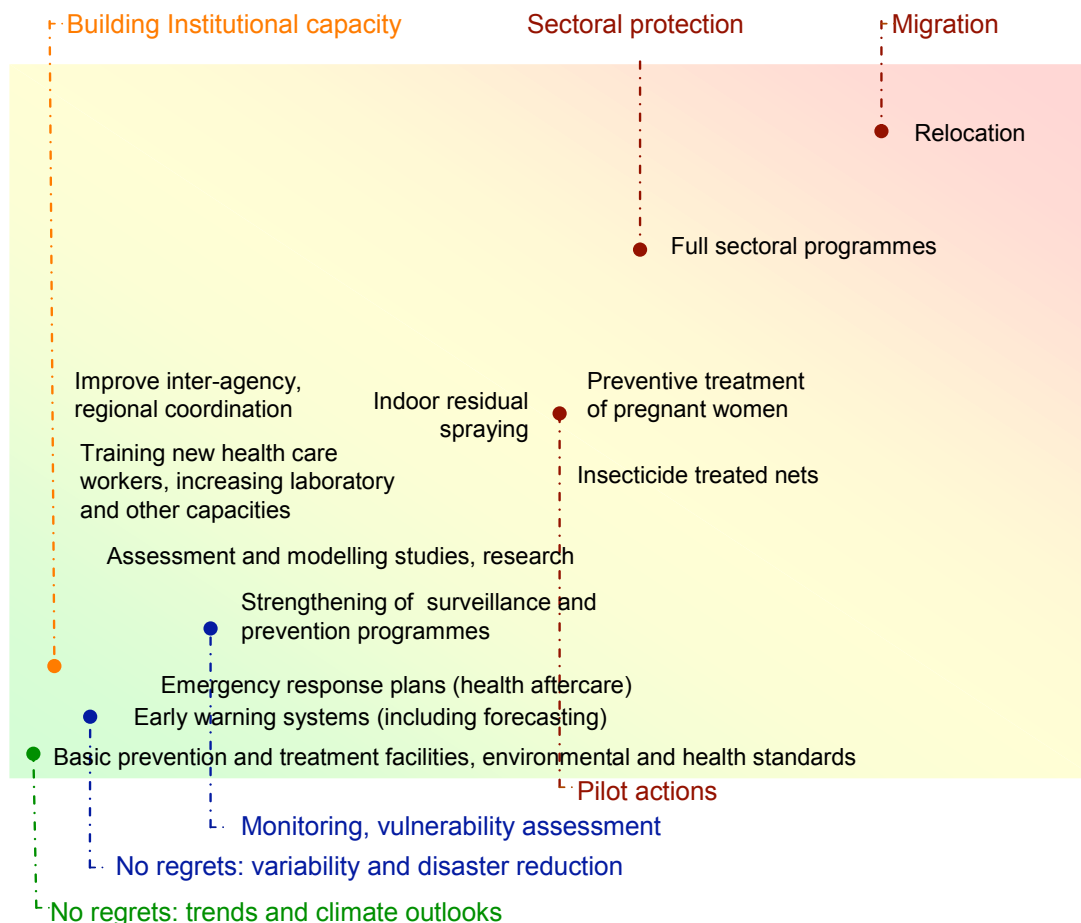
For the various climate related health effects, associated costs include

- Costs of improving or modifying health protection systems to address climate change, for example, expanding health or vector surveillance systems. This includes the costs associated with building new infrastructure, training new health care workers, increasing laboratory and other capacities, etc.
- Costs of introducing new health interventions (e.g. new heat warning systems).
- Additional costs for meeting environmental and health regulatory standards (e.g. water quality standards).
- Costs of improving or modifying health systems infrastructure, for example, adapting hospitals to hotter temperatures.
- Occupational health costs, for example, measures to prevent the adverse impacts of increased heat load on the health and productivity of workers.
- Costs of health research to address to reduce the impact of climate change, for example, evaluation studies.
- Costs of preventing the additional cases of disease due to climate change as estimated by scenario-driven impact models

The various measures are shown against the adaptation signatures below. The legends locate the type of measure and the text in the matrix represents typical strategies in the sector. Those areas in the green in the bottom left are early priorities (adaptive capacity and no regrets). Those in the yellow reflect pilot actions that need testing before full sectoral implementation. The move towards full sectoral programmes – and perhaps more extreme responses to the limits of adaptation are shown in the red areas towards the top right of the diagram.

The study has focused on the potential costs of adaptation for malaria control initiatives in Rwanda, based on four key approaches. 1) quick and effective treatment 2) the provision of prevention services and treatment to pregnant women 3) promoting the use of insecticide treated nets (ITNs) in high risk communities 4) improving epidemic preparedness and response in epidemic-prone areas. In addition, indoor residual spraying (IRS) has been considered as a cost-effective strategy for malaria control. Many malaria vectors rest inside houses after feeding and can be eliminated with this method. The study has then estimated the cost for

- Increased IRS coverage due to expansion of the malaria transmission zone due to climate change;
- Distribution of bednets for the additional population at risk;
- Additional medical tests for new population at risk;
- Preventive treatment of pregnant women;
- Establishing 5 provincial early warning systems.
- The treatment (direct) costs for the anticipated additional endemic cases of malaria.



**Figure 20. Adaptation signatures for health.**

Of the measures listed above, spraying of insecticides (IRS) is the most costly component. IRS, which was until recently not affordable, is currently being carried out on a small scale, covering over 1 million people. With the current temperatures on average more than 1°C over those in the 1980s, the estimated costs required for adaptation to the increased temperatures so far are \$ 17.3 million (of which 10.3 million for IRS). In the 2050s with a smaller population in the altitude belt where spraying is most effective, an additional \$ 12 million annually is required (with the IRS component reduced to \$ 3.4 million). These estimates are based on the current size of the population (2009), and cost-efficacy of current antimalarials and insecticides. It is very difficult to assess the costs to reduce the levels of endemic malaria to levels observed in absence of climate change, in view of the problems encountered in the last 50 years in Africa to deal with endemic malaria. In this study we have not attempted to assess the full additional costs of overheads, staff and infrastructure required to provide services suggested.

The altitudinal stratification of malaria risk used in this impact study could also provide a powerful management tool, in addition to existing methods, to assess risk and implement targeted intervention associated with gradual changes in temperature from climate change, and perhaps those resulting interannual variability.

### **Water and Infrastructure**

Given the potential importance, the study has investigated a number of approaches for assessing the costs of adaptation for the water sector. This includes a partial investment and financial flow analysis

(IFF, UNDP), application of adaptation signatures and a case study on flooding. Together these comprise multiple evidence lines for assessing indicative costs of climate adaptation in Rwanda's water sector. The case study (see box) highlights the need for early feasibility studies, flood risk information and early warning systems, as well as some of the potential barriers to implementation.

### Case Study 1: The Effects of Floods in Rwanda

Existing strategies for flood management were explored at the government and local level. In 2004, the Government of Rwanda (GoR) set up a National Body on Disaster Risk Management to deal with impacts of flooding as well as other natural hazards. The GoR has also set up a national strategy to mitigate natural hazards including floods. This strategy is based on:

- integrated water resources management;
- setting up an information system for early warning of hydrological and rehabilitation of meteorological stations for weather forecast monitoring;
- supporting vulnerable districts in land use planning;
- setting up a rapid intervention mechanisms for disaster preparedness;
- land conservation and protection activities;
- popularizing household water harvesting techniques;
- identifying suitable sites for village construction in line with resettlement programmes in rural areas;
- promotion of non-agricultural income generating activities.

However, the implementation of this plan is not fully realized. There have been challenges in effective intervention for emergency response and a lack of financial capacity, a lesser role for NGO's and land use policy issues with regard to land consolidation and rural resettlement.

The coping and adaptive strategies for dealing with the flood risk was also analyzed as indicator of residents' vulnerability to flooding for the Nyabugogo plain case study. Strategies include self protection, knowledge of apparent risks, and ability to avoid living or working in flood prone areas. Levels of knowledge of flood mitigation measures and capacity to implement them influence these efforts. For example, some residents in Nyabugogo plain increased drainage by constructing temporary ditches to prevent storm water flow into their houses. Others use trenches to divert water away from houses, water proofing to securing structures, sandbags to prevent entrance of water or raising the parcel to a higher level.

The case study shows that these local protection measures are not sufficient. Instead, appropriate flood mitigation measures and urban planning are needed to protect these vulnerable groups. This is a key problem given many properties in Nyabugogo floodplain are informal settlements.

After floods in Bigogwe in September 2007, some adaptive measures were taken. The local community has stopped growing crops in Gishwati highland due to the steep slopes and some relocated. In the previously affected site of Kinamba, 250 households have been relocated, and there are similar plans for other high-risk sites. Consideration has also been given to tree plantation in highlands with steep slopes to slow water movement. Some data on response costs during the 2007 flood in Bigogwe and Kanzenze sectors are available (54 million Rwandan francs). These give an indication of emergency response policies (though they are also an extra category of damage costs).

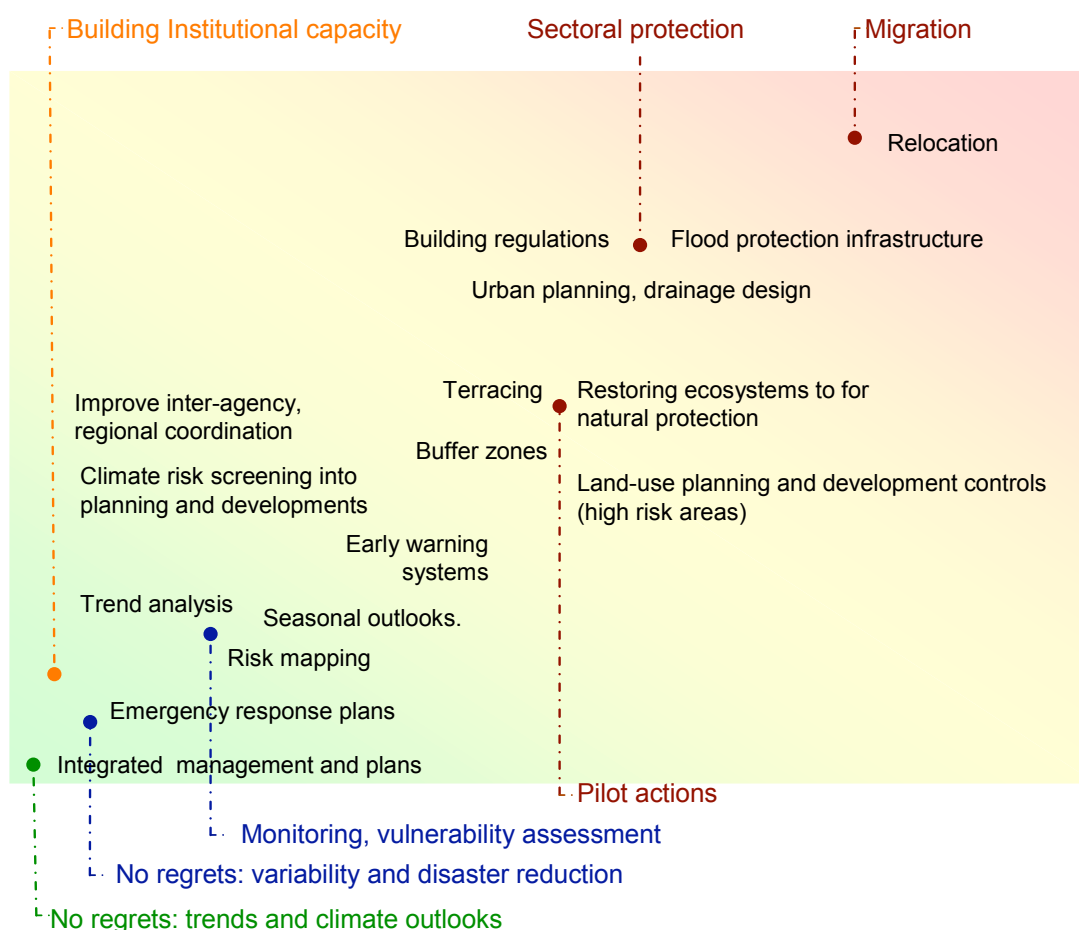


The picture shows a wooden and mud wall house without foundation in lower laying areas of Nyabugogo floodplain within Kigali City. During a flood of April 2006, it almost collapsed because of water flow inside.

A key conclusion is that the current flood challenge in Rwanda requires that new strategies and mitigation measures, which should be implemented in areas identified as being at high risk of floods.

A number of potential adaptation options are available. These can be framed within the signatures approach as below. The legends locate the type of measure and the text in the matrix represents typical strategies in the sector (see health for description).





**Figure 21. Adaptation signatures for water and flood risk to infrastructure.**

This presents some of the early and no regret options. Clearly there are early needs to strengthen the meteorological analysis and forecasting of extreme events, from early warning through to disaster risk reduction. Recent project initiatives by the GoR and development partners to strengthen meteorological station networks and establish early warning systems are positive developments in this direction<sup>20</sup>. However, there is also a need for similar information on hydrological data (e.g. establishing stream flow measuring stations with sufficiently long records).

Many steps associated with current integrated management and sectoral development plans represent no regret adaptation opportunities. These initiatives advance development and are justified by current climate risks, while providing greater resilience to future climate change.

There are also a series of more pro-active steps available. A key element is greater consideration of vulnerability and risks associated with the current development strategy, i.e. land-use, urban and rural settlement planning. This is a particularly relevant for future development of housing and economic zones

<sup>20</sup> For example, the UNEP study on Reducing Vulnerability to Climate Change by Establishing Early Warning and Disaster Preparedness Systems and Support for Integrated Watershed Management in flood prone areas. This is establishing a data coordination network through inter-agency coordination mechanism for hydro-meteorological information. The project will collect climate change data and integrate climate change concerns into relevant national development plans and policies and also be aligned with core UN activities in Rwanda. The project will also identify specific sites for intervention in the priority area defined in the NAPA.

and addressing the very high vulnerability of informal settlements. There is a need for planning across key economic sectors and forms of livelihoods – taking account of other social factors such as the land carrying capacity, the growth of rural population and poor state of existing infrastructure. In addition, there is a need for flood risk mapping and, in turn, for policies for high risk areas which can include managed relocation.

