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Economics of Climate Change
Kenya

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The Economics of Climate Change in Kenya:

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Project Description and Project Team

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).

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 for the study included.

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Key Messages

The economic costs of climate change

- Existing climate variability has significant economic costs in Kenya. Periodic floods and droughts (extremes) cause major macro-economic costs and reductions in economic growth.

- Future climate change will lead to additional and potentially very large economic costs. These are uncertain. However, aggregate models indicate additional net economic costs (on top of existing climate variability) could be equivalent to a loss of almost 3% of GDP each year by 2030 in Kenya.

- Costs include potential threats to coastal zones (sea-level rise), health burdens, energy demand, infrastructure, water resources, agriculture and loss of ecosystem services. The study has addressed the potential impacts and economic costs in these sectors.

- These highlight the importance of preparing for future climate change. While it is difficult to predict effects with confidence, there is a need to plan robust strategies to prepare for the future, rather than using uncertainty as a reason for inaction.

Adaptation

- Adaptation can reduce the economic costs of climate change but it has a cost. The costs of adaptation are still emerging. A number of categories of adaptation have been identified that relate to the balance between development and climate change.

- An initial estimate of immediate needs for addressing current climate as well as preparing for future climate change for Kenya is $500 million / year (for 2012). The cost of adaptation by 2030 will increase: an upper estimate of the cost is likely to be in the range of $1 to 2 billion / year.

- The study has also prioritised early adaptation across the sectors. These studies demonstrate that adaptation has potentially very large benefits in reducing present and future damages. However, while adaptation reduces damages, it does not remove them entirely. Residual impacts in Kenya, particularly for some regions and groups are expected and need to be managed.

Low carbon growth

- The analysis has considered future emissions for Kenya, consistent with planned development. Emissions of greenhouse gases (GHG) could double between 2005 and 2030. Moreover, plans across the economy could ‘lock-in’ Kenya into a higher emission pathway.

- The study has investigated a low carbon alternative pathway. This finds that a large number of ‘no regrets’ options that would enhance economic growth, as well as allowing further access to international carbon credits. They also have economic benefits from greater energy security and diversity, reduced air pollution, reduced environmental impacts.

- The study estimates energy related emission savings of 22% could be achieved by 2020, relative to the baseline, even for a small selection of options. Over 80% of these options can be realized at net negative cost. When carbon credits are included, this amount is likely to be even higher.

- Overall, because of its location, availability of resources and socio-economic conditions, the study concludes that there are significant economic benefits for Kenya in following a low carbon development path, as well as large environmental and social benefits.

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

Executive Summary

This study has assessed '*the Economics of Climate Change in Kenya.* It was funded by DFID and DANIDA 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 Kenya

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

- Periodic floods and droughts (extreme events) already cause major socio-economic impacts and reduce economic growth in Kenya. Recent major droughts occurred in 1998-2000, 2004/05 and in 2009. Major floods occurred in 1997/98 and 2006.
- The economic costs of droughts affect the whole economy. The 1998-2000 event was estimated to have economic costs of $2.8 billion from the loss of crops and livestock, forest fires, damage to fisheries, reduced hydro-power generation, reduced industrial production and reduced water supply. The 2004 and 2005 droughts affected millions of people and the recent 2009 drought has led to major economic costs from restrictions on water and energy.
- The 1997/98 floods affected almost 1 million people and were estimated to have total economic costs of $0.8 to $1.2 billion arising from damage to infrastructure (roads buildings and communications), public health effects (including fatalities) and loss of crops. The more recent 2006 event affected over 723,000 people in Kenya.
- The continued annual burden of these events leads to large economic costs (possibly as much as $0.5 billion per year, equivalent to around 2 % of GDP) and reduces long-term growth. There is some indication that there has been an intensification of these extreme events over recent decades and these may reflect a changing climate already. However, these impacts also have to be seen in the context of changing patterns of vulnerability, for example from changing land–use patterns, rising populations, etc. Nonetheless, a key finding is that Kenya it is not adequately adapted to deal with existing climate risks.

The second key finding is that ***future* climate change will lead to additional and potentially very large 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 Kenya have very high vulnerability. The study has investigated these effects using a number of different approaches.

Top down aggregated estimates

- The study has undertaken top-down aggregated assessments of the economic costs of climate change using global models. These future economic costs are very uncertain. However, aggregate models indicate that the additional net economic costs (on top of the costs of existing climate variability) could be equivalent to a loss of 2.6% of GDP each year[1] by 2030 in Kenya.

- In the longer-term, after 2050, the economic costs of climate change in Africa and Kenya are expected to rise, potentially very significantly. However, the aggregate models report that global stabilisation scenarios towards a 2ºC target could avoid the most severe social and economic consequences of these longer-term changes. This emphasises the need for global mitigation.

Sector (bottom up) assessments

- The study has also undertaken bottom-up assessments of the impacts and economic costs of climate change for a number of sectors, using climate and socio-economic projections.
- Kenya already has a complex existing climate, with wide variations across the country and very strong seasonality. It has two wet seasons and has strong patterns of climate variability and extremes, not least due to the periodic effects from ENSO: El Niño and La Niña, which are associated with extreme rainfall and flooding and droughts (respectively).
- The study has considered projections of future climate change from a suite of downscaled global models for Kenya.
    - *Temperature*. The projections indicate future increases in mean annual temperature (average monthly temperatures) of broadly 1 to 3.5 ºC over the range of models by the 2050s (2046 -2065). There will also be increases in sea level.
    - *Rainfall*. The changes in precipitation are more uncertain. All the climate models show that rainfall regimes will change but these vary with season and region. Most models project rainfall will increase on average, though some models project rainfall reductions in some months for some areas.
    - *Extreme events*. The information on extreme events (floods and droughts) is much more variable and future projections vary widely. Many models indicate an intensification of heavy rainfall in the wet seasons, particularly in some regions and thus greater flood risks. Droughts are likely to continue but the projections are more varied - some models project an intensification of these events, particularly in some regions, though other models indicate reductions in severity.
- 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. The study has applied available projections to sectoral assessments, outlined below.
- *Coastal zones*. The study estimates potentially large economic costs from climate change in Kenya in the absence of adaptation. The study has considered the range of projections for sea level rise from the IPCC, plus an additional scenario based on some of the more recent literature, which reports potentially higher values. The analysis shows that coastal flooding from sea level rise is estimated to affect 10,000 to 86,000 people a year by 2030 (across the scenarios), as well as leading to coastal wetland loss and coastal erosion. The associated economic costs in 2030 are estimated to be $7 - 58 million per year (current prices, no discounting) including flooding. By 2050, these costs could increase to $31 - 313 million per year.

[1] 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.

- *Health*. The study estimates in the absence of adaptation, there could be a potentially large increase in the rural health burden of malaria in Kenya. 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 between 36% to 89% by the 2050s affecting an extra 2.9 to 6.9 million people (across the range of temperature projections). The economic costs of this additional burden are estimated at $45 to 99 million annually in terms of direct costs, but rise to $144 - $185 million if full economic costs are considered (including disutility from pain and suffering). The study has also identified other possible direct and indirect health effects from climate change.
- *Agriculture*. The study has considered the potential effects in the agricultural sector, though this is one of the most challenging areas to investigate due to the complexity of analysis and the wide variations with geographical location. Existing studies report that the economic effects for agriculture 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 high economic costs projected. Moreover, a range of additional factors are also important, which are not included in these assessments, including extreme events, pests and diseases, etc.
- The study has commissioned new studies on shifts in agro-ecological potential, which consider agro-ecological zones, future land use change and productivity, exploring the sensitivity of agricultural and pastoral lands to climate change, within a GIS environment. The analysis assessed the potential shifts in the value of agricultural land, evaluating some 150 land units that are potentially sensitive to climate change. This provides information on the potential changes in land value as a result of climatic events and longer term climate change, under two scenarios. The first assumes a national drought occurs with the most severe impacts in the drylands and relatively modest impacts in the humid highlands. This reduces maize production dramatically and the total value of agricultural land in Kenya is reduced to about two-thirds of the average value. The second investigates the longer term consequences of climate change, assuming wetter conditions prevail, which increases land value in the central zones but not the highlands, with an overall 10% increase in the value of agricultural land.
- *Extreme events*. Even in the absence of climate change, the economic costs of the periodic floods and droughts that affect Kenya 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 event could have direct economic costs of $5 to 10 billion. A key priority therefore is to increase the resilience of Kenya 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 Kenya. These increases in intensity would increase the economic costs of periodic flood events significantly, because the costs rise very sharply 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, which would further increase economic costs.
- *Water resources*. The study has investigated the potential multi-sectoral effects of water resources and climate change using a case study for the Tana River basin using a water planning model. The results vary strongly with the climate projection. The economic impact of climate change (without adaptation) for this one river basin ranges from a benefit of $2 million to a cost of $66 million for hydropower, irrigation and drinking water across the range of projections.
- *Energy.* The study has investigated energy demand. The trend in average temperatures will increase the number of hotter days and increase the cooling burden, particularly in urban areas. These are important for building comfort levels and potentially effects for health. The projected higher

temperatures, combined with higher incomes, will increase electricity demand and have high economic costs: as an example the burden of cooling demand could increase by 240 – 340 % in Mombasa by the 2050s. This will increase electricity demand for cooling and have economic costs, particularly to certain sectors (e.g. tourism).

- *Ecosystem services*. Kenya 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 such as nutrient recycling, regulatory services including flood protection and recreational and cultural services. The study has mapped the potential ecosystem services in Kenya and considered (qualitatively) the potential additional pressures from climate change. The study finds that ecosystem services are integral to the Kenyan economy and underpin large parts of GDP, foreign revenue and export earnings, 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.
- The study has undertaken a number of case studies to provide more detailed local analyses. This has included a case study on sea level rise in Mombasa, flood events, vulnerable groups and iconic ecosystems (including wildlife parks).
- Overall, the bottom-up sectoral analysis indicates that in the absence of adaptation, the aggregated estimates of economic costs - which occur on top of the existing effects of current climate variability - could potentially be very large. **Detailed analysis for coastal zones and health alone indicate future economic costs could be several hundred million dollars a year by the 2050s under some projections**. There are also potential effects on ecosystem services, which whilst difficult to estimate in economic terms, could be as important. The analysis of future costs of extreme events indicates large increases in the economic costs of these events are possible. Finally, there are some possible scenarios of climate change on the water and 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, in terms of the equivalent costs 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.**

2. The Economics of Adaptation in Kenya

Adaptation can reduce the economic impacts of climate change but it has a cost. The costs of adaptation are still emerging and are uncertain. However, this does not mean that no action should be taken. Instead it requires more robust strategies.

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. 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 differ between these four categories.

Top down aggregated estimates

- 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 Kenya.
- The immediate needs (for 2012) for building adaptive capacity and starting to enhance resilience (immediate priorities) are estimated at $100 – 150 million/year. However, a much higher value of $500 million/year or more is warranted if the categories of social protection and accelerated development (to address the current adaptation needs) are included. As highlighted above these categories are associated with current climate variability – such as the existing vulnerability to droughts and 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 $250 – 1000 million per year for Kenya 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 (a total of up to $2000 million /year) are plausible if continued social protection and accelerated development are also included, noting that these are primarily development activities.
- The totals are shown in the table below.

	Adaptation Needs $ Million/year	
Adaptation Strategies	**2012**	**2030**
Development related **1) Accelerating development &** **2) Increasing social protection**	$500 million/year	$500 – 1000 million/year
Climate Change specific **3) Building adaptive capacity &** **4) Enhancing resilience**	$100 – 150 million/year	$250 – 1000 million/year

- Using these numbers, **the study concludes that a conservative estimate of immediate needs for addressing current climate as well as preparing for future climate change is $500 million / year (for 2012). The cost of adaptation by 2030 will increase: an upper estimate of the cost is likely to be in the range of $1 to 2 billion / year.**

Sectoral (bottom-up) assessments

- The study has also assessed the costs of adaptation for Kenya using a sectoral bottom-up approach. This tests the estimates above and gives 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).

- 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.
- For coasts, the study has assessed the costs of adaptation and finds that the potential impacts and economic costs in this sector can be significantly reduced. Adaptation has large potential benefits in reducing coastal erosion and inundation and the number of people potentially flooded could be dramatically reduced.
- For health, the study has assessed the potential costs of adaptation to address the potential increasing burden of malaria and has found that epidemic detection and prevention would be very cost effective.
- For water resources, the study has assessed sectoral activities for climate resilient development and adaptation mainstreaming. It has also investigated adaptation with the Tana River basin case study, assessing the costs and benefits of adaptation strategies. This finds economic impacts of demand-side measures (e.g. increased end use efficiency) are always positive across the range of climate scenarios, but that supply-side and ecosystem interventions only have net benefits under more adverse (highest temperature, lowest precipitation) projections of climate change.
- For agriculture, energy and for extreme events, the study has assessed the scale of effort that may be required and some of the urgent priorities.
- A large number of immediate priority 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 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 (agriculture) and extreme events (flood risk), with the latter linked to the strengthening 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 the potential scaling up of sectoral programmes.
- The sectoral assessments and the case studies show relatively high adaptation costs, which re-enforce the top down adaptation estimates for 2030 and justify investment needs. They also demonstrate the potentially much larger costs when development-adaptation needs are included (the categories of accelerating development to cope with existing impacts and increasing social protection outlined above). 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 Kenya, particularly for some regions and groups of society, are expected and will need to be managed**. They will also be important for recovery after climatic disasters and for future impacts. It is also highlighted that these residual impacts – and their economic costs – are additional to the costs of adaptation. This is important for international negotiation discussions which have tended to focus only on the latter to date.
- Finally, while there is a large need for adaptation finance, **accessing adaptation funds will require the development of effective mechanisms, institutions and governance structures**. There is a need for Kenya 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.

- **Uncertainty is a reason for action**. The future cannot be predicted, but sound national policy, shared knowledge, robust sectoral strategies and capacity for adaptive management are the necessary foundations for being prepared.

3. Low Carbon Growth in Kenya

Emission projections

- **The analysis has first considered current emissions. Kenya currently has relatively low emissions of greenhouse gases (total and per capita). Moreover, Kenya has already introduced a range of low carbon options across many sectors**. These include renewable energy in the electricity sector, more efficient use of biomass and sustainable land use management.
- The study has then considered the potential change in emissions consistent with planned development in the Vision 2030 plan and developed a future emissions profile for Kenya. 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 Kenya is initiating some options that are consistent with a low carbon development path.
- **Under the future 'business as usual' development scenario, the study estimates that total emissions of greenhouse gases will double between 2005 and 2030**. 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 current plans for coal development will increase the carbon intensity of generation.
- **The current plans across the economy (or for some sectors, the lack of plans) could 'lock-in' Kenya 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 international carbon credits, particularly if national level GHG mechanisms emerge. Following these higher carbon pathways will therefore lead to an opportunity loss for Kenya. They could also lead to other economic, social and environmental costs: an example would be the increased congestion, higher fuel costs, greater fuel imports and higher air pollution that would occur unless private car transport is tackled in Nairobi.

Low carbon options

- The study has 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 is potential energy efficiency measures that actually save 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. Many of the options also increase the resilience of the system to future climate change, e.g. such as geothermal offering diversity away from hydro generation (which is vulnerable to droughts).
- The study has evaluated the emission reduction potential for a sub-set of potential sectors and options and compared this against the 2030 baseline. This shows **these options have the potential to produce emission savings of 22% for energy related emissions, relative to the baseline**. Over

80% of these options can be realized at net negative cost. When carbon credits are included, this amount is likely to be even higher.

- **The study also highlights the need to widen this analysis and to develop a longer term strategy up to and beyond 2030**. This needs to consider how international action by developed countries to address climate change might affect Kenya, notably in relation to its planned economic growth in areas such as tourism, agricultural exports, etc.
- Finally, it is essential to consider how best to co-ordinate co-operative regional (East African) responses to enhance opportunities for carbon credits and regional resilience (e.g. electricity transmission networks).
- Overall, **because of its location, availability of resources and socio-economic conditions, the study concludes that there are significant economic benefits for Kenya in following a low carbon development path, as well as large environmental and social benefits**. Such a pathway is strongly in the country'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.

Recommendations

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

A key recommendation is the need for Kenya to get ready and act now

Key elements are to improve estimates; advance institutional and policy development; explore sectoral pilot tests; undertake investment analysis, revisit Vision 2030, to advance low carbon growth paths and to enhance regional co-operation. Specific actions are outlined below.

- *Improving the estimates*. 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 consideration of additional risks not yet covered, e.g. within existing sectors (such as assessing additional health risks), for additional sectors yet covered (e.g. tourism and industry) and for cross-sectoral issues and indirect effects.
    - For the key priorities identified here, a deeper analysis by sector, i.e. to further explore coastal risks, health burdens, agriculture, water/flood risks, energy supply and demand and ecosystem services. This would need a multi-stakeholder assessment of adaptation pathways at different scales, with estimates of costs, focused on short- and medium priorities that are most relevant for policy.
    - On the low carbon side, it would be useful to undertake a more comprehensive analysis of future emission projections and potential opportunities, with full marginal abatement cost curves and analysis of urgent priorities across all sectors.
    - For both adaptation and mitigation, analysis of the costs, including government, the sector and individuals. This step would provide both adaptation and low carbon costs in detail and as part of an investment and financial flow analysis (by sector). Matching the costs against the wide range of potential finance is a prerequisite for a viable investment plan.
    - Taken together, this analysis could form the basis of an expanded climate strategy that links national policy to sectoral objectives and targets, with effective mechanisms for implementation, monitoring, reporting and verification.
- *Urgent priorities*. There are a number of urgent priorities for building adaptive capacity in Kenya that should be fast-tracked, notably in relation to monitoring, forecasting and information (as these

underpin future prediction and analysis) and early warning systems, as well as information provision, monitoring (indicators), and supporting science-policy networks and sectoral focal points. These early priorities are part of a broad strategy to increase the knowledge base, including education and training and strengthening existing programmes.

- *Climate change risk screening*. There is 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.
    - The study recommends that a **national knowledge management system** be developed; with easy access by all stakeholders.
- *Building Capacity*. Access to substantial adaptation funds must be assured. However, **mechanisms, institutions and governance systems for effective use must be developed** to allow Kenya 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.
    - **A national adaptation facility should assess the potential for climate resilient growth across all areas of the economy** and to mainstream adaptation into government departments and with Kenya's development partners.
    - A multi-stakeholder trust fund would enable early and timely action and is an early priority, encouraging learning by doing and establishing the basis for scaling up to sectoral resilience.
- *Low carbon pathways*. There are many benefits if Kenya switches to a lower carbon pathway. However, this will not happen on its own and steps are needed by Government, business and civil society to realise these benefits and to maximise the potential flow of carbon credits under existing and future mechanisms. Specifically:
    - **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 future development** that might 'lock-in' Kenya into higher emissions pathways, notably in energy, transport and urban environment. It would be useful to specifically address these threats and to identify alternatives.
    - All future plans and policies, 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.**
- *National policy and Vision documents*. Planned revision of national policy 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 activities. There is a need to develop a new strategic vision for Kenya that addresses these areas, for example, with **further development of the Vision 2030 document**, including both domestic and international aspects.
- *Regional collaboration*. There is also a need for **regional collaboration and co-operation** across the areas of low carbon growth and adaptation, to benefit from economies of scale and to enhance regional resilience.
- The steps above would provide national action on a low-carbon, climate resilience investment plan and **would establish Kenya as an international leader, with 'early mover advantage' in negotiations and securing finance.**

A summary of key next steps is presented in the tables over the page.

Adaptation Strategies	Priority Actions
Immediate needs & capacity building	• Expanded research assessment into effects, adaptation and economics. Early capacity building and early warning systems • Develop national climate change strategy including knowledge management and screening of sectoral and regional plans for climate risks and adaptation opportunities. Include in national policies. Build into long-term vision (e.g. Vision 2030) • Prepare plans for a national adaptation authority or facility to improve sectoral coordination, link to international finance, and support private sector. Enhance links between adaptation and low carbon.
Climate resilience	• Climate resilient strategies, objectives and targets for immediate concerns (for example, linking cross-sectoral climate monitoring with exposure, impacts and adaptation actions; knowledge management; health and vector-borne disease responses; drought and flood risk screening for new projects) • Develop prototypes of sectoral actions (pilots) and pathways for scaling up to cover all vulnerable regions and populations
Social protection	• Protect vulnerable livelihoods and strengthen existing social protection programmes, expanding the coverage to consider climate change.
Accelerated development	• Adapt existing development projects to include 'no regret' measures to reduce climate risks and opportunities to develop adaptive capacity • Scale up successful prototypes to sectoral development plans

Mitigation Strategies	Recommended Actions
Low-Carbon Growth (LCG)	• Full analysis of baseline projections, low carbon options, costs and potential for prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream LCG in planning. Build into long-term vision (e.g. Vision 2030), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM) • 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. • Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use
Climate resilience & co-benefits	• Climate risk screening of low carbon growth pathways • Explore opportunities in case studies of major low carbon strategies such as geothermal, biofuels and on-farm carbon management and how they might be scaled up to achieve both reductions in future emissions and adaptive development.

Introduction, Objectives and Method

The '*Economics of Climate Change in Kenya'*, funded by DFID and DANIDA and undertaken by the Stockholm Environment Institute (led by the Oxford Office, in conjunction with the SEI office in Nairobi) together with international and local partners[2], has assessed the impacts and economics costs of climate change, the costs and benefits of adaptation and pathways of low carbon growth for Kenya[3].

Background, Aims and Objectives

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

- To assess the impacts and economic costs of climate change for Kenya, 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 GoK'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 Kenya, 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.

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

[2] Camco, ICPAC, IIED, ILRI, SCC-VI Agroforestry, Oxfam Kenya, Metroeconomica. African Conservation Centre, LSHTM, University of Southampton. For a full list, see the back page.
[3] The study is part of a larger East Africa regional study, which includes detailed country assessments for Burundi and Rwanda. 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.

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.

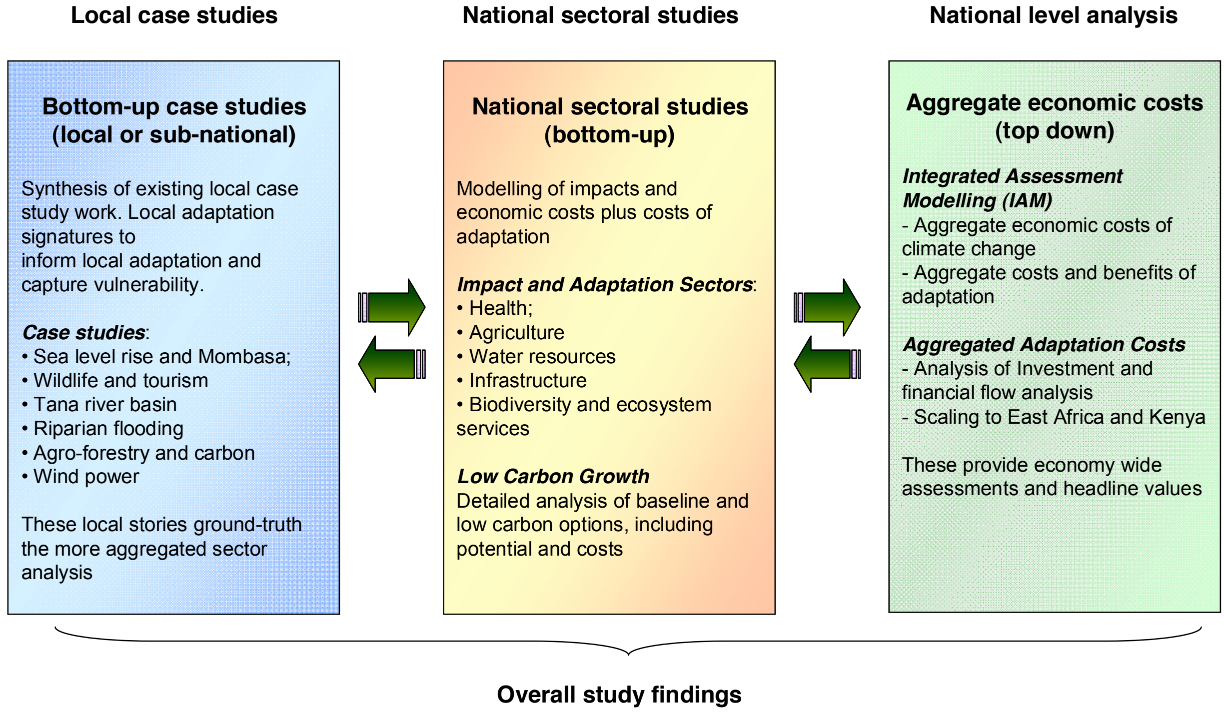

Figure 1. Overview of the lines of evidence.

