The Economics of Climate Change in the United Republic of Tanzania

THE UNITED REPUBLIC OF TANZANIA

UKaid from the Department for International Development

Development Partners Group on Environment and Climate Change

A study by the Global Climate Adaptation Partnership and partners.

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Cover Photographs from:
Robert Okanda, Peres Mwangoka, taken from 'Changing Climate, Changing Lands: Images of Tanzania'

Key Messages

➢ Tanzania currently suffers high economic costs due to extreme events

- Tanzania's economy is very dependent on the climate, because a large proportion of GDP is associated with climate sensitive activities, particularly agriculture.

- Current climate variability, i.e. extreme events such as droughts and floods, already lead to major economic costs in Tanzania. Individual annual events have economic costs in excess of 1% of GDP, and occur regularly, reducing long-term growth and affecting millions of people and livelihoods.

- A key conclusion is that Tanzania is not adequately adapted to the current climate. The country therefore has a large existing adaptation deficit which requires urgent action.

➢ Climate change will lead to potentially high future economic impacts

- Future climate change could lead to large economic costs. While uncertain, aggregate models indicate that net economic costs could be equivalent to a further 1 to 2 % of GDP/year by 2030.

- There are potential threats from climate change to coastal zones (sea-level rise), health, energy supply and demand, infrastructure, water resources, agriculture and ecosystem services, with potentially high impacts and economic costs across these sectors.

- The combined effects of current climate vulnerability and future climate change are large enough to prevent Tanzania achieving key economic growth, development and poverty reduction targets, including the planned timetable for achieving middle income status.

➢ Adaptation can reduce these impacts, but requires significant levels of funds

- Adaptation can reduce the impacts of climate change but it has a cost. Significant funding is required to address the existing adaptation deficit, as well as to prepare for future climate change.

- An initial estimate of immediate needs for building adaptive capacity and enhancing resilience against <u>future</u> climate change is US$100 – 150 million per year. However, additional funding is needed to address <u>current</u> climate risks, with a conservative estimate of an additional US$500 million per year (but probably more). Addressing these current risks and the current adaptation deficit is essential in reducing future impacts and building resilience to future climate change.

- The cost of adaptation increases rapidly in future years. By 2030, financing needs of up to US$1 billion per year are reasonable, and potentially more if further accelerated development is included.

- The study has considered potential priorities to advance adaptation. There is a need to plan robust strategies to prepare for the future, rather than using uncertainty as a reason for inaction.

- Accessing adaptation funds will require the development of effective policy, institutions and mechanisms.

➢ A more sustainable, low carbon pathway would be in Tanzania's self interest

- The current use of energy in Tanzania is leading to economic, social and environmental impacts. The high reliance on unsustainable biomass use is leading to the removal of forests, while the increasing dependence on fossil fuels is leading to fuel price shocks and inflation, affecting the balance of payments and leading to air pollution (indoors and outdoors).

- The analysis has also considered energy and emissions for Tanzania, consistent with planned development. Emissions of greenhouse gases (GHG) could double between 2005 and 2030.

- Increases in emissions will be necessary for Tanzania's growth, and given its development status, there is no suggestion that future emissions should be constrained. However, the emissions growth above is related to a specific development pathway that has increased dependence on fossil fuel use and unsustainable use of natural resources. This will lead to higher fuel costs, greater fuel imports, higher air pollution and increased congestion. Indeed, these factors are likely to reduce future economic growth and development.

- There is an alternative growth strategy, based around low carbon options, that would be more sustainable, and which would have the considerable benefit of providing potential carbon financing.

- The study has found a large number of 'no regrets' options that would enhance economic growth, improve sustainability, and reduce carbon emissions, whilst also allowing access to international credits. Many of these options re-enforce existing objectives, but through the low carbon focus, it would provide a source of finance to fund the transition.

- There are also emerging opportunities from new sources of finances, such as for forestry (REDD+) and from emerging linkages between adaptation and low carbon projects. The study has investigated how to enhance the opportunities for Tanzania.

➢ Tanzania needs to get ready and act now

A number of priority areas are set out in the report. In terms of translating these into concrete action, a number of specific next steps are recommended:

- Tanzania should further build it's national climate change strategy, towards climate resilient and sustainable / low carbon growth. An integrated strategy will encourage synergies and reduce conflicts, and ensure that Tanzania can take advantage of opportunities from the international negotiations.

- The national policy should be linked to sectoral objectives, with effective mainstreaming mechanisms for implementation, monitoring, reporting and verification. However, as well as the current plans, there is a need to include this in longer-term strategy up to and beyond 2030, including in revising the Vision objectives and supporting intermediate objectives and policy, as well as cross-sectoral policy.

- To support all of these areas, there is an urgent need to build capacity, with mechanisms, institutions and governance systems.

Extended Summary

The development partners group, with funding from the UK (DFID), have sponsored this initial study on the 'Economics of Climate Change in the United Republic of Tanzania'. The work is led by the Global Climate Adaptation Partnership, together with the Stockholm Environment Institute, working with other international and local partners. The study has assessed:

1. The impacts and economics costs of climate change in Tanzania;
2. The costs and benefits 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, though it is highlighted that given the range of coverage, the study should be seen a scoping study. The key messages are presented in turn below.

1. The Economic Costs of Climate Change Impacts in Tanzania

***Existing* climate variability already has significant economic costs in Tanzania.**

Existing Climate Variability

The study shows that existing climate variability has significant economic costs in Tanzania.

- Tanzania's economy is very dependent on the climate, because of the large proportion of GDP is associated with climate sensitive activities, particularly agriculture. Because of this sensitivity, periodic droughts and floods (extreme events) cause major socio-economic impacts and reduce economic growth. Recent major droughts occurred in 2005/6 and major floods in 1997/8.
- The economic costs of these events affect the whole economy. Major drought years lead to the loss of crops and livestock, reduce hydro-power generation and electricity supply, and reduce industrial production. The 2005/6 drought affected millions of people and had costs of at least 1% of GDP.
- Tanzania suffers from these periodic extreme events on a regular basis, largely as part of the El Niño – Southern Oscillation (ENSO) cycle. The continued burden of extreme events reduces long-term growth. There is some indication of an intensification of these events over recent decades and this may reflect a changing climate. However, impacts also have to be seen in the context of changing patterns of vulnerability, for example from changing land–use, population growth and economic development.
- A key finding is that Tanzania it is not adequately adapted to deal with existing climate risks.

Future Climate Change

The study has assessed the impacts and economic costs of future climate change. Africa is predicted to have greater impacts from climate change than other world regions, because of higher vulnerability and lower adaptive capacity. Impacts could threaten past development gains and constrain future economic progress.

The study has assessed the aggregate (headline) economic costs of climate change in Tanzania and finds potentially very large economic costs in Tanzania from climate change, on top of existing climate variability.

***Future* climate change will lead to additional and potentially very large economic costs in Tanzania.**

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 (market and non-market costs, on top of the costs of existing climate variability) could be equivalent to a loss of 1.5 to 2 % of GDP each year by 2030 in Tanzania.
- The combined and cumulative effects of current climate vulnerability and future climate change are large enough to reduce the chances of Tanzania achieving key economic and development targets and challenging the timetable for achieving middle income status.
- In the longer-term, after 2050, the economic costs of climate change in Africa are expected to rise, potentially very significantly. However, the aggregate models report that global stabilisation scenarios towards a 2ºC target could avoid the most severe social and economic consequences of these longer-term changes. This reinforces the need for global mitigation as well as adaptation.

Bottom-up national sectoral analysis.

The study has also undertaken bottom-up assessments of the impacts and economic costs of climate change for a number of sectors. In order to assess the impacts and economic costs of climate change, the study has first looked at the current observations as well as the future projections of climate and socio-economic change.

Tanzania has a complex existing climate, with wide variations across the country due to topography and altitude. It has very strong seasonality. It is also affected by strong patterns of climate variability and extremes, not least due to the periodic extreme events (floods and droughts) highlighted above. There have already been changes observed in Tanzania's climate. The National Adaptation Programme of Action reported that minimum and maximum temperatures over the last 30 years show an upward trend at many meteorological stations. Furthermore, it reported that while rainfall trends are more difficult to interpret, in recent periods, rainfall patterns have become more unpredictable with some areas/zones receiving extreme minimum and maximum rainfall.

Future projections of climate change

- The study has produced statistically downscaled climate projections of future climate change for Tanzania from a wide range of climate models. The findings are summarised below:
    - *Temperature*. The projections indicate future increases in average annual temperatures of 1 ºC to 3ºC above the baseline period from a range of models and emission scenarios by the 2050s (the years 2046 - 2065), with projections towards the lower end of this range under a low emissions scenario (B1) and towards the higher end of this range under an unmitigated future global higher emission scenario (A2). By the end of the century (2100) average temperatures are broadly expected to increase in the range of 1.5°C to 3°C for the lower emission scenario and 3°C to 5°C for the higher emission scenario.
    - *Rainfall*. The changes in precipitation from the models are more uncertain. All the climate models show that rainfall regimes will change, but the degree and even the direction of change differ across the models. They also vary widely between seasons, regions and rainfall regimes. Many of the models (but not all) project that precipitation may increase in the future, especially during the late part of summer. Many of the models (but again, not all) also show the potential for drying signals later in the year in southern and central regions, though potential increases at other times.
    - *Extreme events*. The information on extreme events (floods and droughts) is much more uncertain and the model projections vary widely. Many models indicate an intensification of heavy rainfall, particularly in some regions and thus greater flood risks. Droughts are likely to continue, however, while some models project an intensification of these events, particularly in some regions, other models indicate reductions in severity.
- The range of model results highlights the uncertainty in predicting future climate change, especially in relation to scenarios of future rainfall, floods and droughts. 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.
- There is also a need to take account of socio-economic changes that will affect the future impacts of climate change, for example, high population growth (forecast to exceed 100 million people by 2050) and

urbanisation in Tanzania, as well as future economic growth and development baselines. These drivers will have as much potential impact as the changes from climate, and have been considered in the analysis below.

- The Mkukuta vision will reduce some climate impacts through sound development. However, population growth and increased infrastructure will continue to drive major climate costs. The impacts of future climate change are strongly related to development strategies chosen in the next five years.

The impacts and economic costs of climate change by sector

The study has applied available projections to national level sectoral assessments, outlined below[1].

- ***Coastal zones***. The coastal zones of Tanzania contain high populations, significant economic activity and important ecosystem services. These areas are at risk from future sea-level rise. The study has assessed the impacts and economic costs of sea-level rise to Tanzania across a range of future sea level scenarios: the results indicate that without adaptation, the physical, human, and economic impacts will be significant. With no adaptation, the expected number of people at risk of annual flooding is estimated at 0.3 to 1.6 million people per year by 2030, rising to 1.0 to 2.1 million people per year by 2050. The analysis also shows significant loss of land, forced migration (potentially up to hundreds of thousands of people) and that approximately 8% of Tanzania's wetland could disappear by 2050. The study has also estimated the economic costs associated with these effects. Without adaptation, the total annual costs are estimated at between \$26 and \$55 million by 2030 (2005 prices, undiscounted), rising to \$100 to \$200 million/year by 2050, and higher in later years.

- The study has also undertaken a case study on Dar es Salaam, Tanzania's largest city (3 million people), and one of the largest coastal cities in Africa at risk of sea-level rise. It is also one of the fastest growing, with estimates that Dar will become a mega-city of >10 million people by 2040. The study has used land elevation and population data (current and future) to look at the potential number of people and economic assets at risk of coastal flooding due to extreme water levels, i.e. to a 1 in 100 year storm surge flood event, with sea level rise. The results show that currently, about 8% of the land area of Dar es Salaam, 140,000 people, and economic assets worth more than \$170 million, are currently below the 10m contour line, i.e. in potentially vulnerable areas, with 31,000 people considered at risk. By 2030, without adaptation, this will increase to more than 100,000 people and over \$400 million assets (2005 values), and rise further in later years. The analysis highlights that, without action today to ensure sustainable development and planned population settlement, population, economic growth and climate change will increase the exposure to coastal innundation. These future risks are extremely important in relation to the current Dar development plans.

- ***Agriculture***. The agriculture sector is the mainstay of Tanzania's economy, as well as having a key role in sustaining livelihoods. It is also a very climate-sensitive sector. Future climate change has the potential to exacerbate current production risks in agriculture, either from changes in temperature and rainfall trends, from enhanced variability, or from other effects. A number of previous studies have considered the potential effects of climate change on Tanzania, and because these consider different impacts and use different projections and models, they provide a wide range of results. Under some projections and with certain models, some studies predict very negative impacts on the sector. However, for some regions and projections, other studies estimate much lower impacts, with some even showing benefits in terms of increased agricultural yields for some regions.

- The study has undertaken additional new modelling work looking at the cultivation of maize, which is potentially highly vulnerable to climate change (due to the combination of rising temperature and decreasing precipitation). Under more positive climate projections, where rainfall does not decrease, modest impacts are predicted, with even benefits in some regions. However, under some of the more negative high emission projections, where rainfall decreases by up to 15% and there is no adaptation, average maize yields could decrease by up to 16% by 2030 (a loss of around 1 million tonnes/year) and 25 - 35% by 2050 (2 to 2.7 million/tonnes per year). While farm level adaptation would be likely to reduce these impacts, the analysis shows climate change could have very large economic costs, potentially several US\$ hundred millions/year (current price, undiscounted). It is also highlighted that a very complex range of factors will be

[1] Unless otherwise stated, the report uses US\$ at current market exchange rates rather than at current purchase power parity. Future values presented are in current prices and not discounted. The intention of the analysis here is to explore the upper and lower bounds of plausible estimates — it is not possible to produce a fully consistent net present value with the available evidence. For comparison, the current exchange rate is very approximately US\$1 = TZS 1500.

important in determining future effects on agriculture from climate change, which are not included in the current suite of studies, including the effects from extreme events and variability, pests and diseases, etc.

- The study has also undertaken a case study on pastoralists, who have resilience to the historical risk of climate variability in arid and semi-arid lands (ASAL). The case study reports that multiple factors present new risks that will decrease resilience and system stability and that if climate change increases climate variability, this will have significantly impacts.

- ***Health***. Climate change is likely to affect human health in Tanzania. This may happen directly, as with the effects of heat extremes or flood injury, or indirectly, for example, through the changes in the transmission of vector, food or water-borne diseases. There are also a wider set of indirect impacts from climate change on health, which are linked to other sectors (e.g. food security and malnutrition). There are already some observational data that show malaria moving to higher elevations (where the disease is currently limited by temperature). The study has estimated the potential increase in malaria and some other climate sensitive disease from climate change, as part of a scoping assessment. The findings, whilst indicative, estimate that the potential costs of higher treatment costs to address the increased disease burden in Tanzania could be $20 to 100 million /year by 2030, rising to $25 to 160 million/year by 2050 – the range reflecting different climate and development assumptions. The study has also undertaken a qualitative assessment of the potential effects of more extreme high temperatures, looking at the projected number of days exceeding 32°C. The results show significantly increased exceedences in warmer locations such as Dar es Salaam, which as well as potentially leading to additional health impacts, these would reduce labour productivity.