Pilot actions exploring options that might help increase resilience against extreme events should be considered. These could be tested and, if appropriate, formulated into full sectoral plans.

There are also issues associated with infrastructure location and protection. Whilst this includes mixtures of options to increase resilience, i.e. physical barriers and strengthening, the simplest options are to undertake risk screening of development plans– especially for critical infrastructure (power, water supply, water treatment, communications) and ensure sites are located in low-risk zones. Such planning needs to happen in conjunction with development activities, rather than afterwards, as it is more difficult and expensive to relocate or retrofit later. This is also a priority for informal settlements. These areas include the most vulnerable groups, and particularly the very poor, who do not have access to adaptation mechanisms (e.g. insurance) and depend much more on the critical infrastructure for survival. These groups do have some coping responses, but climate change may push these beyond the limits of adaptation and there is a need to include climate risk assessment in urban development programmes.

It is more difficult to cost these early priorities and plans. The full cost of adaptation interventions for flood risk in Rwanda is yet to be clearly established due to the existing challenges in undertaking comprehensive flood risk assessment studies.

### ***Water supply***

While a comprehensive sectoral analysis was not possible, a partial analysis was conducted with available national data. These included baseline information sourced from government investment plans based on Vision 2020 and Millennium Development Goals, as well as joint development projects in water supply and sanitation in Rwanda. Present funding gaps and areas for potential future climate investment opportunities were identified. Full details are presented in a technical annex at the website.

While the vast majority of farmers are rain-fed, subsistence agriculturalists, efforts are being made to increase the proportion of higher-yielding irrigated farmers, particularly in food insecure areas of the Eastern Province. In terms of industrial activities, there are a varied list of users, including agro-processing, chemical industries, printer and paper industries, metal works, mining, non metals & fabrication, leather and tanning, textile and electricity, gas and water supply. There are important cross-sectoral linkages with health in terms of water supply for the domestic sector. Respective urban and rural safe drinking water coverage is estimated at 76% and 68%, with a 71% national average.

Reco-Rwasco (formerly Electrogaz) predicts average growth rates of 3% per year. Given supply deficits in Kigali City and other major towns are currently 54% and 42%, respectively, the likelihood of significant future supply deficits appears high. Under a scenario future of increased supply investments, improved end-use efficiency and lower population growth rates, this water gap may be avoided. However, given the difficulty of anticipating and meeting demand needs, and the substantial investments that have yet to be made in rural and town areas, public and private water managers face an enormous challenge. Uncertain changes in Rwanda's precipitation regime from future climate change, and rising average temperatures, compound this challenge of long-term planning and robust supply investments.

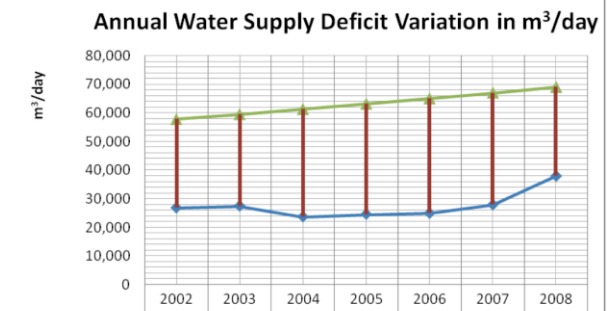
## The water challenge

There are current freshwater deficits in rural and urban areas. As of June 2009, the theoretical deficit in Kigali was 31,200 m<sup>3</sup>/day, with an overall deficit in the major urban centers of 48,000 m<sup>3</sup>/day. To address the deficits, there is ongoing investment. In Kigali City, an additional 10,000 m<sup>3</sup>/day is expected to go online in 2009, bringing a supply capacity of around 40,000 m<sup>3</sup>/day to meet the estimated demand. More than Rwf 40.56 billion was spent to install additional capacities and plant expansions.

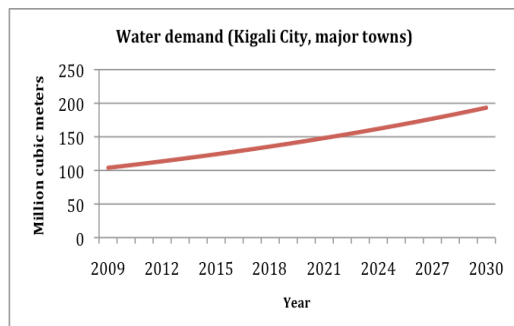
In addition, Rwf 14.57 billion was required for Kigali City water network rehabilitation involving network extensions and upgrading and resizing water storage tanks. However, significant additional funding is still needed to balance new supply with rapidly growing demand.

To meet growing deficits in demand, there is urgent need for renovation and expansion of all operating units consisting of treatment plants and water distribution networks including pumping stations, laboratories and workshops (Reco-Rwasco, 2009).

Based on trends from 2002 to 2008, future water demand for Kigali City and other major towns was calculated for the 2009-2030 time period. It is important to stress that due to the limited availability of data covering rural areas, these calculations are constrained to Reco-Rwasco commercial data for urban centers. These centers represent roughly 17% (1.6 million) of Rwanda's total population (9.2 million, EDPRS, 2009), and are therefore significant underestimates of national water demand.



Annual water supply deficit variation for Kigali City (m<sup>3</sup>/day), Reco-Rwasco, 2009



Projected water demand for Kigali City and other major towns, derived from 2002-2008 data, Reco-Rwasco, 2009.

Future planned policies were taken into account, including water sector reform, Vision 2020 and Millennium Development Goals and the Economic Development and Poverty Reduction Strategy (EDPRS), as well as Environment and Natural Resources Sector Strategic Plan (ENRSSP) [Water is one of the six ENR sub-sectors] and the trans-boundary Nile Basin Initiative (NBI).

## NAPA Rwanda

The NAPA identifies integrated water resource management (IWRM) as its primary approach to the water sector (see earlier), and the priority for climate adaptation. Most of the NAPA priority projects involve elements of an IWRM strategy, including a hydro-meteorological network and early warning system, improved access to drinking water and sanitation, and conservation of lands. Subsequent to the NAPA process, original implementation plans were adapted in light of sectoral development objectives. As a result, the first two priority projects were combined into one single project<sup>21</sup>: Primary project components of the Gishwati adaptation project include:

- Climate risk assessment and forecasting
- Climate change adaptation planning and response strategies
- Demonstration of adaptation practices in the Nile-Congo crest watersheds and Gishwati ecosystem
- Knowledge management, public awareness and dissemination of lessons learned and best practices

<sup>21</sup> "Reducing vulnerability to climate change by establishing early warning and disaster preparedness systems and support of integrated watershed management in flood prone areas" (GEF, 2008). This pilot project focuses solely on the Gishwati watershed and will be implemented by the United Nations Development Programme (UNDP) and United Nations Environment Programme (UNEP) between 2009-2013. Total costs of implementation are an estimated USD\$ 7,041,000, with USD\$ 3,641,000 coming from Least Developed Country Fund (LDCF) and USD\$ 3,400,000 in co-financing (primarily in-kind support from the GoR).

Given the observed increase in floods and landslides in the Gishwati region, the project will work to address these risks through early warning systems, improved management practices and awareness raising at policy and local levels

### **Scaling NAPA projects**

In the wider country context, implementation costs for this pilot project may be interpreted as indicative estimates for similar efforts in other Rwandan watersheds and ecosystems facing increased climate risks and degradation. The estimates can be scaled up to provide a national level adaptation estimate. Note that considerable care must be taken in this broad approach, given the unique vulnerability and development levels of each water system. Nevertheless, indicative costs can be derived for the 11 distinct watersheds, comprising a total of 8 major river systems (See table).

**Table 3.** Indicative costs of protection, early warning and preparedness systems for Rwandan watersheds.

Scale	Total project cost	Finance (US\$)	
		Domestic (21%)	External (79%)
Gishwati watershed	7,041,000	1,500,000	5,541,000
Indicative costs at national level (11 major watersheds)	77,451,000	16,500,000	60,951,000

Source: SOE, 2009 with costs adapted from the GEF Project Identification Form (PIF), 2008.

Note that the indicative costs of US\$ 77.5 million for scaling up watershed protection are roughly in line with existing national plans and public (domestic and foreign) expenditure for watershed management, protection and infrastructure for early warning systems, which total to US\$ 88.5 million<sup>22</sup>. Hence, arguably significant amounts are already being invested in key climate resilient development activities relevant to the water sector.

### **Investment and financial flows (IFF)**

The study also has adopted a partial Investment and Financial Flow adaptation investment assessment for the Rwandan water sector. Key data sources included Rwanda's EDPRS and 2009 Environment and Natural Resources Strategic Sectoral Plan (ENRSSP), state expenditure records for 2009/10, the Strategic Plan for the Transformation of the Agricultural Sector (PSTA II), and medium term expenditure framework (MTEF), in addition to private sector data. These estimates are indicative costs of sectoral development and adaptation mainstreaming. However, more detailed sectoral plans are being developed, e.g. sector-wide approaches (SWAP) and national master plans<sup>23</sup>.

These results show that ENRSSP-estimated public funding allocations are substantial underestimates based on projected financing needs under the EDPRS. This is likely due to the fact that water related

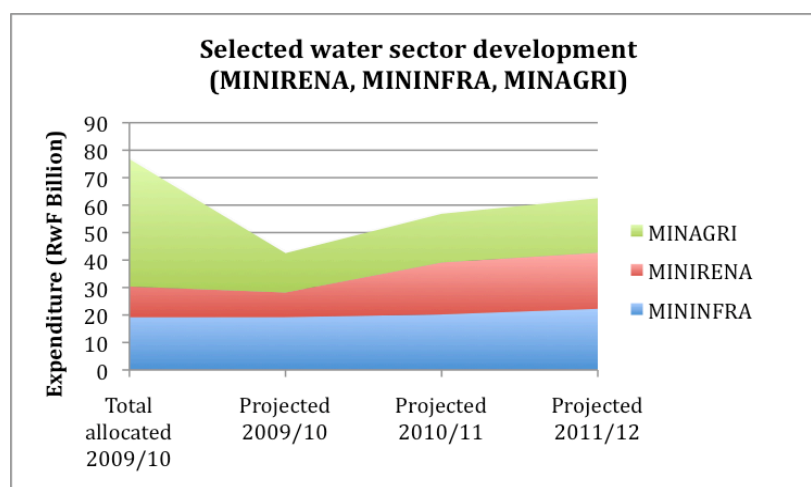
<sup>22</sup> Expenditure for sub-programmes for participatory watershed protection and management within MINAGRI for 2009/10 is US\$ 65.3 million. An estimated US\$ 3.6 million is also being put towards improved weather forecasting and meteorological systems within MININFRA. MINIRENA will receive US\$ 19.6 million for sustainable natural resource management corresponding to holistic, integrated water resource management approaches in line with NAPA recommendations. Of these combined resources, about US\$ 10 million is recurrent expenditure, and \$42 million in development financing from the Government and \$36 million from development partners for 2009/10.

<sup>23</sup> Total estimated funding needs under the EDPRS are Rwf 527 billion, or US\$ 926 million, while the ENRSSP reports Rwf 177 billion or US\$ 312 million. This results in a difference of Rwf 349 billion or US\$ 615 million. In the case of the water sector, EDPRS investment needs (Rwf 146,000,000,000) and allocated public funds Rwf (51,570,444,400) create a theoretical funding gap of Rwf 94,429,555,600 or US\$ 166 million. The first difference to note between EDPRS and ENRSSP sub-totals is that EDPRS figures represent estimated sectoral investment needs (i.e. baseline needs), while ENRSSP represents estimated public budget allocations (baseline allocations). Initial comparison of the two indicates that estimated funding needs are much higher than estimated public allocations to the sector.

program costs inventoried in the ENRSSP due not include the Ministry of Infrastructure's (MININFRA's) substantial water and sanitation infrastructure investment allocations, estimated capital costs for the Ministry of Natural Resources (MINIRENA) sectoral work, or sustainable resource management activities under the Ministry of Agriculture (MINAGRI).

Detailed activities within the programmes range from watershed protection, agroforestry and terracing techniques, to improved rural water supply and enhanced meteorological information networks; all critical baseline adaptation investments for the water sector.

Total public expenditure (domestic and foreign) for the selected sub-programs is shown below. The figure represents baseline investments and financial flows for the current fiscal year and projections out to 2012<sup>24</sup>.



**Figure 22.** Total public expenditure (domestic and foreign) for selected sub-programs.

The sub-programme for sustainable management of natural resources and soil conservation dominates 2009/10 MINAGRI investments at RwF 37 billion (US\$ 66 million). These activities are elaborated in Rwanda's Strategic Plan for the Transformation of Agriculture (PSTA II, 2009), detailed below.

PSTA II sub-program actions

Sustainable management of natural resources and soil and water preservation	
	<ul style="list-style-type: none"> <li>Construct 50 valley dams and reservoirs with conveyance structures for irrigating 3,570 hectares and catchment protection</li> </ul>
	<ul style="list-style-type: none"> <li>Participatory watershed management plans and protection of 20% of the land against erosion via progressive terraces (increasing protected percentage from 30% to 50%), radical terraces, living barriers, contour planting, shift to crops suitable fore erosion control on steeper slopes, etc.</li> </ul>

Source: PSTA II, 2009.