The combined evidence across the framework provides the economic costs of climate change and the costs and benefits of adaptation, to provide information for 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 ground-truth different aggregation levels. A key focus has been to use of complimentary information from the different approaches for iterative analyses, where information from one method informs another.

For the national level and 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 worked to progress analysis of 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 be viewed as only an initial analysis.

Particularly for adaptation 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 a particularly lack of studies in Africa. The study has therefore included methods from more formal cost-benefit analysis to 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.

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 included a collaborative partnership approach with local teams, working with a large number of expert 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) the National Climate Change Activities Coordinating Committee (NCCACC), who acted in the role of a National Advisory Committee to the study. The study was presented at a number of events in country during the period, with an official study launch, interim result presentations and a final study launch to ensure that stakeholders are identified, consulted and informed, with the duel objectives of building national capacity and taking advantage of local knowledge. The study contributed to two week-long workshops to build capacity in Africa. A key part of this process has been feeding into the Kenya National Climate Change Response Strategy (NCCRS).

1. The Impacts and Economic Costs of Climate Change in Kenya

The impacts and economic costs of current climate variability and events in Kenya are already very high. The country is exposed to major floods and droughts, associated with El Niño and La Niña years in addition to other influential regional processes. These extreme events have dramatic impacts on infrastructure, the built environment and the economy, cutting across key sectors including agriculture, industrial processing, manufacturing, tourism, infrastructure, and health. Kenya 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 lead to impacts and economic costs, though there will also be benefits in some sectors and regions.

Climate Projections for Kenya

Kenya has a complex existing climate, with wide variations across the country and with very strong seasonality. Average temperatures show strong differences between the narrow coastal strip, the arid and semi-arid lands and the temperate highland plateau.

Rainfall is particularly variable. The annual cycle is bimodal, with two wet seasons: the long rains from March to May which contributes more than 70% of annual rainfall and the short rains from October to December which contribute less than 20%. 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, though the variability is highest in the arid and semi arid land (ASAL) areas. The western highlands and coastal areas also receive significant rainfall during June to September. 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 1999/2001 drought. Recent El Niño (1997/98) and La Niña (1999/2000) episodes were the most severe in 50 years.

Projections of future climate change are very uncertain. The study compared a range of climate projections for Kenya and investigated meteorological trends, working with local partners and experts, as well as using downscaled international data sets from the climate change explorer (CCE). The Climate Systems Analysis Group (CSAG) (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.

Examples are shown in the figures below for average minimum temperature and rainfall. The first graph plots the increase in average temperature for a number of locations. The second graph plots the future projections of rainfall over the year for the main water catchments. In both cases the graphs show the wide variation in model scenarios.

All of the climate model scenarios show increases in mean annual temperature in future years. Recent studies in Kenya report a rise of almost 1º by 2030 and around 1.5º by 2050 for a mid-range emission scenario. However, the range across all the models is considerably wider than this, with projections from 1 to 3.5 ºC by the 2050s.

There are also rises projected in sea level (discussed in the coastal section below).

Changes in precipitation are more uncertain. Most climate model scenarios project that rainfall will change, with many of the current outputs indicating that average annual rainfall will increase. Again, there is wide model variation: some models show reductions in rainfall in some seasons (see box). While the overall annual trend and rainy seasons are not predicted to change, some models do indicate a shift in the timing of seasons. The model results highlight the considerable uncertainty in predicting future impacts and need to consider a robust approach of adaptation decision making with highly uncertain futures.

The information on extreme events (floods and droughts) is much more variable and future projections vary widely. Many models indicate an intensification of heavy rainfall in the wet seasons, particularly in some regions and thus greater flood risks. Droughts are likely to continue but the projections are more varied - some models project an intensification of these events, particularly in some regions, though other models indicate reductions in severity.

The projections of future climate change in Kenya are uncertain. There is a wide range of the scale of change, 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 (drought and floods).

Nonetheless, the climate is changing already and the most striking conclusions 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.

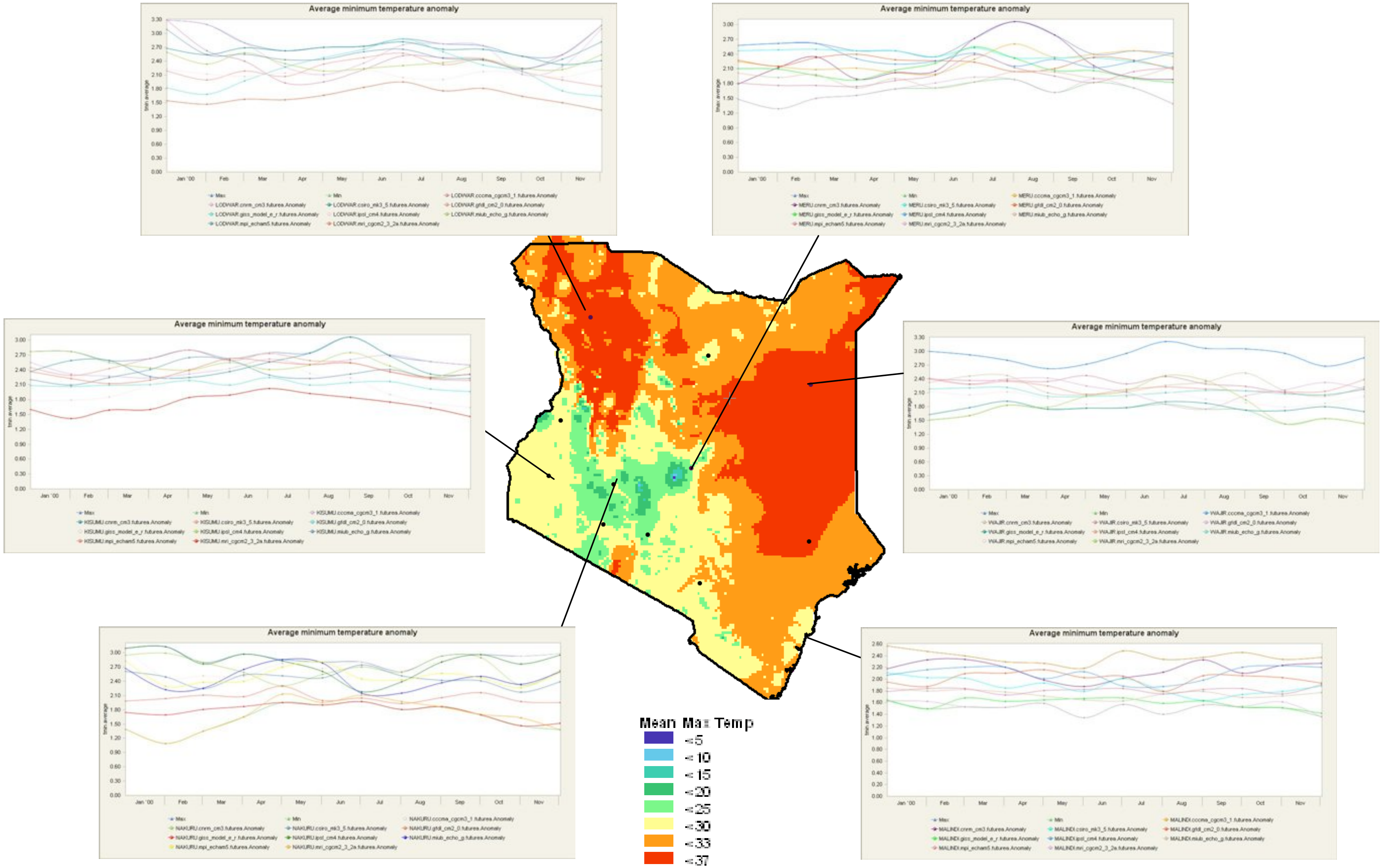

Figure 2. Projected changes in monthly average minimum temperature anomaly across 9 GCM models for period 2045-2065, statistically downscaled. Climate Change Explorer tool, Climate Systems Analysis Group and SEI, 2009.

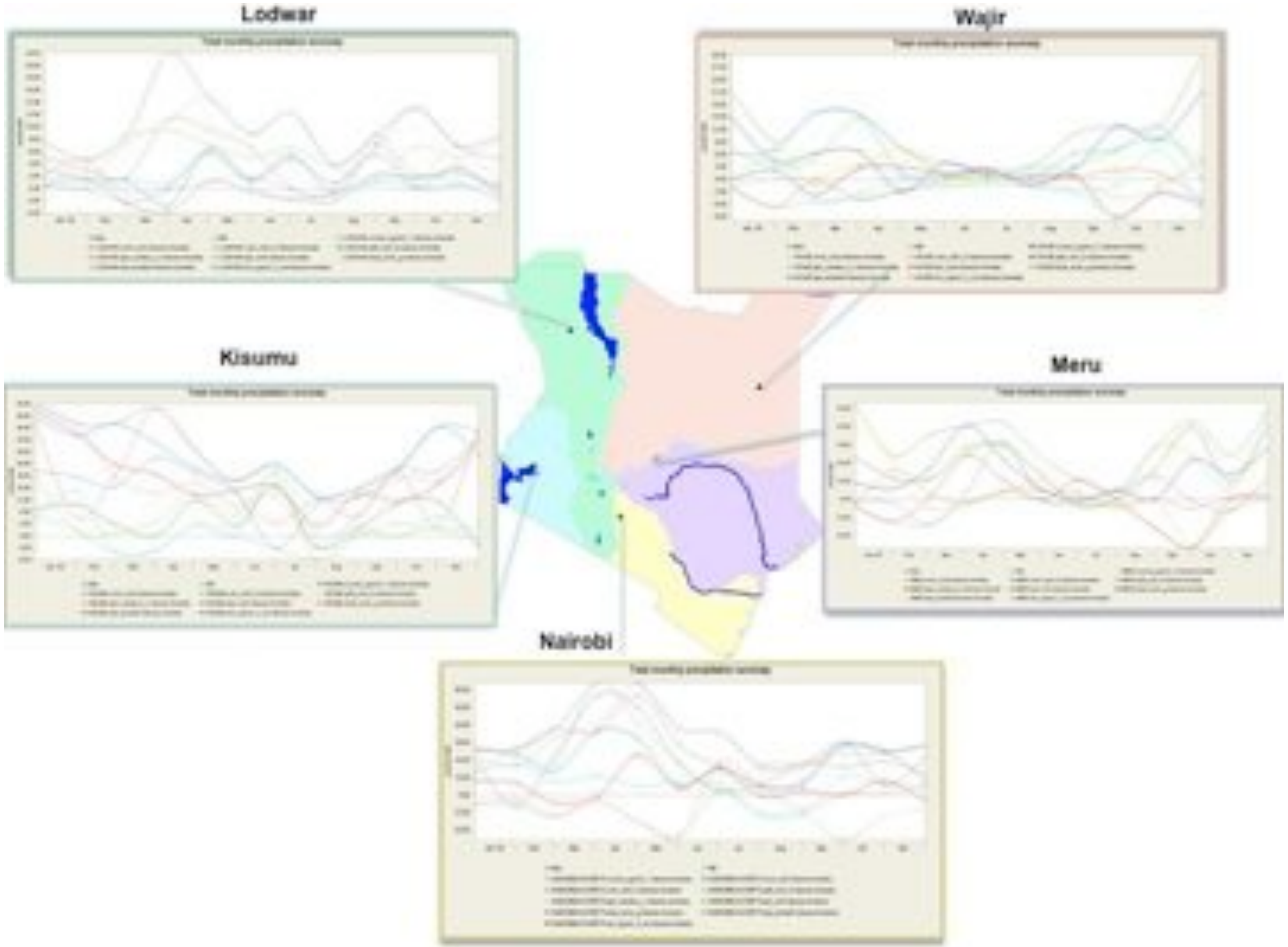

Figure 3. Projected changes in monthly precipitation anomalies across 9 GCM models for period 2045-2065, statistically downscaled to Nairobi, Meru, Wajir, Lodwar and Kisumu (Kenya's catchment basins). Climate Change Explorer tool, Climate Systems Analysis Group and SEI, 2009.

Socio-economic projections

As well as the future change from climate change, the study has also considered the potential effects of socio-economic change and development in Kenya. 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 (e.g. from flood events), 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 study has therefore assessed future climate change – and low carbon potential - against a baseline of expected growth and development consistent with the Vision 2030 goals, i.e. with Kenya becoming a middle income country by 2030. This does assume high levels of population growth, urbanisation and high economic growth. As an example, the population of Kenya is expected to grow to around 63 million by 2030 and 85 million by 2050[4] and with very strong urbanisation trends, with the percentage of urban population rising to 33% by 2030 and almost 50% by 2050[5]. These will lead to very different socio-economic futures and affect economic conditions, resource management and vulnerability.

Aggregated Estimates of Economic Costs of Climate Change in Kenya

The study has used top down economic modelling to estimate the headline effects of climate change in Kenya. This has used a number of the global economic integrated assessment models (IAMs). These models provide highly aggregated information on potential economic costs using a framework that links emissions, climate change and impacts on the economy; though to do this they involve assumptions and simplifications. The study has worked with two of the leading global IAMs; the FUND and PAGE models. Further details are provided in the technical annexes, available on the project web-site.

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 study has then investigated in more detail for Kenya and in relation to mitigation and adaptation.

The FUND model runs estimate that climate change could lead to annual economic costs by 2030 that are equivalent to 2.6% of GDP each year in Kenya (central value, including market and non-market sectors and aggregating positive and negative effects).

The absolute economic costs are estimated to double (in $) by 2050. The model also shows potentially much higher increases in economic costs in the second half of the century. The analysis has been undertaken as part of a wide analysis of all of Africa, shown in the figure.

[4] UN world population prospects 2008, http://esa.un.org/unpp/p2k0data.asp
[5] UN world urbanization prospects 2007 http://esa.un.org/unup/p2k0data.asp

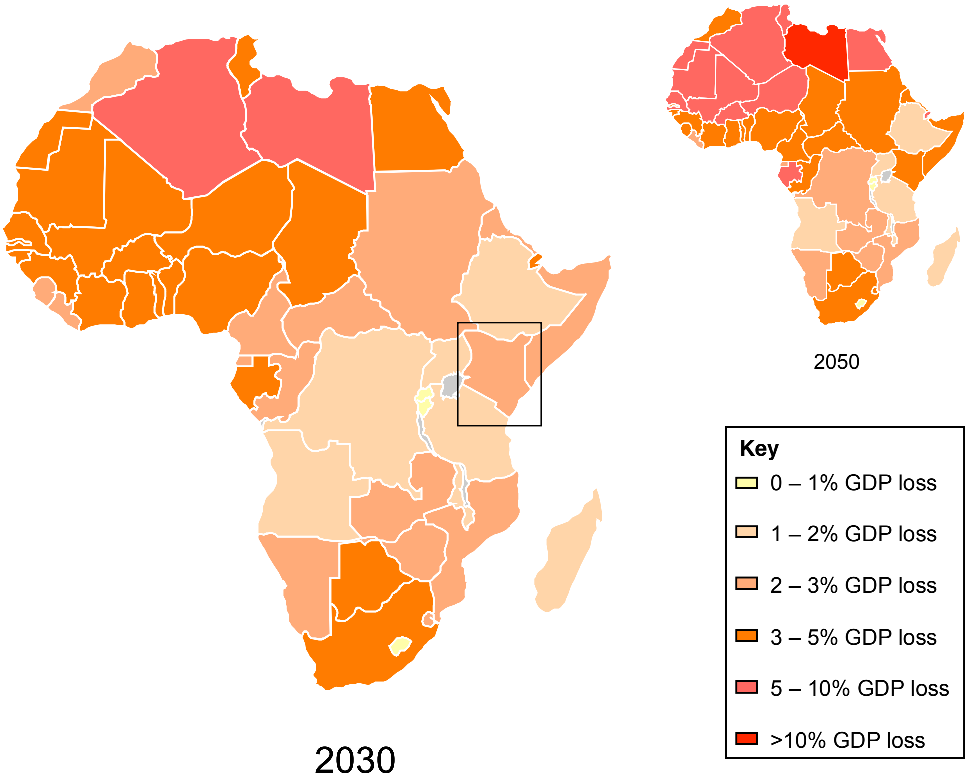

Figure 4. Annual Economic Costs from Climate Change as a Faction of GDP in Africa.
Source FUND national model

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 2ºC 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.

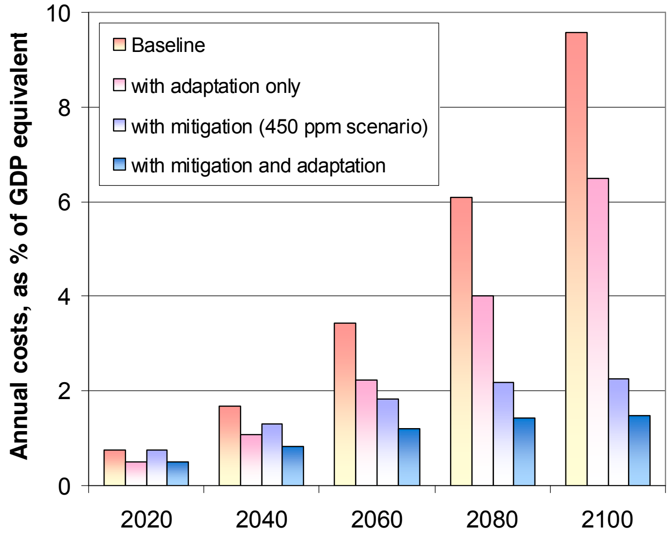

Figure 5. Annual Mean Economic Costs from Climate Change as a Faction of GDP in Africa. With mitigation and adaptation. (Source PAGE model)

These estimates are indicative only. They provide some insights on signs, orders of magnitude, and patterns of effects. Note that the results are dependant on the assumed growth trajectory, population, etc in the model as well as by the assumptions on impacts and economic costs. The results 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 central economic costs of climate change could be equivalent to 2.6% of GDP <u>each year</u> by 2030 for Kenya.

National bottom-up sectoral assessments and case studies

The study has also undertaken bottom-up analysis for the priority sectors at national level. These assessments have, where possible, considered potential impacts and economic costs for a range of sectors and regions that are considered the most vulnerable to climate change (identified in consultation with the national advisory group). This national level modelling has been complemented with local case studies.

To address the uncertainty in the climate projections, the study has used the downscaled outputs from the range of models (see earlier), rather than single future projections. The results are reported by sector.

Coastal zones

<u>Background and impacts of climate change</u>
Kenya has over 1,500 km of coastline, consisting of mangroves, coral reefs, sea grass, and rocky, sandy and muddy shores as well as urban settlements. It has many low-lying coastal regions which are vulnerable to sea-level rise. This includes the major coastal city Mombasa and surrounding towns (see case study box). It also has a large and growing coastal population (over 2 million people).

Sea-level rise, in combination with changes in the frequency and/or intensity of extreme weather events (such as storms and associated storm surges), is expected to increase the flooding and inundation of coastal areas. There are potential threats to coastal environments including low-lying coastal plains, islands, beaches, coastal wetlands and estuaries. These may in turn lead to problems for infrastructure, transportation, agriculture and water resources within the coastal zone. It can affect the services these coastal zones provide in relation to the tourism industry and provisioning services (fishing, aquaculture and agriculture) as well as affecting the valuable ecosystems they contain.

The coastal zones generate significant amounts of economic activity contributing to national wealth, but also provide much wider economic benefits through ecosystem services. The effects of sea level rise will therefore have potentially large economic costs. Areas around the Watamu and Sabaki river estuaries are reported to be the most vulnerable sites, although the low-lying areas are spread along the whole coast.

The direct impacts from sea-level rise include inundation of low-lying areas, shoreline erosion, coastal wetland loss, saltwater intrusion and increased salinity in estuaries and coastal aquifers, higher water tables and impeded drainage and higher extreme water levels leading to coastal flooding with increased damage. Potential indirect impacts include changes in the distribution of bottom sediments, changes in the functions of coastal ecosystems and impacts on human activities. Note that human-induced pressures on the coastal zone (such as the growing population, water abstraction, and alteration of the hydrological regime including the damming of sediments) are likely to exacerbate the effects of sea-level rise. The potential impacts of sea level rise are usually uneven, affecting the most vulnerable, due to their lower ability to prepare, adapt and respond.

Analysis
Coasts are one of the more studied areas of climate impacts and it is possible to assess, at least in indicative economic terms, most of the direct effects. To advance this, the study[6] has investigated the potential effects of sea level rise using the DIVA (Dynamic Interactive Vulnerability Assessment) model, an coastal integrated assessment model that assesses biophysical and socio-economic impact. Impacts were determined with and without adaptation, so that the benefits and costs of protection could be considered. The study has also undertaken a detailed case study with Mombasa, presented in the box. A full technical report is available on the coastal work at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

Consistent with the uncertainty bounding used in the study, a range of scenarios has been explored. This included three scenarios from the IPCC of sea level, plus a fourth scenario based on some of the more recent literature, reporting an upper bound. This leads to a global rise of 0.17m to up to 1.26m from 1995 to 2100. These have been assessed in conjunction with three IPCC socio-economic scenarios describing population growth and density as well as future GDP (A1FI, A1B and B1) for Kenya. The impacts were assessed in the years 2000, 2025, 2030, 2050, 2075 and 2100, focusing on five parameters (1) People actually flooded, (2) Cumulative forced migration, (3) Loss of wetland value, (4) Total residual damage costs, and (5) Total adaptation costs. However, a much wider set of impact categories has been assessed.

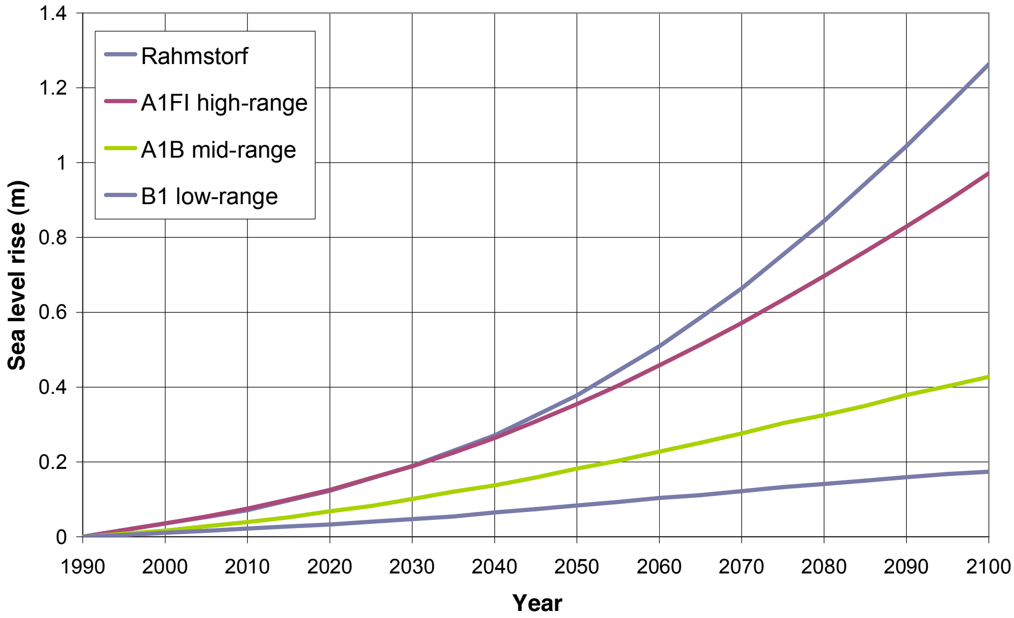

Figure 6. Sea Level Rise scenarios considered

Results
The analysis shows that coastal flooding from sea level rise will potentially flood 10,000 to 86,000 people a year by 2030. It also shows that as sea-level rises more rapidly, coastal wetlands (saltmarshes, mangroves, high and low unvegetated wetlands, mangrove areas and coastal forest areas) will decline in area. These losses have also been expressed in monetary values.