- ***Energy***. Climate change will affect energy supply and demand. On the supply side, hydropower currently provides 55% of the country's power generation, and has been affected heavily by drought events in recent years. This has led to reports by the World Bank of high costs (~$70 million) from the use of incremental thermal generation plants, and reduced economic growth in drought years by more than 1% due to electricity shortages. It has also led to the widespread introduction of small diesel generators, with associated high economic costs, as well as additional air pollution. The study has considered future electricity supply in Tanzania. While there is some diversification away from hydro in future years, it will still remain the dominant electricity capacity and supply technology. Future climate change could exacerbate the current issues with reliability, due to evaporation and also other potential factors associated with river flow and variability. The effects vary with the climate projections, and the wide variation in rainfall, temperature and variability from the models, however, under some scenarios there is the potential for detrimental effects on hydropower generation in southern and central Tanzania central region.

- There are also projected impacts on thermal generation (coal and gas). First, increased temperatures will impact on these plants by reducing generation efficiency. An initial analysis based on the future 2030 grid mix estimates that this will lead to costs (current prices) of $10 million by 2030, which could rise further in future years to 2050. Second, these plants require cooling water, and any detrimental effects on water availability may also therefore impact on these thermal plants (as well as on hydro). There is therefore a potential concern that extreme events in future drought years could reduce supply across the system, rather than only on hydro plants alone.

- The effects of climate change on energy demand are potentially even larger, at least in terms of economic costs. There are well established relationships that link levels of cooling energy demand with income and with temperature. In line with these, future socio-economic development in Tanzania will increase electricity demand. These will be further affected by higher temperatures from climate change. The study has undertaken an initial analysis to investigate the potential implications and costs of these changes. The climate model projections show large increases in cooling degree days (a metric of cooling burden) in Tanzania, with increases of 25 to 100% increase due to climate change. These changes will lead will lead to high economic costs, particularly for urban areas and for some sectors (notably tourism). Importantly, it will also increase peak demand on the electricity supply system, affecting electricity supply and capacity requirements. The indicative analysis here estimates that by the 2030s, climate change could have additional cooling costs of $60 million per year (current prices, no discounting). The continued temperature and per capita income growth would lead to much higher costs by the 2050s. The rising cooling demand from future climate change has not been recognised in energy planning to date in Tanzania, and is identified as a key area for future investigation.

- ***Water*** is a critical sector for Tanzania. In addition to the multi-sector links to agriculture and energy (above), it is important for tourism, industry, and other economic sectors including mining. It also supports livelihoods through fishing and traditional farming irrigation systems, as well as terrestrial and aquatic ecosystems including associated ecosystem services (provision of fuel wood, water purification, climate regulation, etc.). Tanzania's current rainfall – and thus water resources and availability - vary temporally and geographically over the country. Many areas are already subject to water scarcity, and this will increase with population growth. Against this background, climate change has the potential to affect water availability (and potentially water quality), as well as potentially exacerbating the pattern of extreme events. The analysis of future impacts is made difficult by the wide variation of outcomes (positive and negative) from the projections. However, under certain projections, there could be reductions in rainfall, river flow and groundwater systems that will have potentially large impacts (and high economic costs) for household water supply, irrigation, power generation, industry, and the functioning of existing water infrastructure and ecosystems services.

- There are also potential changes from climate change in the intensity and severity of extreme events. Even in the absence of climate change, the economic costs of the periodic droughts (and floods) that affect Tanzania could rise significantly in future years, due to socio-economic change (population and economic growth). Many of the projections indicate a reduction in the return period for heavy precipitation events for some regions of Tanzania, which could increase the economic costs of periodic flood events. The range of model projections is more uncertain for periodic droughts, though under some projections, some regions could be heavily affected. A key priority therefore is to increase the resilience of Tanzania to cope with these extreme events.

- ***Forests***. The potential impacts of climate change on forests are complex, but forests are acclimatised to existing ecological zones, and have long life-times and slow rates of growth. While there are some potential benefits to forests from climate change, there also many threats, either directly (changing temperature, precipitation and variability including extremes) and indirectly (including from effects on soil, moisture, pests and diseases, fire risk, etc.). These may affect growth, tree health, wider biodiversity and even system stability, with potentially irreversible losses. In turn, these impacts will reduce the services and economic value that forests provide, including direct provisioning services (timber, fuel wood, building material), supporting and regulatory functions (soil and flood protection, carbon storage), and cultural and tourism value. Previous studies indicate potentially large changes in ecological zones in Tanzania from climate change, which could have major impacts on current forests. The study has not undertaken new modelling analysis on forests and climate change, and it is highlighted that such analysis is extremely challenging, given the wide range of model projections and the multiple factors involved in impacts. However, the potential effects could be one of the higher economic losses from climate change. It is also highlighted that climate change could therefore affect the UN Reduced Emissions from Deforestation and Forest Degradation (REDD+) scheme, in terms of the future viability of current afforested areas and thus revenues. The issue of the effects of climate change on forest is highlighted as a priority for consideration in the context of REDD development.

- ***Biodiversity and Ecosystem Services***. Tanzania 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, including tourism. There are many stresses on these systems already and climate change will add to these pressures. An initial mapping and review shows that high importance of ecosystem services in Tanzania: they are integral to the economy and underpin large parts of GDP, foreign revenue (including through tourism revenue) and export earnings, as well as sustaining a very large proportion of the population. The effects of climate change could be very severe on ecosystems, and previous work has highlighted the potential for major shifts in agro-ecological zones in Tanzania. However, there are also other potential factors, all of which have to be seen in the context of socio-economic development pressures. In many cases, there are barriers to species and ecosystem movement, which will lead to changes in existing areas and supporting services. Given the linkages across the current economy, any detrimental changes will lead to high economic costs, and further investigation of these effects is a priority.

- ***Impacts Summary***. Overall, the bottom-up sectoral analysis shows that economic costs of climate change in Tanzania could potentially be very large. Detailed analysis for agriculture, coastal zones, electricity and health alone indicate future economic costs could be several billion dollars / year by the 2050s (under some projections). There are also potential effects on ecosystem services, which whilst difficult to estimate in monetary terms, will be important and will have potentially large economic costs. The additional case studies also highlight major impacts in some non-market or informal sectors that are not captured by formal economic analysis, but that are essential to livelihoods.

2. The Costs and Benefits of Adaptation

Adaptation can reduce the impacts of climate change, but it has a cost. The adaptation financing needs for Tanzania are potentially very large.

The study has investigated the potential costs of adaptation for Tanzania. This is an uncertain area, and the costs of adaptation are still emerging. One of the methodological challenges is on to define the boundaries of what is included or excluded in these estimates. Recognising this, a number of categories of adaptation have been identified in the study that relate to the balance between development and climate change. The first 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.

Two other categories are associated with specifically tackling the future risks of climate change 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.

Top down aggregated estimates

The scoping study has investigated the top-down aggregated estimates of the costs of adaptation, using estimates for Africa/East Africa and scaling these to Tanzania. This leads to the following indicative costs.

- The immediate needs (for 2012) for building adaptive capacity and starting to enhance resilience (immediate priorities) are estimated at $100 – 150 million/year for Tanzania. It is noted that this is a significant increase - by an order of magnitude - from the current National Adaptation Programme of Action (NAPA). However, a much higher value of $500 million/year (or probably more) is warranted if the categories of social protection and accelerated development 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 Tanzania 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 in excess of $1500 million /year) are plausible if continued social protection and accelerated development are also included, noting that these are primarily development activities.
- Using these numbers, the study reports a conservative estimate of immediate needs for addressing current climate and 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 could easily be of the order of $1 billion / year, though higher than this if additional enhanced development for resilience and social protection is included.

Sectoral (bottom-up) assessments

- The study has also assessed the costs of adaptation for Tanzania using a national sectoral bottom-up approach, to investigate and validate the estimates above and gives greater insight into sectoral planning.
- This focus on sectoral adaptation also has included a greater focus on uncertainty. To progress this, the study has advanced a framework to prioritise early adaptation, which considers uncertainty within an economic framework.

- The proposed framework identifies early priorities for adaptation of:
    - Building adaptive capacity;
    - Encouraging pilot actions to test promising responses
    - Focusing on win-win, no regret or low cost measures (justified in the short-term by current climate conditions or involving minimal cost); 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 a range of actions. While the broad outline of steps is the same in each sector, 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 consider initial sector actions, and for some sectors, indicative adaptation costs. These have been complemented by case studies which include examples of adaptation projects and costs. The results are summarised by sector below.
- ***Coastal zones***. The study has assessed the potential costs and benefits of adaptation, following on from the national sector study. The results show that when adaptation is applied, in the form of coastal protection (to address floods) and beach nourishment (to counter erosion) the potential impacts and economic costs can be significantly reduced, with the number of people at risk of flooding reduced from 0.3 - 1.6 million per year in 2030 (no adaptation) to 0.04 to 0.1 million per year (with adaptation) with even larger reductions in later years. Similarly, the costs of climate change fall from up to $55 million / year in 2030 (2005 values, undiscounted) to under $20 million / year (with adaptation). The benefits are even larger in the later years. The analysis also shows that adaptation is cost-effective, and has high benefits when compared to costs. Even so, the costs of adaptation are considerable, estimated at $30 to 80 million / year by 2030 (2005 dollars undiscounted) depending on the sea-level rise scenario, rising potentially to $35 to 120 million / year by 2050. Note that even under a case of no sea-level rise, the costs of protection would need to rise to address rising population and assets. Moreover, even with these measures, there are some residual damages (including to coastal wetlands). The results also show that there is a significant need for a current strengthening of coastal adaptation (to cope with the current risks). Other key actions include the need for improved monitoring of both sea level and extreme coastal events (a key step in building adaptive capacity), further work to address spatial and development planning policy for current and future flood risks (especially in key hot spots), improved disaster risk reduction, and the need to move towards integrated coastal zone management (ICZM) to allow iterative and flexible decision pathways to address future climate change.
- The case study in Dar es Salaam has also considered adaptation. The results show that the risks of extreme floods from sea-level rise could be significantly reduced by introducing a sustainable spatial planning policy for population settlement and economic activities, i.e. by steering future development away from low-lying coastal zones to alternative areas that are not threatened by current or future sea-level rise. For example, by restricting growth and development in the most vulnerable areas, exposure to the 1 in 100 year flood event in 2030 is reduced from 200,000 down to 35,000 people and from $400 billion to only US$40 million assets at risk even under the highest sea-level rise scenario. The study highlights, however, that enforcement of such a policy is challenging where informal settlements dominate urbanisation. It also highlights that additional appropriate adaptation measures (e.g. protection in terms of beach/shore nourishment and dikes) could be considered in order to keep risks at an acceptable level, but also highlighting that this will require appropriate capital investment and subsequent maintenance. The importance of these issues is highlighted as a priority in relation to current Dar es Salaam development plans.
- ***Agriculture***. The study has considered the adaptation options and costs to address projected cereal yield losses, using a mix of national analysis and case studies. The study picked options that are robust against future uncertainty. These included: to increase investments in smallholder farmers' irrigation; to introduce soil and water conservation in the highlands; to strengthen the capacity of agricultural research institutes to conduct basic and applied research; to institutionalize climate information data collection, analysis and dissemination in the District Agricultural Development Plans; and to invest in rural road infrastructure. The study has examined current plans, but also future projections, which show even without climate change there is a significant funding increase needed to address the current adaptation deficit – this mirrors the discussion in the top down analysis above. The study has then estimated that the additional cost of adaptation (for the five key policies) to address future climate change, considering an upper emission

scenario. This estimates the total additional investment, which are equivalent to an additional $107 million per year (note this is the total investment cost, presented as a discounted equivalent annual cost and thus is not directly comparable with the coastal numbers above).

- The case study on <u>pastoralists</u> has highlighted a number of adaptation options, including early steps to build capacity, community based adaptation initiatives, and wider cross-cutting policies.
- ***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, alongside enhanced monitoring and surveillance to track the change in the disease burden. It has also considered other potential disease burdens and identified preventative measures and low cost options that would reduce future impacts.
- ***Energy***. For <u>energy supply</u>, a number of potential adaptation options have been identified to address the current adaptation deficit and the future impacts of climate change. For hydro generation, the options include demand management (of water), a no regret option to help manage current and future water sources; integrated basin catchment management; and upstream land management, to improve water availability and address sedimentation and siltation in the flows. There is also a need for capacity building to support these options, for example in strengthening basin water offices to balance hydropower requirements with other demands for water. More generally for the electricity sector, there is also a need to increase the energy diversification of the system (see later low carbon section), noting that the lowest vulnerability will be through renewable (e.g. geothermal) rather than fossil based alternatives. At the aggregated level, development of regional power trading (interconnection of networks) would help in providing greater system resilience, as well as providing other opportunities for power export. For <u>energy demand</u> there is a need to consider and adapt to future cooling demand. The most immediate need is to measure and monitor current usage (linking air conditioning to temperature and demand), to allow greater understanding of current and future demand levels, and to try to introduce more efficient units, an early no regret option. There is also a need to start considering alternatives to air conditioning, through building design to provide passive cooling, at least in new building stock with long life times.
- ***Water***. The analysis of the water sector shows a baseline of increasing water scarcity for both urban (including water for industry) and rural areas, highlighting the challenge for the current plans, due to insufficient levels of investment and the high levels of future socio-economic development. Future climate change could make closing the water supply—demand (deficit) gap even harder, though the key challenge is to consider the high degree of uncertainty. The study has investigated a number of potential adaptation options. For urban areas, these, include investment in catchment management programmes and also demand management (leak reduction and controlling illegal connections). These options have benefits in reducing the current adaptation deficit, as well as enhancing resilience to future climate change i.e. they are no regret options. However, in future periods, under some of the more extreme climate projections, these options may need to be complemented by enhanced storage or supply capacity: early research to investigate the potential for these options would be useful (to learn for future possible implementation). For rural areas, early capacity building options include the need for mapping of rural waterpoints to serve as an input into district-level planning and standardizing technologies. Adaptation measures for the rural sector include development of groundwater wells, shifting from surface water sources to deep boreholes, and an increase in rainwater harvesting structures. In relation to the risks of extreme events from floods, a key priority is to increase the resilience of Tanzania to cope with current extreme events.
- ***Forests, biodiversity and ecosystem services.*** The analysis indicates that the most immediate response needed is to increase monitoring programmes to study the response of forest and tree species and research projects to investigate potential ecosystem shifts. The additional stress of climate change is also likely to mean a greater focus on reducing and managing existing stresses, such as fragmentation, pollution, population encroachment and habitat conversion. Additional adaptation measures are likely to be needed, which include creating forest buffer zones, increasing ecological zone connectivity. Given the irreversibility of land-use changes, these are highlighted as an early priority. Similar measures are also relevant for the wider area of biodiversity and ecosystem services. One key area is the potential for an Ecosystem-based Adaptation (EbA) approach, which seeks to enhance healthy and resilient ecosystems, for example by managing individual components as part a larger landscape and introducing multi-functional land uses and conservation of natural capital. Several no-regret EbA measures have been identified, such as restoring the natural coastal vegetation to enhance coastal forest buffer zones in coastal locations.