Relative to annual ENR funding needs projected by the EDPRS (RwF 105 billion, US\$ 185 million), present expenditures are around US\$ 50 million less than projected needs. It is conceivable that such a

<sup>24</sup> For MININFRA, sectoral investments in water and sanitation infrastructure, and weather forecasting remain fairly constant around RwF 20 billion (US\$ 35.5 million). MINIRENA expenditure increases gradually over the period, nearly doubling from around RwF 11 billion (US\$ 20 million) in 2009/10, to RwF 20 billion (US\$ 36 million). 2009/10 expenditures for water related developments in MINAGRI are very high in comparison, with RwF 46.4 (US\$ 81.5 million), more than MININFRA and MINIRENA combined. These investments differ dramatically from MTEF projected expenditures for the 2009-12 period.

funding gap might be covered by climate adaptation investments – essentially enhanced climate resilience (to address current needs).

On top of this, there is the potential for additional investment needed for enhancing resilience in the sector to future climate change. The standard approach in I&FF analysis is to apply a mark-up to the sector. However, In this case, a detailed look at the projections reveals that on average, precipitation is projected to increase. This makes such a mark-up highly uncertain – and socio-economic development (rather than climate change) is likely to be the key driver in future water demand. This highlights some of the complex attribution issues.

It should be stressed that the above analysis presents only indicative estimates of actual costs and funding gaps, and should be interpreted with caution. Projected investment needs for achieving ENR sectoral development targets will be more thoroughly identified during the public expenditure review (PER), sector-wide approach (SWAp) development program, and specific sectoral strategies (e.g. national water Master Plan) to address discrepancies in projected investment needs.

If further analysis indicates there is underinvestment in areas critical to climate resilient development in water, and other key ENR sectors, filling all or part of such gaps presents is an opportunity for outside investment entities to target adaptation financing. The highlighted funding gap of US\$ 50 million between the EDPRS projected annual funding needs and current 2009/10 public expenditure is an example of such a gap analysis that may help guide adaptation investments. This would support Rwanda in achieving its Vision 2020 and MDG commitments, and possibly increase long-term institutional and local resilience to future climate change.

From these findings, a number of key messages emerge:

- NAPA priority project costs are underestimates: possibly by a factor of two or more. The NAPA projects are only a beginning in terms of prototypes that would lead to scaled up sectoral resilience.
- Indicative costs of US\$ 77.5 million for scaling up watershed protection are roughly in line with existing national plans and public (domestic and foreign) expenditure for watershed management, protection and infrastructure for early warning systems, which total to US\$ 88.5 million.
- Although not explicitly articulated in development plans, activities that can be considered adaptation mainstreaming is being undertaken to a large extent in the water and related ENR sectors, in accordance with NAPA recommendations, namely integrated water resources management (IWRM).
- As a result, a significant 'grey area' exists between adaptation and development investments in the water and sanitation, agriculture, and built environment sectors, and natural resource management.
- Current water and sanitation investment needs for Kigali City, other major towns and rural areas are high and growing: cost-benefit and cost-effectiveness evaluations will be required to screen climate-resilient investments in the future.
- Relative to annual water and related ENR funding needs projected by the EDPRS (RwF 105 billion, US\$ 185 million), present expenditures (RwF 77 billion, US\$ 135 million) are around US\$ 50 million less than projected needs. It is conceivable that such a funding gap might be covered by climate adaptation investments.
- Findings of IFF analysis demonstrates the difficulty of relying on one single baseline projection for future investments, as financial resources and sectoral priorities vary significantly year by year. This emphasizes the need for dynamic development and adaptation mainstreaming investment-planning exercises.
- Ex-post cost-benefit and cost-effectiveness evaluations provide valuable assessments for sectoral planners and investment entities.

## **Energy**

For energy supply, there is a strong linkage with the low carbon growth and water sectors (hydro). The future effects of climate on hydro have been assessed in detail for some Rwandan projects (see previous energy section). Work under the Nile Basin Initiative does not anticipate large reductions in run-off for hydro power, though there is a need for improving hydrological data collection to help in future projections.

A greater concern may arise from the potential for more extreme events, particularly greater rainfall intensity, which would necessitate some planning for greater flood control for existing and future projects and this is a more important priority. Nonetheless, Rwanda is subject to periodic droughts in some regions and there are other socio-economic pressures that may affect water availability for hydro. A more diversified electricity sector, with a range of technologies, would be likely to offer greater resilience to future socio-economic and climate change. This is explored through the low carbon section below and includes diversification to methane generation and other renewables. There has already been some discussion on reducing the vulnerability of Rwanda's energy sector to the impacts of climate change<sup>25</sup>. There is also a need for basic hydrological data collection to enhance capacity for the sector.

For energy demand, the autonomous response to higher cooling demand will be for air conditioning, which will have a cost (additional energy, and depending on how the electricity is provided, potentially higher emissions). There are alternatives to mechanical air conditioning, through passive ventilation, building design, green roofs, etc. However, these require a greater planned response (including e.g. building regulations) and are most cost-effective (or only applicable) at the construction stage. They are particularly important given the long life-span of buildings. While the cooling demand is relatively modest for Rwanda, there could be important issue in relation to peaks of supply.

## **Agriculture**

Many previous assessments already consider short-term adaptation decisions to optimise production and cope with seasonal fluctuations. Assessments also consider potential long-term adaptations in the form of major changes to overcome adversity caused by climate change. However, a single key message for agriculture in Rwanda from the study is to develop a robust, adaptive economy prepared for climate change in a dynamic future. It is beyond the ability of agricultural managers at present to predict future climate change, construct the most effective adaptation options for when they will be needed, and put in place the financial and administrative support for such futures. The aim for agriculture is to ensure response options will be available, appropriate and affordable for the wide range of future conditions that are plausible. Rwanda has already identified vulnerable regions and a range of responses that are a good beginning in this regard.

The Ministry of Agriculture in their plans for 2008 targeted priorities in soil conservation, livestock production, crop production, professional farming, research and transfer of technology, market-oriented production including coffee and tea, rural infrastructure and institutional capacity. The 2008 plan allocated some \$70 million to these priorities.

Two estimates are provided here as illustrative of the scale of effort that may be required and some of the urgent priorities<sup>26</sup>. As a quick guide, the project interpreted existing estimates for the percentage of investment that might be required to adapt to future climate change. The result is a range of values, reflecting plausible scenarios of future investment and the additional cost of climate change.

---

<sup>25</sup> Workshop Report: Reducing the Vulnerability of Rwanda's Energy Sector to the Impacts of Climate Change UNEP GEF Pilot Project implemented by KIST with support of IISD and ACTS Preparation of the Implementation Plan for Phase 2: Field intervention 2007-2009 Prepared by: Jean Claude Uwizeye (CITT/KIST) Anne Hammill (IISD) [http://www.iisd.org/pdf/2007/workshop\\_reducing\\_vulnerability.pdf](http://www.iisd.org/pdf/2007/workshop_reducing_vulnerability.pdf)

See also [http://www.iisd.org/climate/vulnerability/adaptation\\_rwanda.asp](http://www.iisd.org/climate/vulnerability/adaptation_rwanda.asp)

<sup>26</sup> A full Investment and Financial Flows (IFF) analysis for Rwandan agriculture is not possible at present. The new OECD/UNDP guidelines are being pilot tested in Africa. Experience so far suggests this exercise will require at least 18 months to complete in each country.



The analysis begins with the baseline of current investment in agriculture in Rwanda. Two forms of external investment are relevant: Official Development Assistance (ODA) and Foreign Direct Investment (FDI). ODA comes from bilateral and multilateral sources, with a clear development objective (it excludes military aid) (reported by OECD DAC). FDI is private, usually corporate, investment (reported by UNCTAD). In addition, the Government of Rwanda invests in the sector, including research, extension services, support for inputs and major projects. Note that this baseline does not include private investments within Rwanda, although these are likely to be substantial and increasing as Rwandan agriculture becomes more profitable (food crop production increased 15% in 2009 as a result of improved access to fertilizers and better quality seeds, land consolidation and planting techniques.<sup>27</sup>

ODA in 2007 was \$713 million, although the average in preceding years was closer to \$500 million. The proportion of ODA invested in agriculture in Africa is about 5%. However, given Rwanda's agrarian economy, a fraction of 10% is used here (Rwanda currently invests approximately 7% of its budget in agriculture, but would like to reach the Maputo target of 10%). Thus, ODA invested in agriculture for the baseline is on the order of \$70 million. FDI in 2007 was \$67 million. However, less FDI is likely to be investment in agriculture. At 5%, the total FDI for agriculture would be about \$3 million. The Government contributes to agriculture beyond the investment from ODA. This is difficult to judge, and would require a full audit of the sectoral accounts. The Ministry of Agriculture plan for 2009/10 proposes projects that would cost about \$70 million per year. The Government budget is about \$1500 million, and some 11% is devoted to productive services. Assuming most of this is for agriculture (including forestry) and some 20% of the Government budget is from ODA (included above), the additional Government investment might be about \$100 million per year. Thus the baseline investment in agriculture used here is on the order of \$175 million per year (with rounding)<sup>28</sup>.

Future investment is likely to increase, from all sources. However, such investment pathways are impossible to predict over the timescale of climate change. The project (and studies in general) assumes a target year of 2030, similar to the vision exercises that help shape development pathways. The Rwandan vision for 2020 sets a growth target of 7% per year in GDP in order to achieve middle income status by 2020. Recent growth rates have been much higher, in part due to the recovery after regional crises. Targets for GDP are not the same as for ODA and FDI: as an economy accelerates the multipliers for external investment should be higher with a concomitant shift from public to private investment. This bounding exercise adopts two future investment scenarios, applied as well to the Government expenditure (with rounding):

- Low growth: 5% per year increase in investment and Government expenditure, resulting in a total of about \$550 million per year investment in agriculture in 2030.
- High growth: 7.5% per year increase, resulting in a total of about \$925 million in agriculture in 2030

There is very little evidence regarding the additional cost of adapting an investment in agriculture to ensure resilience in the face of future climate change. Some donors are assuming that additional investment would be in the range of 5 to 10% of the baseline investment. Assuming staff and infrastructure are available and most of the adaptation options are substitutes at more or less the same costs, the additional investment might be quite low. On the other hand, provision of physical infrastructure required for additional irrigation, restructuring markets or combating new pests could be quite expensive. As a bounding exercise, two scenarios are:

- Low cost of climate resilience: 7.5% of total investment.
- High cost of climate resilience: 10%.

These estimates give an envelope of adaptation costs:

- Lower benchmark, assuming fairly low future investment in agriculture and relatively efficient adaptation costs: \$40 million per year in 2030.

<sup>27</sup> Government of Rwanda. 2009. Explanatory note to the 2009/10 budget. Kigali.

<sup>28</sup> The GoR's budget for agriculture in 2009/10 was 55.6B RFW (or \$79m). However, there is a potential funding gap which needs to be considered: a recent investment plan, as part of the Comprehensive African Agriculture Development Programme, indicated a funding gap of \$325m.

- Upper estimate, assuming a larger investment stream, a greater share devoted to agriculture and relatively high costs: \$90 million per year in 2030.

The study has also undertaken a case study of adaptation in the agricultural sector, to address soil erosion and enhance climate resilience.

### Case Study 2: Reduced soil erosion and climate resilience (Vi Agroforestry)

Rwanda's landscape is mainly hilly and steep and for this reason, erosion causes loss of fertile topsoil, rendering soils more and more unproductive and threatening the livelihood of 86% of Rwandans who live solely on agriculture. One option to address this is to construct terraces.

The VI programme has facilitated this and has already led to more than 500 hectares of terraces. It reduces soil erosion and reduces effects of drought (slowing down water flow, increasing infiltration), maintaining topsoil, organic matter and water retention. The programme is in the north highlands of Rulindo district, in Kisaro sector. It targets marginal lands, characterised by steep slopes and poor soil.



The benefits include:

- Increased yields and incomes.
- Additional room for livestock fodder, wood production.
- Reduced soil erosion.
- Reduced effects of flooding, improved water quality.
- Technical capacity development.
- Climate change resilience.
- Ensure environmental sustainability.
- Poverty alleviation.
- Promote gender equality

Around 1,000 households have been assisted in making radical terraces in Kisaro, targeting small-scale farmers with landholdings between 0.5 to 5 hectares, many of which are female- and child-headed and/or affected by HIV/AIDS. The estimated investment by Vi-LIFE per hectare is \$580 USD.

The study has taken the project and investigated the costs to investigate the scaling up of such a programme, assuming that terraces will be established on undulating (5-10 degrees), sloping (10-25 degrees) and steep (25-30 degrees) areas in the whole country over a 10 year period, totalling 630,000 hectares. This estimates a total cost of around \$365 million over 10 years. The study has also investigated the technical and institutional barriers to implementation. These include labour and finance as well as technology and the lack of machines to carry out the projects.