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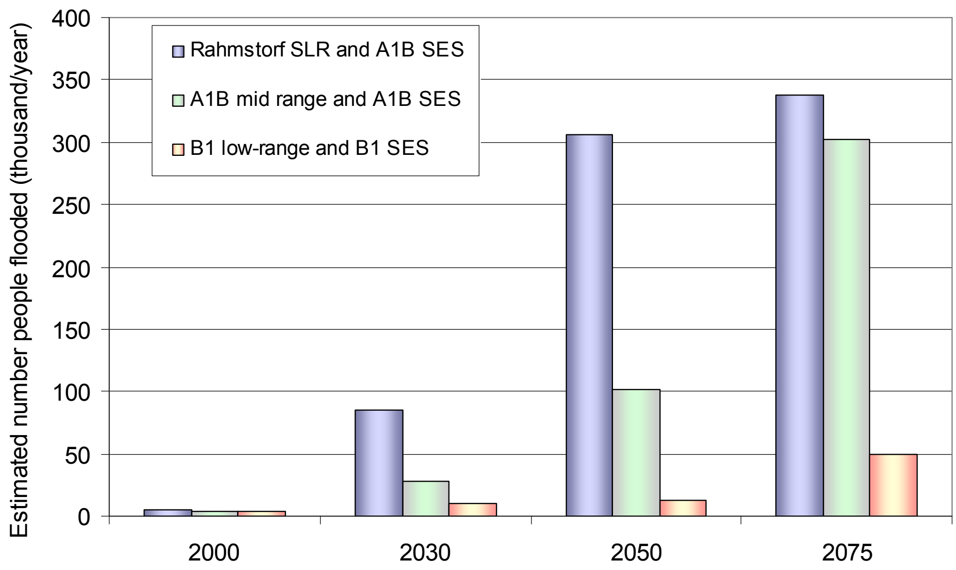
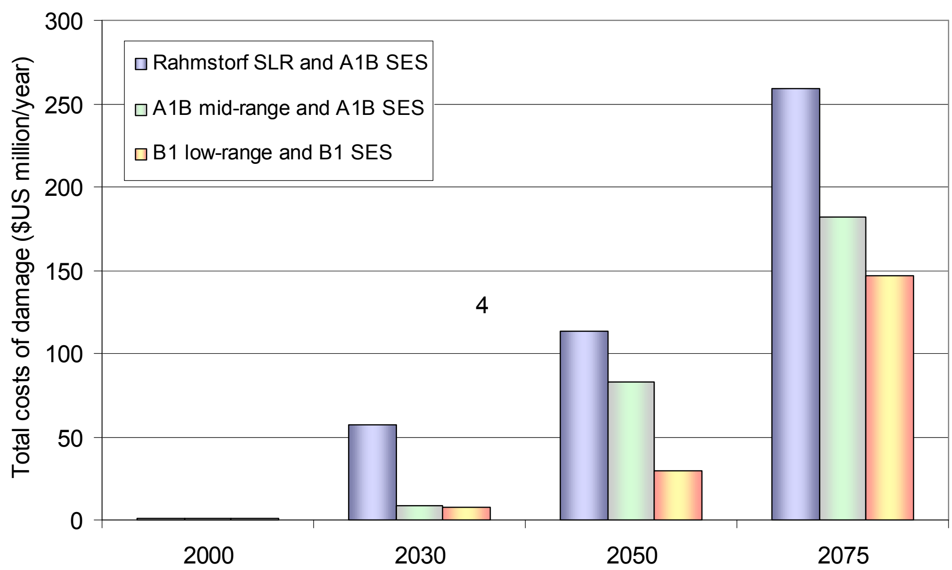
[6] School of Civil Engineering and the Environment, University of Southampton, UK: Sally Brown, Abiy Kebede and Robert Nicholls

The estimated total economic damage costs are $7 - 58 million per year (current prices, no discounting) including flooding, coastal wetland loss and coastal erosion, depending on the sea level rise scenario (without adaptation). By 2050, these could increase to $31 - 313 million per year and would increase further in future years through to 2100. The large ranges reflect the sea level scenarios shown above. The results confirm that without adaptation, the physical, human and economic impacts will be significant.



Estimated number of people flooded



Total economic costs ($US million/year) from all categories (flooding, erosion, ecosystem loss)

Figure 7. Coastal impacts in Kenya.

Note that other climate change impacts such as increased storminess, higher temperatures, reduced precipitation and changes in sedimentation from the Tana and Athi Rivers also have immediate or secondary impacts on the coast. These have not been considered in this study, but could have important effects. In addition to climate change, there are many anthropogenic factors influencing the coast, such as the conversion of wetland to agriculture uses or the reduction of sediment and water fluxes to deltas, often combined with enhanced subsidence. While these factors were not considered here due to lack of data, they should be considered in future studies.

Sea level rise could lead to large impacts and economic costs on coastal zones in Kenya, flooding large numbers of people. The economic costs are estimated to be $7 - 58 million per year by 2030, and could rise to $31 - 313 million per year by 2050.

Case study 1. Sea Level Rise and Mombasa

The coastal city of Mombasa is the second largest city in Kenya after Nairobi. It is the largest international seaport in Eastern Africa and has more than 650,000 inhabitants as well as an important role in the national and regional economy. Mombasa and nearby coastal towns have many low-lying areas and include significant population and infrastructure, and are home to tourism, aquaculture and agriculture. All of these activities are vulnerable to sea-level rise.

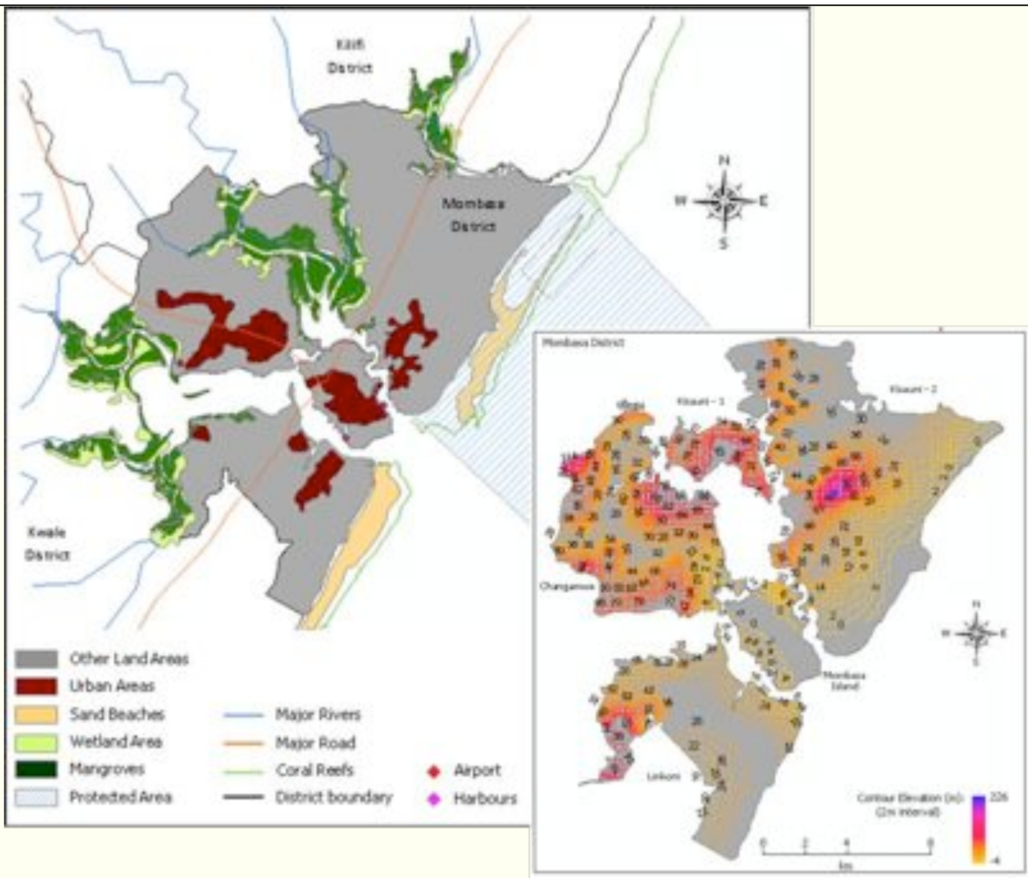
The city has a long history of frequent natural disasters associated with extreme climatic events, most recently the severe flooding in October 2006. This event, caused by intense precipitation, affected approximately 60,000 people in the city and caused damage to important infrastructure. With socio-economic projections indicating that the city will experience rapid population growth and urbanisation, the future impacts of such events can only increase.

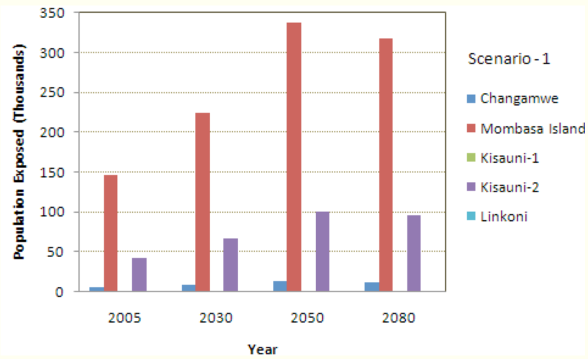
Located in the coastal zone and with an estimated 17 percent of land lying below the 10 metre contour, changes in sea level and storm surges are components of climate change which have the potential to further increase the threat of flooding within the city.

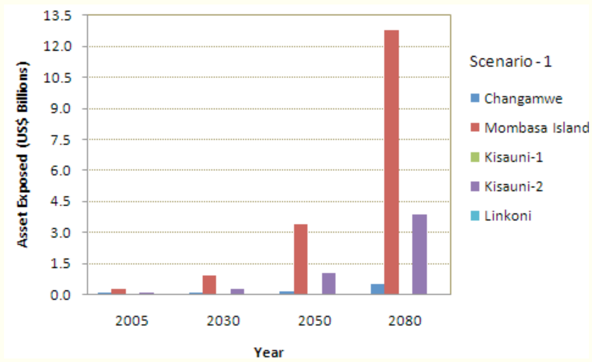
The study has investigated the economic costs of sea level rise in Mombasa to complement the DVIA work above. The area typology and the contour mapping are shown below. The GIS-based analysis results showed that more than 25 percent of the land area of the district lies within a low-lying area of the coastal zone (below 10 metre above mean sea level).

This GIS-based study provides a first quantitative estimate, both now and through the 21st century, of the number of people and associated economic assets exposed to coastal flooding due to sea level rise and storm surges. It gives a good indication of the potential impacts that the city might experience and indicates the magnitude of impacts which need to be considered in planning decisions. Results show that the current exposure to the 1:100 storm surge levels for the Mombasa district as a whole is estimated at more than 210,000 people and over US$ 500 million in assets. By 2080, under the A1B sea-level rise scenario (43 cm rise in sea level by 2100) and the A1 socio-economic scenario with rapid urbanisation, this increases to more than 426,000 people and infrastructure costing approximately US$ 17 billion.

The analysis shows that the projected socio-economic change and the location of population growth play a significant role in the overall increase in population and asset exposure to extreme water levels. About 75 percent of this exposure is concentrated in the Island city of Mombasa where approximately 426,000 people (2080 estimate) are projected to live within the low-lying coastal zone (within 10m of mean sea level). This continues into the future if the projected population growth is distributed across the city. However, if the population of Mombasa Island remains constant at 2005 levels, exposure is reduced by up to one third, with a total of 272,000 people and assets worth to US$ 1.1 billion exposed across the city by 2080. It should be noted that 54% of these reduced totals is still located on Mombasa Island highlighting its vulnerability to extreme water levels.







Population (left) and Assets (right) exposed to a 1 in 100 extreme still water levels in 2005, 2030, 2050, and 2080 under the A1B mid-range SLR and A1 SE scenarios coupled with a rapid urbanisation

This study shows that significant numbers of people in Mombasa are, and will continue to be, vulnerable to flooding due to extreme water levels during this century. However, forward planning to address projected population growth can reduce exposure levels to a significant degree. Appropriate adaptation measures, such as the construction of defences, can be expected to reduce the flooding risk but this was not considered as part of this study. This work has also highlighted that only limited accurate and long-term sea-level rise measurement data exists in the area and the monitoring of both sea level and extreme coastal events need to be continued to enable more detailed studies to be carried out.

Health

Background and impacts of climate change

Climate change is likely to affect human health, either directly such as with the effects of heat or 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 Kenya. 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 the coastal and inland flooding ad as well as potential resurgence of some diseases such as Rift Valley Fever. 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

The study[7] 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://kenya.cceconomics.org/). This section summarises this work.

The current burden of climate-sensitive disease is high in Kenya. The main potential impact identified in most assessments is malarial. It is one of the most physically and economically debilitating diseases in the country. It accounts for an estimated 30% of all out-patient consultations and 19% of all hospital admission. Of the total population, around 23 million (70%) are reported to live in areas at risk of malaria, including 3.5 million children under 5, at particular risk of severe malaria and the disease is a major contributor to the high under 5 child mortality (120 per 1000). For those surviving malaria it has extensive consequences for their educational and social development. For Kenya's over 1 million pregnant women each year, malaria poses threats of severe anaemia and miscarriage. Maternal malaria in more endemic areas is associated with low birth weight, which has important consequences for the child's survival chances during infancy.

Kenya is particularly sensitive to future changes in climate because a large part of the population lives in the highlands, where the disease is, at present, restricted by temperature. The greatest burden of climate-sensitive diseases occurs for the poorest and most vulnerable. A new malaria risk model was applied based on altitude, tailored to assess, on national scale and intermediate/long time scale, the impact of climate change

The product of incidence and population size equates an absolute amount of malaria, and the sum for all altitudes provides a measure for malaria (change), taking into account the altitudinal distribution of the population in the country.

The figure shows the overall analysis and the malaria lapse rate (in green) against rural population (blue bars) plus with 1 and 2ºC increase in temperature, with corresponding shifts of 190 and 380 meters respectively, resulting in an increase in prevalence in mid altitudes and geographical extension at higher altitudes.

[7] London School of Hygiene and Tropical Medicine: Menno Bouma and Sari Kovats, plus Alistair Hunt, Metroeconomica.

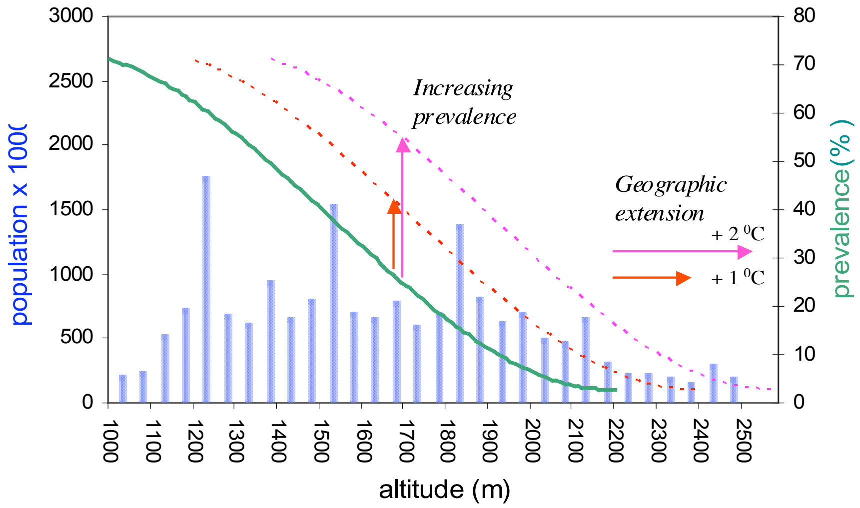


Figure 8. Malaria risk model in Kenya.

The analysis applied the model to the climate scenarios developed in the project (downscaled analysis from eight global climate models). Climate data were provided for two time periods as 30 year averages for the 2050s and the baseline period 1961-2000 for 21 locations in Kenya. The projected increases in average temperature was 2.3ºC for the 2050s compared to the baseline.

Results
The model projects that by 2055, as a result of the central average climate warming (2.3ºC) across the projections, the population annually affected by malaria in rural areas over 1000 metres (which comprises 63.5% of the population of Kenya) would increase by up to 74% (in absence of adaptation). The projected increases in malaria burden are not linearly related with temperature change. Therefore, the main report also presents results for increases in average temperature of 1.2 and 3°C. The increase across the range of temperatures from the projections is 36% to 89%.

Climate change dependent shifts in altitude related malaria, and distribution of the population in the highlands, allows assessment of the impact on malaria's clinical and economic malaria burden. At current population levels (2009), the most conservative assessment taking only temperature changes into account suggests that, annually, an extra 5.8 million people will be affected in the 2050s (with 2.8 to 7.0 million people across the range of temperature projections). Excess mortality in will be in the order of 15,700 people per year, of which 11,400 are below the age of 15. Additional hospitalizations (about 36,400 per year for infants) will stretch existing facilities.

With 1 in 5 admissions in the country due to malaria, and considering that many serious malaria cases do not reach hospital at present, just maintaining the current deserving level of hospital care would require a 20% increase in capacity. 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 regarding morbidity and mortality.

The potential additional cases that might arise have been assessed in economic terms. This reflects the overall change in welfare from resource costs i.e. medical costs, opportunity costs i.e. the cost in terms of lost productivity and dis-utility i.e. other social and economic costs including any restrictions, discomfort or inconvenience (pain or suffering), etc. Note that the direct cost estimates are also, effectively, adaptation costs – either preventative or reactive.

Economic costs
The additional burden of endemic malaria disease in the 2050s was estimated to be over $ 86 million annually (for population levels of 2009, with arrange of $48 to 99 million annually across the temperature projections) based on the clinical and economic malaria burden. This cost increases to the range $144 to 185 million annually if disutility costs (e.g. discomfort pain and inconvenience) are taken into account (range: 10 – 17 $ per case).

There could be a potentially large increase in malaria in Kenya. The study estimates that climate change could increase the rural population at risk by the 2050s affecting 3 to 7 million people a year, with direct economic costs of $48 to 99 million/year and full economic costs of $144 - $185 million/year.

The estimation of the malaria's economic burden resulting from climate change is sensitive to adult mortality resulting from epidemics. The economic value of life years lost resulting from epidemics is estimated at 89 million annually (population 2009, and minimum wage 870$ per year), when predicted mortality is annualized until 2055. Contrary to the declining "epidemic costs" when malaria shifts to less densely populated areas, the "endemic costs" are long lasting, and will continue to rise. A gradually increasing endemic burden of malaria will result in a higher health budget required for malaria control.

Predicted increases in rainfall, which are spatial more heterogeneous, and less robust than those for temperature, could double or treble the predicted increase above. The study found no support for the hypothesis that increased temperatures will limit conditions suitable for the vector in Kenya's warmer and dryer lowlands, and so can off-set the predicted malaria increase in the highlands. The absolute malaria burden resulting from climate change and the associated economic costs will depend on a more accurate assessment of the present burden and the increase of the rural population (at present 1.8% per year). 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.[8]

Finally, it is highlighted that there are other direct and indirect health effects from climate change. Further investigation of these additional areas is a priority.

Extreme Events

Background and impacts of climate change
East Africa and Kenya are affected by 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 impacts and high economic costs.

Analysis
The study has first investigated the historical impacts and economic costs of extreme events--floods and droughts in Kenya.

[8] Studies of climate change and malaria have a long tradition, with Kenya as one of the recurrent case studies. The choice of impact model is a key factor in the uncertainty in resulting scenarios: whether a simple statistical association as used in this study is better than a full epidemiological dynamic simulation remains at the frontier of health research. Probably the more important debate is whether increased income, greater awareness of health issues and investment in health infrastructure—all part of current development (for instance the Gates Foundation focal area) will automatically reduce the climate-driven risk. This is an essential aspect of this study—a good portion of future climate change impacts can be reduced through sound development practice. That said, those costs are still associated with climate impacts at present and should be counted in some was as part of the future adaptation needs.

Floods are part of existing natural variability and historic climate variability, associated with El Niño and La Niña years, has led to major impacts and economic costs during previous events, outlined below.

The total costs arising from 1997/98 floods (from damage to infrastructure, including roads buildings and communications, public health effects, and loss of crops) have been estimated by Karanja and Mutua (2000) and Mogaka et al. (2006). Integrating the results of the two studies and adding in mortality valuation gives cost estimates between $ 850 to $ 1213 million. Note that these floods lead to degradation of infrastructure as well.

The economic costs of droughts have even wider effects across the whole economy, cutting across key sectors. The 1998-2000 drought was estimated at $ 2.8 billion from the loss of crops and livestock, forest fires, damage to fisheries, reduced hydro-power generation, reduced industrial production, reduced water supply, mostly as annual losses. The repeated pattern of droughts and floods leads to longer lasting effects.

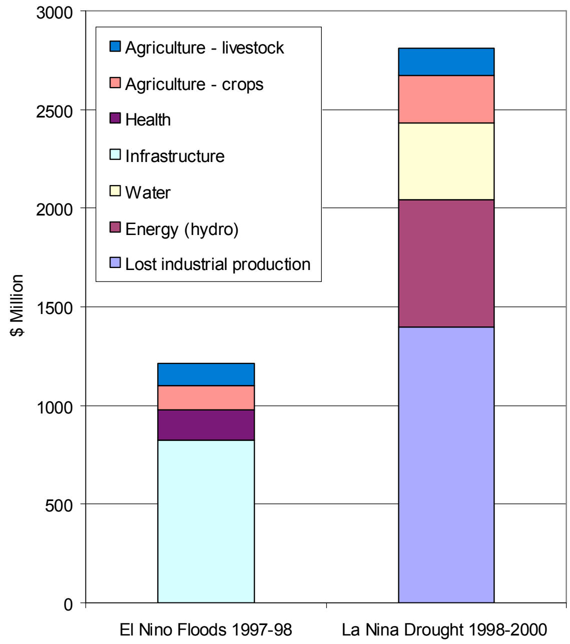


Figure 9. Recent Flood (1997/8) and drought (1998/00) impacts.

These are not isolated events. Recent major droughts occurred in 1998-2000, 2004/05 and in 2009. Major floods occurred in 1997/98 and 2006. The assessment has also undertaken a case study[9] on riparian flooding, outlined in the box below – a full version of the study is available web-site (http://kenya.cceconomics.org/).

The continued annual burden of these events leads to large economic costs (possibly as much as $0.5 billion per year, equivalent to around 2 % of GDP) and reduces long-term growth. There is some indication that there has been an intensification of these extreme events over recent decades and these may reflect a changing climate already.

However, the potential impacts of such events are determined by socio-economic trends, as much as climate. Indeed a significant part of the recent historic trends in the increasing damages that have been seen over recent decades (to floods) can be attributed to the increase in population, including urbanisation, and increased value of assets in flood-prone areas, to changes in the terrestrial system, such as deforestation and loss of natural floodplain storage, as well as to changes in climate. Nonetheless, a key finding is that Kenya it is not adequately adapted to deal with existing climate risks.