- ***Adaptation Summary***. The sectoral assessments and the case studies show relatively high adaptation needs, which re-enforce the top down adaptation estimates for 2030 and justify investment. The studies demonstrate that adaptation has potentially very large benefits in reducing present and future damages. Across all the sectors, options have been identified that work within a framework of decision making under uncertainty, focusing on key areas that provide robust options to enhance resilience, as well as helping to address the current adaptation deficit. Interestingly, many of these options are cross-sectoral in nature, and build on existing good development policies.

- While adaptation reduces damages, it will not be able to remove the impacts of climate change entirely. Residual impacts in Tanzania, particularly for some regions and groups of society, are expected and will need to be managed. These residual impacts – and their economic costs – are additional to the costs of adaptation.

- 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 Tanzania to agree on next steps, the future focus and to build capacity, including national and sectoral planning objectives, enhanced knowledge networks and verifying outcomes of adaptation strategies and actions.

3. Sustainable Energy Use and Low Carbon Growth in Tanzania

The study has considered the potential benefits of sustainable energy use, aligned to low carbon growth and the emerging opportunities under the various international mechanisms. The main focus is a technical assessment of the near and medium term potential of Tanzania to invest in more sustainable, lower carbon projects / programmes, which have economic development and growth benefits, as well as conserving the natural resource base.

Current baseline: energy use and the economy

The study has first considered the baseline energy use and the relationship with the economy.

- Forests provide over 90% of the national energy supply through wood fuel and charcoal. This reflects a lack of affordable and reliable energy alternatives.

- There are various reported figures, but recent estimates put annual forest loss at 1.2%, driven largely by biomass energy demand and land-use change. This rate of deforestation is unsustainable. While there are Government tree planting programs and land being set aside for forestry and national parks to address this problem, this remains a key concern.

- Related to this, the current production and use of biomass (for charcoal) is extremely inefficient, which leads to unnecessary biomass use. These low grade technologies also lead to health impacts from indoor air pollution.

- The access to electricity is limited and subject to many outages, which disrupt business activities and reduces economic growth: costs are incurred from lost production and revenues, damage to equipment, back-up production, etc. The value of lost (unserved) load has been estimated by the World Bank at several % of GDP. The situation is compounded by high system losses and inefficient tariff structures. Moreover, current access to grid electricity is very low in Tanzania, reducing the availability of modern energy services for households and businesses.

- Tanzania's reliance on fossil fuels is increasing, as the energy system diversifies away from dependency on hydro generation for electricity and biomass for non-commercial sector energy needs. This is also being driven by high growth rates in fossil intensive sectors, notably transport. An increased use on fossil fuels will increase energy security concerns and expose the economy to price fluctuations, as well as macro-economic burdens (balance of payments, fuel price shocks and inflation). As an example, in 2007, high oil price increases led to a significant increase in the cost of imports. These fossil fuels also lead to high environmental impacts, including outdoor and indoor air pollution.

- High population growth and the continuing rapid rate of urban growth have put significant pressures on existing urban infrastructure, especially in Dar Es Salaam. The problems are evident in terms of urban road congestion, where vehicle numbers exceed road capacity, which leads to lost time (and lost profits). There has also been considerable unplanned development.

- Future socio-economic trends, not least growing population and urbanisation, will exacerbate these existing energy access issues and associated impacts.

- Tanzania's economy is heavily based on natural resource use. The annual levels of growth needed to match the development objectives in the Vision document (8% annual GDP growth), and the type of economy outlined in the document (a semi-industrialised economy, with a comparable industrialised sector to most middle income countries) may be restricted by increasing reliance on, and inefficient use, of fossil fuels.

Against this background, a more sustainable, low carbon growth pathway has the potential to address the issues above, whilst also providing Tanzania with additional carbon finance to help invest. In addition to reducing carbon, many of these options could lead to more growth and development through protecting natural resources, improving environmental quality, delivering economic opportunities and reducing reliance on fossil imports.

Low Carbon Options can help deliver more Sustainable Economic Growth, and provide access to finance to fund this transition.

Emission projections

To determine the current or future role carbon financing could play in providing funding for investment in the economy, it is important that the level of GHG emissions is assessed through the development of a current year inventory and projections.

- The analysis has first considered current emissions. Tanzania currently has relatively low emissions of greenhouse gases (total and per capita). Current year emissions are dominated by the forestry and agriculture sectors, illustrating the importance of these sectors to the economy but also the very low fossil energy use in the economy.
- Per capita emissions are estimated at 1.3 tCO_2e per capita (all GHG, excluding forestry) and 2.7 tCO_2e per capita, when forestry emissions are included, though it is noted that actual CO_2 emissions are very low. Tanzania has also 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.
- However, emissions are rising rapidly and will continue to do so. The study has estimated future emissions in line with planned development as set out in the Vision 2025, and based on population forecasts from the UN. The projections show that future total and per capita GHG emissions rise significantly, even though Tanzania is already initiating a number of low carbon options.
- Under this future 'business as usual' scenario, the study estimates that total emissions of greenhouse gases will more than double between 2005 and 2030.
- These future increases are driven by the continued and increasing use of biomass for energy, rapid transport growth and agriculture sector activities. Emissions in other sectors will also rise, such as the electricity generation sector, where planned increases in the use of fossil generation (due to the need for diversification and use of indigenous resources) will increase the carbon intensity of generation. The increases would occur at a time when there are likely to be greater economic opportunities for international carbon credits, particularly if national level GHG mechanisms emerge.

Of course, increases in emissions will be necessary for Tanzania's growth, and given its development status, there is no suggestion that future emissions should be constrained.

However, the emissions growth above is related to a specific development pathway that has high fossil fuel use and unsustainable use of natural resources. Such a pathway will lead to an increase dependence on, and inefficient use, of fossil energy, with associated economic, social and environmental impacts, for example, increased congestion, higher fuel costs, greater fuel imports and higher air pollution.

There is, however, an alternative growth strategy, based around low carbon options, that would be more sustainable, and which would have the considerable benefit of providing potential carbon financing.

Low carbon options

Having established projections of future emissions, the study has investigated the potential for more sustainable, low carbon options, focusing on options that:

- Generate *carbon financing* opportunities, providing investment and financing from projects / programmes that reduce CO_2 emissions.
- Have strong *policy co-benefits,* aligned to current or planned policies.
- *Strengthen development and growth,* by stimulating new economic sectors and reducing costs e.g. through energy efficiency measures.
- Have a*daptation synergies,* where these investments align with actions needed to enhance climate resilient growth. This is seen as a particularly important area, as it provides the potential for win-win policies.

The study has found opportunities exist across all sectors of the economy, for example:

- Reducing the reliance on wood fuel energy and protecting the forests would promote sustainable resource use, protecting biodiversity and the economic sectors that rely on forest resources. It also reduces household exposure to pollution and promotes more modern energy forms. The REDD+ mechanism offers an important source of financing that should facilitate conservation.
- Alongside this, increased switching to modern fuels in household and other end use sectors is important. Co-benefits include cleaner, modern energy for cooking, particularly for a growing urban population. This will require increased access to affordable electricity. However, as continued biomass use will be necessary; improving efficiency will be vital as part of a move towards sustainable use.
- Tanzania has long invested in renewable generation through the development of hydro generation. There is considerable potential for other renewables including wind, solar and particularly for geothermal. The latter would have the benefit of reducing the vulnerability of the current hydro- dominated electricity system, whilst also providing potential low carbon finance. Promoting both grid and household-based renewables will further strengthen energy independence so long as it is carefully planned.
- To facilitate these changes, investors will need to be incentivised through the tariff structure and be able to use the carbon financing mechanisms. Promotion of solar home systems is already being developed; mitigating the problems of affordability will be key for rural technology dissemination.
- Developing a sustainable transport system would help reduce reliance on oil imports, protect urban environmental quality, enhance urban infrastructure, reduce congestion and potentially help develop a sustainable biofuel sector. This also includes promotion of vehicle efficiency.
- Agricultural sector measures are also available, including viable carbon finance projects. In addition, many of these measures increase the climate resilience of systems and enhance productivity.

Economic Benefits of Sustainable / Low Carbon Options

A range of potential options that could help Tanzania move towards a more sustainable growth path, have been assessed. These options would also generate carbon finance to support investment.

- These low carbon projects can help safeguard forests, reduce reliance on energy imports, provide more access to modern energy services, promote more sustainable biomass use, promote efficient and clean transport systems, and enhance economic competitiveness.
- 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 existing development objectives.
- The introduction of carbon financing has the potential to increase the relative attractiveness of these options and to help finance their introduction.

To compare these options, the study has assessed the marginal abatement costs of options in terms of the cost-effectiveness of emission reduction potential.

- An important insight is that many low carbon measures are ‘no regret’, i.e. negative or negative cost. This implies that such investments should be made irrespective of whether carbon finance is available, as over their lifetime such investments save money. These arise from improvements in transport efficiency, domestic stoves and agriculture, as well as for the electricity sector. 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, as well reducing air pollution and reducing environmental impacts, and often enhance resilience to future climate change.
- The availability of carbon finance would help the introduction of these options, and provide a shift towards a sustainable, low carbon development path.

Implementation issues

To implement these options, financing will be critical to raise the necessary capital. In addition, a range of additional financing will be needed (to provide capital), as well as some additional existing barriers. Various regulatory, institutional and financing barriers will need to be overcome, such as:

- Economic / market barriers (e.g. no finance, poor commercial case): Tanzania has been slow in accessing the international carbon finance markets to date, with only one project registered under CDM and only recent uptake of voluntary credit schemes in the forestry sector. Commercial banks seem currently unwilling to lend to low carbon projects due to the track record in implementation. There is also a mismatch between the short term domestic deposit base and the long term tenor required for capital intensive projects, creating a role for international financial institutions. It is noted, however, that many of these are common issues across Africa, and there is a need for systemic barriers to be addressed in future negotiation mechanisms.
- Low levels of information / awareness: The relatively low levels of absolute and per capita emissions, lack of track record in low carbon development and competing priorities of poverty alleviation have resulted in low levels of awareness. Climate change continues to be seen through a development aid perspective, rather than from the perspective of domestic led economic restructuring or growth.
- Policy / regulatory framework: The development of a coordinated climate policy framework is at an early stage. The fiscal framework to support low carbon options remains under-developed. For example, utilities pricing supports traditional fossil fuel generation at the expense of other renewables, with limited use of technology specific tariffs.
- Technical problems of use in-country: Tanzania lacks the necessary operation and maintenance infrastructure to support complex technologies. Solar PV, however is building economies of scale and may be the first break-through technology. It is highlighted that this is a common problem in Africa, and there are key issues on technology transfer that need to be addressed in the international negotiations.
- Lack of skills / know-how: This is particularly pertinent to technical and financial project preparation, and acts as a barrier under CDM applications. Skills and training are of particular importance for those areas where behaviour is a significant element in emissions, such as forestry and agricultural soil management practices.
- Limited institutional capacity: Multiple institutions play a role in low carbon policy development with a clear need for streamlining roles and responsibilities. This is particularly true of Forestry management and transport planning, which account for the bulk of forecast growth in Tanzania’s GHG emissions. Building institutional capacity is key to making low carbon development work.

Despite the challenges, there are positive signs that Tanzania is beginning to embrace low carbon options both through its policies and regulatory structures. Nevertheless, these would benefit from further alignment. There are also clear signs of growing momentum within the private, voluntary and education sectors which are crucial to creating the implementation capacity required, and which may serve as a basis for scale-up of low carbon options over coming years.

Linking low carbon and climate resilient growth

In terms of the linkage between low carbon investments and climate resilient growth, the study finds a mix of potential synergies and conflicts. A number of areas are highlighted:

- The impact of climate change will affect the energy system of Tanzania, and is important in considering the potential development of current and also more sustainable growth pathways.
- Increases in temperature will increase demand for cooling, which will in turn increase energy demand through air conditioning. These changes could be very significant in terms of average and peak demand (see earlier section) and they should be considered in current electricity planning.
- The combined effects of changes in future temperature and precipitation could affect the electricity supply industry, particularly given the high proportion of hydro power but also some thermal generation, though the projections are uncertain. There is a need to screen future power proposals and look to building resilience through a combination of options (see earlier adaptation section).
- There are existing risks from current climate variability (droughts and floods), which could increase in the future, and again requires risk screening for new proposals for infrastructure.
- Future climate change could have important impacts on agro-ecological zones, affecting forests. This is a key point in relation to REDD+. The limited studies that are available indicate potentially large threats, which could affect the viability of afforested areas and thus the viability and revenues from such schemes. Research into possible ecosystem shifts and suitability under changing climates is highlighted as a priority for consideration, as well as increased monitoring programs to study responses of forest and tree species.

Other issues

- The analysis here has focused initially on domestic aspects. However, there is a need for Tanzania to consider low carbon growth, and enhanced energy resilience, in a regional context. There is also a growing recognition that co-operative regional (East African) responses could enhance opportunities for carbon credits as well as provide enhanced resilience (e.g. through interconnections). The consideration of these regional perspectives is considered a priority for future discussion.
- This study has not assessed the potential effects of international climate change policy on Tanzania. However, certain areas of existing economic activity, which also have high planned growth in Vision 2025, could be affected by international action, notably the international tourist sector and higher value added agricultural and horticulture products (through supply chains). Given their importance to the economy, it is considered a priority for Tanzania to consider the implications of international climate policy on domestic growth plans.
- A final issue is the consideration of a more radical policy shift for Tanzania. Because of the level of current development and the importance of near-term decisions in determining the long-term economic and social structure of the country, it might be possible to truly promote a more visionary approach to low carbon development and climate resilient growth within the context of environmental sustainability and economic growth in Tanzania. This would position the country internationally along a very progressive vision.

Low Carbon Summary

Tanzania is a growing economy, aiming for strong development and growth over the next 10-20 years. However, the unsustainable use of natural resources and the increasing reliance and inefficient use of fossil fuels threatens these objectives. A more sustainable pathway could be adopted, to ensure that Tanzania can become a middle income country whilst protecting its natural assets and environment.

This sustainable pathway aligns with low carbon development. This therefore provides the opportunity for Tanzania to access carbon financing to help invest in sustainable technologies. It would also address provide significant co-benefits (economic, social and environmental), which are very much aligned with domestic policy priorities. While Tanzania is and has already implemented many lower carbon opportunities, the move to adopt a more strategic approach to a low carbon- climate resilient growth pathway would enhance these benefits, and maximize the opportunities for Tanzania to benefit from the available international funds.

Overall, the study concludes that because of its location, availability of resources and socio-economic conditions, there are significant benefits for Tanzania in promoting low carbon projects to ensure a more sustainable growth pathway. Such a pathway appears strongly in the country's self-interest, providing potential extra investment from carbon financing and numerous policy co-benefits.