Finally, the study has developed adaptation signatures, drawing upon NAPA profiles from Rwanda and elsewhere and Government plans. An adaptation signature is an idealised project that suggests a pathway of responses to build capacity across the range of threats and opportunities and vulnerable populations and regions. Further descriptions of the agricultural signatures are available separately; as a indication of the scale of effort required:

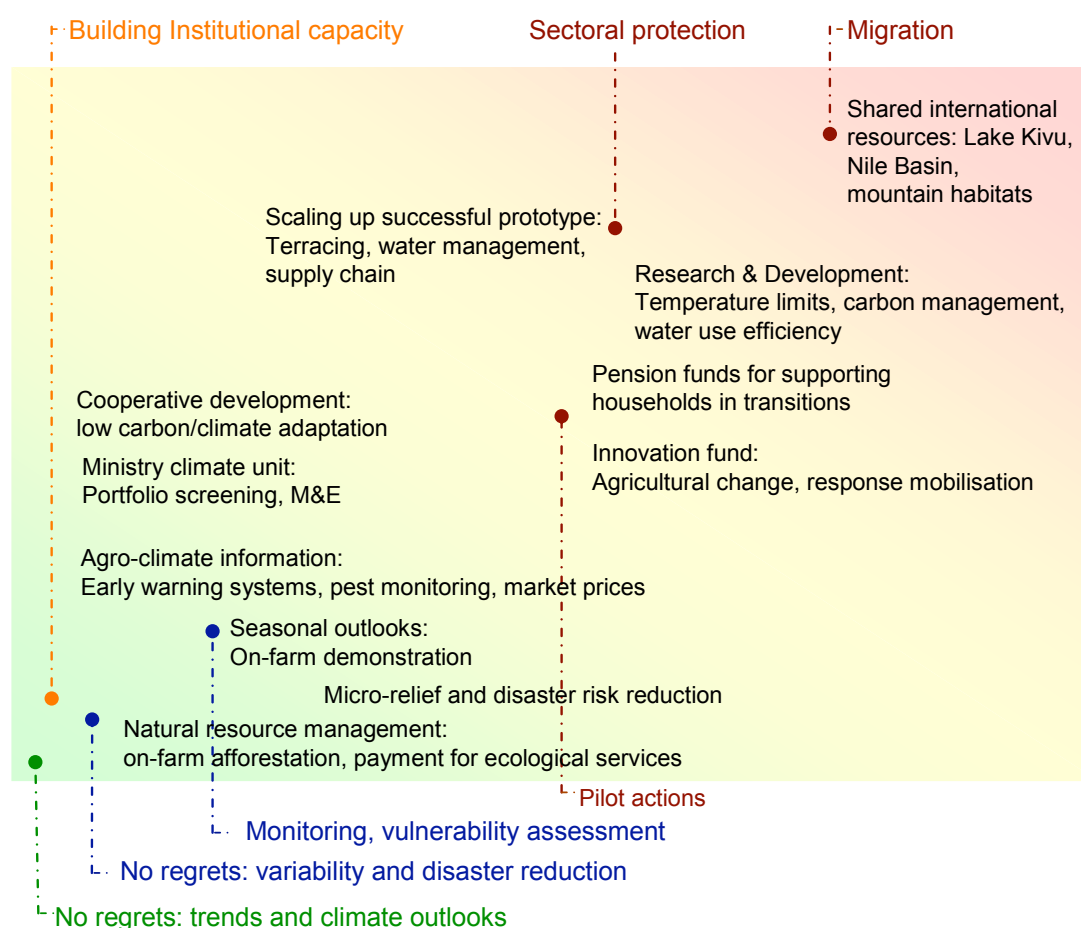
- The medium term strategy proposes 10 areas of programmatic development for agriculture (but note there are synergies with water, energy and other sectors). These range from soil conservation to research and institutional capacity building. In each of these areas, additional climate change adaptation requirements can be readily identified.
- A prototype climate-adaptation action would be essential for each of these activities, while scaling them up to ensure adequate coverage across the regions might require 5 projects for each activity.

Thus, by 2030, some 50 projects would provide a reasonable basis for ensuring the agricultural sector is 'adapting well' to both current and future climate conditions.

- The annual cost of projects of this sort can only be estimated as an illustrative exercise. Most NAPA projects are in the range of \$0.5 to 2.5 million per year. A somewhat conservative estimate would be \$1 million per year for each of these 50 prototypes. Thus the annual cost of adaptation would be on the order of \$50 million per year by 2030.

Note that this estimate is for the additional burden of climate change. The foundations of an adaptive sector, more closely related to development, natural resource management and poverty reduction strategies, is essential. Such costs are at least as much as the additional costs illustrated above, and may well be much higher if major infrastructure is required.

The study also developed adaptation signatures, drawing upon NAPA profiles from Rwanda and elsewhere and Government plans. An adaptation signature is an idealised project that suggests a pathway of responses to build capacity across the range of threats and opportunities and vulnerable populations and regions. The legends locate the type of measure and the text in the matrix represents typical strategies in the sector (see health for description).



**Figure 23. Adaptation signatures for agriculture.**

Further descriptions of the agricultural signatures are available separately; as a indication of the scale of effort required:

- The medium term strategy proposes 10 areas of programmatic development for agriculture (but note there are synergies with water, energy and other sectors). These range from soil conservation to research and institutional capacity building. In each of these areas, additional climate change adaptation requirements can be readily identified.
- A prototype climate-adaptation action would be essential for each of these activities, while scaling them up to ensure adequate coverage across the regions might require 5 projects for each activity. Thus, by 2030, some 50 projects would provide a reasonable basis for ensuring the agricultural sector is 'adapting well' to both current and future climate conditions.
- The annual cost of projects of this sort can only be estimated as an illustrative exercise. Most NAPA projects are in the range of \$0.5 to 2.5 million per year. A somewhat conservative estimate would be \$1 million per year for each of these 50 prototypes. Thus the annual cost of adaptation would be on the order of \$50 million per year by 2030.

Note that this estimate is for the additional burden of climate change. The foundations of an adaptive sector, more closely related to development, natural resource management and poverty reduction strategies, is essential. Such costs are at least as much as the additional costs illustrated above, and may well be much higher if major infrastructure is required.

### ***Biodiversity and Ecosystem Services***

As highlighted earlier, ecosystem services provide multiple benefits to the population and economy that span across most sectors. The discussion of agricultural and water adaptation are discussed above. This section concentrates on the adaptation aspects associated with biodiversity and the wildlife, notably because of their importance for tourism revenues.

A number of potential adaptation measures are available. There are a number of general approaches that these can adopt.

- To maintain and increase ecosystem resilience: enhancing the ability of ecosystems to absorb and recover from change whilst maintaining and increasing biodiversity needs to be enhanced.
- To accommodate the potential impacts of climate change: considering both gradual change and extreme weather events – the latter of particular relevance for Rwanda.
- To facilitate knowledge transfer and action between partners, sectors and countries: successful adaptation requires that biodiversity conservation is integrated with other land and water management activities.
- To develop the knowledge/evidence base and plan strategically: to effectively plan for an uncertain future, the best available evidence is needed to develop techniques that allow biodiversity to adapt.
- To use adaptive conservation management. This relates to the use of a flexible approach for effective conservation.
- To enhance monitoring and indicators, to allow evidence to be collated, existing schemes to be strengthened and new requirements incorporated.

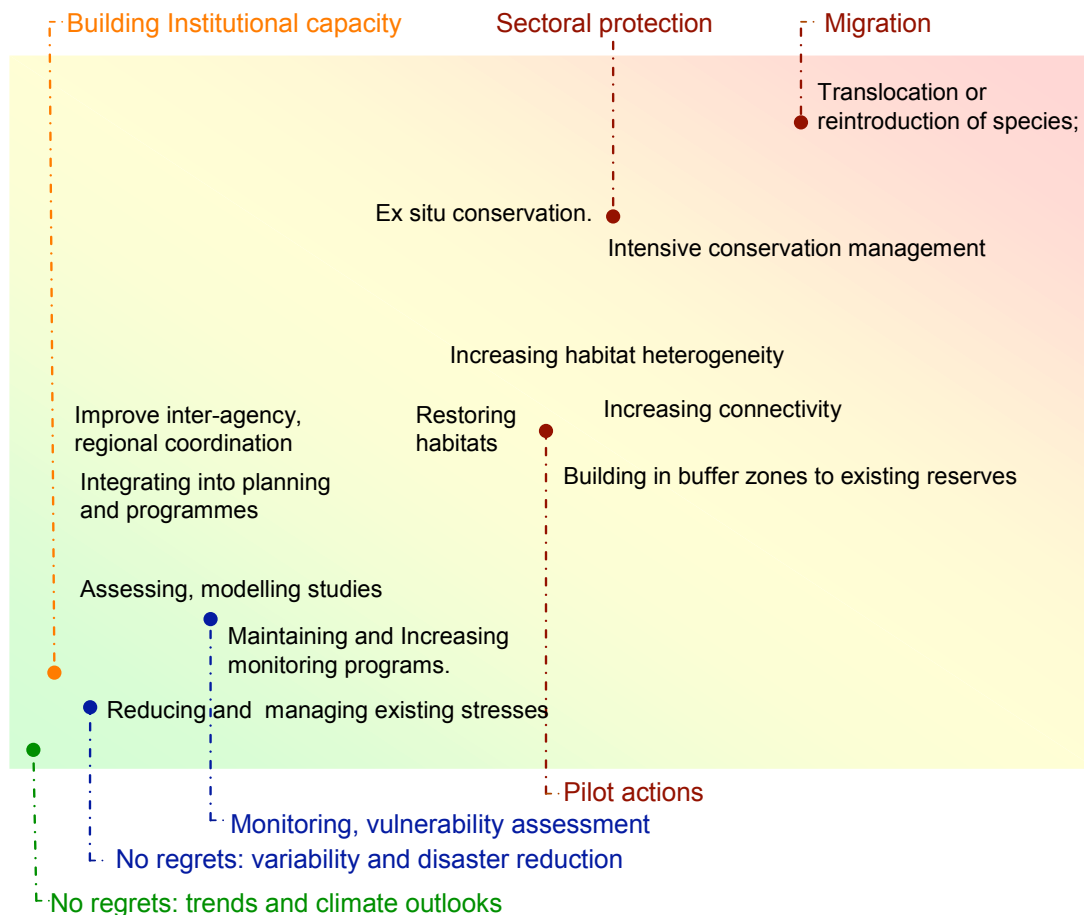
A key feature of these adaptation measures is the need to build in flexibility, i.e. adaptive management, because the future effects on ecosystems are particularly uncertain. However, the uncertainties of the precise nature of future climate change and its impacts on biodiversity must not delay practical action.

These lead to a range of potential adaptation response, many of which build on addressing existing risks or extending existing conservation. They include:

- Reducing and managing existing stresses, such as fragmentation, pollution, over-harvesting, population encroachment, habitat conversion and invasive species;
- Maintaining ecosystem structure and function;
- Increasing and maintaining basic monitoring programs;

- Integrating climate change into planning exercises and programmes;
- Assessing, modelling, management, and experimental spatial scales for improved predictive capacity;
- Improving inter-agency and regional coordination;
- Increasing the size and/or number of reserves;
- Restoring habitats;
- Increasing habitat heterogeneity within reserves and between reserves;
- Building in buffer zones to existing reserves;
- Increasing connectivity, for example with the use of wildlife corridors or stepping stones, removal barriers for dispersal, linking of reserves, reforestation;
- Studying response of species to climate change (physiological, behavioural, demographic);
- Intensifying conservation management to secure populations, including for threatened and endangered species;
- Translocating or reintroducing species;
- Ex situ conservation.

These interventions can be framed within the signatures approach. The legends locate the type of measure and the text in the matrix represents typical strategies in the sector (see health for description).



**Figure 24. Adaptation signatures for ecosystem (wildlife).**

This section highlights some of the early and no regret options, such as addressing existing stresses (also related to development), assessing vulnerability and putting in place monitoring programmes, and a focus

on building capacity to address climate change risks and improve co-ordination. It also explores a series of steps for pilot actions, looking at potential options that might help increase the resilience of existing ecosystems. These could be tested and then if appropriate, formulated into full sectoral plans.

It is more difficult to cost these actions as the literature does not contain appropriate estimates. The case study has also explored potential options and some initial estimates of costs.

### **Case Study. Mountain Gorillas**

As highlighted in the section above, while there are high uncertainties involved in trying to predict future effects, there are still adaptation responses that can be initiated, provided these have a flexible approach.

Several initiatives are taking place in the region to enhance the protection of the national parks and reduce the threats to the mountain gorilla population, whilst still benefiting the local communities in the area. The Rwanda Environment Management Agency (REMA) is conducting research to better understand the effects of climate change in the region and the role of environmental protection to reduce future climate risks, working in collaboration with the Meteorological Directorate and the Ministry of Agriculture. There are also other organizations including the African Wildlife Foundation (AWF) and the World Wide Fund for Nature (WWF) which are leading the International Gorilla Conservation Programme (IGCP) covering the entire mountain gorilla range in Rwanda, Uganda and DRC, working closely with the respective protected area authorities. The IGCP supports the development of a regional mountain gorilla conservation policy, but also works to reduce local community dependence on park resources, minimise human-gorilla conflict and support a more equitable distribution of the benefits from gorilla tourism. Several other initiatives (e.g. Great Apes Survival project, CMS Gorilla Assessment, Concerted Action) are combining efforts for the protection of the gorilla habitat against a background of multiple stresses, violence and economic disintegration in the region (UNEP/CMS 2008). A strong co-ordinated and harmonized regional (Rwanda, Uganda and DRC) approach is needed.

One additional option is the development of payment for ecosystem services (PES) schemes in the region. Ecotourism in the Virungas is still under-developed and has great potential, generating resources for conservation and involving and encouraging local communities in conservation activities as well as providing them with economic benefits. These could also consider carbon markets, notably schemes for Reducing Emissions from Deforestation and Degradation (REDD).

The study has also explored the potential costs of adaptation. To investigate, it has considered the case of the Gorilla Conservation Agreement, which came into effect as a legal framework that will reinforce and integrate conservation efforts in the region and has been signed by six of the ten gorilla range states. The Agreement will be implemented via a regional Action Plan. As part of the Action Plan, range state authorities and international partners are requested to:

- Establish additional protected areas and ensure connectivity: networks of connected protected areas through biological corridors that help conserve species and habitats, and maintain ecosystem services;
- Enforce protection in protected areas: based on the idea that well managed areas should not suffer encroachment and deforestation;
- Establish buffer zones around protected areas;
- Improve ecosystem management in forest concessions and promote sustainable agricultural practices;
- Create awareness among the local population of the value of ecosystem services and biodiversity, and improve forest monitoring schemes;
- Enhance regional and international collaboration on forest conservation;

Some of these costs have been estimated by MINITERE (2003) in dealing with the cost of conserving and protecting the gorilla population in Rwanda. These include many of the adaptation areas highlighted in the signature above. It has been calculated – in approximate terms - that just under \$1 million should be invested in the protection of the Volcanoes National Park to achieve the objectives established under the Rwanda's National Great Apes Survival Plan 2003-2008. Climate change might be expected to increase these conservation costs, Flexible approaches are needed to deal with changing conditions and futures. This includes building the capacity and the incentives to increase options that are economically attractive for the local population and can reduce pressure on the natural capital.