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

[9] Brian Otiende Oxfam Kenya

Case Study 2: Riparian Flooding

Riverine floods are the most dominant floods in Kenya and affect both the rural and urban areas in form of flash and urban floods. Perennial floods affect low-lying regions of Kenya, such as river valleys, marsh areas, lakeshores and the coastal strip. The Lake Victoria Basin in western Kenya and Tana River Basin in southeastern Kenya are the most flood-prone region in the country. The Budalangi and Kano flood plains in western Kenya and Tana River flood plains in the southeastern region of the country are the worst affected areas by floods during the short and long rain seasons of March-April-May and October-November-December respectively.

This high vulnerability in western Kenya is as a result of high poverty rates, poor land use patterns (deforestation and settling and cultivating along river banks), low education and illiteracy levels and the low state of infrastructure. While much of the economic costs of floods are captured in the assessment above, these do not fully reflect the effects on rural populations, non-market sectors and the non-formal economy.

Thousands of people in the country's flood-prone areas were displaced and rendered homeless with internally displaced persons (IDPs). The El Niño of 1997/98 affected over 1.5 million people in four East African countries including Kenya and the capacity restraints on health resources as a result led to over 3 million families suffering from poor health. The 2006 floods affected over 723,000 persons in Kenya.

Ecological damage resulting from flooding has negative impacts on the tourism industry in Kenya. Coral reefs, a major attraction of tourists in the coastal town of Mombasa were damaged from sediment deposits, and coral production was inhibited by lack of light. More than 50 percent of the coral reefs in Malindi were killed as a result of the 1997/98 El Niño flood.

The study has also explored the potential economic costs of climate change in Kenya. It has investigated a "historical analogue" approach to consider the impacts of different climate related events. However, a key part of this analysis is to recognise that these future effects will occur under different future socioeconomic conditions from those experienced in the historic weather events above. These will, in turn, influence the degree to which impacts can be expected and the values attributed to them.

While it is impossible to consider all factors 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 and GDP. The study has considered the potential changes in terms of major effects associated with drought and flood events. 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 extreme events, both for floods and droughts, are likely from socio-economic trends (population and GDP per capita). These socio-economic trends could, even without climate change, increase the economic costs of large-scale flood or drought events by as much as a factor of 5 by 2030, i.e. a periodic large-scale event could have direct economic costs of $5 to 10 billion. A key priority therefore is to increase the resilience of Kenya to cope with these extreme events.

Climate change is likely to further increase the economic costs of these events. However, the projection of these events is extremely challenging and any model outputs remain uncertain.

Even in the absence of climate change, the economic costs of the periodic floods and droughts that affect Kenya will rise significantly in future years, due to socio-economic change (population and economic growth). A key priority therefore is to increase the resilience of Kenya to cope with these extreme events.

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[10]).

Many of the projections indicate an increase intensity of extreme rainfall events in much of East Africa, including in Kenya. As an example, during the short-rains, there are some projections of increases in intensity from 10 to as much as 50% in the 10-year high rainfall events over the north of East Africa by the end of the century (i.e. 2100).These are associated with higher flood risks. As outlined above, flood events have major effects on key infrastructure, through inundation leading to disruption and loss of operations, flood damage to physical infrastructure, or from river floods washing away and damaging infrastructure (including rain induced land-slides). When this affects critical infrastructure, e.g. water treatment, electricity, etc., it has much greater risks to the local population in terms of health risk and fatalities. These increases in intensity would also 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 build resilience to floods is therefore a key priority for Kenya.

While many of the models predict increases in rainfall on average, droughts are likely to continue. However, what is less clear is whether the intensity of these events will change. Some of the projections considered indicate low-rainfall extremes (potentially associated with droughts) could actually become less severe, at least for some regions of Kenya. Other models project a potential intensification of these events. Nonetheless, the potential change, on top of the current droughts,make this a priority area.

Water Sector

Background and impacts of climate change
Water is a critical sector and climate change affects the whole water cycle and water ecosystems. Changes in river flow and groundwater systems will affect water availability and the function and operation of existing water infrastructure (including hydropower, inland navigation, irrigation systems, drinking water supply and waste water treatment). Water is also essential in energy supply, agriculture, tourism, industry, etc. across the Kenyan economy. Ancillary stresses of pollution, salinisation, sedimentation and over-extraction of groundwater exacerbate vulnerability to current and future climate risks.

Analysis
The study has investigated the potential multi-sectoral effects of water resources and climate change using a case study for the Tana River basin using a water planning model, WEAP (see www.WEAP2100.org). A full technical report is available at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

Results
The case study[11] and results are outlined in the box below. Overall the analysis shows that that the economic impacts of climate change (without adaptation)[12].

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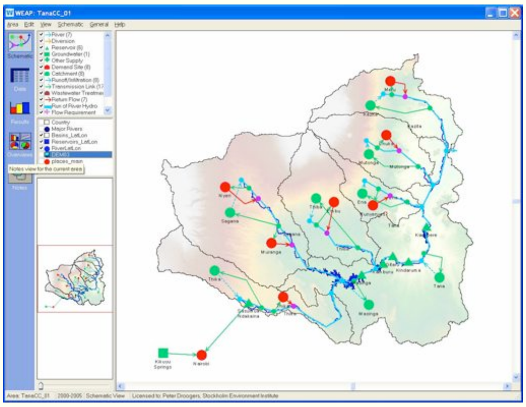
[10] Shongwe, M.E., van Oldenborgh and van Aalst (2009). Submitted to Journal of Climate. Projected changes in mean and extreme precipitation in Africa under global warming, Part II: East Africa. Nairobi, Kenya, 56 pp.
[11] Peter Droogers (FutureWater)

Case Study 3: Water Resources in the Tana River Basin

The study has undertaken a detailed case study, running the WEAP water catchment model for the Tana River basin to investigate the potential impacts and adaptation.



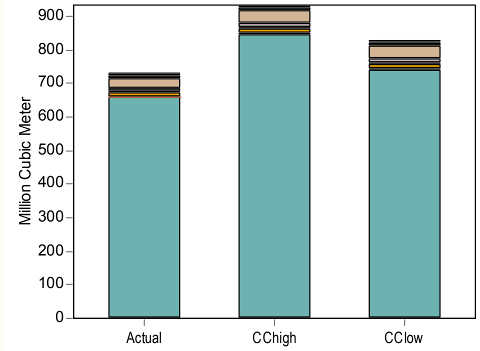
Model representation of the Tana River Basin

The study assessed the impact of climate change on:

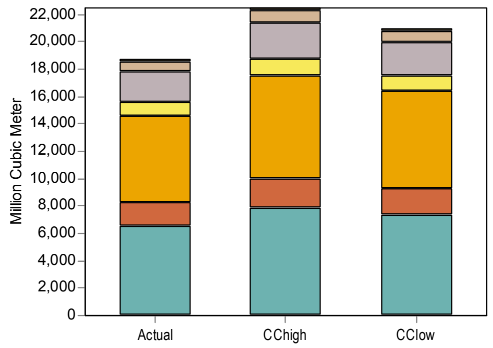
- Hydropower generation
- Irrigation water shortage
- Rainfed agriculture shortage
- Urban water shortage

Without adaptation, for the low climate projection (= lowest increase in temperature and highest increase in precipitation) climate change will have a small positive impact. Unmet demand for urban and irrigation is somewhat lower. For hydropower, although rainfall is higher, evapotranspiration is even higher, leading to a somewhat lower inflow into the reservoirs. Overall there is a small positive impact at an overall value of about $ 2 million.

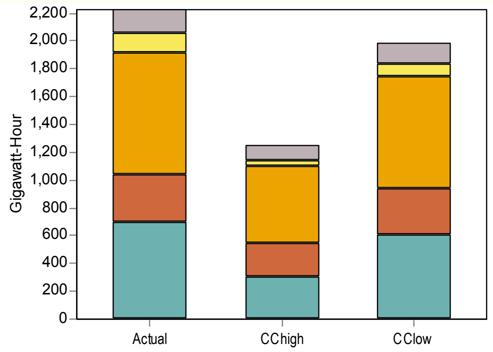
The high projection has a very negative impact with increasing water shortages for urban and irrigation and a substantial loss in hydropower, with estimated costs of $ 66 million for hydropower, irrigation and drinking water.



Changes in water demand for domestic and irrigated agriculture for current and the two projections 2050s.



Water demand for land for the current situation and the two projections 2050s.



Hydropower generation for the current situation and the two projections around 2050s.

Figure 10. Results from the WEAP model case study of the Tana River, Kenya

[12] Note the study assessed the effects of future climate change on current conditions. There is a need to develop socio-economic projections that include future water supply and demand: such analysis is resource intensive but a priority for future analysis.

The water supply case study on the Tana River shows that the economic impact of climate change for this one river basin ranges from a benefit of $2 million to a cost of $66 million for hydropower, irrigation and drinking water across the range of projections.

Energy sector

Background and impacts of climate change

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.

The energy sector is affected by the potential changes in extreme events (floods and droughts), 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 important in economic terms.

The study has investigated the effects of climate change on the energy resources and demand of Kenya. The potential effects on electricity supply are included in the Tana river basin analysis (above).

The study has also investigated the potential changes in energy demand from higher average temperatures. Outside temperature affects heating and cooling requirements and so influences energy demand. Energy demand increases with colder temperatures (heating in homes, offices and factories) and with higher temperatures (cooling). 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, itself 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).

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 wealth, 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 and low carbon growth).

The net changes in energy demand will vary with location across Kenya. 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 higher 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.

Analysis

The study undertook surveys and analysis[13] to build up a picture of current electricity cooling demand. Discussion with KPLC on power demand variations with temperature in Kenya report there is an observed change in electricity demand during the cold season in Nairobi (for heating) and the hot season for Mombasa (for air conditioning) although no documented data or statistical correlations exist. The survey work also reports growing demand from larger corporate organizations for air conditioning

[13] Samuel Mayieko and Joan Sang, Camco.

The study team also interviewed air conditioning retailers to investigate levels of demand, efficiency levels, etc. This shows some high increases in service sector and industrial demand in some regions (particularly in North the Eastern Province of Kenya and Mombasa), though more generally, demand seems to be limited by high electricity tariffs.

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.

Results

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 low cooling demand for Nairobi, but already significant demand in Mombasa.

Under model-simulated baseline conditions, there rise to between 150 and 320 CDD in Nairobi and 150 and 320 in Mombasa by the 2050s. This is a 240 to 340% (average 300%) rise in the cooling burden for Mombasa. This will increase electricity demand for cooling and have economic costs, particularly to certain sectors (e.g. tourism). Note there may also be some economic benefits, however, from reduced heating demand in colder periods, e.g. in Nairobi. The existing data limitations prevent economic analysis, though this is highlighted as an important future sector for analysis.

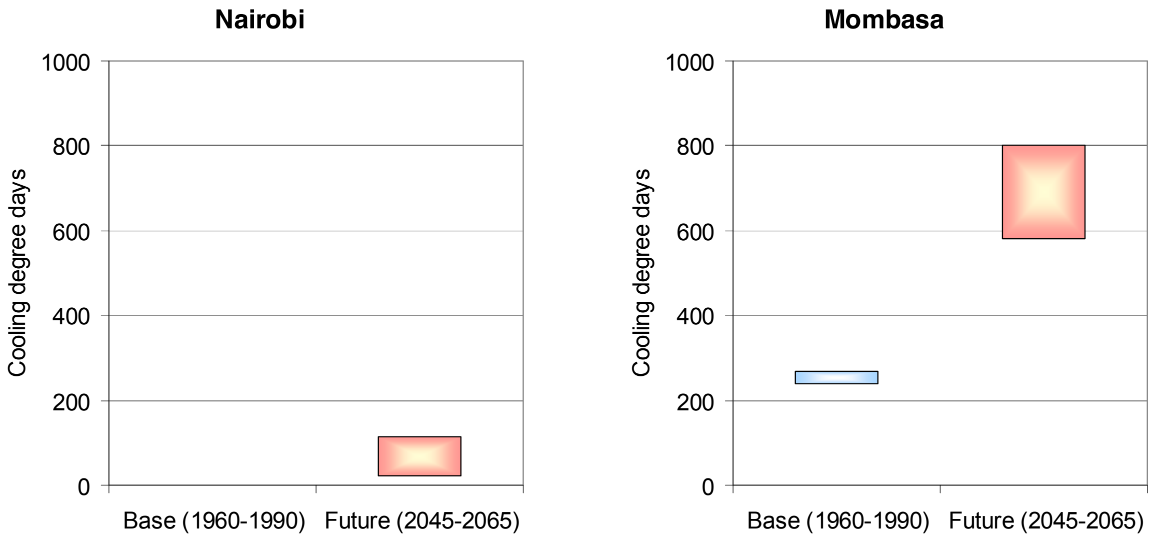


Figure 11. Cooling degree days (Nairobi and Mombasa). Current and future range (2050s)

Higher temperatures and rising incomes will increase cooling demand leading to increased electricity use and economic costs. These will be greatest in warmer areas: to illustrate, the burden of cooling demand may increase by 300% in Mombasa by the 2050s.

There may also be an emerging cross-sectoral issue of energy use in water supply (pumping, desalination, recycling, water transfers) in the longer-term, in relation to lower water availability in arid areas, and again the potential for conflicts between adaptation and mitigation, versus the need to ensure low carbon growth. These have not been considered in the study, but are an area for future investigation.

Agriculture

Background and impacts of climate change

Agriculture is still a mainstay of the Kenyan economy, sitting alongside remittances and tourism as one of the top earners of foreign exchange. While urban growth continues to benefit from rural to urban migration, most of the Kenyan population is still rural and some 75% of the population engages in agriculture to some extent. However, on-farm crop production is a declining source of household income, a common trend in developing countries. Agriculture as a portion of Gross Domestic Product (GDP) is not insignificant, at some 25% in recent years. Additionally, livestock production is central to livelihoods and food security in the arid and semi-arid lands (ASALs).

For the majority of the poor in Kenya, agriculture is a main livelihood strategy. About half of the population of Kenya is below the poverty line, while only 5% of the national income is held by the poorest 20% of the population and nearly half of the national income is held by the richest 20%. The dominant farm type is a smallholding: 0.9 ha is the average size at present. 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. These will be potentially exacerbated by a mix of climate and socio-economic change. However, the prediction of these effects is extremely complex.

Analysis and results

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_2 fertilisation effect. Given much of Kenyan agriculture is currently rain-fed, there are also potentially wide ranging effects from the potential changes in precipitation. Moreover, there are a number of complex interactions with other factors, e.g. extreme events (heat, floods, and droughts), soil, pests and diseases, and complex interactions with other key sectors, e.g. water availability for irrigation, 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 (autonomous reactions). The net effects of all these changes are extremely hard to predict. In face of this complexity it is impossible to predict future climate change impacts in Kenya.

The study has considered the potential effects of climate change on agriculture. A full technical report is available on the study at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

The study has reviewed previous studies that have assessed the potential changes for agriculture in Kenya. This includes alternative approaches for assessing potential effects. Ricardian based analysis (Kabubo-Mariara and Karanja, 2006) analyzed data and reported increased winter temperatures are associated with higher crop revenue, increased summer temperatures have a negative impact and increased precipitation was positively correlated with net crop yield. Applying this to climate analysis for global model outputs for 2030, they predicted a substantial impact on net crop revenue, but with differences with potential zones, predicting a 1% gain in high potential zones but a 22% loss in medium and low potential zones. However, these projections do not fully reflect the range of climate model projections. Alternative approaches, based on crop models have also been applied to Kenya, looking at individual crop varieties using impact assessment based approaches. These also reveal mixed patterns with strong differences between areas, with some areas showing higher yields or potential for new crop varieties, whilst other showing negative effects (e.g. with studies of maize yields).

The study has also considered a more comprehensive analysis of the interplay of biophysical, socio-economic and decision-choice factors for agiculture, all operating across spatial and social scales of space and time. The 'cloud' diagram below suggests some of the factors involved in agriculture.

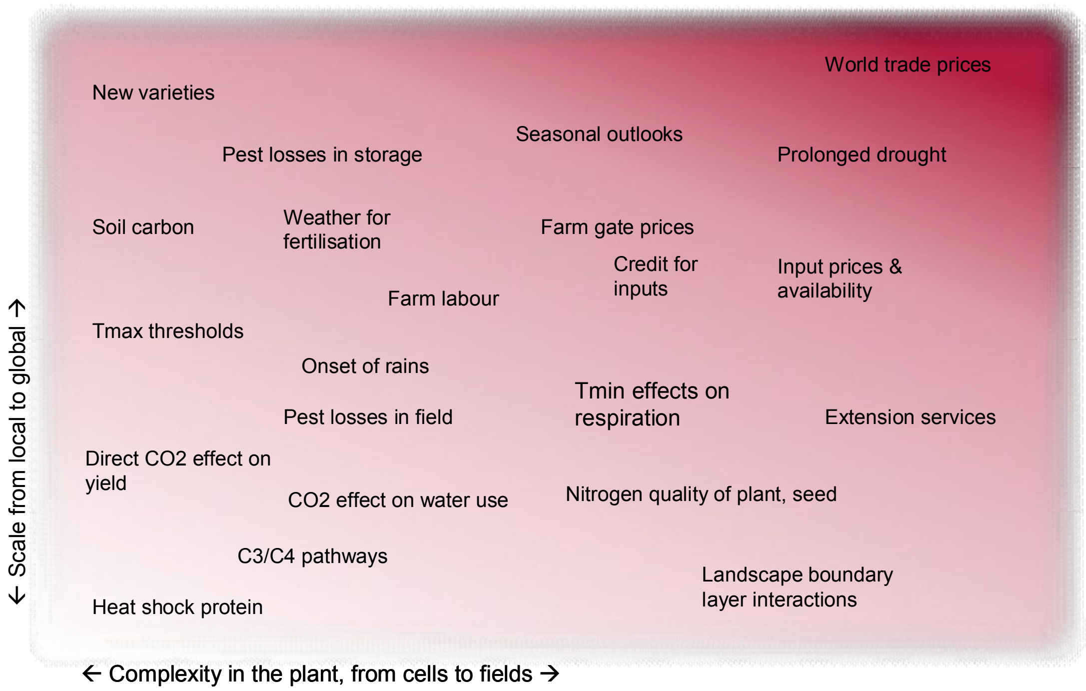


Figure 12. Range of factors affecting vulnerability, impacts and adaptation to climate change

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

Warmer conditions in the highlands might benefit crops, with longer seasons and more radiation. Seasonal shifts have been noted in recent years, with the short rains starting in December rather than October. The balance of rainfall and evapotranspiration may well shift: pastoralist communities have reported land cover changes in the semi-arid lands toward more shrubs. Intense rainfall and long term droughts are already features of the Kenya climate and certain to continue to be significant hazards.

The study has also commissioned new studies on shifts in agro-ecological potential[14]. This builds on the work on agro-ecological zones, land productivity and climate change, exploring the sensitivity of agricultural and pastoral lands to climate change and using the agroclimatic index in Kenya, within a GIS environment. The analysis assessed the potential shifts in the value of agricultural land, evaluating some 150 land units that are sensitive to climate change. These results are intended to frame the potential changes in land value as a result of climatic events and longer term climate change. As a bounding exercise, two scenarios were constructed. The first assumes a national drought occurs with the most severe impacts in the drylands and relatively modest impacts in the humid highlands. This is a familiar pattern, where production of maize is reduced dramatically in zones III and IV, resulting in a spike in demand that cannot be met from the traditional surpluses in zones I and II. In this case the total value of agricultural land in Kenya (as calculated in the ILRI data) is reduced to about two-thirds of the average

[14] International Livestock Research Institute (ILRI): Joseph Maitima, Simon Mugatha, Patrick Kariuki, Lea Mariene

value. The second ‘experiment’ is intended to reflect the longer term consequences of climate change. It assumes that wetter conditions prevail in zones IV, V, VI and VII, leading to an increase in the value of land. Values increase in the middle zone (III) but not in the humid highlands. The result would be an increase in the value of agricultural land of some 10%.

Related studies on climate change vulnerability, impacts and adaptation in the drylands and effects on pastoralists and agro-pastoralists have been undertaken, in consultation with the Ministry for the Development of Northern Kenya and other Arid Lands. An initial report on climate change and humanitarian crises has been prepared by the SEI office in Nairobi (Ali et al. 2009) and further work is planned in conjunction with the International Institute for Environment and Development. However, these studies have not undertaken an economic analysis of current impacts and future adaptation as yet.

Biodiversity and ecosystem services

Background and impacts of climate change

Kenya has very diverse ecosystems that range from coral reefs and mangroves along the Indian Ocean coast to arid shrub land in the north, to dense mountain forests, and to the shores and waters of Lakes Victoria and Turkana.

These ecosystems provide multiple benefits to society, that 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, educational and cultural benefits).

Climate change is likely to have major effects on managed and natural ecosystems and associated ecosystem services. The impacts are complex but potentially arise from temperature increases, shifts in climatic zones, melting of snow and ice, sea level rise, droughts, floods and other extreme weather events. Particularly vulnerable areas include arid lands (from water scarcity and heat stress), coastal zones due to pressure from sea level rise and Mountain regions.

Climate change will cause climatic zones (and their ecosystems) to move, potentially by tens to hundreds of kilometres by the end of the century (depending on the scenario used). The success of this movement will depend on various factors: the capacity of a species to migrate (e.g. migration will be easier for birds than for plants or especially forests), the connectivity within the landscape structure (i.e. availability of stepping stones and/or habitat networks), and the presence of receptor habitats within the new climate range of a species. This is obviously problematic in populated areas and highly fragmented agricultural landscapes.

Climate change presents one of the most important threats to biodiversity/ ecosystems and their functions and services. Natural systems are vulnerable to such changes due to their limited adaptive capacity.

Analysis and Results

The study has mapped the role that ecosystem (see figure below) and ecosystem services play role in Kenya’s economy, people’s livelihoods, and human well-being. A full technical report is available on the study at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

About 75% of Kenyans base their livelihoods on agricultural activities and the sector contributes a large % of GDP (see section above), even more so when indirect links to other sectors are counted. The sector also covered 60% of total export earnings, 45% of government revenue, and 62% of jobs in the formal economy. In addition to agriculture, nature-based tourism, fishing, timber and charcoal production are other important sources of income in the country.

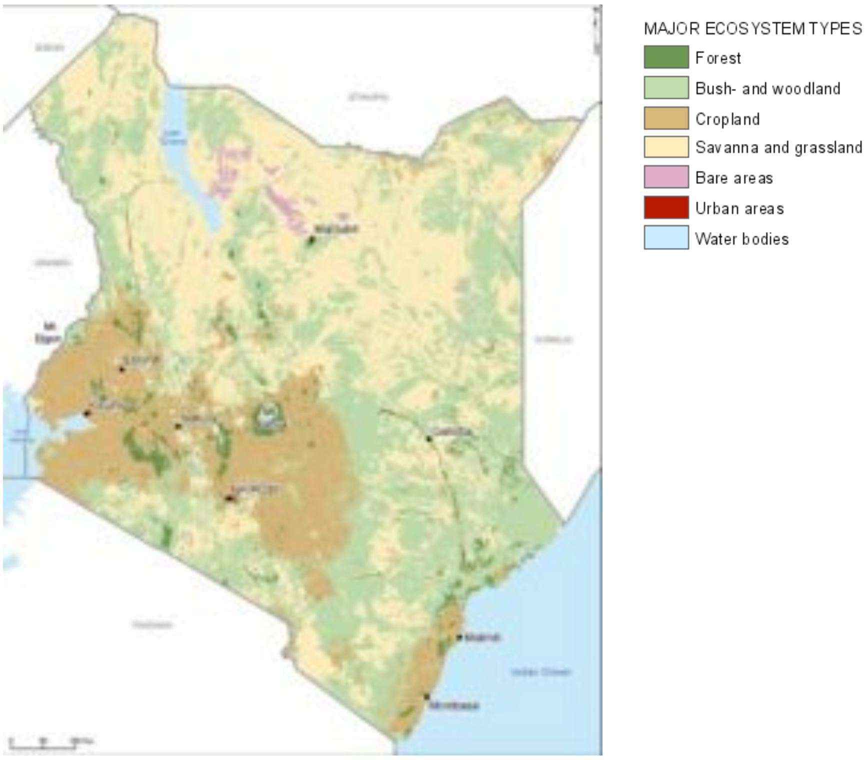


Figure 13. Major Ecosystems in Kenya (1995-2000)

A number of these ecosystems services are already critically stressed. These include the maintenance of biodiversity; food provision; water supply, purification and regulation; and energy resources. Stresses vary in each Province. The table below shows the distribution of main issues related to ecosystems degradation in Kenya. The study has investigated each of these ecosystem services and assessed their vulnerability to current stresses and sensitivity to climate.