Recommendations

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

The key recommendation for Tanzania is to get ready and act now

The priority areas are set out below:

- Improving the estimates. Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. While there are recent studies which have started which will help address the gaps, a number of specific issues are highlighted.
    - There is a need to need to address the current economic costs of existing climate variability in Tanzania. One way to advance this might be through a more detailed economic study on current costs and how this affects GDP. This information could also be presented in a way that communicated the impacts on individual Government budget lines, to help mainstream actions to address the current adaptation deficit.
    - Good progress has been made on impacts (the 2009 Climate Impacts Assessment by government) and a recently started project on impacts and vulnerability. However, A broader consideration of additional risks not yet covered, e.g. within existing sectors (such as assessing additional health risks beyond malaria), and sectors not yet covered (e.g. tourism and industry), as well as a much greater focus on cross-sectoral issues and indirect effects.
    - 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, as well as on the links with climate change impacts. This would also be extremely beneficial in the context of emerging mechanisms. This could lead to a set of priority measure (e.g. a ten step plan) for low carbon options.
    - For both adaptation and low carbon growth, analysis of the costs and benefits, including to government, the sector and individuals. This step could 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. A key focus here is to consider adaptation and low carbon issues together.
    - Further work should also be undertaken on the potential macroeconomic and distributional (equity) effects of impacts, adaptation and low carbon policies, and more detailed assessment of the costs and benefits to different sectors / stakeholders.
    - Taken together, this analysis could form the basis of an expanded national climate strategy (see below) 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 Tanzania, which include but go well beyond those identified in the NAPA. This includes a focus on early no regret options, but also fast-tracked monitoring, forecasting and information provision (as these underpin future prediction and analysis), strengthening early warning systems and disaster risk management (including post-disaster coping mechanisms) and sectoral focal points and cross Government collaboration. There is also a need for sector priorities to be identified.
- Building Capacity. Access to substantial adaptation funds must be assured. However, mechanisms, institutions and governance systems for effective use must be developed to allow Tanzania to access these funds. Similarly, there are issues on further enhancing low carbon capacity, which will be key to the development of future plans. For both of these, there is a need to build capacity across all sectors, not just

in key Ministries. This requires early and concerted action to build capacity across all stakeholders, with additional people, resources, research, training and expanded and new institutions. Related to this there is a need to address technology needs and transfer, building on the recent work that government has completed.

- Risk screening for both climate resilient and low carbon growth. There are already plans in Government to mainstream climate change, and this reflects the need to build future climate change risk screening into all development and planning, at a sectoral and regional level. This recognises that there are many benefits if Tanzania switches to a more sustainable and lower carbon growth 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. Similarly, there is a need to further consider and adapt to climate change, looking not just at the project level, but up to the macro-economic level. Specifically, i) climate resilient and low carbon plans should cut across all sectors and mainstreamed into sector plans (noting actions are already underway to start this within Government), ii) areas of development that increase future threats to climate change, but also future mechanisms or obligations in future years, should be identified, iii) linkages between adaptation and low carbon development (especially in relation to opportunities for finance) should be further 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 could lead to a new strategic vision for Tanzania that addresses these areas, for example, with further development of the Vision 2025 document, as well as supporting intermediate indicators and targets.

- 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. Given the many trans-boundary impacts of climate change, the need for international co-operation to address these, and the potential for regional opportunities, this is a key area. There is also a need to examine the potential international dimension of climate change and how this might affect Tanzania.

The areas above would provide national action on a low-carbon, climate resilience investment plan and help Tanzania in negotiations and securing finance.

In terms of translating these into concrete action, a number of specific next steps are recommended:

1. For Tanzania to produce and implement a National Climate Change Strategy, explicitly considering and linking adaptation (climate resilience) and low carbon growth opportunities. The Government of the URT produced an initial National Climate Change Action Plan in 2009. This could be further elaborated into a major National Climate Change Strategy, which includes climate resilient (adaptation) and sustainable / low carbon growth. This should also include emerging issues such as the NAMAs (Nationally Appropriate Mitigation Actions). Putting this in an integrated strategy will encourage synergies and reduce conflicts. The inclusion of the economics (and the costs and benefits) in this strategy will also ensure that Tanzania is well placed to take advantage of opportunities from emerging negotiation discussions. There are already plans for a Climate Change Strategy and Action plan within Government, and ensuring this is taken forward with appropriate resources, is the key priority over the coming year.

2. Such a national strategy should also be linked to sectoral objectives, with effective mechanisms for implementation, monitoring, reporting and verification. This would build on the existing plans in Government to mainstream climate change and would help implement the national strategy, but will require co-ordination and integration.

3. To integrate climate change – and opportunities – into the strategic vision. As well as the step above, Tanzania should go further and start building climate change (resilience and low carbon) into longer-term strategy, including in any revision of the Vision document, and intermediate objectives and policies.

4. To undertake a capacity needs assessment and implement this. To support all of the priority areas above, there is an urgent need to build capacity, with mechanisms, institutions and governance systems, etc. A key way forward would be to undertake a capacity need assessment, and develop (and implement) a plan.

5. To fast track the implementation of a major case study. Finally, early practical examples will help build confidence. Domestically there is a need to demonstrate the benefits of such policies. Internationally, there is a need to demonstrate the investment environment in Tanzania. There would be major benefits in an early implementation study, to fast track and demonstrate the benefits of climate resilience and low carbon

growth. One way to progress this might be through a sub-national level: for example, a suitable pilot area might be to implement a low carbon – climate resilience strategy for Zanzibar.

A summary of the key steps for adaptation and sustainable / low carbon growth are presented below.

Adaptation	Recommended Actions
Immediate needs and capacity building	• Early capacity building (institutions and organisations). • Early warning systems, meteorological capability, and post-disaster coping mechanisms. • Enhanced monitoring of key impacts. • Expanded research into impacts, adaptation and economics. • Extend national climate change plans into major national climate change strategy, including analysis of costs and investment plans. • Extension of existing screening of sector and regional plans for climate risks and adaptation opportunities, including in national policy and into long-term vision (Vision 2025). • Build on existing national adaptation authority, expanding capacity and looking to enhance sectoral co-ordination, link to international finance and support private sector. • Enhance links between adaptation and low carbon development.
Climate resilience	• Climate resilient strategies, objectives and targets for immediate concerns. • Screening for new projects, policies and programmes. • Develop prototypes of sectoral actions and demonstrate with pilot, to allow later scaling up.
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 and to reduce climate risks, and opportunities to develop adaptive capacity. • Scale up successful prototypes to sectoral development plans.

Low Carbon	Recommended Actions
Low-carbon growth	• Full analysis of baseline projections, low carbon options, resilience to climate change, costs and prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream low carbon investment in planning. Build into long-term vision (e.g. Vision 2025), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets and in REDD. • Prioritize forestry, 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. • Conduct an early study, to fast track and demonstrate the benefits and financing possible from such a strategy at a sub-national level: an example of a suitable pilot area might be to undertake a study for Zanzibar.
Climate resilience and co-benefits	• Climate risk screening of low carbon growth pathways. • Consideration of energy demand (cooling) and supply (hydro, fossil stations) effects from climate change, with associated adaptation (diversity, demand management). • Analysis of potential impacts of climate change on forestry (REDD), research into ecosystem shift, and introduction of monitoring and move towards early adaptation. • 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.

Table of Contents

1. Introduction, Objectives and Method 1
   1.1 Background, Aims and Objectives 1
   1.2 Methods 1
   1.3 Study team, Local Governance and Partnerships 3
2. The Economic Costs of Current Climate Variability in Tanzania 3
   2.1 Background 3
3. Projections of Climate Change for Tanzania 6
   3.1 Existing climate 6
   3.2 Climate Change Projections 7
   3.3 Socio-economic projections 13
4. Aggregated Estimates of the Economic Costs of Future Climate Change in Tanzania 17
   4.1 Background 17
   4.2 Results 17
5. Review of Sectoral Impacts and Economic Costs 20
   5.1 Coastal zones 20
   5.4 Agriculture and Livestock 26
   5.2. Health 33
   5.3 Energy 37
   5.5. Water Sector 46
   5.6 Forests, Biodiversity and Ecosystem Services 48
   5.7 Summary of Sectoral Analysis 55
6. Aggregated Estimates of Adaptation to Climate Change in Tanzania 57
   6.1 Background 57
   6.2 Top down analysis of Adaptation 58
   6.3 Discussion of Adaptation and Uncertainty 60
7. Sector Estimates of Adaptation to Climate Change in Tanzania 63
   7.1 Coastal Zones 63
   7.4 Agriculture 70
   7.2 Health 75
   7.3 Energy 79
   7.5 Water 81
   7.6 Forestry, Biodiversity and Ecosystem Services 83
   7.8 Summary 87
8. Sustainable Growth and Low Carbon Opportunities in Tanzania 90
   8.1 Introduction 90
   8.2 Future emission projections 92
   8.3 Low Carbon Options 94
   8.4 Economic Benefits of Sustainable / Low Carbon Options 101
   8.5 Challenges to Accessing Carbon Financing 104
   8.6 Linking low carbon and climate resilient growth 108
   8.7 Conclusions and Recommendations 109

References 113

Project Description and Project Team 118

1. Introduction, Objectives and Method

The development partners group, with support from the UK (UK Aid for the Department for International Development, DFID) have funded this study on the '*Economics of Climate Change in the United Republic of Tanzania'*.

The work has been led by the Global Climate Adaptation Partnership, together with the Stockholm Environment Institute, working with other international and local partners, and has assessed the impacts and economics costs of climate change, the costs and benefits of adaptation and pathways of low carbon growth for Tanzania. This follows on from similar studies in East Africa [2].

1.1 Background, Aims and Objectives

The key aims of the study were:

- To assess the impacts and economic costs of climate change for Tanzania, 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;
- To assess the potential for low carbon growth;
- To build national capacity and take advantage of local knowledge;
- To use the results to enhance the evidence base to inform and guide the negotiation position;
- To inform decision-making at domestic, regional and international level on the economics of climate change in Tanzania, 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 has a focus to help stimulate the government, private sector and civil society debate actions on the development and implementation of policies to adapt to and mitigate climate change.

This document – the final report from the study – summarises the findings of the project.

1.2 Methods

The study had a number of different objectives, each aimed towards different potential stakeholders. The information needed to meet these objectives includes 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. However, at the same time, data and information was needed to help inform national, regional and even local priorities. Tackling all of these aims in a single study is challenging, therefore, the study adopted a multi-level approach, using different aggregation levels to 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 sector by sector impact assessment at national level using a more bottom-up assessment, as well as a national low carbon analysis. The third was a series of sub-national-local case studies on vulnerability and adaptation and low carbon growth. 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.

[2] The study follows on from part of a larger East Africa regional study. The project has also benefited from related economics of climate change projects including the AdaptCost project (funded by UNEP) which is assessing adaptation costs at the African scale.

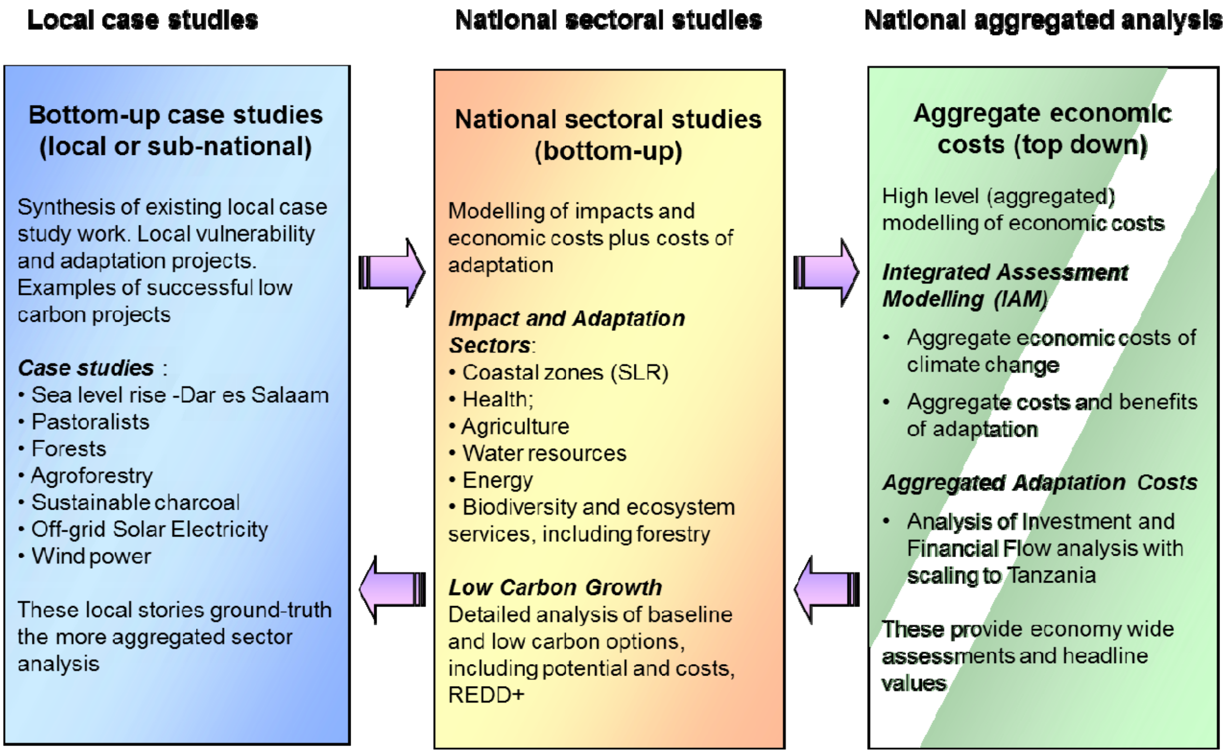


Figure 1. Overview of the lines of evidence.

The information across the three levels provides outputs for different aggregation levels and objectives.

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.

The combined evidence across the framework provides a view of the economic costs of climate change impacts and adaptation in Tanzania.

The analysis provides high level information for policy as well as useful outputs for setting national and sectoral priorities and action plans.

The methods for economic assessment, especially for adaptation, are still evolving. There are very few detailed assessments 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.

1.3 Study team, Local Governance and Partnerships

The team assembled for the study includes a number of international experts on impacts, adaptation and low carbon growth. It also includes a collaborative partnership approach with local teams, working with a large number of expert teams in–country, from a selection of universities and organisations. A full team description is included at the end of the document.

The study emphasises national ownership through the inclusion of national organisations and consultation. The study was presented at a number of events in country during the period, with an official study kick-off, interim result presentations and a final study consultation meeting, before the final launch. This ensured that stakeholders were identified, consulted and informed, with the duel objectives of building national capacity and taking advantage of local knowledge.

The study has emphasised national ownership by the discussion of approach and results in workshops and meetings with various Ministries in the United Republic of Tanzania.

2. The Economic Costs of Current Climate Variability in Tanzania

2.1 Background

Tanzania – as with all of East Africa - is affected by current climatic variability and periodic extremes, with serious floods and prolonged drought, associated primarily with El Niño – Southern Oscillation (ENSO) events.

These extreme events have dramatic impacts on infrastructure, the built environment and the economy. They cut across key sectors including agriculture, industrial processing, manufacturing, tourism, infrastructure, and health. These have large impacts and high economic costs.