## ***Synthesis and Recommendations***

The study has investigated the top-down aggregated estimates of the costs of adaptation. This has used estimates for Africa/East Africa and scaled these to Rwanda.

The immediate needs (for the year 2012) for building adaptive capacity and addressing early priorities requires a significant scaling up from the current NAPA estimates (\$8 million), estimated at \$50 million/year. However, a much higher value of approximately \$300 million/year is warranted if the categories of social protection and accelerated development (to address the current adaptation deficit) are included. As highlighted above these categories are associated with current climate variability – such as the existing vulnerability to floods - and are therefore associated with development, rather than with future climate change. However, investment in these areas provides greater resilience for future change and they are essential in reducing future impacts.

The estimated costs of adaptation will rise in future years. The aggregated estimates provide a possible range, with implications for the source and level of finance required. Estimates of medium-term costs to address future climate change are typically of the order of \$50 – 300 million per year for Rwanda by 2030, focused on enhancing climate resilience. Note that the investment in 2030 builds resilience for future years when potentially more severe climate signals occur. However, higher values (in excess of \$600 million /year) are plausible if continued social protection and accelerated development are included, noting that these are primarily development activities.

The study has also assessed the costs of adaptation for Rwanda using a sectoral bottom-up approach, to test the estimates above and to give greater insight into sectoral planning.

The study has advanced a framework to prioritise early adaptation in the sectoral analysis, which considers uncertainty within an economic framework. This identifies early priorities for adaptation of:

- Building adaptive capacity;
- Focusing on win-win, no regret or low cost measures (justified in the short-term by current climate conditions or involving minimal cost);
- Encouraging pilot actions to test promising responses; and
- Identifying those long-term issues that require early pro-active investigation (though not necessarily firm action).

A series of ‘adaptation signatures’ have been developed to identify actions in each of these four categories for each sector. The broad outline of steps (as above) is the same in each sector. However, the exact activities vary, hence the use of a ‘signature’ concept that considers options on a case by case basis. These signatures have been to develop indicative adaptation costs for the health, water and agriculture sectors. These have been complemented by case studies which include examples of adaptation projects and costs.

In the health sector, the potential costs of adaptation to address the potential increasing burden were considered based on treatment and prevention costs. In the water sector, water resource investments were assessed across sectoral activities to identify areas for climate resilient development and adaptation mainstreaming, based on the Rwanda’s NAPA and EDPRS recommendations for integrated water resource management (IWRM), as well as 2009/10 public expenditures and MTEF projections. In the agricultural sector, estimates are provided to illustrate the scale of effort that may be required and some of the urgent priorities.

A large number of immediate priorities areas and no regrets options have been identified from these assessments. As examples, they include the strengthening of effective surveillance and prevention



programmes for health linked to enhanced meteorological systems and similar strengthening programmes in other areas (e.g. expanded monitoring of key ecosystems). They also include capacity building to strengthen the meteorological and hydrological analysis and forecasting for seasonal outlooks and forecasting (agriculture) and extreme events (flood risk), with the latter linked to the strengthening and development of early warning and disaster risk reduction, as well as risk mapping and basic screening in planning. Finally, they include pilot actions across all sectors and for promising options (e.g. terracing, malaria prevention) the potential scaling up of sectoral programmes.

They outline the need to develop and adopt more proactive, systematic, and integrated approaches to adaptation in key sectors (water resources, agriculture, energy, and forestry) that involve adaptive capacity, technical and non-technical adaptation measures. The focus on early adaptive capacity and no regrets measures (many linked to development) are key.

The sectoral assessments and the case studies show relatively high adaptation costs, which confirm the lower end of the adaptation estimates for 2030 above and justify investment needs. They also demonstrate the potentially much larger costs when development-adaptation needs are included. The studies demonstrate that adaptation has potentially very large benefits in reducing present and future damages, as well as taking advantage of improved-conditions. Finally, the studies demonstrate that adaptation has potentially very large benefits in reducing present and future damages.

The additional information from the case studies highlights the potential role of adaptation in addressing the most vulnerable. This is an important dimension – without these case studies – and the information provided, a more aggregated economic analysis would only focus on those areas that gave greatest economic benefit, rather than necessarily towards those who might have the greatest needs.

***The study shows potentially high costs of adaptation to address climate change. The estimates confirm the lower end of the top-down estimates. They also demonstrate the potentially much larger costs when development-adaptation needs are included, including addressing the current climate variability and adaptation deficit.***

However, while adaptation reduces damages, it does not remove the impacts of climate change entirely. Residual impacts in Rwanda, particularly for some regions and groups of society, will need to be considered. They will also be important for recovery after climatic disasters and for future impacts. These residual impacts will be much higher unless a global stabilisation target is agreed. Indeed, under a business as usual scenario, it is likely the level of impacts will exceed the limits of adaptation in later years. It is highlighted that the costs of adaptation are only part of the full costs of climate change: both adaptation costs and residual effects are therefore important for international negotiation discussions.

There are also issues in relation to the need to consider regional level action – whether this is to address trans-boundary issues or the potential for regional issues that will have knock-on effects to Rwanda. These will require joint policies and cooperation. These regional aspects are being addressed through consideration of the overall Economics in East Africa work.

There is a need for Rwanda to agree on next steps, the future focus and to build capacity, including national and sectoral planning objectives, enhanced knowledge networks and verifying outcomes of adaptation strategies and actions. To advance this, the study has considered the implications of the analysis and formed recommendations.

A public institution such as a national adaptation facility could be established to assess the potential for climate resilient growth across all areas of the economy, and to mainstream adaptation into government ministries and with Rwanda's development partners. Involvement of Rwanda's finance and planning

ministries is critical for budgetary alignment with adaptation strategies. The Vision 2020 plan should be revisited in light of the potential effects of climate change and opportunities for adaptation (and for low carbon growth). A detailed assessment of future adaptation needs, e.g. based on the OECD investment and financial flow analysis, by sector would establish a needed benchmark for development planning and firm basis for increased funding.

Adaptation Strategies	Priority Actions
<b>Immediate needs &amp; capacity building</b>	<ul style="list-style-type: none"> <li>• Expanded research assessment into effects, adaptation and economics. Early capacity building, e.g. meteorological data/systems and early warning systems</li> <li>• Develop national climate change strategy including knowledge management and screening of sectoral and regional plans for climate risks and adaptation opportunities. Include in EDPRS revision. Build into long-term vision (e.g. next Vision 2020)</li> <li>• Prepare plans for a national adaptation authority to improve sectoral coordination, link to international finance, and support private sector. Enhance links between adaptation and low carbon.</li> </ul>
<b>Climate resilience</b>	<ul style="list-style-type: none"> <li>• Develop climate resilience strategies for immediate concerns (e.g. cross sectoral meteorological systems, information and forecasting, health and malaria monitoring and actions, flood risk screening)</li> <li>• Develop prototypes of sectoral actions (pilots) and pathways for scaling up to cover all vulnerable regions and populations</li> </ul>
<b>Social protection</b>	<ul style="list-style-type: none"> <li>• Protect vulnerable livelihoods and strengthen existing social protection programmes, expanding the coverage to consider climate change.</li> </ul>
<b>Accelerated development</b>	<ul style="list-style-type: none"> <li>• Adapt existing development projects to include 'no regret' measures to reduce climate risks and opportunities to develop adaptive capacity</li> <li>• Scale up successful prototypes to sectoral development plans</li> </ul>

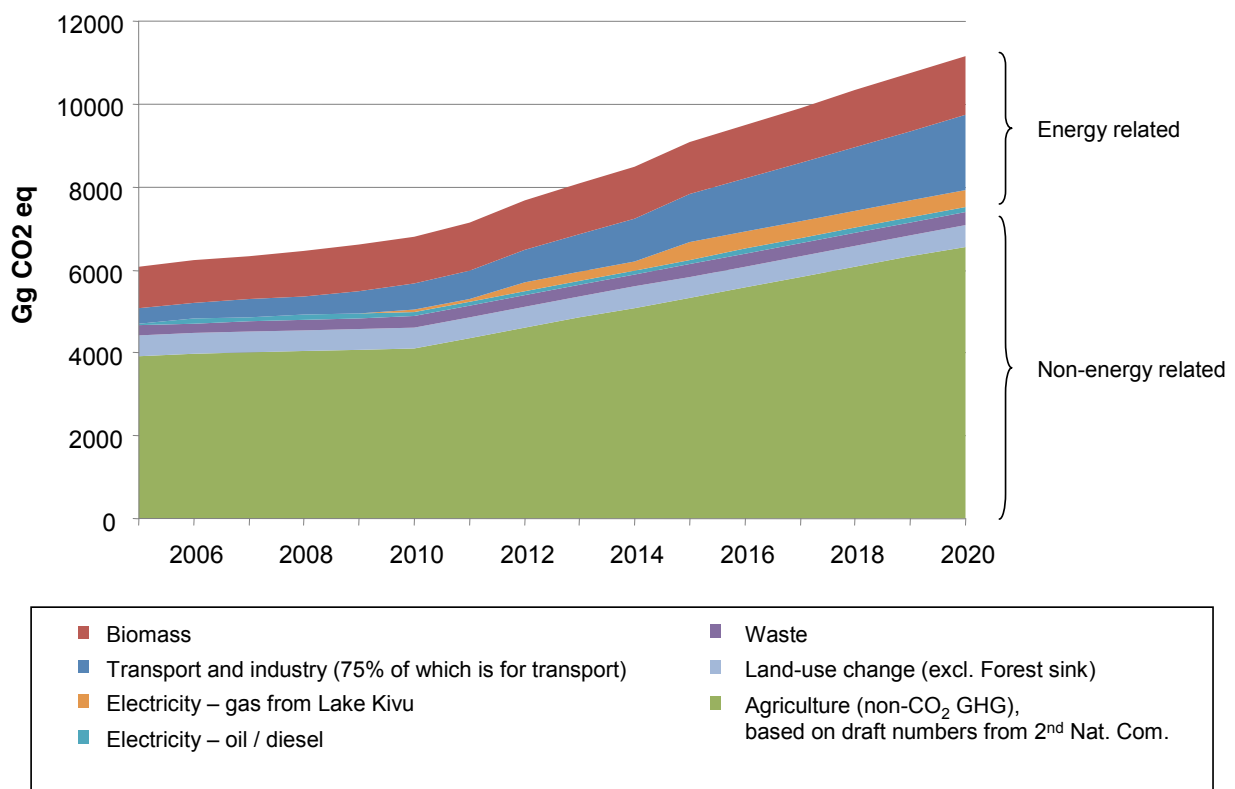
Finally, while there is a large need for adaptation finance, and entitlement to substantial funds must be assured, accessing these funds will require the development of effective mechanisms and institutions. This requires early and concerted action to build capacity across stakeholders and with the affected communities themselves.

## 4. Low Carbon Growth in Rwanda

The study has estimated the potential for low carbon growth in Rwanda, looking at the potential changes in emissions consistent with planned development in the Vision 2020. The implications of this development pathway have been estimated and an alternative, low carbon growth plan looking for carbon financing opportunities has been developed. A longer technical report is available on the low carbon study at the study web-site (<http://rwanda.cceconomics.org>). This section summarises this work.

Rwanda currently has relatively low emissions of greenhouse gas emissions (in total and per capita terms). This is due to a high proportion of renewables in the electricity sector and the high use of biomass energy by households. The largest emitting sector is agriculture, primarily from emissions from livestock. The next most significant sector is energy consumption, primarily from consumption of oil products in transport and industry. However, emissions are growing quickly and energy sector emissions are estimated to have increased by 50% over the last decade. Moreover, the strong growth planned in the Vision 2020 will increase future GHG emissions and per capita emissions significantly.

The study has first developed a baseline, using the growth projected in the Vision 2020, as well as other changes from population and urbanisation trends. It is estimated that the policies in the Vision will lead to a high increase in emissions under a future 'business as usual' scenario. The graph below provides an illustration of the expected emissions to the year 2020 for the different sectors. There is a clear indication of the growing importance of agriculture (though predictions are more uncertain) and transport.



**Figure 25. Graph of projected GHG (Gg CO<sub>2</sub> eq.) including land-use in Rwanda (note uncertainties in projections and excludes forests/sinks, thus indicative only)**

Source: study team, based on the 1st and draft 2nd National Communication.

These projections are preliminary. A key recommendation is for future work to develop a more comprehensive emissions profile by sector.

In many areas, Rwanda is already initiating measures and policies that are consistent with low carbon development. These provide practical demonstrations of the benefits of such policy. The most obvious progress is in the electricity sector, where carbon intensity has been falling, as well as reducing energy costs and improving the environment. There has also been progress in more efficient use of biomass in the domestic sector, which has wider environmental and social benefits. A selection of projects is shown below.