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

The study has then investigated the potential vulnerability of these services to future climate change, evaluating against the baseline projections and strategies in the Vision 2030 document and exploring a series of case studies (see box).

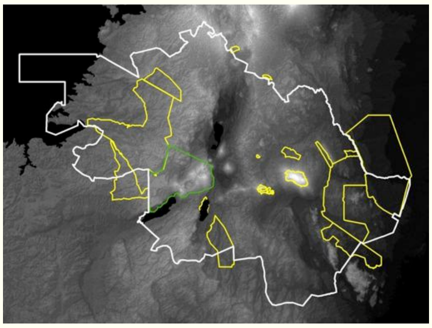
Case Study 4. Ecosystems Services: Exploring Potential Economic and Livelihood Impacts of Climate Change and Possible Adaptation Mechanisms in the Kenyan Rangelands

A number of case studies are being investigated on ecosystems services. These include:

- Value of ecosystem services in the Tana River catchment, Kenya, to avoid production, water and livelihoods losses and benefit from green water management.
- Costs of protecting the Mau Complex, Kenya, to avoid water and energy shortages downstream.
- Potential economic and livelihood impacts of climate change and possible adaptation mechanisms In the Kenyan rangelands.

These are presented in the full annexes (http://kenya.cceconomics.org/). One of the case studies assesses the biodiversity vulnerability of kenyan flora and fauna to climate change[15], looking at the Kenya-Tanzania Borderlands, drawing on a larger study by the team.

The Borderlands are particularly rich in wildlife, but also represent rangelands that account for over 65% of livestock productivity. The study has assessed the threat to biodiversity posed by climate change in Kenya through the use of environmental envelopes to quantify the sensitivity of multiple taxa to climate change and human impact. It also looks at the impact of landuse and landuse change on livelihoods and assesses the connectivity of nationally, privately and communally protected areas as a spatial mechanism for cushioning the impact of climate change to biodiversity.



Study area - protected areas yellow / green

Initial results suggest potentially significant shifts in species and habitats over time, with increasing conflicts between rapidly expanding agriculture into previously marginal areas, and pastoral communities and biodiversity. For biodiversity, these challenges will be most acute for narrow ranged species and those confined to highland areas. For people and their livelihoods, it is the dominant production system in the region that will be most affected – pastoralism.

The lack of flexibility / mobility is highlighted by the case of national parks and reserves in Kenya in the face of projected changes in climate. A preliminary analysis of protected areas and rainfall indicates that the majority of the national parks and reserves in Kenya are in areas with mean annual rainfall ranging between 500 mm and 800 mm. The projected changes in rainfall vary across the projections, but do indicate (on average) wetter conditions. This has some potential to affect the suitability of these areas though could be managed by more intensive management. A greater threat potentially arises from changes in extremes. This is already evidenced in the existing drought events.

Summary

Overall, the bottom-up sectoral analysis indicates that in the absence of adaptation, the aggregated estimates of economic costs - which occur on top of the existing effects of current climate variability - could potentially be very large.

Detailed analysis for coastal zones and health alone indicate future economic costs could be several hundred million dollars a year by the 2050s under some projections.

[15] African Conservation Centre, Dr. Jeff Worden, Dr. David Western, Lucy Waruingi

There are also potential effects on ecosystem services, which whilst difficult to estimate in economic terms, could be as important. The analysis of future costs of extreme events indicates large increases in the economic costs of these events are possible. Finally, there are some possible scenarios of climate change on the water and 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, in terms of the equivalent costs to GDP. 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 GDP. Finally, **there is also likely to be a strong distributional pattern of effects, with some sub-regions and some groups affected more than others.**

2. Adaptation Costs and Benefits in Kenya

The study has considered the costs and benefits of adaptation. A number of approaches have been used, including top-down and bottom-up analysis. The top-down analysis has reviewed the existing estimates of adaptation costs for Africa and scaled these to East Africa and Kenya. A full technical report is available on the adaptation costs at the web-site (http://kenya.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. 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 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 2030 (i.e., the medium-term vision 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. Note however that investment in these areas will provide greater resilience to future climate change and the ability to mobilise resources for an uncertain future.

Based on review the study estimates:

Urgent needs, for 2012:

- A minimum of $ 50-75 million / year for immediate priorities and building capacity.
- Some early anticipatory adaptation, likely to be of a similar order of magnitude as above.
- Social protection, with implied costs of $450-660 million / year (but related to development).

- A potentially large cost for accelerated development (overcoming the historic adaptation deficit).

Benchmark costs for 2030:

- Continued investment in capacity, estimated at $20–50 million per year.
- A significant increase in enhancing climate resilience in new investment: a minimum of $100 - $400 million / year but possibly as high as $250 - $1000 million / year.
- Further social protection might be the same order of magnitude as above (i.e., $500 million / year).
- Additional funding to accelerate development investment to ensure climate resilience, estimated at $50 – 475 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.

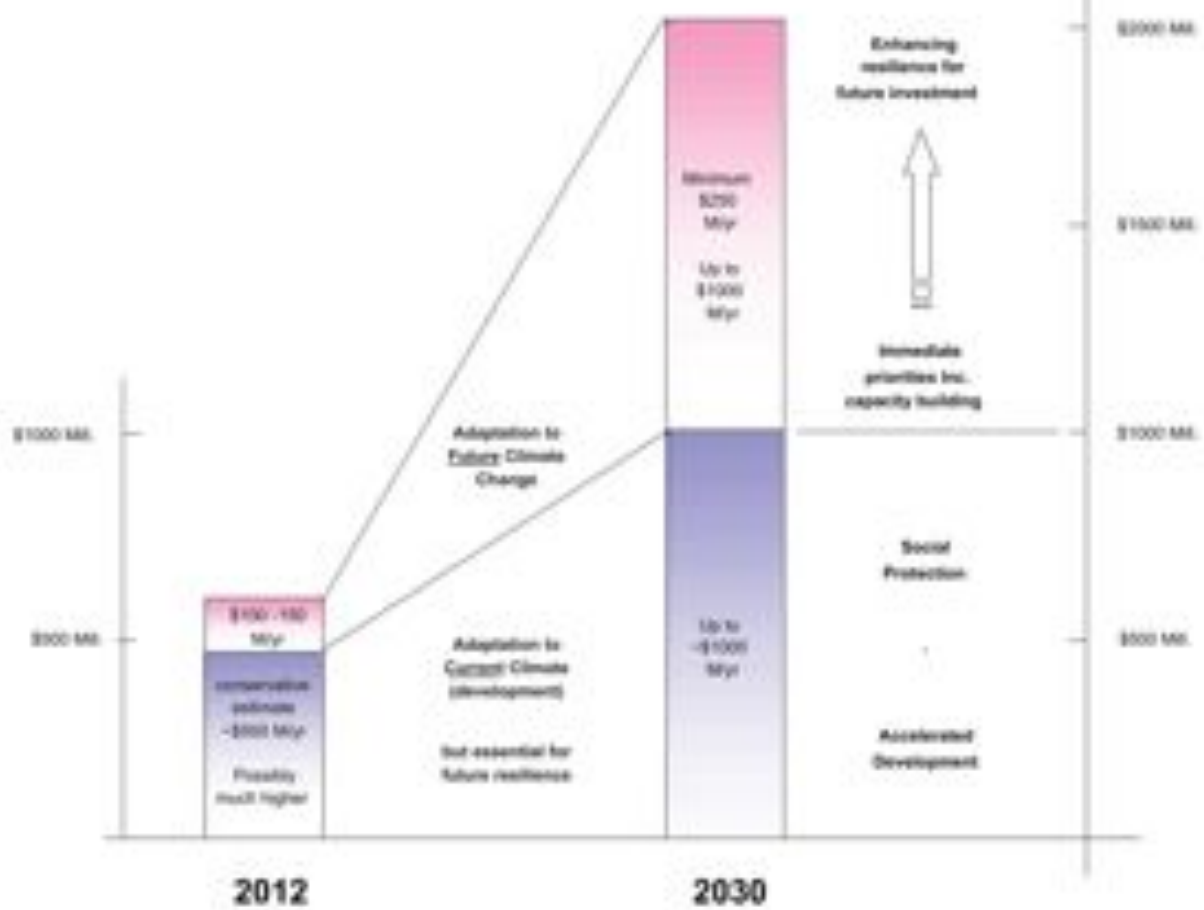


Figure 14. Indicative costs of adaptation to current and future climate n Kenya, $ million/year

The study concludes that a conservative estimate of immediate needs (for 2012) is $ 500 million / year. These adaptation costs are similar in order of magnitude to current ODA.

The adaptation needs by 2030 will increase: **an upper estimate of the cost is in the range of $ 1 to 2 billion / year.**

> ***Adaptation costs are strongly influenced by what is included or excluded.***
>
> ***The top-down analysis indicates that a conservative estimate of immediate needs for addressing current climate as well as preparing for future climate change is $ 500 million / year (for 2012).***
>
> ***The cost of adaptation by 2030 will increase: an upper estimate of the cost is likely to be in the range of $ 1 to 2 billion / year.***

National Bottom-up 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. Different evidence lines help cover against this uncertainty.
- 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 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, etc. 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 need to consider the effects of current climate variability and any adaptation deficit, especially in the context of immediate vulnerability – a key concern for Kenya. Second, a focus on a short-term policy window, consistent with the 2030 timescale. Third, the longer term aspects associated with post 2030 analysis. This is essential to capture the full climate signals, to consider the long life-times (e.g. infrastructure) and to consider whether short-term actions increase or decrease future resilience or cut off future flexibility or options.

- The issue of timescales is linked to an 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 lifetimes 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.

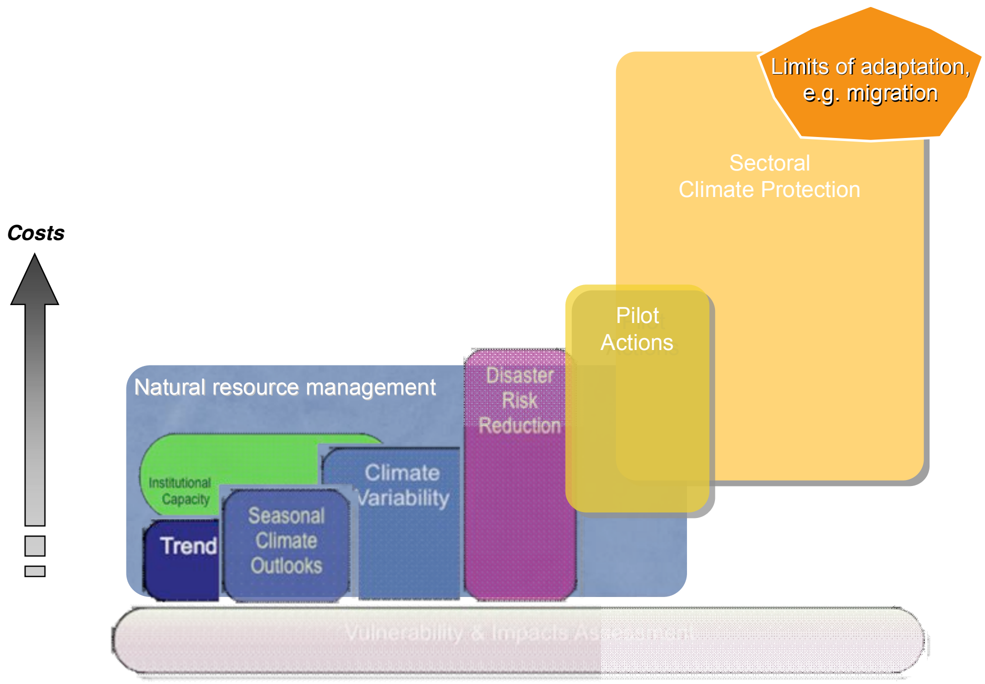


Figure 15. An ensemble of adaptation strategies is required

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.

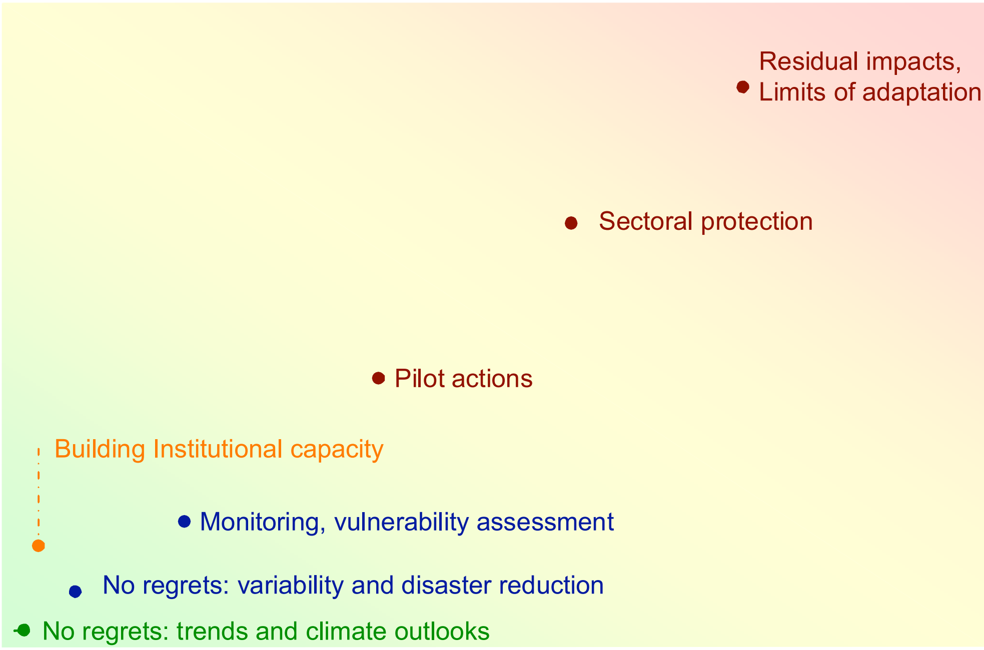


Figure 16. Examples of adaptation strategies

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

Coastal zones

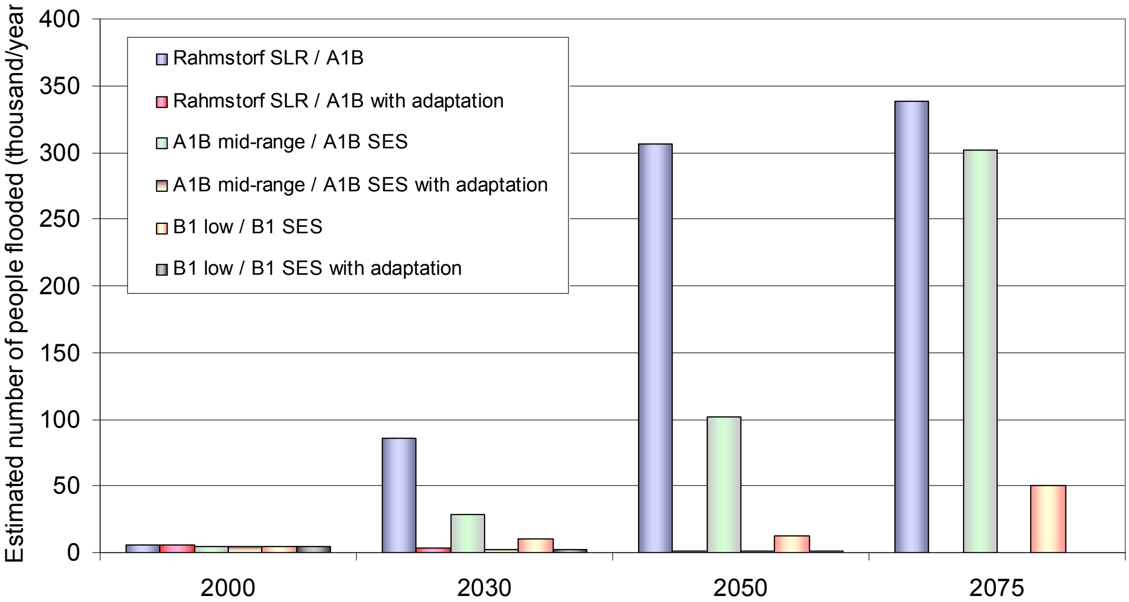
The study has considered the potential costs of adaptation for coastal zones. Protection is required in a diverse range of coastal environments, such as cities, ports, deltas and agriculture areas. Coastal protection to sea-level rise is often a costly, but a straightforward way to overcome the adverse impacts of climate change. There are a large number of potential adaptation options, particularly for protecting market sectors. These adaptation strategies include coastal defences (e.g. physical barriers to flooding and coastal erosion such as dikes and flood barriers); realignment of coastal defences landwards; abandonment (managed or unmanaged); measures to reduce the energy of near-shore waves and currents; coastal morphological management; and resilience-building strategies.

This has also used the DIVA model. A full technical report is available on the analysis at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

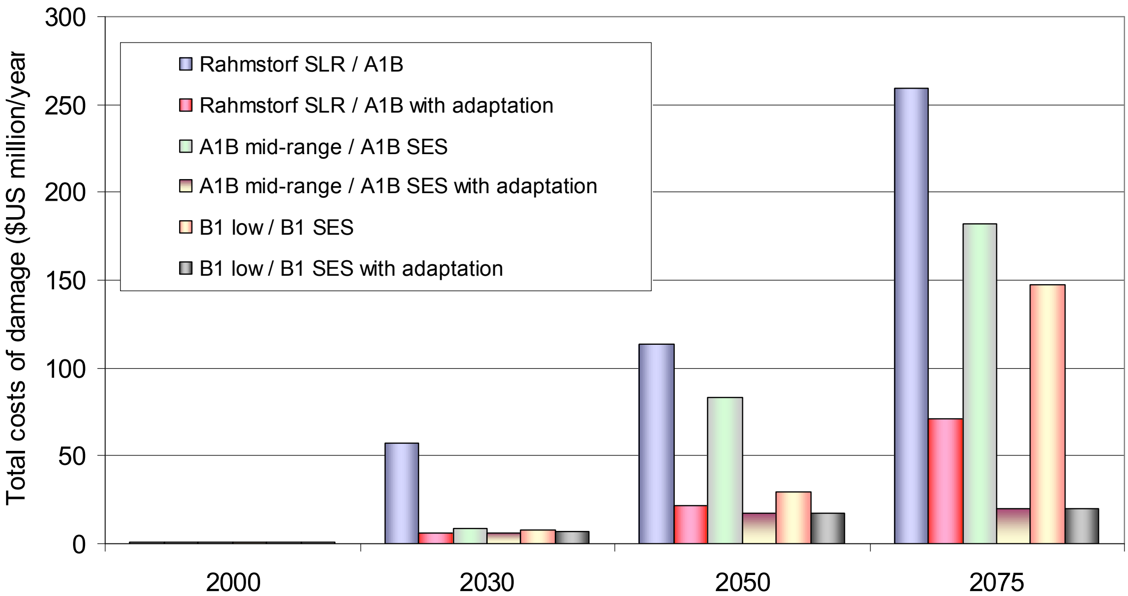
This captures a sub-set of these adaptation measures, focusing on the hard adaptation of the construction and increase in height of flood defence dikes to manage flooding, and beach nourishment to manage erosion. Beach nourishment was based on cost-benefit analysis, while the dikes were based on a demand for safety function, which is applied depending on population density.

When adaptation is applied, the potential impacts and economic costs above can be significantly reduced. The study shows that adaptation has large potential benefits in reducing coastal erosion and inundation. The number of people that could be flooded is dramatically reduced, and is one- two orders of magnitude lower at 2,000 to 11,000 people per year in 2030 across the range of scenarios. The total costs are also significantly reduced. These are shown in the graphs below.

The cost of adaptation in 2030 is estimated at $28-56 million / year depending on the sea level rise scenario. These costs could rise to $80 million / year by 2050 and much higher further in the future. Note even with adaptation, there is some residual damage. The finding is that coastal protection appears to substantively reduce the threat imposed by sea-level rise at a relatively low cost, and in the analysis here, that the benefits of adaptation far outweigh the costs.



Estimated number of people flooded, with and without adaptation



Total economic costs ($US million/year) from all categories (flooding, erosion, ecosystem loss)
With and without adaptation

Figure 17. Adaptation costs in the coastal zone. Source: DIVA.

However, some additional factors are important. Adaptation will be more costly and difficult than the headline costs above suggests, as the DIVA analysis does not fully explore costs at a local level and changes to cost throughout time. This reflects several factors: (1) the adaptation costs are partial, (2) the large adaptation deficit, reflecting that Kenya is poorly adapted to today's climate, and (3) the low adaptive capacity.

Moreover, while it possible and probably desirable to protect many areas of coasts through adaptation, this does not fully capture the full role of Kenya's coastline. Under projected climate change and sea level rise, coastal ecosystems will be threatened. These habitats could be severely reduced or disappear during the 21st century.

Adaptation can reduce down the impacts of sea level rise significantly and has high benefits when compared to costs. Nonetheless, the cost of adaptation in 2030 is estimated at $28-56 million / year by 2030, rising to $80 million / year by 2050.

The study also highlights some specific additional issues associated with the adaptation signature, highlighting the need for disaster risk management, but also reversibility and flexibility, highlighting that there is a strong potential for development to increase future vulnerability, i.e. if future economic zones are located in areas that have high future risks with sea level rise. While this involves urban planning and development issues, it is a potential no regret option. The analysis also highlights consideration of future thresholds for flooding for the city, to allow decision pathways to be developed.

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 generally:

- 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, across all the potential future risks, the potential 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 novel health interventions (e.g. heat wave warning systems).
- Additional costs for meeting environmental and health regulatory standards (e.g. air quality standards, water quality standards).
- Costs of improving or modifying health systems infrastructure, for example, adapting hospitals to hotter summers.
- 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 using 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.