The study has undertaken a review and analysis of the current economic statistics (GDP) of Tanzania and the implications of the current climate variability, especially from major floods and droughts[3] on the economy.

There were major droughts in Tanzania in 1996-97, 1999-2000, and a very severe drought in 2005/2006.

- The (La-Niña) event of 1996/97 was responsible for the severe drought that occurred in most parts of Tanzania leading to insufficient rainfall for hydroelectric power generation and urban water supplies. Crop failure was widespread and rangelands could not support livestock resulting in large production shortfalls. In 1997, growth dropped to 3.3% from the previous year's 4.2%, attributed mainly to electricity shortages and load shedding arising from reduced hydro-electricity (World Bank, 2004).
- The drought of 2005/2006 affected most parts of the country, triggering food shortages and a power crisis, and reducing economic growth (relative to projections). In 2005 the agricultural sector grew by only 5.2% compared to 5.8% growth in 2004. This was attributed to the severe drought that affected most parts of the country, triggering food shortage and power crisis (URT, 2005). Another estimate reports that this major drought was estimated to have cut GDP growth by 1 % in 2006 (ECA, 2009).

There have also been severe floods of 1997/1998, as well as major episodes in 2000/01 and recent flooding in Kilosa in 2009.

- The 1997/98 El Niño, for example, resulted in cereal deficit of almost 1 million tonnes in Tanzania, leading to a national food crisis. The livestock sector also underwent severe losses due to increased disease infection, drowning, damaged water facilities (dams, boreholes, water troughs), and disruptions in market infrastructure and road systems (Kandji et. al., 2006), though in some marginal agriculturally areas, the additional rainfall led to higher production.

[3] Note that there are complex definitions of 'meteorological drought' – the wording is used in this section in general terms. Note that the effects of droughts on GDP are complex. While in general, drought periods reduce GDP, events can be regional or temporal, and this can influence the degree of impact, as well as many other confounding effects.

- The EMDAT database (EMDAT, 2008) reports that the floods in early 2007 in Tanzania were widespread (Kigoma, Tabora, Rukwa, Shinyanga. Nzega, Kishapu, Shinyanga Rural, Mwanza and Tanga. Hanang and Babati Districts) leading to major damage and displacement.
- The restoration costs of infrastructural losses from the (2009) flooding in Kilosa have been estimated at 200 billion Tanzanian shillings, around 0.02% of the 2009 GDP for Tanzania (Munishi et al 2010)).
- There are also additional costs from these events in terms of disaster response, for example, information from the International Federation of the red cross &red crescent societies (IFRC, 2010) indicates large IFRC and donor funding to address the events of 2006 drought and 2010 flood.

The estimates above show that current climate variability has macro-economic impacts in Tanzania, i.e. which are measurable in terms of GDP.

The reasons for this are explained by the economic structure of the country, which remains heavily dependent on rain fed agriculture - the sector contributing around 27% to GDP, around 30% of exports, as well as 65% of raw materials for domestic industry. A key issue is the high importance of food crops (65% of agricultural GDP). These agricultural activities are very climate-sensitive activities. Historically the country was also heavily dependent on hydro-generation for electricity (almost entirely so before 2003) which led to major supply issues in drought years.

The impacts of droughts shock on GDP has been highlighted as a particular issue for Sub-Saharan Africa (see Benson and Clay, 1998) and for neighbouring Kenya (Mogaka et al 2006) and the EAC (GTZ, 2009), indicating individual major drought years have economic costs that can be very significant (e.g. 5% of GDP) and that combined effects of floods and droughts over the long term have been estimated to cost the Kenyan economy annually 2.4 percent of GDP. The estimates above for Tanzania, which indicate major drought years reduce GDP by 1% or so, are therefore considered a possible underestimate.

These annual events impact negatively on growth and output, as well as affecting millions of livelihoods. The continued burden of these events over time leads to large economic costs and reduces long-term growth. Moreover, the full economic costs (including non-market sectors) of these events are likely to be even higher than reported.

As well as affecting sectoral output, these events have macro-economic consequences through price changes, diversion of resources for rebuilding, etc. These long-term effects maybe even greater than the immediate effects of events, and may lead to wider issues, for example comparative investment in relation to other countries.

For individuals, these events can be catastrophic, from the effects of individual events (on homes, assets and livelihoods), or from the cumulative effects over time, and consequential effects on assets, investment, health and education (especially for children), etc. These effects therefore will have major impacts on the achievement of the Vision 2025 objectives, and the growth trajectories for the country.

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 trends in the costs 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 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 Tanzania it is not adequately adapted to deal with existing climate risks.

While this provides a key finding, the study has found there is little comprehensive information or systematic documentation and publication of these existing impacts. This is required to build up a knowledge base of how much damage is occurring and where. Current national annual statistical summaries need to incorporate the information which will contribute to the monitoring of current climate variability, noting this information is key for national communications to the Framework Convention on Climate Change, and other actions including emerging adaptation financing.

Conclusion and Recommendations

Current climate variability already has macro-economic impacts, i.e. which are measurable in terms of GDP. The reasons for this are explained by the economic structure of the country, which remains heavily dependent on agriculture. While the importance of disaster risk reduction is being recognised and plans are being introduced, the full economic implication of current climate variability has not fully filtered across all of government, including at the highest level. This is important because Tanzania has the potential to improve economic growth by reducing the current adaptation deficit – and the continued (compound) increase in growth from doing this would be very significant.

This leads to an initial recommendation. There is still a need to address the current economic costs of climate variability in Tanzania. One way to advance this might be through a more detailed study of the current costs of climate variability, and an assessment of how this affects GDP. This information could also be presented in a way that communicated the impacts on individual budget lines and ministries. This would help mainstream actions to address the current climate variability and adaptation deficit.

Existing climate variability has significant economic costs in Tanzania. The periodic droughts and floods lead to large economic costs, with major annual events in excess of 1% of GDP. The cumulative effect of these events reduces long-term growth.

A key finding is that Tanzania is not adequately adapted to deal with existing climate risks. Further work is needed to build up a more systematic analysis of current costs.

3. Projections of Climate Change for Tanzania

The study has considered the current climate of Tanzania, as well as future projections of climate change. A full technical report is available on this work[4]. This section summarises the analysis and findings.

3.1 Existing climate

Tanzania has a complex existing climate, with wide variations across the country and very strong seasonality. The country extends from the Indian Ocean coastline to more than 1000 km inland, and the topography ranges from sea level to over 1,600m altitude in the west, with much of the country above 1000m altitude with some areas above 1500m in the centre and north. The northern borders lie almost on the equator and this places Tanzania in the tropics: hence the climate is driven by tropical processes. However, the range of altitudes results in a significant climate gradient across the country. Average temperatures show strong differences between the coastal strip, interior and highlands (at altitude).

The tropical location also means that the seasonality is tied to the movement of the Inter-tropical Convergence Zone (ITCZ) which moves north and south during the year. The ITCZ often results in a double rain season which can be seen at a number of locations in Tanzania. This occurs as the ITCZ moves southwards at the beginning of summer and then northwards at the end of summer. Rainfall is associated with the shift in the ITCZ, hence an early summer and a late summer rainfall season. However, there are widespread regional variations of this effect, for example, the presence of Lake Tanganyika to the west and Lake Victoria to the north are sources of moisture to surrounding areas.

Tanzania experiences a mean annual rainfall varying from below 500 mm to over 2500 mm annually, largely depending on altitude and area. Rainfall patterns in the country are divided into: tropical zones, on the coast, where it is hot and humid (rainy season March-May): semi-temperate zones in the mountains and northern highland regions with the short rains (Vuli) in October-December and the long rains (Masika) in February –May: and drier zones (Kiangazi) in the plateau region with considerable seasonal variations in temperature, and includes semi-arid areas, as well as other regions which primarily experience a unimodal rainfall pattern whereby most of the seasonal rainfall is during the months of November to April.

Recognising this variation is important when considering subsequent impacts and adaptation responses. These variations are important for agro-ecological zones. The First National Communication (United Republic of Tanzania, 2003) reports that Tanzania has annual mean temperature ranging from a mean daily temperature of between 24ºC - 34ºC, but within the plateau, mean daily temperatures range between 21ºC - 24ºC and in the highland areas temperatures range from 15ºC - 20ºC. The ocean coastline strip (Jack, 2010) is warm and generally wet, for example with Dar es Salaam experiencing daily maximum temperatures ranging between 29°C and 32°C and a mean of over 1000 mm/year of rainfall. This is in contrast to Tabora in the centre which experiences average daily maximum temperatures that are slightly cooler, ranging from 27°C and 31°C, but with a mean annual rainfall of less than 500 mm/year[5].

The NAPA (URT, 2007) provides some early observational trends, reporting a steady increase in temperature for the past 30 years, the drop of water levels of Lakes Victoria, Tanganyika and Jipe in recent years and the dramatic recession of 7km of Lake Rukwa, and the loss of 80% of the glacier on Mount Kilimanjaro. It also reports that recently, rainfall pattern has become more unpredictable with some areas/zones receiving extremely minimum and maximum rainfall per year.

In addition, there are complex patterns of climate variability, which are due to many factors, notably the El Niño – Southern Oscillation (ENSO) events but also sea surface temperatures in the Indian (Indian Ocean Dipole). Although differences exist between the exact effects of El Niño on the north and the south of the country the

[4] Climate Projections for United Republic of Tanzania, by Chris Jack, of the Climate Systems Analysis Group, University of Cape Town, available at the web-site (http://economics-of-cc-in-tanzania.org/).
[5] Similar values reported in the NAPA, which highlights the Coastal Regions and the off-shore Islands have average temperatures ranges between 27 ºC and 29ºC, while in the Central, Northern and Western parts temperatures range between 20ºC and 30ºC and higher between the months of December and March. It also reports that in the Northeast and Southwest mountainous areas and Makonde Plateau and in some parts (Southern Highlands) the temperatures are lower.

broad pattern is increased rainfall during El Niño years and decreased rainfall during La Niña years, frequently leading to floods and droughts – see previous section. Flooding is particularly severe when an El Niño year occurs in combination with the positive phase of the Indian Ocean Dipole, as was the case for the major floods in the north of the country in 1997.

An analysis of 6 meteorological stations in Tanzania carried out by New et al (2006) as part of a larger assessment for Africa showed clear evidence of decreasing numbers of cold days and nights and a decrease in cold waves. There has also been an increase in the number of heat-waves, and in the frequency of hot nights. There has been an increase in the average intensity of rainfall, a small increase in the maximum number of consecutive wet days and a mall increase in the maximum number of consecutive dry days.

The analysis for this study (Jack, 2010) has also investigated current climate inter-annual variability. Observed climatologies of temperature show a normal seasonal cycle of temperature. Most locations have a fairly small seasonal temperature variation of around 3°C to 4°C which is not uncommon in tropical areas, though there are greater variations in the north. Much higher variability exists for rainfall, with high variability in monthly rainfall totals, especially in the rainy seasons with differences as high as 250mm/month between the 10th percentile and 90th percentile values.

3.2 Climate Change Projections

Tanzania will be affected significantly by future climate change. To understand these potential changes, it is necessary to consider the modelled projections of climate change. It is highlighted that such projections are uncertain.

The earlier US Country Studies Programme assessment of vulnerability and adaptation response options for Tanzania (1997), using Global Climate Change Scenarios, projected a rise in the mean daily temperature, on average, by 3ºC - 5ºC throughout the country, and a rise in the mean annual temperature on average by 2ºC - 4ºC. The study also reported a projected increase in rainfall in some parts of the country, but decreases in other parts: areas with a bimodal rainfall pattern were projected to have increased rainfall ranging from 5 percent to 45 percent, while areas receiving uni-modal rainfall reduced rainfall ranging from 5 to 15 percent. These results are also reported in the NAPA.

Other studies (OECD, 2003) investigate climate change scenarios across multiple general circulation models and report increases in country averaged mean temperatures of 1.3°C and 2.2°C projected by 2050 and 2100, which are broadly consistent, though lower than, in the Initial National Communication (URT, 2003).

This study has updated the climate change analysis, defining a set of climate projections for Tanzania using downscaled international data sets from the climate change explorer (CCE) at the Climate Systems Analysis Group (CSAG) (www.csag.uct.ac.za), based at the University of Cape Town (Jack, 2010). This system operates an empirical downscaled model for Africa and provides meteorological station level responses to global climate forcings across the African continent. It uses results from a number of global climate models (GCMs), revealing the differences in projections. This has the advantage of using a number of models. As all future data is unvalidated, the study has assumed that all models represent an equally likely response[6]. The study has developed climate projection envelopes which represent to the range of responses produced by the GCMs.

In practice, it is acknowledged that each GCM has a particular bias for a particular variable in a particular region. This bias can be significant in the case of precipitation. When developing future projections it is therefore important not to look at the raw GCM output fields only, but to also look at the anomalies between the GCM 20th century simulation and the future simulation. These anomalies are calculated for each GCM and represent the GCM response or delta given the GHG forcing. In the figures below both the absolute downscaled GCM projection envelopes and the anomaly envelopes are presented. The absolute values are still useful to show the GCM seasonality as well as the agreement between GCMs.

The resolving scale of GCMs has improved significantly in the last 10 years with many state of the art GCMs able to resolve at a scale of around 100km. The CMIP3 archive[7] of GCMs are typically of lower resolution than

[6] Note that while it is possible to focus on the GCM that best represents the region –a GCM that accurately simulates observed climate does not necessarily accurately respond to changes in GHGs

[7] Climate Model Intercomparison Project http://cmip-pcmdi.llnl.gov

100km with resolution ranging between 200km and 400km. These scales are too course for most users who are dealing with national issues such as water management and agriculture. To address this, the approach uses downscaling, based on the observation that local scale climate is largely a function of the large scale climate modified by some local forcing such as topography. There are two main types of downscaling, dynamical and empirical. Dynamical downscaling utilises a higher resolution, limited domain, dynamical model that follows the same principles as a GCM but because of the limited domain is able to be run at much higher spatial resolutions. Dynamical downscaling offers a physically based regional response to the large scale forcing. However it is complicated by similar problems to those of GCMs, namely bias and error.

Empirical downscaling utilises various statistical methods to approximate the regional scale response to the large scale forcing. Various methods have been developed. The method used for the projections below is called SOMD (Self Organising Map based Downscaling, Hewitson and Crane, 2006) developed at the University of Cape Town. The method generates a statistical distribution of observed responses to past large scale observed synoptic states. These distributions are then sampled based on the GCM generated synoptics in order to produce a time series of GCM downscaled daily values for the variable in question (e.g. temperature and rainfall). An advantage of this method is that the grid scale GCM precipitation and surface temperature are not used by the downscaling.

The CMIP3 archive GCMs are used in this study. The downscaling methodology requires daily archive fields which have limited the number of suitable GCMs that can be applied to Tanzania to a total of 9 out of a possible 21 in the archive.