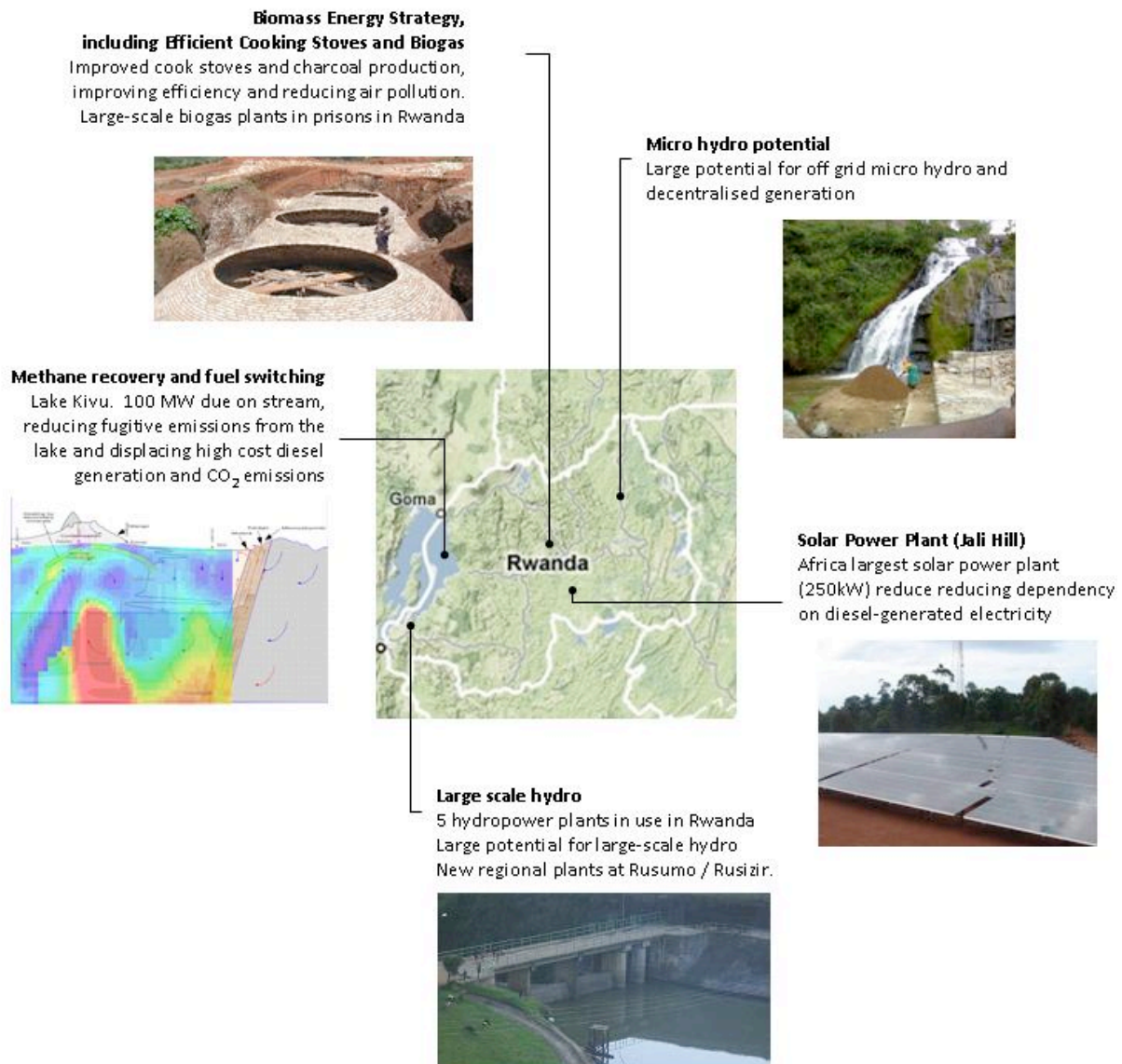


Figure 26. Examples of existing low carbon projects in Rwanda

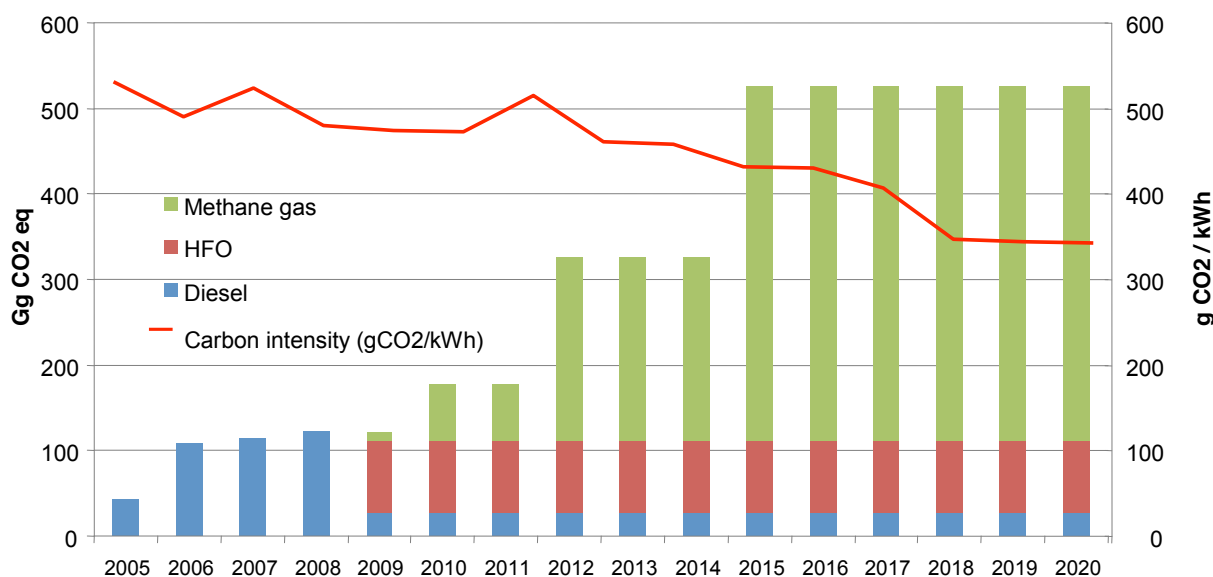
Source pictures: MININFRA

However, there are greater opportunities and the study has considered these by sector.

## Electricity

Rwanda already has a low carbon electricity sector and this will continue. The study has estimated future possible electricity generation and emissions, using demand forecasts from Vision 2020, and a project-by-project basis, to assess existing and planned capacity. This includes the Lake Kivu project, planned hydro (Rukarara and Nyabarongo), greater access to regional hydro projects (Rusizi III / IV and Rusumo) and removal of rented diesel after the start of the Jabana Heavy Fuel Oil (HFO) plant early in 2009. An estimate has also been made for later extensions of the Lake Kivu project up to a total of 200 MW (100 MW in 2015, though this may come on line with 50 MW in 2014 and the rest a few years later).

Approximate projected estimates of CO<sub>2</sub> emissions from the generation sector are shown below. These indicate significant absolute increases, albeit from a low base, due to the increased level of generation (rising supply), and due to the CO<sub>2</sub> from methane generation (using the Lake Kivu resource<sup>29</sup>). However, while emissions are increasing, the sector is becoming less carbon intensive. The carbon intensity per unit of generation (grammes of CO<sub>2</sub> per kWh supplied) is falling, thus the Rwandan electricity generation is broadly on a low carbon trajectory. The fall happens as oil-fuelled plant become a relatively lower proportion of the overall generation mix, with demand growth met by renewables (hydro) which are zero carbon, and the methane Lake Kivu methane project, which is medium carbon intensity.



**Figure 27. Projected CO<sub>2</sub> emissions for the Electricity Sector and CO<sub>2</sub> intensity of generation (g/kWh, indicated by the red trend line)**

This lower carbon path offers significant economic benefits through lower prices. At present, the average cost of diesel generation is about \$0.26/kWh in Rwanda vs. the overall average cost of generation of \$0.14/kWh (as quoted in the World Bank Lake Kivu study), though other sources cite an average of \$0.20/kWh or \$0.23/kWh. The cost of generation from Lake Kivu IPP should be about \$0.06-0.07/kWh (though other sources cite \$0.09/kWh). This will lower the overall cost of power generation significantly, with some estimates of a reduction of 50%.

<sup>29</sup> In this analysis above, we assume that the methane in the lake is continually being generated (self generating). However, while the methane itself may be of biomass origin, it may not have been produced from biogenic substrates. Thus for combustion, we assumed CO<sub>2</sub> emissions are treated similar to fossil fuel gas. Note also that we assume that the methane in the lake would not have been emitted from the lake within the conventional time-scales for carbon reporting, thus there is no net effect in reducing the release of methane which has a higher GHG potential. We also assume that CO<sub>2</sub> from the extraction process is re-injected to below 200 metres depth, to prevent short-term release. It is assumed that gas engines are used

The low carbon projects (including hydro) will provide greater energy security, reductions in air pollution, reduction in forests (and deforestation) for energy, reduction in energy imports (balance of payments) and offer potential for electricity exports (regional). There is also the benefit of potentially reducing the risk of a gas eruption from the methane in the Lake.

However, these predictions are conditional on regional hydro (or other low carbon renewables) coming on line. Moreover, a third phase of Lake Kivu (>200 MW capacity total) would increase the carbon intensity of Rwandan generation overall, as the carbon intensity of the project (at around 450 – 500 gCO<sub>2</sub>/kWh) is much higher than average generation mix (see red line in the figure above).

We highlight that any carbon intensity targets in the electricity sector could be made difficult with a change in the ratio of Lake Kivu: renewables, as greater Kivu capacity is added in future years. To reduce carbon intensity other zero carbon resources – notably hydro, geothermal and possibly wind (currently being assessed) could be considered in the generation mix. Such alternatives would need to be considered against the very low costs of generation at Kivu, though geothermal might offer a lower cost alternative. . Alternative might, also free up the methane resource for other uses (for example, for fertilizer manufacture, CNG, etc).

If overall generation emissions were to start to rise, e.g. with a third phase of Lake Kivu, this could increase average carbon intensity of the overall generation sector at the time when international negotiations are likely to get much stricter and when there are likely to be greater opportunities for carbon credits for Rwanda, i.e. it represents a potential lost opportunity for Rwanda for future credits - though the value of the flow of credits from this one plant alone is very small (and the plans could always be scaled down if needed<sup>30</sup>). However, the general concept of the reduced opportunities from higher carbon alternatives in future years – especially if replicated across all economic sectors - is an important one, especially in the context of emerging national level mechanisms.

It is also useful to look at what could be achieved in terms of a lower carbon path below the 'planned policy estimate'. The simplest scenario would be based on the further introduction of renewable energy, e.g. geothermal, wind, hydro, to replace the existing diesel and HFO plants, rather than further extensions of Lake Kivu (see notes above about Kivu). At this stage we have not considered a scenario where renewables displace planned Kivu capacity, as this appears to be an important source for ensuring supply diversification, and which is very economic.

The study has considered the potential for extended renewables (beyond the plans above). It has also considered the levelised costs of generation, Using this analysis, on a project basis (not taking account of grid operation / risk), most renewable options with the exception of solar PV and thermal, micro-hydro and pumped storage are cheaper than diesel generation. Geothermal is particularly low cost, suggesting continued resource assessments in Rwanda are very worthwhile.

The existing fossil-based plants do have some important advantages, in relation to load balancing and peaking supply, and these need to be balanced in planning. Some consideration would need to be given to grid operability before removing this fossil generation; in addition, the HFO plant is new and therefore shutting this plant down early may not be economically viable.

Distributed or off-grid generation may have an important role to play in providing electricity in those areas where grid distribution is not possible, or economically viable. In 2020, the forecasts for electrification show that 35% of households will be connected; this therefore leaves a significant potential for micro-scale generation

---

<sup>30</sup> Note there is also the potential that later phases of the Lake Kivu projects could be used for exports, and displace other power in the region. The overall impact of this would depend on the generation mix displaced, though emissions from the plant would still be associated with Rwandan national emissions under current reporting.

These low carbon options also allow further access to international carbon credits. These would also have wider economic benefits from reducing air pollution, reduced environmental impacts associated and greater energy security and diversity. Many of the options also increase the resilience of the system to future climate change, e.g. by offering diversity away from hydro generation which is vulnerable to outages in droughts years (see previous sections).

The study has also considered the potential low carbon options in the other two key sectors: transport, particularly due to private car use and increased freight on roads; and agriculture due to livestock, arable output and changing agricultural practices. Low carbon options are available at low cost but will require specific policies for implementation.

## **Transport**

Transport represents the fastest growth source of emissions, and is a key issue because of growing urbanisation. At present, Rwanda has an extremely small number of road transport vehicles, with only 75,000 registered total vehicles (vehicles recorded since 2001), a large proportion of which are motorcycles. However, vehicle numbers are growing rapidly. In 2008, Rwanda imported 67.5 million litres of petrol, 99.2 million litres of diesel and 15.0 million litres of kerosene. The Vision 2020 document anticipates that petroleum product consumption will increase by more than 10% per annum, thus by 2020, fuel imports could have grown significantly (to a total of 500 million litres of petrol and diesel).

Rwanda faces higher costs for this fuel than most other countries owing to its distance from a port and the delays of bringing the fuel across borders. Low carbon options would therefore have economic benefits (lower costs and reduced payments of imports), potentially allowing scarce foreign exchange to be better spent on capital goods to enhance the growth potential. It is noted that the development of the road system is important for growth, indeed, the improvement of the road network and access is likely to be important for future planned improvements in the agricultural sector. However, a key issue surrounds the growth of urban transport. This is of greatest concern for the capital, Kigali (see box).

### **Urbanisation and transport in Kigali: the potential for another Nairobi?**

The population of Kigali was 800 000 in 2005 (and around 9% of the total population of 9 million). It is forecast to grow to around 1.6 million by 2015 (UN Urbanisation Prospects/UN World Population Prospects (2008).

By 2020 the total urban population in Rwanda (all urban areas) is forecast to reach 4 million (30% of the population of 13 million) and by 2030 to reach 6.5 million (40% of the total population of 16 million). Much of this growth will occur in the capital.

These population and urbanisation rates are likely to lead to a very strong rise in transport demand. Historic assessments in other world regions show that as incomes increase due to economic growth, demand for private vehicle transportation (cars) increases significantly.

One possible future for Kigali, therefore, is towards heavier car use. This will lead to air quality pollution and urban congestion. A possible regional analogue is Nairobi in Kenya. The city has a population of 2.8 million (2005) and has exceptionally high traffic congestion, which translates into loss of time, increased fuel use, higher emissions (GHG) and poor air quality, exacerbated by the prevalence of old vehicles with poor fuel efficiencies and no pollution controls. The economic costs of lost time, higher fuel costs (an hour spent in traffic jams in Nairobi wasted 1.3 litres of fuel per car) and health related illness are already extremely large.