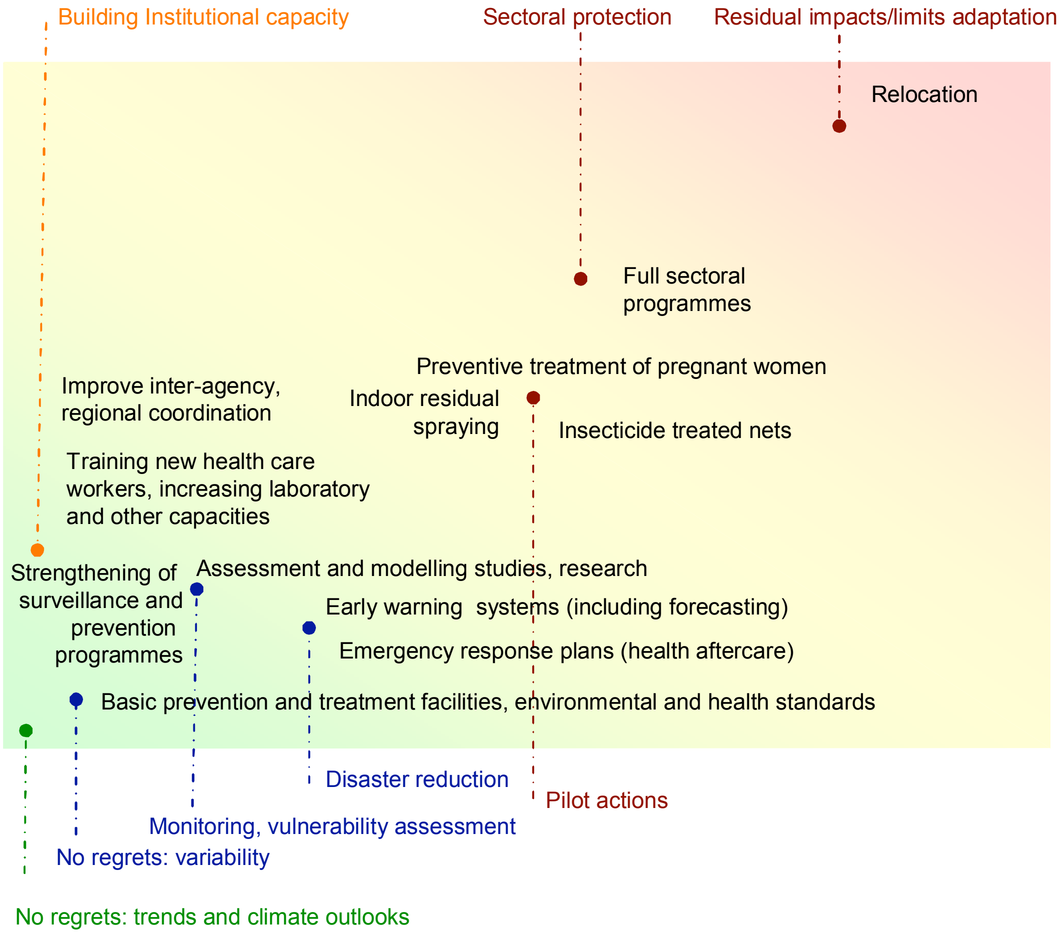


Figure 18. Adaptation signature for health.

The study has focused on the potential costs of adaptation for malaria control initiatives in Kenya. A full technical report is available at the web-site (http://kenya.cceconomics.org/).

The economic burden resulting from projected climate change on endemic malaria in terms of direct and indirect costs has been estimated. Where morbidity is concerned, treatment and costs can be viewed as remedial activities. However, malaria's most important determinant is economic. Malaria and poverty are intimately linked and in Kenya the lower socio-economic classes (household income < $ 50 per month) bear the brunt of the disease. The most certain way to avoid the consequences of climate change is to improve living standards, thus enhancing entitlement and affordability of adequate healthcare and prevention. However, the increasing economic and psychological burden resulting from aggravated malaria is likely to further undermine the population's capacity to cope with the disease. The malaria control initiatives for endemic areas in Kenya are based on:

1) Quick and effective treatment
2) The provision of prevention and treatment of pregnant women
3) Promote the use of insecticide treated nets (ITNs) in high risk communities (National Malaria Control Strategy MOP PMI, 2008).

In areas of aggravated malaria there would be no change required in policy. Additional infrastructure and staff will be required to address the increased health care demands. In areas which become endemic with the malaria lapse rate shifting to higher altitudes, new facilities will have to be establishes and new staff trained and employed. The cost of additional health care facilities and staff is not assessed in this report.

There is more extensive scope to prevent the economic and societal impact of epidemic malaria. With increasing ambient temperatures large number of people, not previously exposed, can be protected from the worst consequences of epidemic malaria. In recent years Kenya has started to use Indoor Residual Spraying (IRS) in highland areas to control malaria in low endemic areas and to prevent epidemics. It should be borne in mind that this initiative for IRS followed the rise in malaria since the 1980 and associated epidemics. It should therefore be seen as an adaptation when temperature as a driver is accepted. As the economic costs associated with epidemics are highest in the next 2 decades due to the altitudinal distribution of the population, and will decrease over time, adaptive initiatives to protect the population from epidemics appears a high priority.

Kenya's malaria control initiatives include the Improvement of epidemic preparedness and response in epidemic-prone areas (the National Malaria Control Strategy MOP PMI, 2008).

- MEWS**.** Malaria Early Warning Systems, monitoring environmental risk parameters and early detection.
- Pregnant Women. The existing policy for pregnant women in endemic areas is treatment (SP) 2 times (ITPt) during pregnancy to reduce the adverse effects of malaria. There is increasing support for all pregnant women in low endemic and epidemic areas to be targeted and the study considered this policy over the "endemic intercept", covering the area of potential periodic epidemics, parallel to the proposed area of ITNs (see figure). However, during perceived high risk years (e.g. during warmer El Niño years), this policy can be adapted to take interannual variability into account.
- Diagnostic Tests (RDT). In high endemic areas, most treatment is on presumptive basis. In low endemic and epidemic areas false positive clinical malaria diagnosis results in reduced cost-benefits, particularly in view of the much more expensive ACTs which now have replaced cheaper chloroquine. As every episode requires confirmation or exclusion of malaria, rapid diagnostic tests are important.

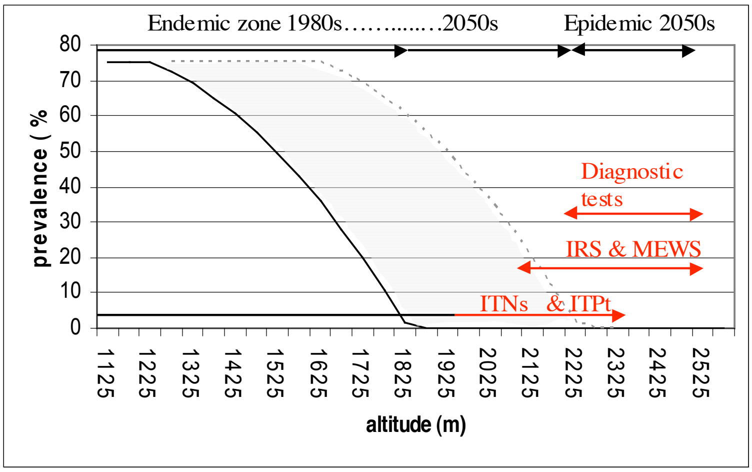


Figure 19. Adaptation for low endemic and epidemic areas. Proposed adaptation policy (red) around the 2250 m. intercept for the 2050s.

The study has estimated the cost for

- IRS coverage in low endemic and potential epidemic areas (shifting to higher altitudes 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
- Treatment (direct) costs for additional malaria cases

The total annual costs are estimated at around $23 million/year (central value, with a range across the projections). The main costs for diagnosis and prevention ($ 15 million) is associated with IRS. Annual cost for treatment of additional cases is estimated at$ 8 million.

Based on the association between GDP in Africa and malaria, a predicted 74% increase of malaria in areas over 1000 meter in the 2050s is associated with a decrease of GDP by approximately 40% (based on current GDP 2008).

Adaptation appears highly cost-effective for reducing the threat of malaria, reducing potential impacts significantly at relatively low cost.

Extreme Events

The study has considered the potential adaptation options for flooding, concentrating initially in this area as there appears to be a greater confidence in the future climate signal. These have been investigated in the case study, see box.

Case Study 2: Riparian flooding and adaptation

This case study investigates adaptation policy and costs. It highlights that future development planning must focus on various strategies cutting across key economic sectors and forms of livelihoods in the region having considered other social factors such as the land carrying capacity, the growth of rural population and poor state of existing infrastructure.

It identifies that the cost of adaptation interventions for flood risk in Kenya are yet to be clearly established due to the existing challenges in undertaking comprehensive flood risk assessment studies. Consistent with the signatures approach it highlights the need for early feasibility studies, flood risk information and early warning systems, and also highlights some of the potential barriers to successful implementation.

It also considers the issues associated with infrastructure protection. This includes mixtures of options exist to increase resilience, i.e. physical barriers and strengthening, managed or unmanaged relocation, resilience building (increasing margins, looking for alternatives), etc. However, a key element is greater consideration of vulnerability and risks in development strategy, i.e. land-use, urban and spatial planning. This is a particular issue in future development, housing and economic zones.

Planning the location and resilience of critical infrastructure (to low risk locations) is also essential in reducing future impacts. This needs to happen during development, rather than afterwards, as it is more difficult and expensive to relocate or retrofit later. This is a particular 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 key 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.

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).

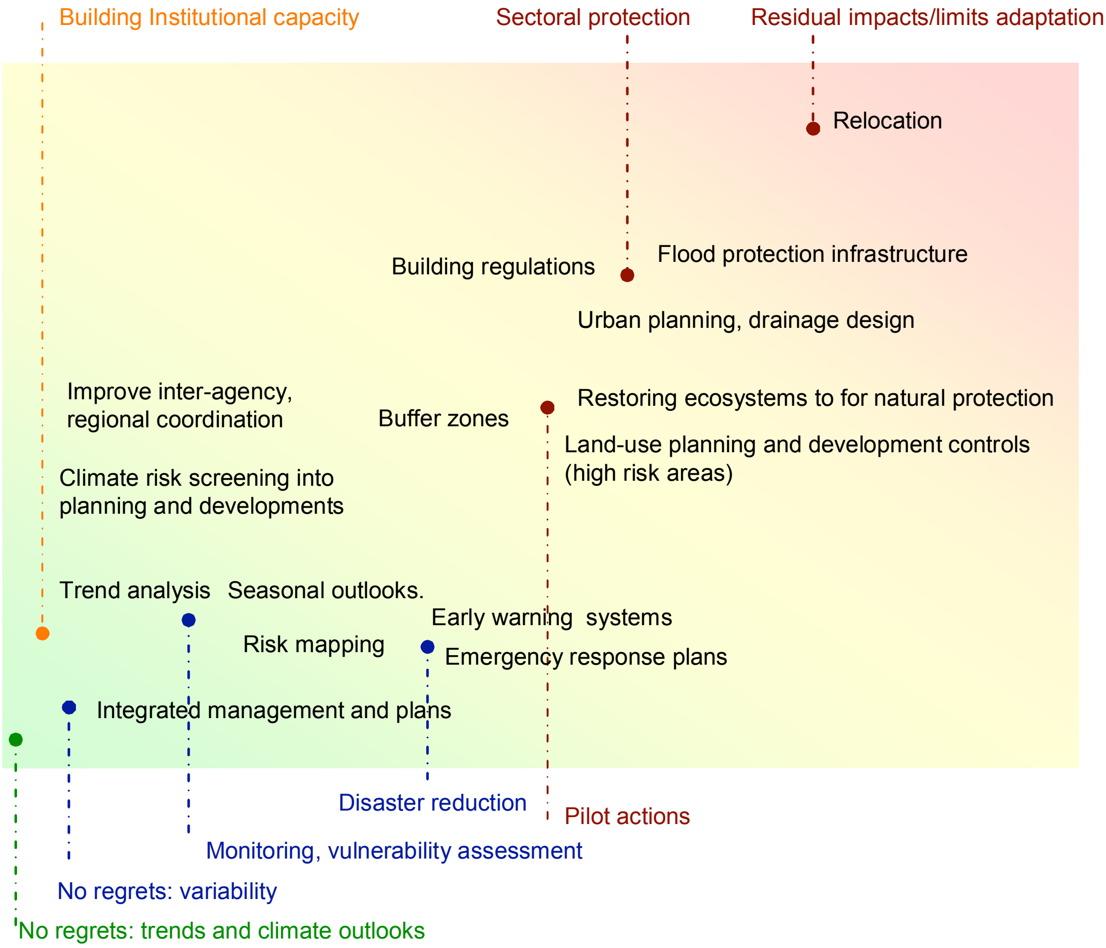


Figure 20. Adaptation signature for floods.

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, linked through to early warning and disaster risk reduction.

Many steps associated with current integrated management and sectoral development plans represent no regret adaptation opportunities. These 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 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.

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.

This 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 Kenya are yet to be clearly established due to the existing challenges in undertaking comprehensive flood risk assessment studies.

Water Resources and Supply

Given the potential importance, the study has investigated a number of potential approaches for assessing the potential costs of adaptation for the water sector. This includes a partial investment and financial flow analysis, application of adaptation signatures, a basin-level case study for costing integrated adaptation strategies (WEAP model). Together these comprise multiple evidence lines for assessing indicative costs of climate adaptation in Kenya's water sector. A full technical report is available at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

The first approach has used a form of IFF analysis – defining first a baseline with all current policies and plans. Rather than superimposing a climate change scenario, it instead looked at closing the current adaptation deficit, which exists now and in the future through the funding gap to achieve sectoral objectives. In the water sector, the study built up this analysis around the Kenyan Sectoral Investment Plan (SIP), structured around objectives for sub-sectors including i) Water Services, ii) Sanitation, iii) Irrigation, Drainage & Land Reclamation and iv) Water Resources Management. The combined needs which address the current adaptation deficit (but also provide greater resilience to the future) could reach as high as $ 1.4 billion. The addition of these costs would more than double anticipated sectoral investments across all public and private investment entities. As highlighted above, there is substantial overlap between developments versus climate adaptation in these estimates: indeed this is primarily development orientated.

The study has also extended the Tana river case study to consider adaptation, outlined in the box.

The water supply case study on the Tana River shows economic impacts of demand-side measures (e.g. increased end use efficiency) are always positive, with benefits from $ 11 million to $ 29 million for low and high climate scenarios. Supply-side and ecosystem interventions have net benefits only under more adverse climate futures.

Case Study 3: Water Resources Adaptation in the Tana River Basin

A coherent set of four adaptation strategies have been defined to be evaluated:

1. Demand-side management: e.g. improved irrigation and end-use efficiency across demand nodes.
2. Supply-side management: e.g. water harvesting interventions to mitigate over-abstraction, or perhaps "harder" options such as reservoir construction or simulation of natural flood cycles (important to balance user demand (electricity/irrigation) and allocate for downstream agriculture and pastoral livelihood needs.
3. Ecosystem protection: e.g. sustainable land management (SLM) interventions in upstream agriculture to reduce soil erosion and dam siltation, improve electricity production efficiency, etc.
4. Full sectoral protection": Implementing all of the above activities in the basin.

For the low projection slightly less electricity is produced under climate change. Although rainfall is higher, evapotranspiration is even higher, leading to a somewhat lower inflow into the reservoirs. However, two adaptation strategies, supply-side and full, can generate even more electricity compared to the current situation. For the more extreme climate change projection impact on generated hydropower is severe and electricity production is expected to reduce substantially but again appropriate adaptation strategies might overcome this negative impact.

For the Tana River basin, the analysis assessed the costs and benefits of adaptation strategies. Economic impacts of demand-side measures (e.g. increased end use efficiency) are always positive--benefits range from $ 11 million to $ 29 million for low and high climate scenarios. Supply-side and ecosystem interventions have net benefits only if the climate changes in the direction of the high scenario.

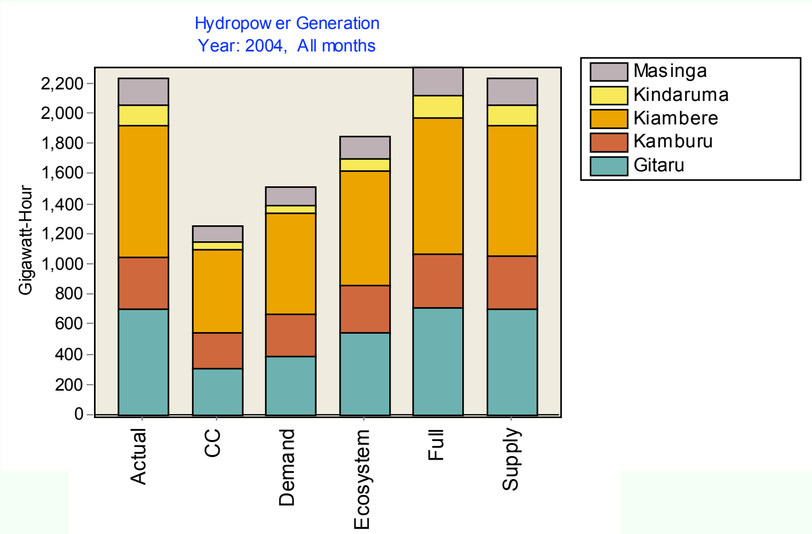


Figure 21. Hydropower generation for the current situation and the high climate change projections as well as the four adaptation strategies.

Energy supply and demand

For energy supply, there is a strong linkage with the low carbon growth. Alongside the supply side water adaptations (in the Tana case study) there is a simple adaptation response in terms of energy generation diversification. This is justified already for the current climate because of the greater vulnerability of hydro generation to the periodic droughts. This is explored through the marginal abatement cost analysis in the low carbon section below, but includes diversification to other renewables, particularly geothermal.

For energy demand, the autonomous response to higher cooling demand will be for air conditioning. There are alternative 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-time of buildings.

The study survey on energy use and air conditioning found some recognition in Kenya by environmental designers/architects, who are already considering:

- Orientation of buildings in the East-West direction for optimization of sun shading.
- Natural ventilation of buildings to allow air movement. This involves glazing of one part of the building which forms cooler and warmer sides thus creating pressure which allows hot air to escape.
- Use of wind catchers which trap cool air from outside, which then drops into the building by gravity.

Some of the possible adaptation options suggested though the surveys to reduce air conditioning demand in buildings already in existence in Kenya included:

- Use of passive devices, e.g. air fans that are less energy intensive.
- Change of partitioning of buildings.
- Introduction of sun-shading elements.
- Restructuring of buildings (internal walls) to increase air circulation.

Nonetheless, there is lack of awareness of the need to design environmentally sensitive buildings in the country (though a unit on the design of environmentally sensitive buildings has been introduced in the syllabus of an architectural course in Kenyatta University).

This is an area that is of particular interest, because of the linkage with additional energy use and additional greenhouse gas emissions. Failure to build adaptation into building design will increase air conditioning demand in existing warmer regions and increase GHG emissions.

However, implementation is likely to be made more challenging by the necessary legislation and policies to support design, the lack of awareness on the need to design these options into buildings, even among the architects (including of the economic benefits compared with the use of air conditioning) and the lack of knowledge on building related fuel consumption and greenhouse emissions.

Agriculture

Many previous assessments already consider short-term autonomous adaptation (to optimise production). They 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 Kenya from the study here is to develop a robust, adapting 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.

Agriculture in Kenya is changing already, in mixed modes and with uncertain futures. The division of land between subsistence and cash cropping, upland and lowland and dryland and irrigated, a common typology some decades ago, is increasingly blurred in the mosaic of agricultural landscapes. Greater investment in farming is apparent in commercial sites such as flower and horticulture near Naivasha. New farms have emerged where land has been opened for settlement, partly related to irrigation. Still, the tea plantations cap the highlands and extensive herding is precarious in the semi-desert regions, so recently suffering extreme drought.

The study has developed an adaptation signature, a review of costs proposed in other African NAPAs, and worked through a bounding exercise in an IFF type assessment to look at multiple lines of evidence. A full technical report is available at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

The study has developed six development pathways, central to the future of agriculture in Kenya. These are summarised along with an indication of their exposure to climate risks and opportunities, and the potential for climate adaptation. This diversity of pathways suggests that land use in Kenya is changing, and such changes in the future could alter exposure to climatic stresses and options for adaptation

- Smallholders supported by off-farm income, kitchen gardens with small portion of household income
- Smallholders are semi-commercialised in cash crops but households rely on diversified incomes
- Commercial farming through cooperatives and land aggregation
- Commercial large farms, either new lands or external investments
- Agropastoralism with substantial livestock enterprises
- Settled pastoralists with development services, rangeland management

The IFF analysis looked across various investment lines and considered previous projects to investigate potential additional funding for enhancing resilience. This provided a lower benchmark, assuming fairly low future investment in agriculture and relatively efficient adaptation costs of around $50 million per year in 2030. An upper estimate, assuming a larger investment stream, a greater share devoted to agriculture and relatively high costs was $170 million per year in 2030.

Although Kenya is not an LDC, some insight into urgent needs for adaptation can be gleaned from looking at the range of NAPA projects proposed by other countries A range of projects is relevant to agricultural adaptation, including awareness, agriculture, natural resource management, pastoral, water, drought and flood. This gives a total cost of pilot projects for immediate investment, by 2012, of $8 million to $40 million per year. These costs are within the range of current investments anticipated in the Kenya medium term vision. Thus it appears that climate adaptation would warrant a doubling of immediate investment in agriculture in Kenya in order to build the information base and adaptive capacity to ensure effective responses in the future.

Finally, the study has developed an adaptation signature for agriculture in Kenya. They are presented here in an idealized form—representing a broad strategy that coheres with various development objectives and visions. They include:

1. Community based agricultural improvement to reduce impacts of climatic variability.
2. Catchment rehabilitation, land use and environmental services.
3. Climate early warning and information systems.
4. Rangeland management and livestock services.
5. Agricultural research, extension and farm demonstration.
6. Livelihood support, micro-finance and disaster risk reduction.
7. National market development, land tenure and sectoral policy.
8. Food supply chain management integrating pest control, transport losses and consumer utilization.

The signature is shown below.

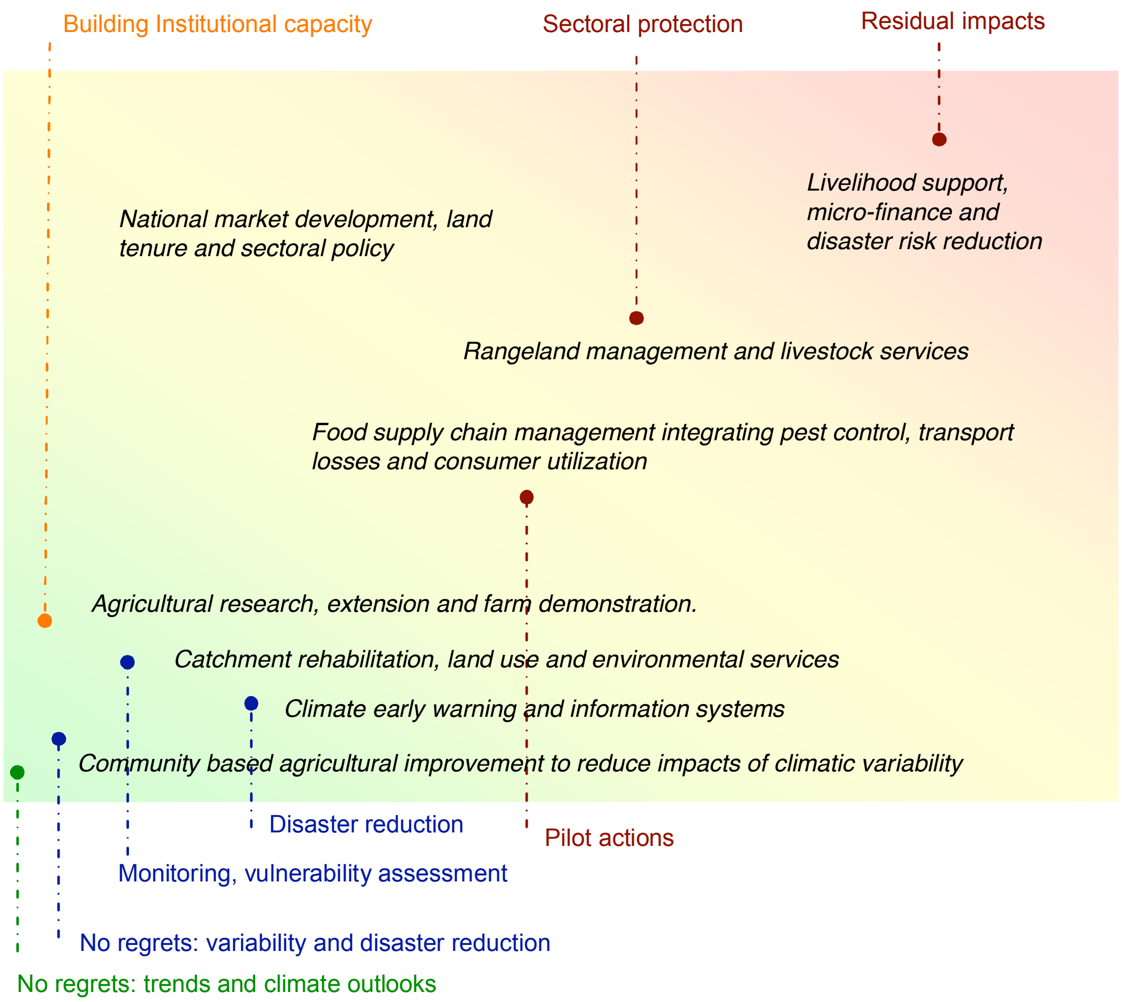


Figure 22. Adaptation signature for agriculture.