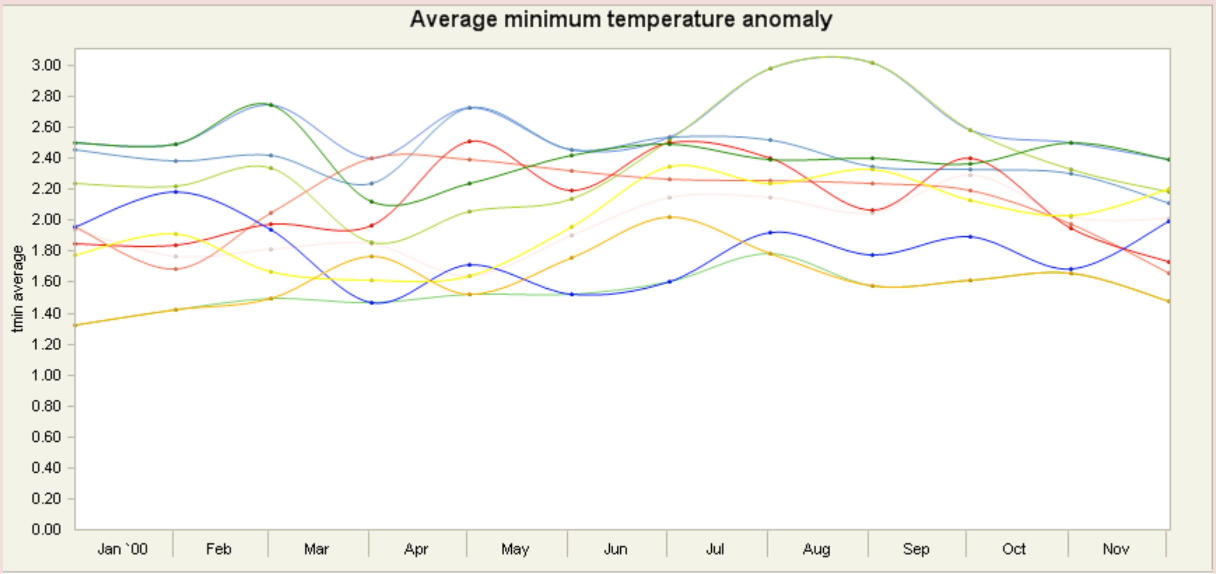
In each, the analysis has provided:

- A simulation of the 20th Century climate (1961 to 2000) forced by observed GHG concentrations. This simulation is the GCMs representation of the observed climate period. It is important to note that there is no correspondence between real years and the years of the 20th Century simulations. This means one can expect no likeness between a particular year in the 20th Century simulation and that year in the observational record.
- A number of simulations of future periods and GHG concentration scenarios. For this study the two future periods of 2046 – 2065 and 2081 – 2100 were selected, each assessed with two future emission scenarios of the IPCC (B1 and A2), reflecting a low and high emission projection.

Each GCM simulation was downscaled to a number of regional locations within Tanzania and various appropriate climatological summary statistics were produced. These are presented below in the form of climate projection envelopes. As mentioned above, projection envelopes capture the range of GCM responses to GHG forcing and represent the level of agreement or disagreement between the GCMs.

Example of how the climate projection envelopes are derived

For each of the six stations, the study has produced five projections for each model, the 20th century simulation (1961-1990) and then two projections for the period 2045-2065 (for the A2 and B1 emission scenarios) and the period 2081 – 2100 (again for two emission scenarios). The statistical downscaling has been undertaken with nine GCMs. In each case, the study has considered the absolute projections, for example of temperature, but also the marginal change (the anomaly). For each projection period, the models are compared through the use of envelopes. An example is shown below for Arusha. The first graph plots the change (the increase) in average temperature over the months of the year, for the future period 2045-2065, showing each of the nine model outputs. This shows the wide range of projections with model and with time of year. A similar plot is included below for precipitation, which shows a much greater variation, with the models showing a range of positive and negative effects, but also strong variability in the change across months of the year.



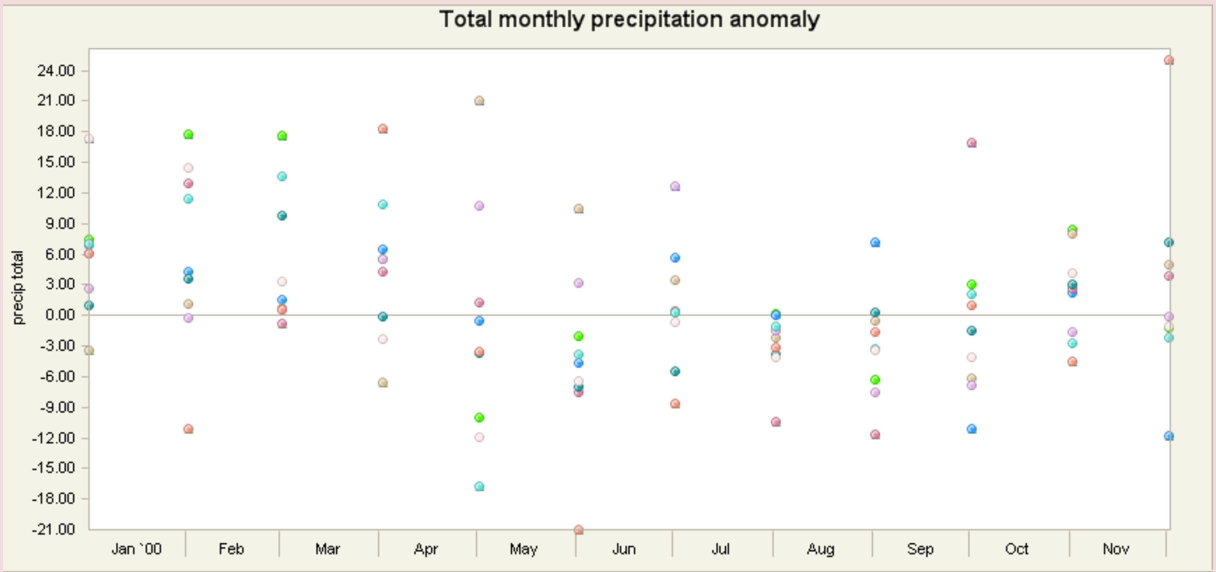


Figure 2. Projected changes in monthly average minimum temperature (top) and monthly average precipitation (bottom) across 9 GCM models for period 2045-2065 (A2), statistically downscaled. Climate Change Explorer tool, Climate Systems Analysis Group and SEI, 2010. station Arusha.

Temperature

All 9 models used agree that minimum and maximum temperatures are expected to increase, although the size of the change varies, including across regions. For the period 2046-2065, average annual temperatures are broadly expected to increase in the range of 1°C to 3°C (with very indicative ranges of 1 – 2°C for the B1 scenario and 2 - 3°C for the A2), though there are variations by region and time of year. For the end of the century (2081-2100), average temperatures are broadly expected to increase in the range of 1.5°C to 3°C for the lower emission B1 scenarios and 3°C to 5°C for the higher emission A2 scenario.

The results are shown in the Figure below, reporting the A2 scenario for the period 2046-2065 for monthly mean maximum temperature. In each case, the top box shows the absolute projections, with the grey envelope showing the current modelled climate and the pink envelope showing the future period. The bottom box shows the change from the (modelled) current climate in blue. The projections for the B1 and later periods are included in the technical report.

Precipitation

The pattern for precipitation is less clear. The climate models disagree over whether there will be an increase or a decrease in precipitation over most of Tanzania.

The results are shown in the Figure below, reporting the A2 scenario for the period 2046-2065 for monthly precipitation. In each case, the top box shows the absolute projections, with the grey envelope showing the current modelled climate and the red envelope showing the future period. The bottom box shows the change from the (modelled) current climate in blue. The projections for the B1 and later periods are included in the technical report.

The key finding is that in all cases the climate envelopes show very wide variation, that include both negative and positive changes (i.e. decreases and increases in rainfall). The changes also show wide variations with location and with season, especially between the bimodal rainfall regimes in the north and the uni-modal rainfall areas in central and southern.

Many of the models (but not all) project that precipitation may increase in the future, during the late part of summer, but with some very slight signs of drying during the early summer. Such changes are indicative of a seasonal shift with weaker early season rains and stronger later season rains. Many of the models (but again, not all) also show the potential for drying signals later in the year in southern and central regions, though potential increases at other times of year.

The model results highlight the considerable uncertainty in predicting future impacts and the need to consider multiple models, but also consider a robust approach of adaptation decision making. Even with model improvements, there will remain significant uncertainty – and new or more detailed model runs will not provide definitive answers in the near term.

Finally, the analysis has considered the potential changes in extreme events.

The information on extreme events (floods and droughts) is much more variable and future projections vary widely. El Niño will continue to have a large impact on inter-annual variability, though it is unclear how climate change will affect the frequency and magnitude of El Niño events, and thus what effect this will have in Tanzania.

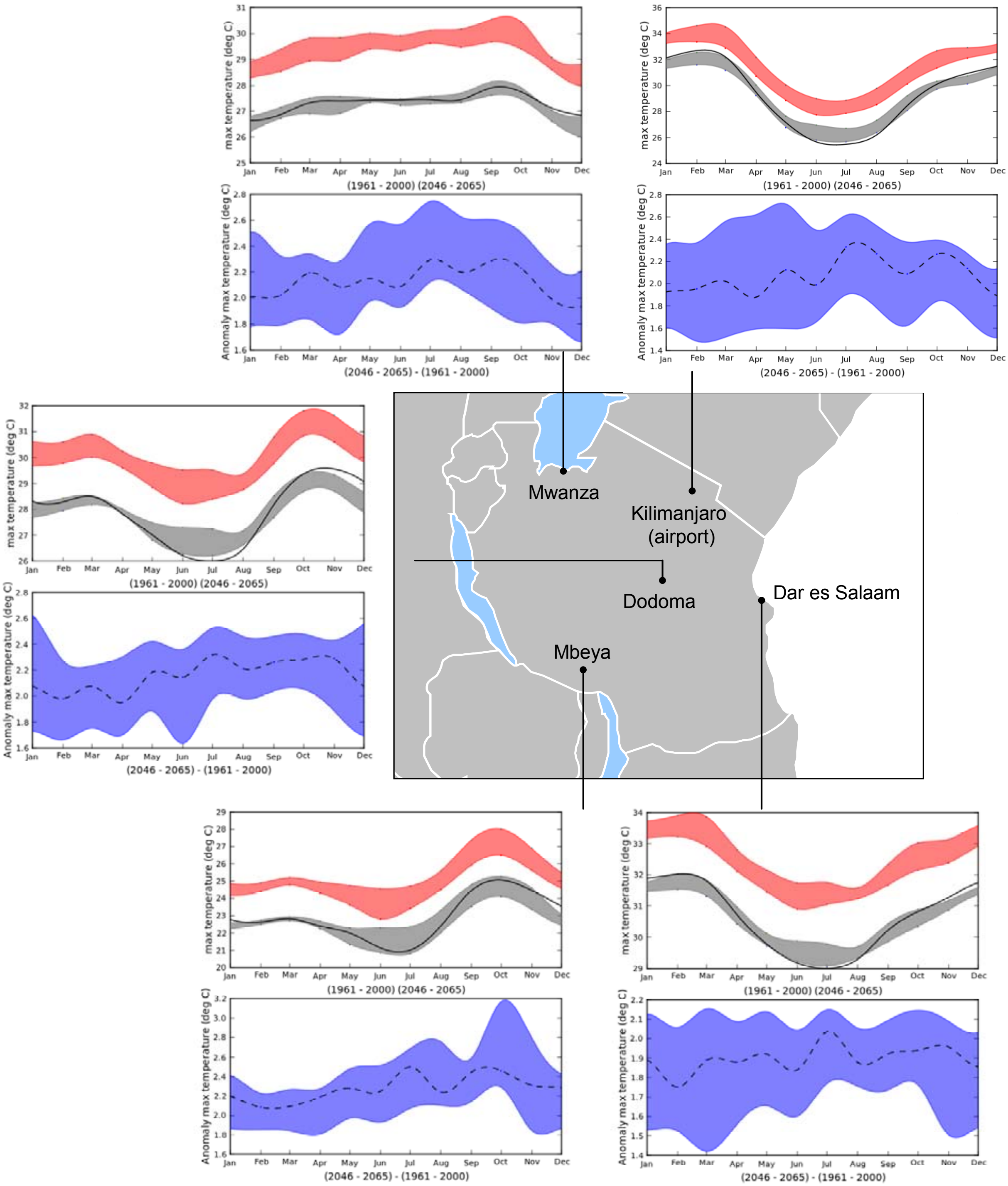


Figure 3. A2 Scenario, Projections and anomalies of monthly mean maximum temperature (2046 - 2065)

In the top box, the black line represents the multi-model median. The grey envelope represents the envelope of climate model projections for 20th century period. The pink/red envelope represents the future period (2046-2065 or 2081-2100). In the bottom box, the blue envelope shows the change (the anomaly) from current. Source CSAG.

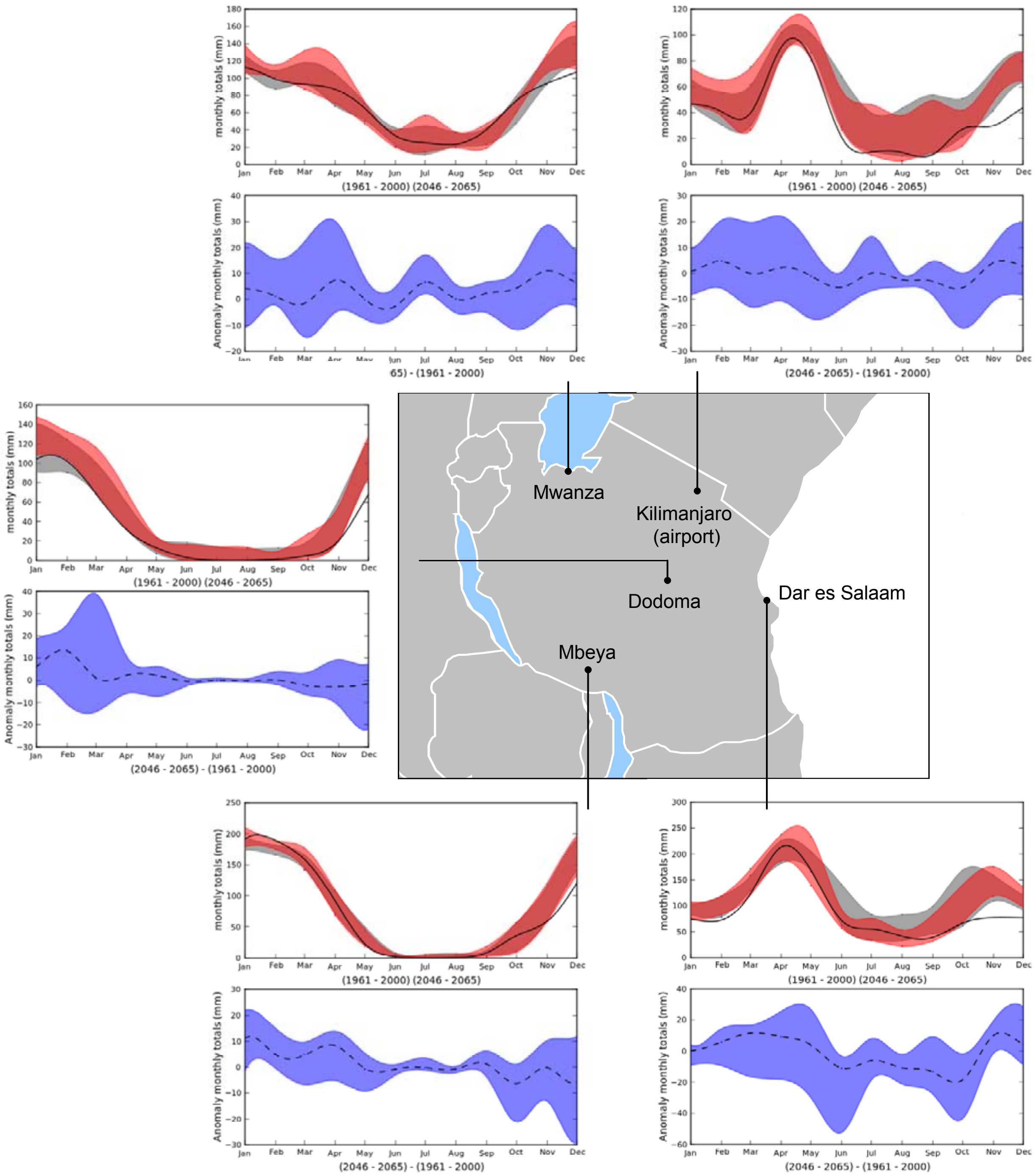


Figure 4. A2 Scenario, Projections and anomalies of monthly precipitation (2046 - 2065)

In the top box, the black line represents the multi-model median. The grey envelope represents the envelope of climate model projections for 20th century period. The red envelope represents the future period (2046-2065 or 2081-2100). In the bottom box, the blue envelope shows the change (the anomaly) from current.