There are, however, alternative patterns. The ratio of car use to income varies dramatically between North America and Europe. This is due to a combination of factors that include spatial design and land-use pattern/controls, fuel prices and urban transport policy. The most efficient cities (Madrid, Amsterdam) have very low private car use per capita income.



The growth in transport and urban planning is one area where a business as usual path might 'lock-in' Rwanda to a higher carbon future: once urban planning decisions are made they have long life-times and are difficult to reverse. The rises in a private car based structure would increase emissions at a time when there are greater opportunities for future carbon markets and reduce opportunities from any national based mechanisms.

To our knowledge, there is no low carbon plan for the transport sector currently for Rwanda. The recently published energy policy (GoR 2009) does have objectives consistent with a lower carbon future (e.g. promoting energy efficiency through maintenance and fuel efficient driving, encouraging mass transport, reducing pollution through cleaner petrol and diesel fuels and encouraging research into alternative transport fuels, including biodiesel).

A range of potential options for the transport sector have been considered.

Option	Cost-effective?	Adaptation synergies	Co-benefits	Barriers
More fuel efficient vehicles	Yes		Reduced fuel costs Energy security benefits Lower AQ pollution (per vehicle) Reduced accidents as modern vehicles	Price differential versus less efficient vehicle Effective enforcement
Advanced technology vehicles e.g. hybrids	Not currently		Reduced fuel costs Lower AQ pollution (per vehicle)	Investment per the alternative Maintenance of newer technologies
Use of biofuels	Dependent on feedstock – and use levels	Land security may be affected by climate impacts	Energy security benefit due to less petroleum use	Conflict with crop production
Modal shifts from road transport to rail and public transport systems	Situation specific		Improved urban environment (AQ, noise, safety) Reduced accidents	Very high capital investment
Non-motorized transport (cycling, walking)	Yes		Reduced vehicles on road Exercise	Higher incomes drive demand for private vehicles
Driving behaviour	Yes		Reduced fuel costs Reduce accidents	Difficult message to promote Difficult to enforce
Road charging			Funding for infrastructure	Lack of public support
Traffic management systems			Reduce congestion	

Given the high price of transport fuels in Rwanda, efficiency measures are economically favourable. Options that encourage more efficient (less fuel intensive) mass transit are similarly attractive. In theory, the same could apply to biofuels, particularly with potential carbon financing, however there are issues with large-scale production (limits beyond 5- 10% of biofuel added to conventional fuel, competition for land resources, and pressures on natural resources<sup>31</sup>). One other potential policy that is being considered is the use of the Lake Kivu gas resource for a 50 MW gas to liquid plant, producing diesel, jet fuel and

<sup>31</sup> Current Government policy is to encourage careful research to be conducted into the potential of large-scale biofuel production in Rwanda taking into account not just the direct costs and benefits, but indirect opportunity costs - reductions in food crops and import substitution or export cash crops, the implications for use of water resources and the environment, net employment implications. It is also to support the development of small-scale biofuels projects which can supply biofuels appropriately and economically for particular applications e.g. remote rural grinding mills. The government and a private sector investor have recently agreed to growth jatropha in marginal land next to Akagera Park.

kerosene: this would reduce fuel imports, though it would actually marginally increase domestic emissions from the process.

Nonetheless, avoiding the future growth in emissions from this sector will be challenging. Policies to address transport often have high political barriers, because policies are often unpopular, and have strong distributional consequences (for the poor). However, failure to address this area will result in higher GHG emissions, air quality problems, and high levels of congestion which could have high economic costs, as well as the economic effects of higher levels of fuel imports (discussed above). Therefore policies could be developed now to ensure a more efficient way of transport (railways, mass urban transport, town and spatial planning) while at the same time increasing efficiency of the existing systems through a range of measures such as tax policies, environmental standards for transport, traffic congestion management by construction of new roads, change in driving behaviour, new types of fuel such as bio-fuels or Compressed Natural Gas (CNG).

The study has considered a range of low carbon options for the transport sector, focusing initially on fuel efficient vehicles and public transport. It is highlighted that this is a priority sector for future consideration and this will require a much greater focus on sustainable travel, with stronger policy and a mix of integrated urban planning, public transport provision and efficient and low carbon vehicle options. In a rapidly urbanizing country, such a strategy is challenging to implement, but is essential to avoid the lock-in towards a high emission private car oriented society.

### ***Agriculture and other sectors***

The outline of the agricultural sector was presented earlier. The study has considered the greenhouse gas emissions potential, though these are indicative values only – additional information is needed to establish the method used to make estimates more robust, and develop better activity estimates for future years. Nonetheless, this highlights some key issues for the sector:

- The ambition to intensify agricultural production could increase GHGs through more intensive use of land for crops. This could be through increase use of nitrogen based fertilisers, which are carbon intensive to produce. Intensification needs to consider good nutrient management, low impact farming measures (reduced tillage), and ways of ensuring carbon storage in soils is maintained / enhanced. This of course has to be balanced against the critical issue of food security.
- There is already a deficit in livestock production supply relative to demand. Furthermore increasing population and growing income will lead to increasing demand. Livestock is a high source of methane emissions. Careful management of an increasing livestock herd will be needed to minimise methane (CH<sub>4</sub>) emissions<sup>32</sup> per unit of livestock production.
- Agriculture is an important sector to Rwanda, and will continue to remain so for the foreseeable future. Developing a low carbon strategy in tandem with any adaptation strategy will be key to ensure Rwandan agriculture remains and moves further to being a lower GHG sector in the future whilst coping with climate impacts.

It is highlighted that some existing policy in the agricultural investment plan (increased livestock herds and increased fertilizer use) will have consequences for baseline emissions and there is a need for further assessments of the GHG impact of agricultural policies.

A number of options have been considered to reduce emissions here, including cropland management, grazing land management and pasture improvement, livestock management.

#### **Cropland management**

- Nutrient management, particularly with respect to method and timing of fertiliser application, to improve nitrogen use efficiency.

---

<sup>32</sup> Methane is a greenhouse gas and has a global warming potential which is much higher than CO<sub>2</sub>.

- Reducing or no tillage farming practices. Soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion; reduced tillage can avoid / reduce losses.
- Water management. Increased or more effective irrigation can enhance carbon storage in soils through increased yields and residue returns. On the negative side, this can see any potential gains offset by energy for pumping, increased emissions from fertilisers.
- Rice management. Reduce CH<sub>4</sub> emissions through various practices including draining and using alternative rice varieties.
- Agro-forestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. On the positive side, this has strong synergies with forest protection, and adaptation. On the negative side, one finds lower intensity of yields.
- Returning cropland to another land cover, increasing the carbon storage in soils / vegetation.

#### Grazing land management and pasture improvement

- Grazing intensity (and timing) can influence the removal, growth, carbon allocation, and flora of grasslands, and therefore affecting level of carbon accrual in soils
- Increasing productivity e.g. fertilisers. Application can increase yields and carbon storage. However, it can also lead to nitrous oxide N<sub>2</sub>O emissions (another powerful greenhouse gas emission) thereby offsetting some of the benefits.
- Nutrient management – as mentioned above for croplands
- Reducing biomass burning, as this can reduce emissions from combustion, plus reduce other direct and indirect effects on green house emissions and climate change.
- Species introduction: Introducing grass species with higher productivity, or carbon allocation to deeper roots, has been shown to increase soil carbon.

#### Livestock management

- Improved feeding practices, for example, feeding more concentrates, normally replacing forages. Although concentrates may increase daily methane emissions per animal, emissions per kg feed intake and per kg-product are almost invariably reduced.
- Specific agents and dietary additives. A wide range of specific agents, mostly aimed at reducing methane emissions, are being investigated.
- Longer-term management changes and animal breeding. Increasing productivity through breeding and better management practices, such as a reduction in the number of replacement heifers, often reduces methane output per unit of animal product.

#### Other measures include:

- Management of organic/peaty soils. Due to the high storage of carbon in such soils, use of these soils for agriculture can lead to CO<sub>2</sub> / N<sub>2</sub>O emissions in particular. This is because soils are drained, which aerates the soil, favouring decomposition. Emissions can be reduced by practices such as avoiding row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table. The most important mitigation practice is avoiding the drainage of these soils in the first place or re-establishing a high water table
- Restoration of degraded lands, which may lead to enhanced carbon storage. Such measures have strong synergies with adaptation.
- Manure management. Animal manures can release significant amounts of N<sub>2</sub>O and CH<sub>4</sub> during storage, but the magnitude of these emissions varies. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling, use of solid covers, mechanically separating solids from slurry, or by capturing the CH<sub>4</sub> emitted. The manures can also be digested anaerobically to maximize CH<sub>4</sub> retrieval as a renewable energy source and there are already some of these systems in place.

Some of the potential policies to enhance agricultural productivity and agricultural intensification will have some potential conflict with low carbon growth, i.e. on their own they may increase emissions. The

measures above could help address these potential increases. There may also be some potential schemes that could reduce emissions, e.g. in relation to enhancing carbon uptake in soils with soil fertility improvements, that are not currently covered by mechanisms, but that would also have the benefits of enhancing future resilience, e.g. against extreme events.

Industry is a relatively small part of Rwanda's emissions, and in the medium to long term, growth of the service sector is the target for Rwanda's economy (which has a lower carbon intensity than heavy industry). Nonetheless a number of options are available to reduced emissions. Measures are highlighted in Rwanda's National Communication. Additional measures, notably around no regrets options, have been assessed.

For the domestic (household) sector, biomass accounts for the vast majority of energy needs (94%), as well as providing energy for small-scale commercial and public sectors. The Vision 2020 suggests that biomass use will increase by 2.3% annually, in line with population growth, though this does not factor in rising per capita energy needs from economic growth.

An important initiative in this area is the Biomass Energy Strategy (MARGE 2008), which sets out what the strategy could achieve in respect of reductions in biomass use. This is due to improved stove efficiency, charcoal conversion improvements and fuel substitution. Other fuels that may well reduce future use of biomass include peat and biogas. The National Domestic Biogas Programme (NDBP) has an objective to install at least 15,000 biogas digesters in rural households owning 2 – 3 cows by the end of 2011. Biogas technology has also been successfully introduced in prisons; this is set to be expanded out to schools and hospitals (GoR 2009).

Peat may also play an increasing role with reserves estimated at 155 million tonnes. Peat can replace firewood for domestic cooking and heating if technical adaptations of the stoves for smoke evacuation are properly taken care of; further research is ongoing about how to use peat. Other uses are also being considered – a cement factory is expected to start the large scale use of peat for heating purposes by 2008/09. An energy company is also preparing a 10 MW peat generation project to produce electricity primarily for the cement factory, with any surplus to grid. However, while peat is a potentially significant resource to meet some energy needs, the IPCC does not regard peat as carbon-free. In the latest guidelines, it states that while peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels. Therefore, the CO<sub>2</sub> emissions from combustion of peat are included in the national emissions as for fossil fuels (IPCC 2006).

The final sectors covered have been waste and forestry. Waste emissions are considered to increase at the same rate as population, while emissions / removals in LUCF sector are held at the same level. While there are likely to be some increasing pressures on forestry resources due to population and economic growth, policy makers have realised the importance of this resource.

According to the EPDRS (GoR 2007), forest cover targets in the Vision 2020 are 30%, up from the current level of 20% (in 2006/7). In addition, this report states the objectives of the 2008-2012 strategy to increase the proportion of protected areas for biodiversity preservation from 8% to 10% in 2012. Forest and agro-forest coverage is scheduled to increase from 20% to 23% of total surface land area, and annual wood consumption is due to be reduced by 30% from the 2002 figure. Soil erosion and soil fertility decline will be reduced by 24% over the EDPRS period.

Curbing deforestation is part of a low carbon pathway, and is now the subject of potential new financing flows (reducing emissions from deforestation and forest degradation in developing countries (REDD)) and also provides protection of natural habitats and ecosystem services.

***There is already progress in Rwanda on low carbon projects, but there is a need to tackle the transport and agricultural sectors, the largest source of future emissions.***

***There are also current plans across all sectors that could 'lock-in' Rwanda into a higher emission pathway. Failure to tackle these will reduce future economic opportunities from the carbon finance markets, especially if future national level mechanisms appear.***

***In response, this initial study has identified a large number of low carbon options, which have economic benefits now, and also offer opportunities for carbon financing***

### ***Investigating the costs and wider co-benefits of potential options***

As highlighted above, there is the potential to implement no regret (win-win) measures across many areas of economic activity in Rwanda, which are immediately available at a low cost, and can improve economic efficiency, as well as delivering low carbon and development objectives.

They also provide important co-benefits from reducing energy imports, enhancing energy security, improving air quality and health, reducing pressures on natural resources, and improving adaptation capability by exploiting synergies. There is also a large and untapped potential for low carbon - pro-poor economic growth projects, which can achieve poverty reduction and emission benefits through low carbon energy access programmes.

We highlight that many such options already feature in government planning, such as further exploitation of hydro resources, assessment of other renewable energy sources (wind, geothermal, biogas) and improving efficiency of biomass use.

It is also important to adopt low carbon trajectories to ensure future growth avoids getting 'locked' in to high emission pathways, and to allow maximum potential for capturing financing opportunities now and in the future. In advancing all of these areas, there is an important role for domestic policy (taxation, regulatory, incentives etc) to encourage low carbon technology development, diffusion and deployment. This also includes the reform of fossil fuel subsidies and low electricity tariffs.

The study has considered a number of the most promising low carbon options that could put Rwanda on to a lower carbon development and growth pathway, focusing on those sectors where emissions are projected to be significant. In addition, there has been discussion about the issues of implementation (particularly barriers) and some of the policies that may be required to ensure such options are taken up.

In this development and economic context, emission reductions are effectively a co-benefit of other policy drivers, and the introduction of these options is driven by self-interest, economic and development objectives. However, the introduction of carbon financing has the potential to increase the relative attractiveness of these options and to help finance their introduction.