The estimated costs of adaptation for these have been derived, through an initial scoping assessment. This implies potential costs of pilot adaptation signatures for agriculture of some $60 million per year by 2012. potentially rising with scale up to $380 million per year by 2030. Note that the higher costs here related to the additional elements of development versus additional climate change only.

For agriculture, the estimated costs of adaptation of pilot adaptation signatures has been estimated at some $60 million per year by 2012, potentially rising with scale up to $380 million per year by 2030. However, the higher costs relate to the additional elements of development versus additional climate change only.

Including only (a) capacity building and immediate needs and (b) enhancing the climate resilience of future investment (anticipatory adaptation), which would capture pilot tests and institutional development only gives lower estimates. If additional categories, more strongly associated with development and the inadequate capacity to cope with existing climatic conditions and risks, are included, rather than just future climate change, higher costs are derived. Perhaps half of the estimates for 2030 for the upper estimate would fall within this category.

Climate change adaptation cannot prevent all future impacts from climate events (e.g., the sudden storm), episodes of prolonged adverse weather (e.g., a drought lasting two years) and shifts in long-term climatic resources (e.g., the sub-humid agro-ecological zone becoming too dry to reliably cultivate maize). The aim of adaptation should be 'adapting well' to achieve resilience in the face of the range of potential threats while taking advantage of new opportunities. Climate risk management requires a suite of approaches to ensure adequate responses are available by all stakeholders; it cannot prevent all risks from occurring. The study has estimated the potential residual impacts that might occur, even with adaptation in place.

The study has also undertaken a case study to look at sustainable agriculture land use management practices, which have potential benefits with respect to adaptation – mitigation linkages.

Case study 5: SCC-Vi Agroforestry Project in Kisumu: Adaptation – Mitigation Linkages

The study has investigated the SCC Vi Agroforestry programme which focuses on interventions that mitigate agriculture greenhouse gases and land degradation by promoting sustainable agriculture land use management (SALM) practices (nutrient management, soil and water management and agroforestry). It also contributes to build resilient farming systems, disaster risk reduction, developing local capacities and tackling drivers of farmers' vulnerability to climate change effects.

The Kisumu project demonstrates the potential of smallholder farmers to develop, manage environment and mitigate/adapt to climate change through adoption of agroforestry and related sustainable land management technologies. The implementation of such community projects can be done with groups, farmer organizations and local institutions to bring about community empowerment and climate resilient livelihood development. The project works with small scale, resource poor farmers who only require assistance in terms of local capacity building. The projects have high livelihood and environmental benefits.

The study has used the estimated project costs and scaled up to work up an estimate of potential costs of adaptation. The implementation costs have been estimated at sub-location level, working with 500 households. This gives a total cost per farm household of $ 50 for 3 years ($ 17 /hh/year). The cost estimates have been scaled up to suitable agro-ecological zones (humid-semi arid) to estimate the next step on the adaptation signature. The study has also looked at the potential for carbon finance revenues. The budget needed to cover those AEZ is $ 58.8 million annually during the intensive period (3 years) and $ 21.6 million annually during the extensive period (3 years) giving a total of $ 241 million.

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 maintain basic monitoring programs;
- Integrating climate change into planning exercises and programmes;
- Assessing, modelling, management, and experimental spatial scales for improved predictive capacity;
- Improve inter-agency, 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, behavioral, demographic);
- Intensive conservation management to secure populations, including for threatened and endangered species;
- Translocation or reintroduction of species;
- Ex situ conservation.

These 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).

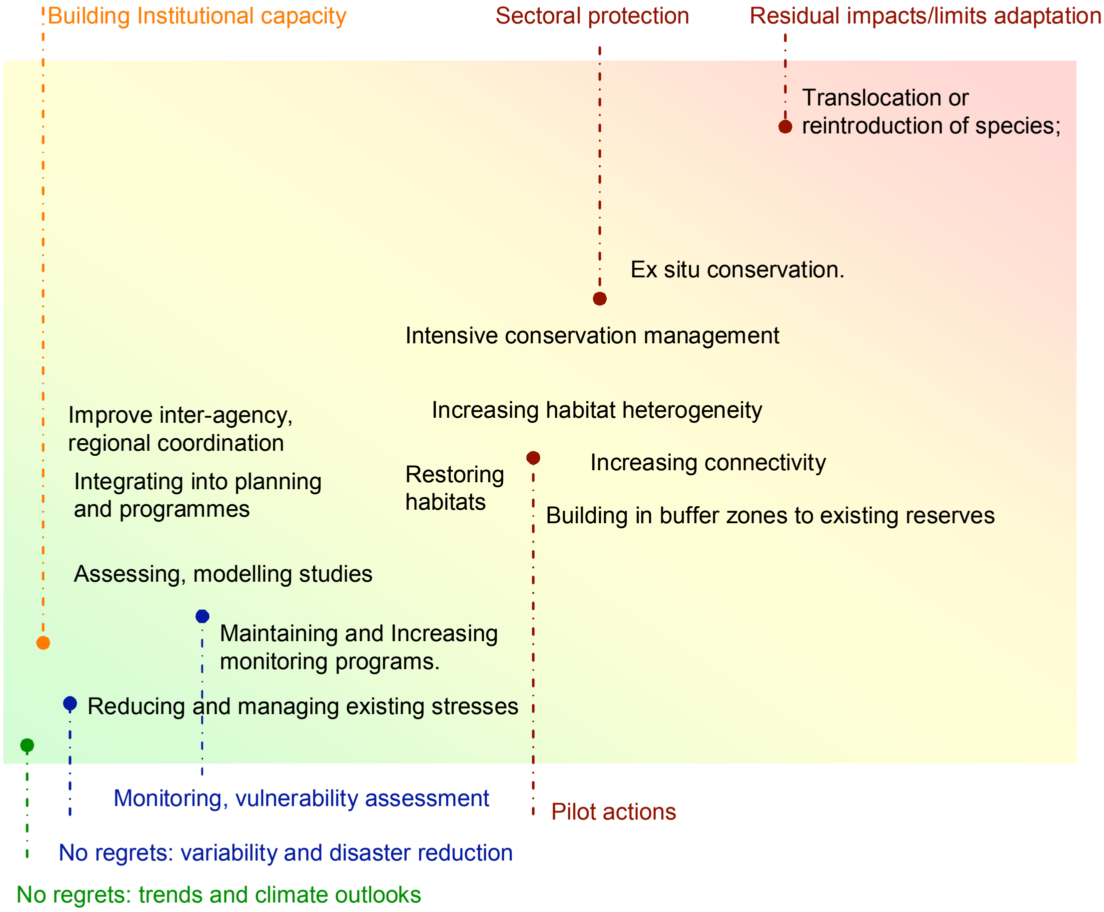


Figure 23. Adaptation signatures for ecosystem (wildlife).

This 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 action, 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. The case studies outlined in the previous section have considered adaptation (see box).

Case study 4: Ecosystems Services: Exploring Potential Economic and Livelihood Impacts of Climate Change and Possible Adaptation Mechanisms in the Kenyan Rangelands

The combined effects of land use change and increased climatic uncertainty will have far reaching implications for people and ecosystems throughout the borderlands region. Adaptation strategies need to integrate local action with the development and establishment of appropriate policies, legal mechanisms and support systems to enhance economic, social and ecological sustainability of the rangelands and the pastoral livelihood system. Sustainable adaptation strategies must be built on a sound foundation of traditional and scientific knowledge. When assessing the potential of adaptation strategies, it is critical to consider not only the short and long term costs and benefits for any particular target variable (e.g. livelihoods, biodiversity, etc) but also the potential impact on fundamental processes and system potential. Almost by definition, adaptive strategies which favor flexibility and potential will be most effective in the face of increasing climatic uncertainty. Similarly, strategies which preserve the adaptive potential of the system will be most effective in the long run.

In the rangelands of the borderlands region, some possible strategies for reducing pastoral vulnerability and preserving adaptive potential would include the development of grass banks as integrated dry season forage reserves and conservation areas, and livestock breeding and marketing programs. ACC has piloted a livestock breed improvement program and has begun working with communities to set aside land for re-seeding and development into drought refuges. These drought refuges also act as wildlife concentration areas which in turn support ecosystem services and tourism. Due to increasing human populations and land fragmentation, maintaining connectivity and other critical ecological processes and services is an essential component of enhanced resilience.

Institutions are an essential component of any successful adaptation strategy. Grass root institutions that enable and empower the landowners to be directly engaged in the management of the health of the land and natural resources therein are critical. One such institution is the South Rift Association of Landowners (SORALO), which brings together 14 group ranches spanning both Narok and Kajiado districts. Other institutions that ACC has supported are Maasai Mara Management Association (MMMA) and the Amboseli Ecosystem Trust. Similar institutions exist in the north – The Northern Rangelands Trust. Such institutions give opportunity to the landowners to participate in decision making and policy development. Such institutions will also require alliances and synergies with other, more formal institutional levels such as governments, civil society and the private sector. An understanding of the changing nature of institutions in pastoral societies and the critical role of local initiatives for the sustainable management of natural resources will essential to any successful adaptation initiatives.

The generation and integration of both scientific and indigenous knowledge will be an essential tool for adapting and expanding traditional coping mechanisms with the incorporation of learned information through science and research. Hybrid knowledge systems should be generated not only by academic research but also through the engagement of local community resource assessors who facilitate the collection and exchange of information on the impacts of climate change and system vulnerabilities.

Increasingly, the provision and protection of key ecosystem services will be a key component of adaptation in the borderlands region. The preservation of open space for the benefit of rapidly increasing urban populations, the provision of clean air and water, carbon sequestration, and biodiversity conservation are all services which will continue to increase in value as land use change and climate uncertainty intensifies. The value of these services both in ecological and monetary terms is largely unexplored. In particular, the carbon potential of the rangelands represents a significant economic asset which is yet to be unexploited.

Summary

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 Kenya, shown below.

	Adaptation Needs $ Million/year	
Adaptation Strategies	**2012**	**2030**
Development related **1) Accelerating development &** **2) Increasing social protection**	$500 million/year	$500 – 1000 million/year
Climate Change specific **3) Building adaptive capacity &** **4) Enhancing resilience**	$100 – 150 million/year	$250 – 1000 million/year

The study concludes that a conservative estimate of immediate needs for addressing current climate as well as preparing for future climate change is $500 million / year (for 2012). The cost of adaptation by 2030 will increase: an upper estimate of the cost is likely to be in the range of $1 to 2 billion / year.

The study has also assessed the costs of adaptation for Kenya using a sectoral bottom-up approach. This tests the estimates above and gives 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; encouraging pilot actions to test promising responses; and identifying those long-term issues that require early pro-active investigation.

A large number of immediate priority 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 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 (agriculture) and extreme events (flood risk), with the latter linked to the strengthening 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 the potential scaling up of sectoral programmes.

The sectoral assessments and the case studies show relatively high adaptation costs, which re-enforce the top down adaptation estimates for 2030 and justify investment needs. They also demonstrate the potentially much larger costs when development-adaptation needs are included (the categories of accelerating development to cope with existing impacts and increasing social protection outlined above). 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 Kenya, particularly for some regions and groups of society, are expected and will need to be managed. They will also be important for recovery after climatic disasters and for future impacts. It is also highlighted that these residual impacts – and their economic costs – are additional to the costs of adaptation. This is important for international negotiation discussions which have tended to focus only on the latter to date.

3. Low Carbon Growth in Kenya

Introduction

The study has estimated the potential for low carbon growth in Kenya, looking at the potential changes in emissions and low carbon growth opportunities, consistent with planned development in the Vision 2030. A full technical report is available on the low carbon study, at the web-site (http://kenya.cceconomics.org/). This section summarises this work.

Future emission projections

Kenya currently has relatively low emissions of greenhouse gas emissions (in total and per capita[16]). This is due to a high proportion of renewables in the electricity sector and the use of biomass energy by households. The largest emitting sector is agriculture, primarily from emissions from livestock, followed by energy consumption, primarily from consumption of oil products in transport and industry. In many areas Kenya 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, industrial energy efficiency and sustainable land use management. A selection of projects is below.

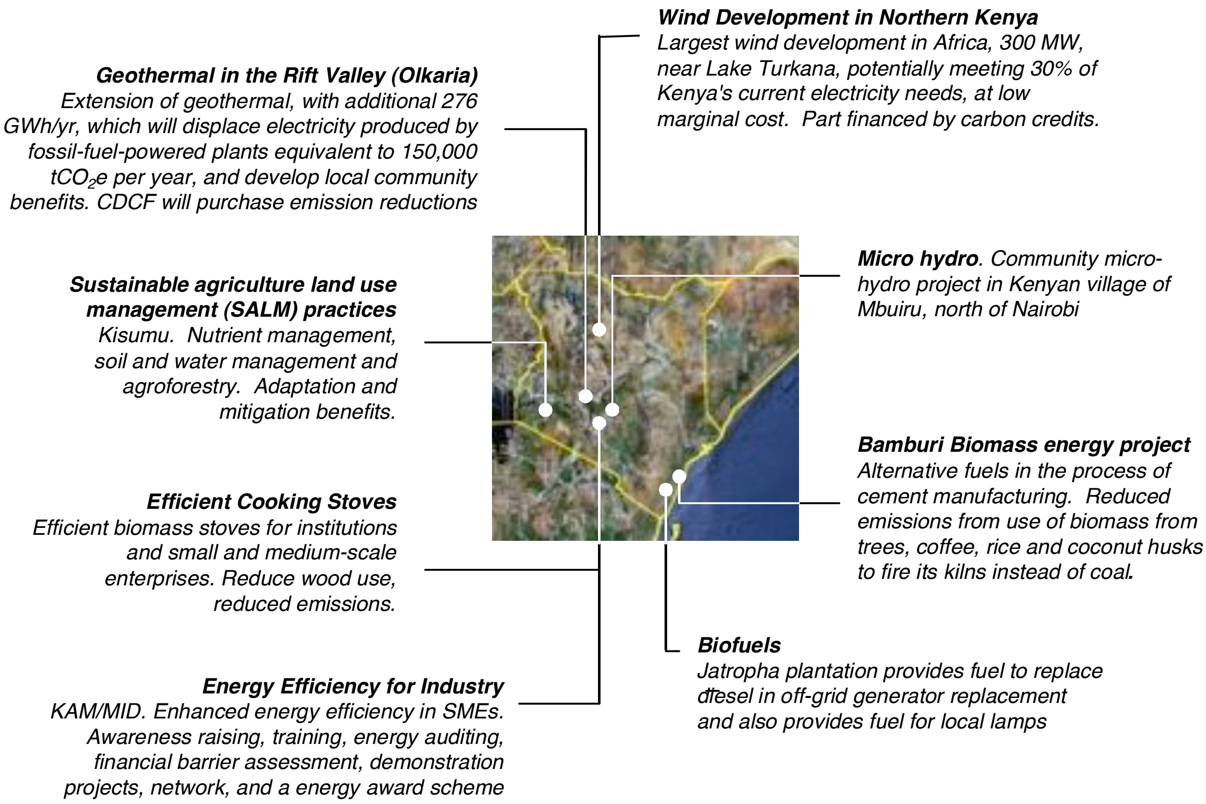


Figure 24. Examples of existing low carbon projects in Kenya

[16] Kenya has low emissions in global terms (ranked 76th globally) and also low per capita emissions of 1.3 tCO_2 (all GHG but excluding LUCF). This compares to per capita emissions of around 11 tCO_2 in the UK and over 20 in the USA. World Resources Institute, Climate Analysis Indicators Tool (CAIT).

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 2030 will increase future GHG emissions and per capita emissions significantly.

To investigate this, the study has then considered the potential change in emissions consistent with planned development in the Vision 2030 plan and developed a future emissions profile for Kenya. 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, even though Kenya is initiating some options that are consistent with low carbon development.

Using a simple projections approach, the economic growth and development associated with Vision 2030 is projected to double emissions of greenhouse gases between 2005 and 2030 (from 42 to 91 Mt CO_2). It is also estimated that Kenya's per capita emissions could increase to over 1.5 tCO_2 by 2030, note this is a lower relative rise as future population increases reduce per capita emissions. The projection is shown in the Figure below. The 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 current plans for coal development will increase the carbon intensity of generation.

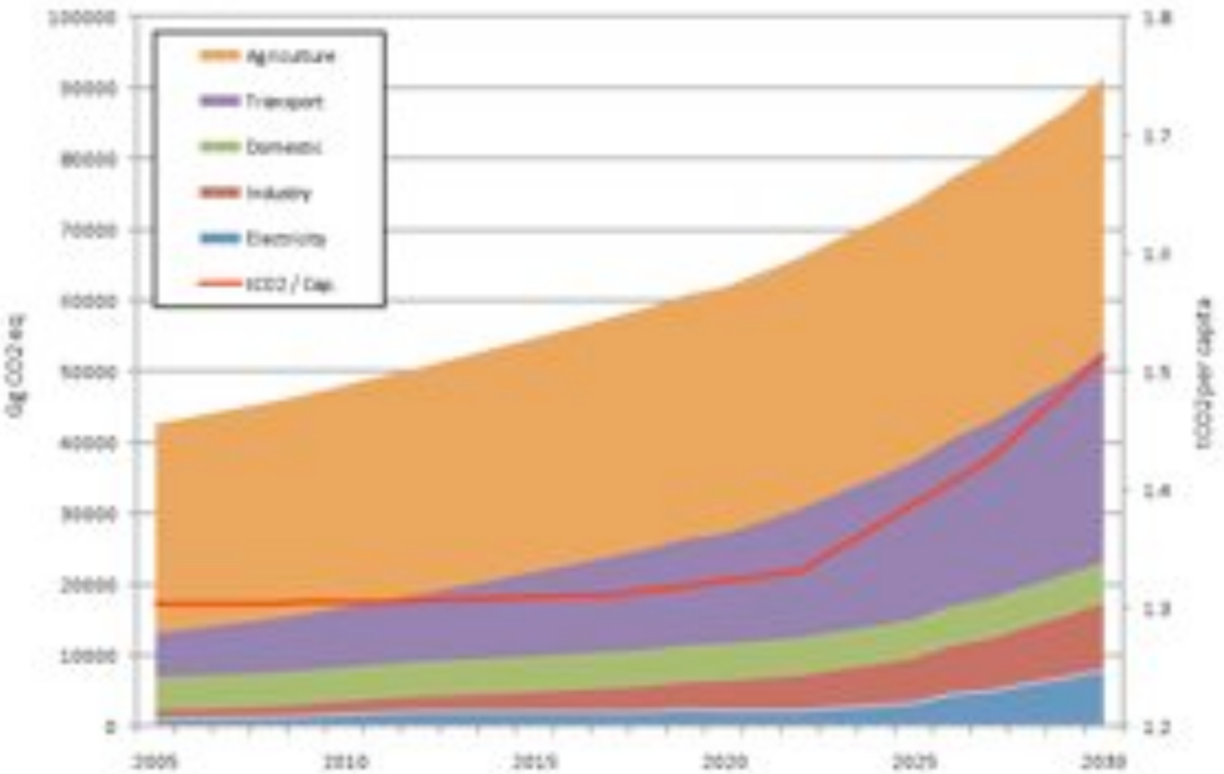


Figure 25. Projections of Kenya's GHG emissions (Gg CO2 eq.), 2005-2030

Furthermore, the current plans across the economy (or for some sectors, the lack of plans) could 'lock-in' Kenya 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 international carbon credits, particularly if national level GHG mechanisms emerge. Following these higher carbon pathways will therefore lead to an opportunity loss for Kenya. 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 unless private car transport is tackled in Nairobi.

There is progress already being made in Kenya, but there is a need to extend this to tackle the transport and agricultural sectors, the largest source of future emissions.

There are also examples of current plans, such as the introduction of coal or urban planning based on high private car use, that will 'lock-in' Kenya into a higher emission pathway. Failure to tackle these areas will reduce future economic opportunities from the carbon finance markets, especially if future national level mechanisms appear.

Low Carbon Options

The study has investigated low carbon options across the economy by sector, developing a low carbon alternative pathway.

Analysis of the Electricity sector

Kenya already has a low carbon electricity sector. The overall plans for the electricity sector indicate an even lower carbon generation mix in future years, dominated by geothermal capacity and high levels of imports (dominated by hydro generation) from Ethiopia. This low carbon electricity will result in low carbon energy for the consumers in end use sectors. However, these reductions are potentially offset by planned use of coal fired generation, and post 2020, the reductions in emissions in the power sector may be reversed if the planned development in the least cost plan are implemented. The emissions profile for the sector under the least cost plan is shown below. The graph shows the total absolute increase in emissions from the sector. Note that the red line reflects the average carbon intensity of the Kenyan electricity mix. It can be seen that the carbon intensity is currently falling, but would increase post 2020 with the introduction of more coal.

Figure 26. Projected CO_2 emissions by generation type (2008-2029)[17], and CO_2 intensity of generation (g/kWh)[18]

[17] Assumed efficiencies: gas (45%), coal (35%), diesel (35%). Oil based generation assumed to be diesel not HFO

[18] Generation levels adjusted for losses before intensity calculation

As highlighted above, these increases in emissions in the sector would occur at exactly the time when international negotiations are likely to get much stricter, and where the opportunities for future credits is likely to be more financially advantageous to Kenya, i.e. they represent a lost opportunity for Kenya for future credits, because of the 'lock-in' of high emission plant.

The study has investigated other low carbon options as an alternative, developing a lower carbon alternative pathway to the least cost plan. It finds that there are other lower cost opportunities for renewable power generation, which would allow further access to international carbon credits.

It is clear that renewable electricity generation makes economic sense, not only for centralised generation but for off-grid application, particularly for rural areas where access is limited and alternative diesel generation is very expensive. For example, solar systems are widely used in rural homes and communities.

In addition to the direct economic benefits of low carbon alternatives, the study finds that this alternative low carbon pathway would have wider economic benefits from reducing air pollution, reduced environmental impacts associated with coal extraction and greater energy security and diversity.

The study has also undertaken a case study looking at wind generation, the benefits and the potential barriers.

Case study 6: Lake Turkana Wind Power

The Lake Turkana Wind Power project is a large scale wind project (widely cited as the largest wind farm in Africa) being developed in the Marsabit region. It is a 310 Megawatt (MW) wind power farm in Loyiangalani, Laisami District, Northeastern province of Kenya and will consist of 365 turbines each with a capacity of 850 kilowatts (kW). The plant will add approximately 25% to the current existing capacity of Kenya (online 2012) and will supply up to 1,500 GWh of electricity per year. It is expected that levelised generation costs will be around US$ 0.06/kWh and the project will replace electricity generated by fossil fuel fired power plants and generate average emission reductions of just over 900 thousand tCO2 per year, equivalent to $12 million/year on current rates.

The study has undertaken a case study on the project, assessing the barriers. This found that many project developers consider the current renewable tariffs to be too low. The costs of generation were also a barrier, due to the higher marginal costs compared to hydro. However, the potential for energy mix diversification, particularly due to the effects of periodic droughts on hydro, is an extremely important aspect in addressing current climate variability as well as enhancing future resilience. Another barrier has been the lack of transmission infrastructure in place – a general problem for renewables.