Source CSAG.

A review of model projections for East Africa (Shongwe et al, 2009) looking at the longer term (where the climate signals are clearer) reveals that many models indicate the intensity and frequency of heavy rainfall extremes may increase in the wet seasons, particularly in some regions of Tanzania. This would imply greater flood risks.

The impact on drought events is more uncertain. Droughts are likely to continue but the projections are more varied - some models project an intensification of these events, particularly in some areas of Tanzania such as the south, though other models indicate reductions in severity.

The projections of future climate change in Tanzania 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 key conclusion is that the climate of 2030 (and beyond) is very unlikely to be the same as at present. It is essential to recognise this uncertainty, not to ignore it. There is a need to plan robust strategies to prepare for uncertain futures and not to use uncertainty as a reason for inaction.

3.3 Socio-economic projections

As well as the future change from climate change, the study has considered the potential effects of socio-economic change and development in Tanzania. This is important because the future economic costs of climate change are strongly influenced by socio-economic drivers, such as population growth, increased wealth, land-use change, etc. as these affect the potential size of future impacts. It is also stressed that even without future climate change, these socio-economic factors would increase some economic costs in the future, for example, by influencing the number of people and lost assets from floods, changes in land-use even if there was no future climate change.

Taking account of these future changes is difficult and adds uncertainty, but to ignore them assumes that future climate change in Tanzania will take place in a world identical to today. Previous studies show that these future socio-economic changes are often as important as climate change in determining future economic costs. Moreover, in many cases, future development will reduce vulnerability (and thus impacts), though in cases it will also increase it. While the range of possible changes is complex to incorporate in subsequent analysis, it is possible to at least quantitatively consider population and economic growth in subsequent impact assessment, and qualitatively consider other factors. These projections have also been taken account of in the low carbon analysis.

Population

One of the key factors facing Tanzania is population growth. Historic and projected population growth for Tanzania is shown in the figure below, split by rural and urban populations.

The population is forecast to grow significantly from just under 40 million currently[8], to 75 million by 2030, and 110 million by 2050 (Source: UN, 2010). This is due to a combination of birth rates and life expectancy. There is also a significant shift from a rural-dominated population to one with a large urban population (UN, 2007), i.e. rapid urbanisation, with the percentage of urban population rising to almost 40% by 2030 and over 50% by 2050. These rapid demographic changes will be important in future impacts, adaptation and emissions.

[8] The national bureau of statistics reports current (2009) population at 40.7 million for the Tanzanian mainland.

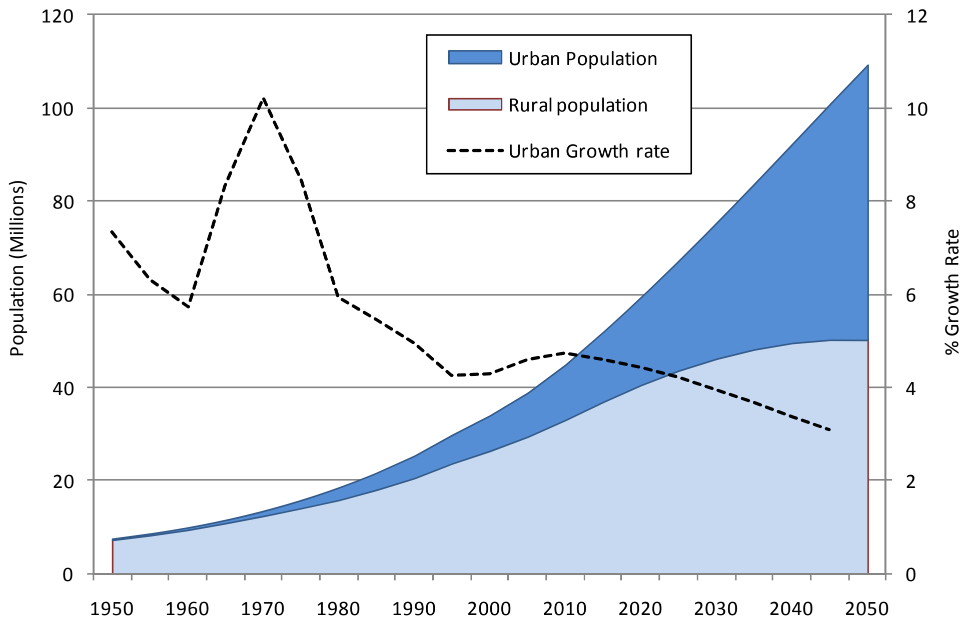


Figure 5. A2 Growth in population in Tanzania between 1950-2005 (historic) and 2005-2050 (projected)

Source: World Population Prospects, United Nations, 2010; UN, 2008: UN, 2007)[9]

The urban growth in Dar es Salaam is particularly high and is projected to increase from a population of 2.7 million (2005) to just over 5 million by 2020, and become a mega-city (a city with a population greater than 10 million) by 2040.

Of course urbanisation does have benefits, not least as providers of opportunities for employment and investment. However, rapid urbanisation puts pressure on social services, consumes energy, and in some cases can increase urban inequalities.

Economic growth, per capita income, and the Vision

The study has also looked at planned development and economic growth, consistent with the Tanzania Development Vision 2025 goals and other policies. The Vision 2025 (URT, 1999) sets out five areas:

- High quality livelihood.
- Peace, stability and unity.
- Good governance,
- A well-educated and learning society; and
- A competitive economy capable of producing sustainable growth and shared benefits

A number of these are particularly relevant to the study, outlined in the box below: These will significantly affect future socio-economic development and vulnerability to future climate change – also, climate change will potentially affect the achievement of these objectives detrimentally.

[9] UN (2010). Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp, Accessed April 27, 2010

High quality Livelihoods. A high quality livelihood for all Tanzanians is expected to be attained through strategies which ensure the realisation of the following goals:

- Food self-sufficiency and food security.
- Universal primary education, the eradication of illiteracy and the attainment of a level of tertiary education and training that is commensurate with a critical mass of high quality human resources required to effectively respond and master the development challenges at all levels.
- Gender equality and the empowerment of women in all socio-economic and political relations and cultures.
- Access to quality primary health care for all.
- Access to quality reproductive health services for all individuals of appropriate ages.
- Reduction in infant and maternal mortality rates by three-quarters of current levels.
- Universal access to safe water.
- Life expectancy comparable to the level attained by typical middle income countries.
- Absence of abject poverty

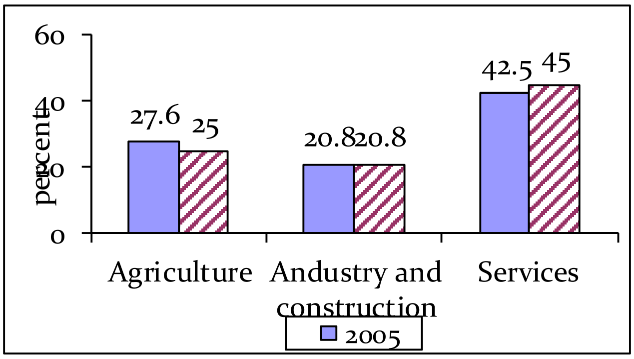
Strong and Competitive Economy, with the economy expected to have the following characteristics:

- A diversified and semi-industrialized economy with a substantial industrial sector comparable to typical middle-income countries.
- Macroeconomic stability manifested by a low inflation economy and basic macroeconomic balances.
- A growth rate of 8% per annum or more.
- An adequate level of physical infrastructure needed to cope with the requirements of the Vision in all sectors.
- An active and competitive player in the regional and world markets, with the capacity to articulate and promote national interests and to adjust quickly to regional and global market shifts.

[4]

The current share of major sectors to the economy is shown below. Similar values are reported in the detailed statistics of the National Economic Survey of Tanzania (URT, 2009). However, these estimates contrast with some other estimates, which indicate a higher share of agriculture.

In 2009, the GDP amounted to. 28,212,646 million Tanzania shilling at current prices, with per capita income of shs. 693,185 (Tanzanian mainland, National Economic Survey of Tanzania, URT, 2009). There are varying estimates of the $US equivalent – depending on whether rates are adjusted for market prices or purchasing power parity. The World Development Indicators (World Bank, 2010) reports current Tanzanian GDP at US$21.6 billion (2009), while the CIA handbook (CIA, 2010) reports at US $21.3 billion (official market exchange rates, and $57.6 billion when PPP adjusted). Per capita income is therefore an average of around $500 a year.



Shares of Major Sectors in GDP 2005 and 2009

Source: MOFEA (2010) Guidelines for the Preparation of Medium Term Plan and Budget Framework for 2010/11 –2012/13.

The economic growth rates anticipated in the Vision are very important in determining the level of future economic costs, future adaptive capacity, etc. The Vision anticipates a growth rate of 8% (annual GDP growth rate). Similar economic growth rates (8 – 10%) are also included in the recent National Strategy for Growth and Reduction of Poverty (NSGRP II or MKUKUTA II) (United Republic of Tanzania, 2010), which outlines an objective for GDP growth to be between 8-10% per annum by 2015[10]. These growth rates would increase the economy to around $100 million by 2030 (per capita income, taking into account population growth, of $1300 per person).

The aim is for the transformation of the economy from a predominantly agricultural one (as now) with low productivity to a diversified and semi-industrialized economy with a modern rural sector and high productivity in agricultural production which generates reasonably high incomes and ensures food security and food self-sufficiency. This will affect the likely vulnerability of the economy to climate, as it helps move the economy away from very climate sensitive sectors (agriculture).

The vision also anticipates the diversification of the economy will be based on a dynamic industrialization programme focused on local resource-based industries (agro-industries) and capable of meeting the needs of other sectors whilst continuously developing activities that have dynamic comparative advantages. Note that while this moves the economy to a greater industrial focus, this industry is likely to still be reliant on climate sensitive agriculture for primary resources.

The Mkukuta vision would reduce some climate impacts through sound development. However, population growth and increased infrastructure will continue to drive major climate costs. The impacts of future climate change are strongly related to development strategies chosen in the next five years.

[10] Munishi et al (2010) reports growth rates of 7.1% in 2007, 7.5% in 2008 and 8.9% in 2009, which indicates such rates are achievable (though note that while these rates are set out in the national policy objectives, there is no guarantee that they will be achieved over time).

4. Aggregated Estimates of the Economic Costs of Future Climate Change in Tanzania

The study has first used a number of aggregated integrated economic models, which can estimate the potential economic costs of climate change. These reflect a top-down analysis of the potential impacts to Tanzania.

4.1 Background

There are relatively few estimates of the economic costs of climate change, and the costs and benefits of adaptation. Of the estimates that do exist, many derive from a set of aggregated economic models known as Integrated Assessment Models, or IAMs. These models provide a way to value the economic costs of climate change over time, at a global and continental scale (e.g. Africa), in a single iterative framework, and to look at the potential costs and benefits of adaptation. They are therefore an extremely important part of the overall evidence base on the economics of climate change.

The models combine the scientific and economic aspects of climate change within a single, iterative analytical framework. They typically include an energy/economy/emissions module, a climate module and an impact/valuation module. The models have an additional element where climate impacts feed back to the socio-economic module thereby linking emissions, climate modelling, climate change impacts and the economy. To make analysis of economic costs manageable, they use simplified analysis of climate projections - rather than full-scale climate models. The models do not undertake physical impact assessment per se, but instead link changes in climate to economic values, using relationships between climate change and economic damage. Some models (such as the PAGE model) use generic categories of damages to do this, working with the broad categories of market and non-market sectors. Other models (such as the FUND model) use reduced form equations that work at a sectoral level, so that economic costs are estimated for agriculture, human health, sea level rise, etc.

The results of these models from a large part of the economic evidence base on climate change. For example, they were used to provide the headline economic costs in the Stern review (2006), i.e. that '*BAU climate change will reduce welfare by an amount equivalent to a reduction in consumption per head of between 5 and 20%*'. They have also been used in recent economic studies on climate change in East Africa, including the related studies in Kenya and Rwanda (SEI, 2009). The study has applied similar approaches to investigate indicative headline estimates for Tanzania.

4.2 Results

The economics study has used top down economic modelling to estimate the headline effects of climate change in Tanzania. This has used two of the global economic integrated assessment models (IAMs). The study has worked with two of the leading global IAMs; the FUND and PAGE models.

The first finding from these model runs is that the relative economic costs (as a % of GDP) from climate change in Africa are generally 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 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 Tanzania and in relation to mitigation and adaptation. The first model, FUND (The Climate Framework for Uncertainty, Negotiation, and Distribution model), is an IAM which couples demographics, economy, technology, carbon cycle, climate, and climate change impacts. The FUND model runs commissioned estimates that climate change could lead to economic costs equivalent to 2.7% of GDP each year in Africa by 2025 (central value, including market and non-market sectors).

An additional more disaggregated version of the model has also been run, the FUND national model, with the results shown in the figure below[11] – with strong orange and red colours showing higher levels of equivalent

[11] This map was based on a FUND national model run commissioned by David Anthoff and outlined above. A separate report is available on the integrated assessment model runs.

GDP loss in 2030. This shows that the economic costs of climate change are likely to differ across countries in Africa.