In considering options, the study has considered a range of options in terms of whether they:

- Further the goals of development, including poverty alleviation and economic growth.
- Promote greater energy security, reducing reliance on high price fossil / electricity imports.
- Enhance environmental sustainability or have environmental co-benefits.
- Meet objectives of, or at least not conflict with, adaptation strategies.
- Provide opportunities for investment through carbon financing.

It has also considered issues with technology modernization, financing and scaling and barriers to update. The key priority options include:

- Electricity sector decarbonisation, including decentralized technologies
- Reducing transport fuel consumption through improved vehicle efficiency
- Introducing efficient public transport system
- Improving the efficiency of the biomass stove stock
- Industry efficiency improvements
- Reducing agriculture emissions through livestock and cropland management
- Reducing forestry emissions through forest protection and afforestation

In assessing these measures, their marginal abatement cost (cost-effectiveness) and emission reduction potential in indicative terms are estimated. To do this the study has estimated:

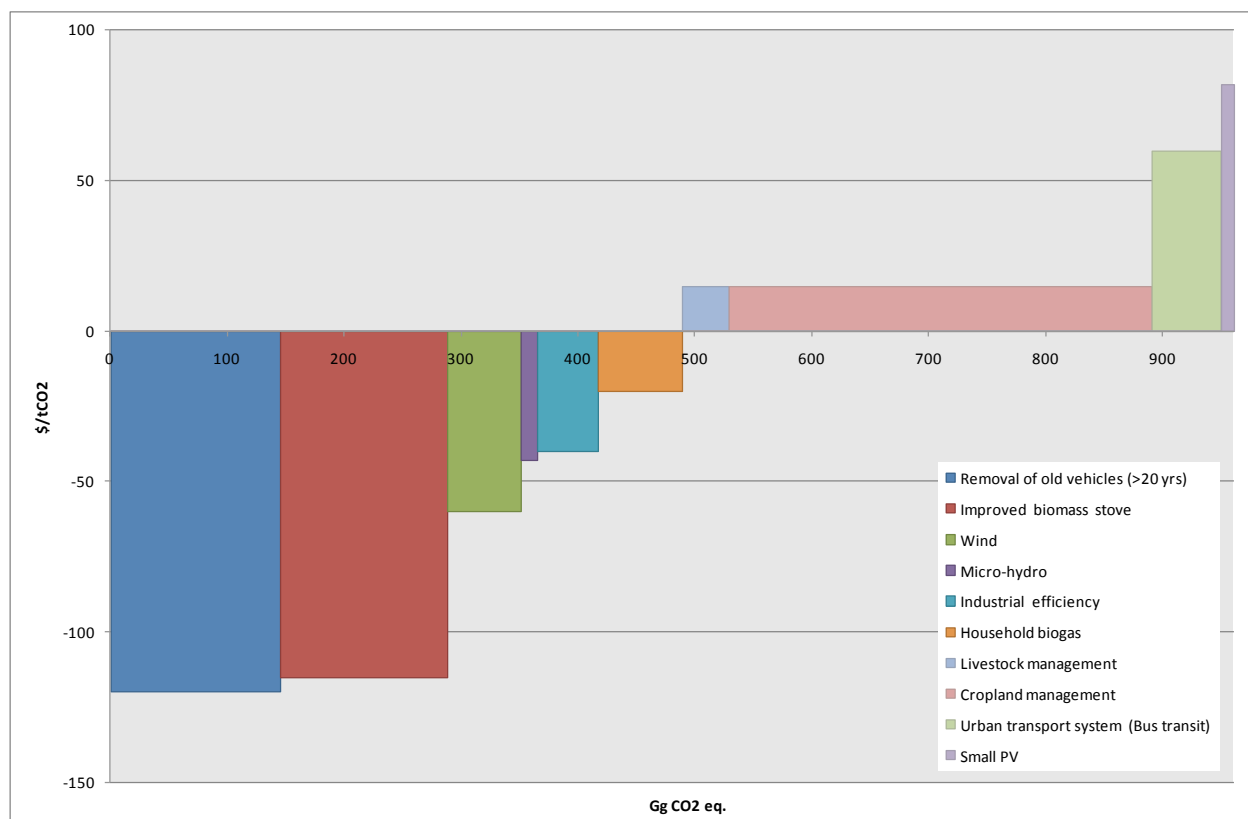
- The indicative unit marginal abatement cost of potential measures, comparing the potential emissions reductions of a measure against the potential annual emission of carbon, thus expressing options in terms of their cost-effectiveness, or \$/tCO<sub>2</sub> abated.
- Assessing the potential opportunity for the options looking at current activity levels and projections through to 2020.
- Combining these to build up an indicative marginal abatement cost curve, i.e. looking at the attractiveness of options in terms of their cost-effectiveness, and assessing the potential total reductions they could achieve through implementation.

The curve is shown below. Many 'no regrets' or low cost options are available, particularly from improvements in transport efficiency, domestic stoves and agriculture. These options have the potential to produce significant emission savings and can be realized at negative cost, i.e. the economic benefits outweigh the costs. An example would be with an energy efficiency that actually saves the individual or company money (e.g. from reduced fuel costs) when compared to the current baseline. This illustrative cost curve highlights the abatement costs and potential of a number of key options that could be considered for moving Rwanda towards a lower carbon pathway. The abatement costs are broadly representative of cost information largely sourced from the East African region; however, the reduction potential numbers are illustrative and based on notional potentials, which require further analysis.

Reducing deforestation and afforestation measures are not included in the above but are also important, as part of the range of options for moving to a lower carbon future, and generally considered relatively low cost.

Note that the above of course does not highlight the many co-benefits associated with the different measures, nor the necessary linkages with adaptation. This shows the importance of a wider framework for assessing low carbon measures, as outlined in the technical report.

***The analysis of a selection of low carbon options shows a potential to reduce baseline energy emissions relative to the baseline: with many options that can be realised at negative or low cost even without carbon financing. These options also have a large number of co-benefits with economic, social or environmental benefits.***



**Figure 28. Indicative marginal abatement cost (MAC) curve of selected energy sector measures for Rwanda.**

### ***Regional and International aspects***

The analysis here has focused initially on domestic aspects. However, there is a need for Rwanda to consider low carbon growth, and enhanced energy resilience, in a regional context. This includes the potential for co-operative regional (East African) responses to enhance opportunities for carbon credits. The consideration of these regional perspectives is considered a priority for future plans and is being addressed in the overall East Africa study.

Finally, there is also a need to consider how the international action by developed countries to address climate change might affect Rwanda, notably in relation to its planned economic growth in areas such as tourism, export products, etc.

### ***Recommendations***

In summary, because of its location, availability of resources, and socio-economic conditions, the study concludes that there are significant economic benefits for Rwanda following a low carbon development path, as well as large environmental and social benefits. A low carbon pathway is strongly in Rwanda's self interest, and would also provide potential extra investment from carbon financing. The alternative low carbon path investigated produces very real economic, environmental and social benefits, including ancillary benefits of reduced imports, improved air quality, improved energy security, and reduced pressure on natural resources.



In many areas, Rwanda is already initiating measures and policies that are consistent with low carbon development. However, there are also potential areas, such as in relation to urban planning, that will 'lock-in' Rwanda into a higher emission pathway. Failure to tackle these high emission growth areas will reduce future economic opportunities from the carbon finance markets, especially if future national level mechanisms appear.

The key aim for Rwanda is to continue the switch to a lower carbon pathway, to further realise these benefits, and to maximise the potential for the flow of carbon credits under existing and future mechanisms.

Mitigation Strategies	Recommended Actions
<b>Low-Carbon Growth (LCG)</b>	<ul style="list-style-type: none"> <li>• Full analysis of low carbon options, costs and potential for prioritisation and development of strategy for mechanisms.</li> <li>• Develop national strategies to mainstream LCG in planning, including a revised EDPRS and possibly new Vision.</li> <li>• Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM)</li> <li>• Prioritize agriculture, transport and electricity generation low carbon measures, considering short-term opportunities but also longer-term areas where potential 'lock-in' and identify alternatives. Improve sectoral co-ordination.</li> <li>• Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use</li> </ul>
<b>Climate resilience &amp; co-benefits</b>	<ul style="list-style-type: none"> <li>• Climate risk screening of low carbon growth pathways</li> <li>• Consider opportunities to achieve robust development, e.g. in planning hydropower (large reservoirs, small in-stream turbines), biofuels, on-farm carbon management (e.g. zero grazing, woodlots)</li> </ul>

Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. There is a need to improve the baseline projections of future emissions. There is also a need for a systematic analysis of low carbon options, their abatement potential and their costs (a full cost curve).

Any development, including low carbon investment, should consider future climate change, which necessitates climate risk screening in future low carbon plans across all sectors. Potential linkages between adaptation and low carbon development (especially in finance) should be explored.

Low carbon plans should extend beyond power generation. This is clearly being observed in the domestic sector, through initiatives under Rwanda's Biomass Energy Strategy. However, the major emissions in Rwanda come from other sectors, particularly transport and agriculture, and these are likely to rise dramatically in future years. For transport, while efficiency gains offer significant opportunities, the demand for private transport is likely to increase significantly. This will require a robust strategy focused on improved public transport, demand management and especially urban planning. For agriculture, there are low cost, low carbon options. There are also significant opportunities through afforestation in the emerging negotiation discussions. All of these will require the mainstreaming of low carbon policy across all of Government.

Rwanda can gain long-term economic, environmental and social benefits through moving on a low carbon growth path, combined with climate resilient growth. Especially in terms of ensuring energy security through the use of local energy resources, the decreased dependence on energy and fossil fuel imports and thus price fluctuations, improving the air quality and health of Rwandans and reducing the pressure on the natural environment.

National action on a low-carbon, climate resilience investment plan would establish Rwanda as an international leader, with the 'first mover advantage' in negotiations and securing finance.

Finally, the potential for a more radical policy shift is also highlighted as an option for Rwanda. Because of the level of current development and the importance of near-term decisions in determining the long-term economic and social structure of the country, it might be possible to truly promote a visionary approach to low carbon development and climate resilient growth within the context of environmental sustainability and economic growth, i.e. to set a new model for Africa. This would position Rwanda internationally along a very progressive vision, consistent with the recent Presidential statements on climate change and in adopting green technology<sup>33</sup>.

*'From the African standpoint – we have more or less stood on the periphery of this debate on the basis that climate change is an industrial problem, born in the West and destined to be solved by these very nations. This should no longer be the case – whether in terms of robust participation in discussion on climate change, or in adopting green technologies for saving our planet'*

---

<sup>33</sup> For example, remarks by his Excellency, Paul Kagame, President of the Republic of Rwanda, at the UNGA Summit on Climate Change, Tuesday 22 September 2009.  
<http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/Rwanda.pdf>

## 5. Project Description and Project Team

The project has been funded by DFID, the UK Department for International Development.

The **Stockholm Environment Institute** (SEI Oxford Office) led the study. SEI is an independent, international research institute, engaged in environment and development issues at local, national, regional and global policy levels. The SEI has a reputation for rigorous and objective scientific analyses of complex environmental, developmental and social issues. The Oxford office leads development of the weADAPT.org platform, managed by the Global Climate Adaptation Partnership ([www.ClimateAdaptation.cc](http://www.ClimateAdaptation.cc)).

This study was commissioned under DEW Point, the DFID Resource Centre for Environment, Water and Sanitation (Bruce Mead) which is managed by a consortium of companies led by Harewelle International Limited. The project team included.

- SEI Oxford, UK: Tom Downing, Paul Watkiss, Jillian Dyszynski, Ruth Butterfield, Tahia Devisscher, Steve Pye, Jane Olwoch (RSA).
- SEI Nairobi: Basra Ali, Brian Harding, Adriaan Tas, Mark de Blois.
- IGAD Climate Prediction and Applications Centre (ICPAC).
- Metroeconomica: Alistair Hunt and Tim Taylor.
- London School of Hygiene and Tropical Medicine: Menno Bouma and Sari Kovats.
- ILRI: Joseph Maitima, Simon Mugatha, Patrick Kariuki.
- IIED: Muyeye Chambwera and Tom Birch.
- Vi-LIFE Programme: Bo Lager, Jorge Suazo, Faustin Rwamuhizi, Ylva Nyberg.
- GGISNUR: Jean Pierre Bizimana, Theodomir Mugiraneza, Robert Ford, contributors, Dr Jean Nduwamungu, Dr Emmanuel Twarabamenye, Marie Christine D. Simbizi, Edward K. Mwesigye.
- Rwanda NGOs Forum on water, sanitation and environment (RWASEF). Frank Habineza and contributors.

**For further information, contact:** Tom Downing, Director of SEI in Oxford ([tomdowning.sei@gmail.com](mailto:tomdowning.sei@gmail.com)) or Paul Watkiss, Project Director ([paul\\_watkiss@btinternet.com](mailto:paul_watkiss@btinternet.com)). To follow up in Rwanda, contact Sion McGeever, DFID ([S-McGeever@dfid.gov.uk](mailto:S-McGeever@dfid.gov.uk)).

### Full project reports

More detailed technical annexes to support this document are available on the project website:  
<http://rwanda.cceconomics.org> or <http://rw.cceconomics.org/>

### Acknowledgements

The project has been funded by DFID. Additional resources on the economics of climate adaptation and low carbon growth in Africa were provided under the AdaptCost project from UNEP and the EC ClimateCost project.

We acknowledge the valuable contributions of many people and organisations. In particular we would like to thank the national steering committee, led by Mr Prosper Musafiri (DG Minecofin) and Dr Rose Mukankomeje (DG REMA). We would also like to thank Rwandan Ministry of Health and TRAC Plus Malaria Unit.

We acknowledge the valuable contributions of many people and organisations. Although the study was commissioned by DFID, the views expressed in this brief are entirely those of the authors and do not necessarily represent DFID's own views or policies, or those of DEW Point.