Any future plan has challenges for implementation, and may be vulnerable to climate impacts in future years. On implementation, large-scale investment is required in plant and transmission systems; however, there are opportunities for carbon financing as shown in recent plant expansions. Vulnerability may come from over-reliance on hydro (imports and domestic), particularly during drought years when the demands on water are significant. This latter point is extremely important. There is a need to consider the potential effects of climate change on the electricity sector itself. Other parts of the study have shown that there are projected scenarios which might increase the vulnerability of the Kenyan power sector to future climate, notably in relation to future hydro power. There is a need to undertake a climate risk screening analysis for the electricity generation plans, and to adjust the plans accordingly. This includes both domestic generation, but also for planned imports, especially as these are from climate sensitive technologies (hydro).

However, as shown in the projections above, electricity generation emissions are a low proportion of future Kenya GHG emissions. Therefore a much wider economy-wide view is needed to advance low carbon growth and the study has investigated this.

Analysis of the Transport sector

The transport sector, as shown in the projections above, is one of the main drivers of increasing GHG emissions in future years. As incomes increase through economic growth, demand for private vehicle transportation increases significantly and there is likely to be greater demand for freight transport.

As well as the effects on emissions, road transport leads to additional effects, notably traffic congestion, which translates into loss of time, increased fuel use, higher GHG emissions and higher air pollution (with associated health impacts). Congestion is acute in urban areas in Kenya, particularly in Nairobi. There is also prevalence of old vehicles with poor fuel efficiencies.

Tackling transport emissions is difficult, because it often requires major transport and planning policies. However, a range of low carbon options are available at low cost. Kenya has the opportunity to plan for the increased demand for transport in a sustainable way, though this will require stronger policy with 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 ensure effective and efficient transport systems, particularly in such urban areas.

The importance of an integrated approach for mobilisation is critical, and modern urban transport systems are needed, to provide adequate transport infrastructure and ensure quality of urban environments. This can be advanced with lower carbon options. Low carbon approaches offer many benefits in reducing the social and economic costs of congestion and reducing pollution and noise from transport, as well as having potential benefits through reducing the levels of oil use and imports. These aspects are recognised and as part of implementing the Vision for the transport sector, the Ministry of Transport (2009) has developed a Transport Sector Plan.

The study has assessed two priority options for Kenya to reduce emissions significantly in the transport sector– improving the efficiency of the road vehicle fleet and introducing efficient public transport systems. Emission reductions are likely to be co-benefits of effective and sustainable urban planning, meeting urban transport needs through public transport, and reducing oil consumption. However, it is highlighted that other options are needed which include policies to address vehicle demand and use, new and 'leapfrog' technology. Restraining vehicle demand and use focuses on changing behaviour through various different mechanisms (increasing costs of road use through tolls, higher taxes on fuels, improving public transport alternatives, parking constraints) but have many barriers. New technology available in developed countries focuses primarily on improving efficiency of vehicles by restricting low efficiency vehicles on the market or subsidizing higher efficiency vehicles. This could also include use of cleaner fuels e.g. biofuels. 'Leapfrog' technology are emerging technologies (e.g. electric vehicles) that would help developing countries avoid the high fossil transportation sector that the developed world experiences, and has been locked into. These are priority for future studies.

Analysis of the Agricultural and Forestry sectors

The agriculture sector is the largest of the economy, and constitutes the single largest source sector of GHGs, particularly CH_4 from enteric fermentation and N_2O emissions from soil cultivation. Whilst it is very difficult to project agriculture emissions, it is likely that livestock and arable output will grow with population, a strong export sector and changing agricultural practices e.g. increased use of fertilisers.

There are a range of measures that could be considered to address these sources. They are primarily based around:

- Cropland management;
- Grazing land management and pasture improvement;

- Livestock management.
- Other management activities

These options are low cost but often difficult to implement due to scale issues. Such options also have to complement other priorities such as food security and land productivity.

It is also important to highlight that agriculture is a very climate sensitive sector and will be affected by climate change (see earlier section). The consideration of options to reduce emissions in this sector must be undertaken alongside consideration of the potential effects of climate and enhanced resilience.

The study has also considered the forestry sector. Maintaining and expanding the forests of Kenya is critical for ensuring that natural resources are safeguarded. Forests also play an essential role in both climate change mitigation (acting as sinks) but also an important role in adaptation (e.g. water catchment management and soil protection). Protecting and expanding forest cover as part of a low carbon strategy would be supported by a range of other equally important sustainability drivers. Agro-forestry can also be an important sustainable and integrated way of protecting forests whilst maintaining small-scale agriculture, and has strong links to adaptation strategies (see SCC-Vi Agroforestry project in Kisumu case study in adaptation section of this study). The sector also has potential for two carbon finance opportunities from carbon projects and REDD (Reduced Emissions from Deforestation and forest Degradation). Again, as with agriculture, the forestry sector is potentially vulnerable to the future effects of climate change, particularly due to the long life-times - stands established now are likely to be situ for decades and will therefore be exposed to the more significant climate signals.

Household and Industry sectors
Biomass will remain one of the primary sources for meeting energy needs in future years. In 2030, it is projected to still provide 60% of household energy requirements. However, electricity will become increasingly important. Due to the low carbon electricity generation predicted in future years, this sector will remain relatively low carbon.

There are significant opportunities for further reducing emissions in this sector through more efficient use of biomass and increased uptake of renewable technology to meet all energy needs. Moreover, more efficient use could see reduction in resource pressures on the fuelwood supply, as well as other benefits. The technology-based options that could be considered for displacing or reducing reliance in solid biomass-based energy include:

- Improved stove efficiency
- Solar cookers
- Biogas digesters (particularly on smallholdings)

The stove options are very cost-effective and require low capital investment. There are also wider co-benefits in terms of reduced health impacts resulting from lower levels of indoor air pollution, reduced cooking time, reduced time spent gathering fuel and lower burden on forests

The industrial sector including manufacturing, are projected to drive Kenya's economic growth in future years, as the economy moves away from agriculture. An important issue facing this sector are high energy costs; energy efficiency savings are therefore an important means for becoming more competitive, and would of course have positive impacts on reducing carbon emissions. Energy use is not very efficient compared to major developing economies, with high energy intensity. In the past, investment in energy efficiency has been impeded by the low power tariffs and price controls, though this is being addressed.

There is considerable potential for energy efficiency improvement and the study has investigated these potential benefits. This has estimated potential for energy savings, and marginal abatement costs.

The issue of future climate change is also relevant for this sector. Most of the increase in cooling demand from hotter temperatures is unlikely to be met, but it will still have implications for industrial cooling, household comfort levels (especially in major cities) and the service sector including tourism. This is one area with a very strong adaptation – low carbon linkage: the traditional response to higher cooling burden is for mechanical air conditioning. Greater efficiencies are possible, but alternatives (e.g. passive ventilation, building design, urban planning, etc) offer alternatives. These have not been considered here but are highlighted for future analysis.

Economic Benefits of Low Carbon Options

As shown in the sections above, there is the potential to implement measures across many areas of economic activity in Kenya, which are available at low cost now, and can improve economic efficiency, as well as delivering low carbon and development objectives.

This initial study has identified a very large number of low carbon options, which could actually have economic benefits now, and also offer new opportunities for carbon financing. These measures have wider economic, environmental and social co-benefits.

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 (geothermal) 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 from the sectoral analysis that could put Kenya on to a lower carbon development and growth pathway, focusing on those sectors where emissions are projected to be significant.

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 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.

To assess these low carbon options, the study has assessed the marginal abatement cost (cost-effectiveness) and emission reduction potential in indicative terms. 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 $/t$CO_2$ 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.

It shows that 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. This includes all measures below the line, with a negative cost $/t$CO_2$.

These options actually save money and make the economy more competitive: 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. These options therefore promote rather than undermine the ambitions of growth. This is particularly the case concerning energy efficiency measures, which reduce fuel costs. The negative cost or ‘no regrets’ options include improvements in transport efficiency, domestic stoves and agriculture.

The first measure listed in the legend is the most cost-effective, shown as the furthest left on the MACC figure. Subsequent measures are listed in order of cost-effectiveness. The cost curve identifies that significant ‘no regrets’ potential is available (almost 50% of stated potential), particularly from improvements in transport vehicle efficiency, and performance of domestic stoves. The agriculture sector options are low cost (<$15 /t$CO_2$), resulting in no regrets / low cost options accounting for over 80% of stated potential.

The carbon credits that could be available for emission reductions are not included in the estimates in the above cost curve analysis. If they were, the negative cost potential would increase, and the less cost-effective options would appear more attractive, as shown by additional measures below the red line, which represents a $20 carbon price. Access to these credits would further increase the number of options that are economically advantageous. This is an important point in the context of future potential and financing.

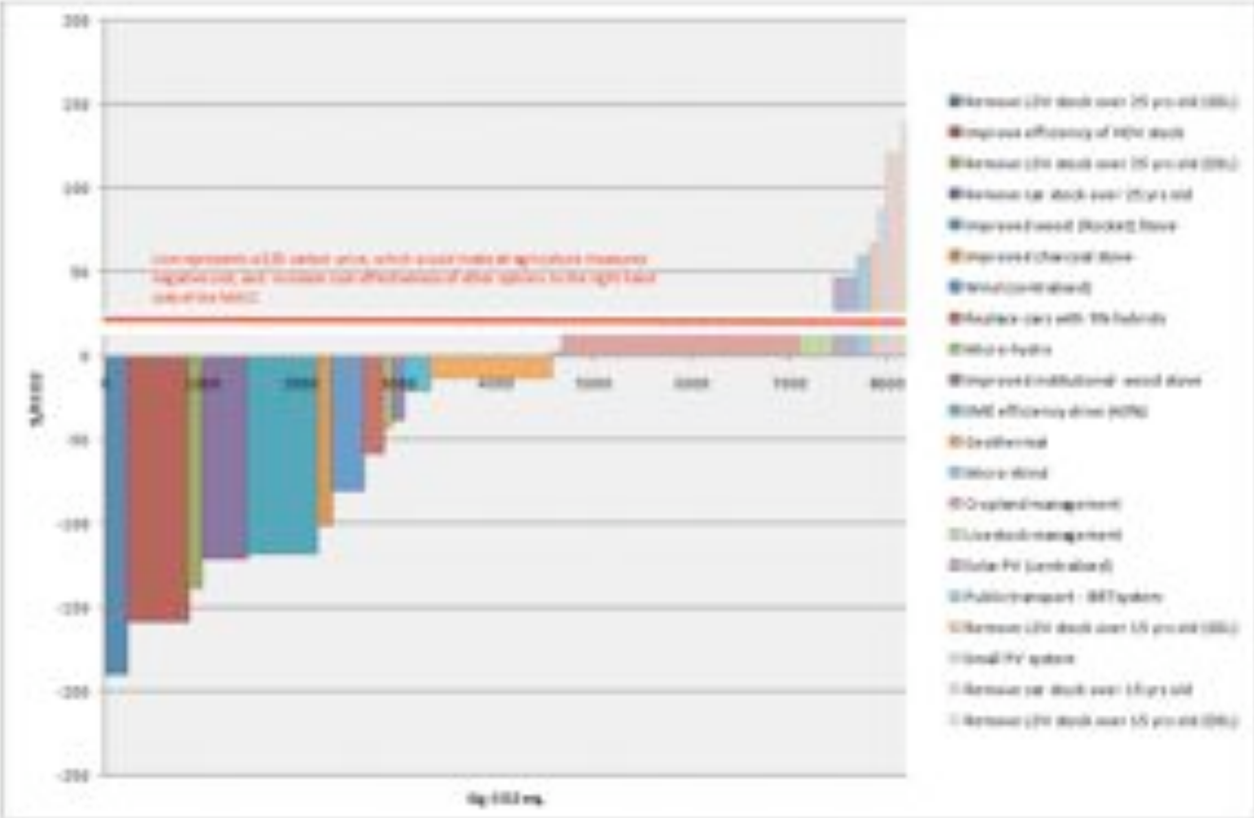


Figure 27. Indicative MAC curve ($/tCO$_2$ vs/ Gg) of selected abatement measures for Kenya in 2020[19]

The emission reduction potential shown in the above MAC curve for 2020 is compared against the 2020 baseline for energy sectors (see graph below). These sectors have the potential to produce savings of 22% relative to the baseline. Of the potential savings, over 80% can be realised at negative or low cost. When carbon credits are included, this amount is likely to be an even higher potential.

The analysis of a selection of low carbon options shows a potential to reduce baseline energy emissions by 22% relative to the baseline: over 80% of these options 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.

[19] Future cost are discounted at 10%, using the net present value.

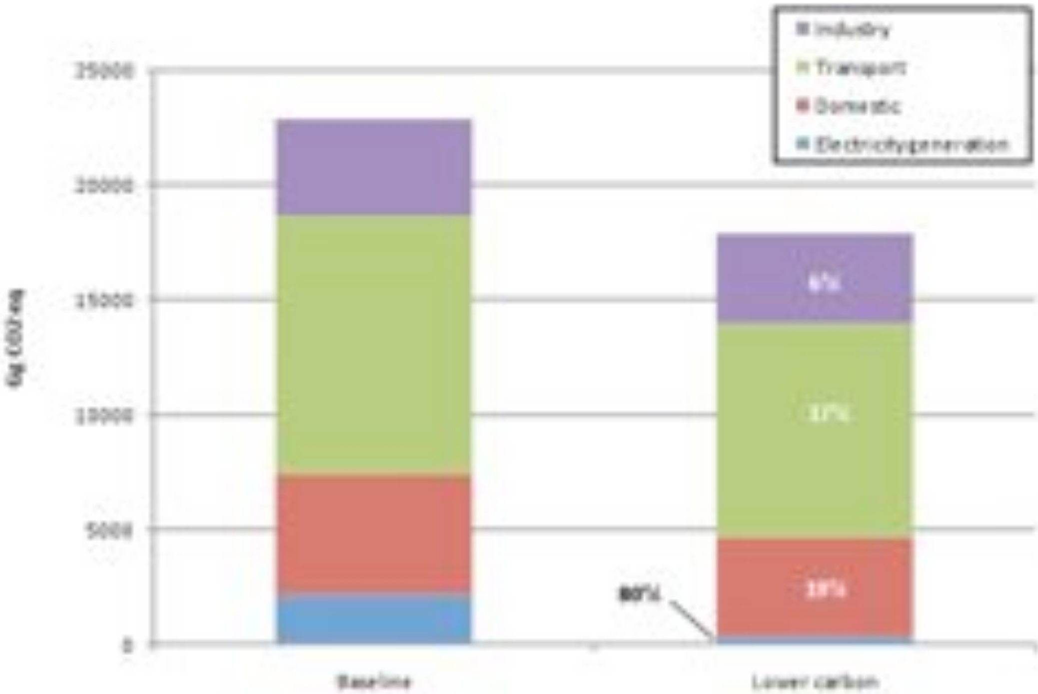


Figure 28. Kenyan emission in 2020 under the baseline and *lower carbon* case and emissions reductions from the selection of options

* The % labels in the *Lower carbon* case denote % reduction by sector relative to baseline

The graph above reflects energy sectors (industry, transport, domestic and electricity). The inclusion of agriculture sector emissions results in an overall reduction of 13%. This is lower than the 22% reported above due to the high level of the emissions from this sector.

The measures shown in the above cost curve are listed below, showing what the policy driver might be for introducing a given option and the co-benefits of the measure if indeed the measure was being appraised for carbon mitigation.

The analysis demonstrates that many of the options are important and consistent with objectives of sustainable economic growth. The costs analysis suggests that many of the above measures are also cost-effective, and can save money for the economy rather than add significant financial burden. Further work is required to develop other options and provide a more comprehensive picture of the different opportunities, building on this emerging picture of a lower carbon future.

Low Carbon Options considered. Policy drivers and co-benefits.

Option	*Policy driver*	*Co-benefits*
Expanding use of renewables (centralised)	Expanding capacity to meet future needs based on strong resource base	Reduce reliance on / payments for foreign fossil imports More cost-effective across many types Leverage carbon finance to fund investment Potential to build regional expertise, and export No air quality pollution
Decentralised generation from renewables	Rural electrification	Lower cost than alternative fossil generation Limit requirements for expensive grid expansion Sustainable energy for local economic growth No air quality pollution
Introducing improved stoves	Reduce biomass demand	Reduce indoor air pollution, and therefore health impacts Reduce fuel costs Protecting fuel Saving economic / leisure time (wood collection)
Improving efficiency of road transport fleet	Reducing reliance on fossil fuel imports	Reduce reliance on / payments for foreign fossil imports Reduce costs of vehicle use Reduce air pollution Reduce road traffic accidents (due to newer cars)
Planned public transport scheme for Nairobi	Meeting urban transport demand	Reduce congestion Reduce air and noise pollution levels Save travel time / enhance productivity Reduce road traffic accidents
Tackling energy inefficiency in SMEs	Reducing industry fuel costs, increasing competitiveness	Reduce fuel costs, enhance competitiveness Enhance energy security Reduce air pollution
Improve livestock and cropland management	Improve agriculture productivity and reduce land degradation	Protect / enhance arable land quality Safeguard rural livelihoods Increase economic productivity of sector
REDD / Afforestation	Protect forestry-dependent economy and energy supply security	Protect biodiversity, and dependent sectors Ensure security of wood fuel supply

Regional Policy and Kenya

The analysis here has focused initially on domestic aspects. However, there is a need for Kenya to consider low carbon growth, and enhanced energy resilience, in a regional context.

The least cost plan does include hydro generation imports (mostly from Ethiopia). As well as the positive aspects of such plans in increasing generation availability, there is also a need to consider the potential resilience that such regional networks might offer (though also potential risks) in a future climate. This is particularly important because of the large regional network of hydro power, particularly in the context of future average and extreme events from climate change.

There is also a growing recognition that co-operative regional (East African) responses could enhance opportunities for carbon credits.

The consideration of these regional perspectives is considered a priority for future plans.

International Climate Policy and Kenya

This study has not assessed the potential effects of international climate change policy on Kenya, but this is an issue that has emerged in the stakeholder consultation.

Key concerns have been raised over certain areas of existing economic activity, which also have high planned growth in Vision 2030. This includes the continued plans for a high value international tourist sector. It also includes high value added agricultural and horticulture products. However, both of these are reliant on international aviation. The action taken to address greenhouse gas emissions in developed countries could have knock-on effects to these sectors in Kenya, for example, in relation to the additional costs of carbon. This could affect demand or comparative advantage. Given their importance to the Kenyan economy, export earnings, balance of trade, etc. it is considered a priority for Kenya to consider the implications of international climate policy on it's domestic growth plans.

The study therefore highlights the need to develop a longer term strategy up to and beyond 2030 that considers these international aspects.

Summary

Overall, because of its location, availability of resources and socio-economic conditions, the study concludes that there are significant economic benefits for Kenya in following a low carbon development path, as well as large environmental and social benefits. Such a pathway is strongly in the country'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.

4. Recommendations

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

A key recommendation is the need for Kenya to get ready and act now

Key elements are to improve estimates; advance institutional and policy development; explore sectoral pilot tests; undertake investment analysis, revisit Vision 2030, to advance low carbon growth paths and to enhance regional co-operation. Specific actions are outlined below.

- *Improving the estimates*. 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 consideration of additional risks not yet covered, e.g. within existing sectors (such as assessing additional health risks), for additional sectors yet covered (e.g. tourism and industry) and for cross-sectoral issues and indirect effects.
    - For the key priorities identified here, a deeper analysis by sector, i.e. to further explore coastal risks, health burdens, agriculture, water/flood risks, energy supply and demand and ecosystem services. This would need a multi-stakeholder assessment of adaptation pathways at different scales, with estimates of costs, focused on short- and medium priorities that are most relevant for policy.
    - On the low carbon side, it would be useful to undertake a more comprehensive analysis of future emission projections and potential opportunities, with full marginal abatement cost curves and analysis of urgent priorities across all sectors.
    - For both adaptation and mitigation, analysis of the costs, including government, the sector and individuals. This step would provide both adaptation and low carbon costs in detail and as part of an investment and financial flow analysis (by sector). Matching the costs against the wide range of potential finance is a prerequisite for a viable investment plan.
    - Taken together, this analysis could form the basis of an expanded climate strategy that links national policy to sectoral objectives and targets, with effective mechanisms for implementation, monitoring, reporting and verification.
- *Urgent priorities*. There are a number of urgent priorities for building adaptive capacity in Kenya that should be fast-tracked, notably in relation to monitoring, forecasting and information (as these underpin future prediction and analysis) and early warning systems, as well as information provision, monitoring (indicators), and supporting science-policy networks and sectoral focal points. These early priorities are part of a broad strategy to increase the knowledge base, including education and training and strengthening existing programmes.
- *Climate change risk screening*. There is 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.
    - The study recommends that a **national knowledge management system** be developed; with easy access by all stakeholders.
- *Building Capacity*. Access to substantial adaptation funds must be assured. However, **mechanisms, institutions and governance systems for effective use must be developed** to allow Kenya 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.
    - **A national adaptation facility should assess the potential for climate resilient growth across all areas of the economy** and to mainstream adaptation into government departments and with Kenya's development partners.

    - A multi-stakeholder trust fund would enable early and timely action and is an early priority, encouraging learning by doing and establishing the basis for scaling up to sectoral resilience.

- Low carbon pathways. There are many benefits if Kenya switches to a lower carbon pathway. However, this will not happen on its own and steps are needed by Government, business and civil society to realise these benefits and to maximise the potential flow of carbon credits under existing and future mechanisms. Specifically:
    - **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 future development** that might 'lock-in' Kenya into higher emissions pathways, notably in energy, transport and urban environment. It would be useful to specifically address these threats and to identify alternatives.
    - All future plans and policies, 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.**
- National policy and Vision documents. Planned revision of national policy 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 activities. There is a need to develop a new strategic vision for Kenya that addresses these areas, for example, with **further development of the Vision 2030 document**, including both domestic and international aspects.
- Regional collaboration. There is also a need for **regional collaboration and co-operation** across the areas of low carbon growth and adaptation, to benefit from economies of scale and to enhance regional resilience.
- The steps above would provide national action on a low-carbon, climate resilience investment plan and **would establish Kenya as an international leader, with 'early mover advantage' in negotiations and securing finance.**

A summary of key next steps is presented in the tables over the page.

Adaptation Strategies	Priority Actions
Immediate needs & capacity building	• Expanded research assessment into effects, adaptation and economics. Early capacity building and early warning systems • Develop national climate change strategy including knowledge management and screening of sectoral and regional plans for climate risks and adaptation opportunities. Include in national policies. Build into long-term vision (e.g. Vision 2030) • Prepare plans for a national adaptation authority or facility to improve sectoral coordination, link to international finance, and support private sector. Enhance links between adaptation and low carbon.
Climate resilience	• Climate resilient strategies, objectives and targets for immediate concerns (for example, linking cross-sectoral climate monitoring with exposure, impacts and adaptation actions; knowledge management; health and vector-borne disease responses; drought and flood risk screening for new projects) • Develop prototypes of sectoral actions (pilots) and pathways for scaling up to cover all vulnerable regions and populations
Social protection	• Protect vulnerable livelihoods and strengthen existing social protection programmes, expanding the coverage to consider climate change.
Accelerated development	• Adapt existing development projects to include 'no regret' measures to reduce climate risks and opportunities to develop adaptive capacity • Scale up successful prototypes to sectoral development plans

Mitigation Strategies	Recommended Actions
Low-Carbon Growth (LCG)	• Full analysis of baseline projections, low carbon options, costs and potential for prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream LCG in planning. Build into long-term vision (e.g. Vision 2030), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM) • 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. • Look for synergistic adaptation – low carbon project opportunities, e.g. agro-forestry and sustainable land-use
Climate resilience & co-benefits	• Climate risk screening of low carbon growth pathways • Explore opportunities in case studies of major low carbon strategies such as geothermal, biofuels and on-farm carbon management and how they might be scaled up to achieve both reductions in future emissions and adaptive development.

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