The national FUND model estimates that climate change could lead to annual economic costs by 2030 that are equivalent to 1.5% of GDP each year in Tanzania (central value, including market and non-market sectors and aggregating positive and negative effects). Note that these values are derived from a self-consistent model analysis, thus they should not be applied to the GDP forecasts in the previous section[12], though with the current Vision growth rates assumed, they would imply economic costs of around $US1.5 billion a year by 2030 (2009 prices, undiscounted).

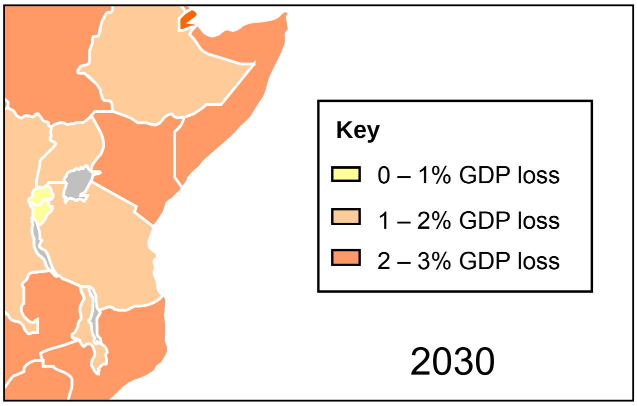


Figure 6. Potential Annual Economic Costs of Climate Change in East Africa as Equivalent % of GDP

Source: FUND national model for the DFID East Africa Economics of Climate Change Study

A second series of runs with another IAM model, PAGE2002[13], has investigated the aggregated costs of climate change in Africa for different scenarios, including the 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 below, with aggregated results for Africa. This shows that that there will be high economic costs even with adaptation. The model indicates broadly similar findings to the FUND model above, reporting values of 1.5% by 2040 (see below) for Africa under a baseline scenario of no mitigation.

An additional run has been undertaken with a stabilisation scenario, which has 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 under this scenario are manageable. This emphasises the need for global mitigation, as well as local adaptation. Note that economic costs – and adaptation needs - are fairly similar in early years in both scenarios, due to the change already locked into the system.

[12] The underlying economic costs in the model report net costs (the sum of positive and negative effects) at $266 million/year (US$1995 prices) in 2030 which based on the modelled GDP for Tanzania in the model ($18 billion in 2030, again in 1995 prices), is equivalent to 1.5% of GDP. It estimates that these the net economic costs of climate change will increase to $496 million by 2050, though these are still equivalent to approximately 1.5% of GDP, because of the increase in GDP over this period. It is not correct to take these modelled values and apply out of context to current and projected GDP from other sources, because the original model is built around a set of self-consistent economic assumptions and data, i.e. one should not apply the 1.5% GDP equivalent figure to the estimated GDP of Tanzania in 2030 (based on the Vision), noting that doing so would give a far higher number of $US1.6 billion per year (current prices, market exchange rates). Note Munishi et al, 2010 did apply the estimates above from the current study team to indicate the economic costs of climate change in Tanzania. It used the upper estimates above of 2% of GDP equivalent, and assumed that Tanzanian GDP rises from $20.5 billion in 2009 at an annual (continued) growth rate of 6.8% over future years. Based on these assumptions, it reported that the costs of climate change to Tanzania would be 1 billion in 2030 rising to 1.5 billion in 2050 (though there are some issues with the estimation of baseline GDP growth rate).
[13] This work was undertaken by Chris Hope, the developer of the PAGE model. A separate report is available on the integrated assessment model runs.

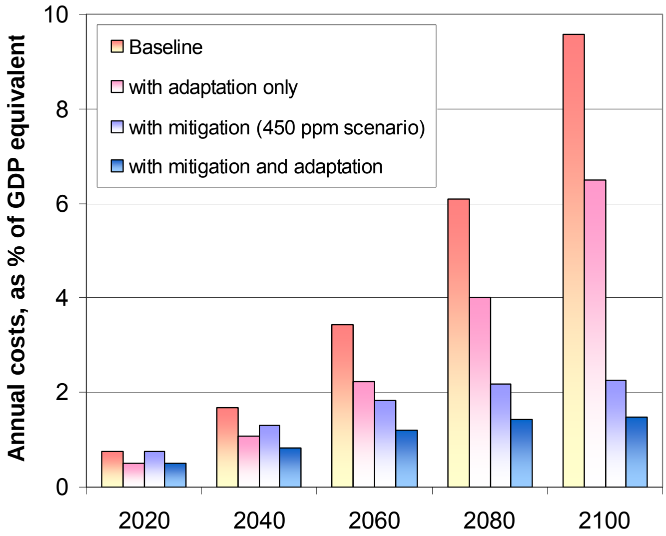


Figure 7. Annual Mean Economic Costs from Climate Change as a Faction of GDP in Africa**.** With mitigation and adaptation**.** (Source PAGE model)

These estimates are indicative only. They provide insights on signs, orders of magnitude, and patterns of effects. Note that the results are dependent 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).

The compound effects, year on year, from such a high level of economic costs would be very significant. It would reduce year on year growth rates, and would therefore prevent Tanzania from achieving key economic and development targets in the Vision and PRS. It would also mean a delay in the anticipated timetable for the country to achieve middle income status

While there is high uncertainty, the integrated assessment models indicate that the central economic costs of climate change could be equivalent to 1.5% of GDP <u>each year</u> by 2030 for Tanzania.

This would impact significantly on economic growth and development objectives, delaying or even preventing Tanzania's progress towards middle income status.

5. Review of Sectoral Impacts and Economic Costs

The study has also undertaken a sectoral analysis of the impacts and economic costs of climate change in Tanzania. The material is reported by sector below.

5.1 Coastal zones

Tanzania's mainland coastal area stretches for over 800km of coastline, rising to 3400 km when associated islands are included. The main coastal features include mangrove forests and swamps, estuaries, coral reefs, seagrass beds, inter-tidal flats, and sandy and muddy beaches. Overall, approximately 25% of the total population lives along the coastline (Torell et al., 2004) and the coastal population is growing. Tanzania has eight major coastal towns, with Dar es Salaam being the largest coastal city with highest population densities. These cities also significantly contribute to the regional and national economy and Dar es Salaam is an important port city.

The coastal zone varies from 20km to 70km in width, gradually rising to a plateau (Argawala et al., 2003). It supports significant economic activity associated with industry, agriculture, forestry and fisheries, and tourism and contains considerable infrastructure and assets. It contributes around one-third of Tanzania's GDP and 75% of the country's industries are in urban coastal areas. These coastal zones therefore contribute significantly to national wealth. They also provide much wider economic benefits through ecosystem services: coral reefs are an important resource (for tourism and fisheries); wetland habitats are important for the coastal fisheries industry; and mangroves provide physical protection against coastal erosion as well as providing resources for households.

Few if any of these coastal areas are prepared for the impacts of today's extreme events, let alone climate change, particularly sea-level rise. With a large and growing population in the coastal zone and a low adaptive capacity due to low national wealth and other development indicators, Tanzania is highly vulnerable to sea-level rise from climate change. Against this background, the study has undertaken a detailed analysis of the impacts of climate change on coastal zones. A full technical report is available on this work[14]. This section summarises the analysis and findings.

The Key Risks from Climate Change and other drivers

Sea-level rise, in combination with changes in the frequency / intensity of extreme weather events is expected to increase the flooding and inundation of coastal areas. There are potential threats to coastal environments and ecosystems including low-lying coastal plains, islands, beaches, mangroves, coastal wetlands and estuaries. There are also potential threats to infrastructure, transportation, agriculture and water resources within the coastal zone, as well as tourism and provisioning services (fishing, aquaculture and agriculture).

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 higher extreme water levels leading to coastal flooding with increased damage (Nicholls et al., 2007). Potential indirect impacts include altered functions of coastal ecosystems and impacts on human activities. Human-induced pressures on the coastal zone (e.g. rising population, water abstraction, etc.) are also likely to exacerbate the effects of sea-level rise – though these would also even in the absence of climate change.

The magnitude of sea-level change impacts will vary from place-to-place depending on topography, geology, natural land movements and any human activity which contributes to changes in water levels or sediment availability. The potential impacts are uneven, and are likely to affect the most vulnerable, due to multiple stresses and their lower ability to prepare, adapt and respond.

However, there are other factors that are important in determining future impacts. Even without climate-induced sea-level rise, there are some damages and costs that will increase, due to the growing population, population

[14] The Implications of Climate Change and Sea-Level Rise in Tanzania: The Coastal Zones by Abiy S. Kebede, Sally Brown and Robert J. Nicholls of the School of Civil Engineering and the Environment, University of Southampton, Southampton, UK, available at the web-site (http://economics-of-cc-in-tanzania.org/).

density, and GDP in vulnerable areas (see earlier socio-economic sector). For many coastal impacts, these drivers have the potential to lead to increases in damages that are at least as large, and potentially larger, than from climate change. An important aspect is therefore to consider the combined effects of climate and socio-economic change together (noting that climate change is only responsible for the marginal change above the future scenario of socio-economic change).

Finally, any changes from climate change have to be seen against a background of the decline in natural resources and biodiversity, evidenced by deteriorating conditions of coral reefs (including from destructive fishing methods), and continuing reduction in the area of mangroves and coastal forests. This degradation is attributed to unsustainable use of coastal resources as well as pressures from the growing coastal population and development.

Previous studies in Tanzania

Previous studies (Mwaipopo, 2000), have estimated that in Tanga, in the northeast region of the country, around 3500 hectares of land area (and 1000 hectares of mangroves) would be at risk from 0.5m of sea-level rise, as well as 3300 hectares of total land area (and 1800 of seasonal swamps) in the Bagamoyo area, as well as about 2800 hectares of mangroves in the Mtwara area. With a 1m sea-level rise, it is estimated that 9 km^2 and 2,100 km^2 land could be lost due to erosion and inundation respectively. Dar es Salaam and the islands of Zanzibar and Pemba have the highest population densities that might be threatened due to climate change and sea-level rise, and Dar es Salaam has been the subject of several studies (see the case study box below). However, while the country appears to be one of the African countries most at risk of the impacts of climate change and sea-level rise, the literature appears very limited, indicating the need for further work.

Analysis

Coasts are one of the more studied areas of climate impacts and it is possible to assess indicative economic costs. The study considered the potential effects of sea-level rise using the DIVA (Dynamic Interactive Vulnerability Assessment) model (Hinkel, 2005; Vafeidis et al., 2008; Hinkel and Klein, 2009; http://diva-model.net), a coastal integrated assessment model that assesses biophysical and socio-economic impact. The study was based on selected climate (*i.e.*, sea-level rise) and socio-economic (*i.e.*, population and GDP) scenarios. Impacts were determined with and without adaptation, so that the benefits and costs of protection could be considered.

A range of scenarios were explored, with three scenarios from the IPCC, plus a fourth based on more recent literature, reporting an upper bound. This leads to a global rise of 0.17m up to 1.26m from 1995 to 2100, based on a continent level analysis. The scenarios are shown below. Note that for more detailed analysis in the future, further adjustments are needed to take account of local conditions (local variations and local measurement data (see later discussion), subsidence, etc.).

These changes in sea level 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). These include the rapid population growth in the country, as well as per capita GDP increases. The impacts were assessed in the years 2000, 2025, 2030, 2050 and 2075.

- The damages in physical terms, including total land loss (due to erosion and submergence), people actually flooded, and cumulative forced migration (since 2000),
- The loss of wetland value (monetary): comprising monetary values of coastal forest, low un-vegetated wetland, and mangroves in Tanzania,
- The total damage costs (in monetary terms) including land loss costs, forced migration costs, salinisation costs, sea flood costs, and river flood costs,

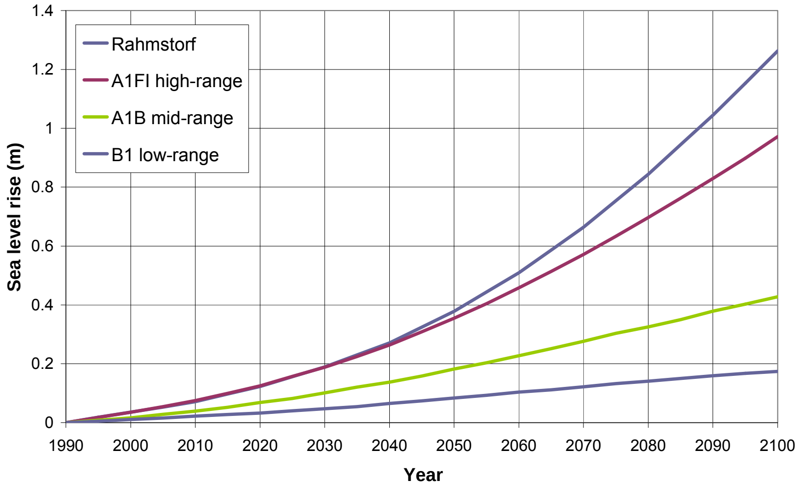


Figure 8. Sea Level Rise scenarios

Adaptation costs and benefits were also assessed (see later chapter). Note that all costs are presented in 2005 US$ and are not discounted.

Results

The analysis shows that without adaptation, the physical, human, and economic impacts of sea-level rise will be significant. The results are summarised below.

- Cumulative Area of Land lost. With no adaptation, the cumulative land loss (from submergence and erosion) is estimated in the range between 1924 and 7624km^2 in 2030, and ranging between 3884 and 8603km^2 by 2100 across all the scenarios. More than 99% of these damages are caused by submergence.
- Land loss due to erosion. With no adaptation 12 km^2 of land could be lost to erosion, rising up to 82km^2 land area by 2100.
- Land loss due to submergence. With no adaptation, the total land loss is estimated between 3576 and 7614km^2 in 2030, and increases between 7563 and 8522km^2 in 2100 across the sea-level rise scenarios. For a reference scenario of no climate-induced sea-level rise, a total land loss of 1924km^2 in 2030 is projected. This highlights that impacts could be significant even without climate change.
- People Actually Flooded. With no adaptation, the expected average number of people subjected to annual flooding, 0.3 to 1.6 million people will experience flooding at least once a year in 2030, rising to 1.0 to 2.1 million people per year by 2050. This is shown in the figure below. Even under the no climate-induced sea-level rise scenario, impacts are significant, and the number increases due to coastal development and local sea-level rise caused by subsidence from about 99,000 people per year in 2000 to over 234,000 people per year in 2030. Note that this occurs from sea level rise but also the underlying socio-economic factors (e.g. population) – which can be seen on the figure in the final column (no sea level rise).
- Forced migration. With no adaptation, it is assumed that if land is lost (due to submergence based on the area below the one year flooding level), then the people dwelling on the land will be forced to migrate. With 5cm–19cm global sea-level rise in 2030, between 67,000 to 852,000 people could be forced to migrate since 2000. In 2100, this could increase to 1.1 to 1.2 million people forced to migrate across the range of sea-level rise scenarios. Under the no climate-induced sea-level rise scenario, as high as 34,000 people in 2030 and over 506,000 people in 2100 will be forced to migrate since 2000.
- Wetland loss. Approximately 8% of Tanzania's wetland could disappear by 2050. The results confirm that without adaptation, the physical, human and economic impacts will be significant.

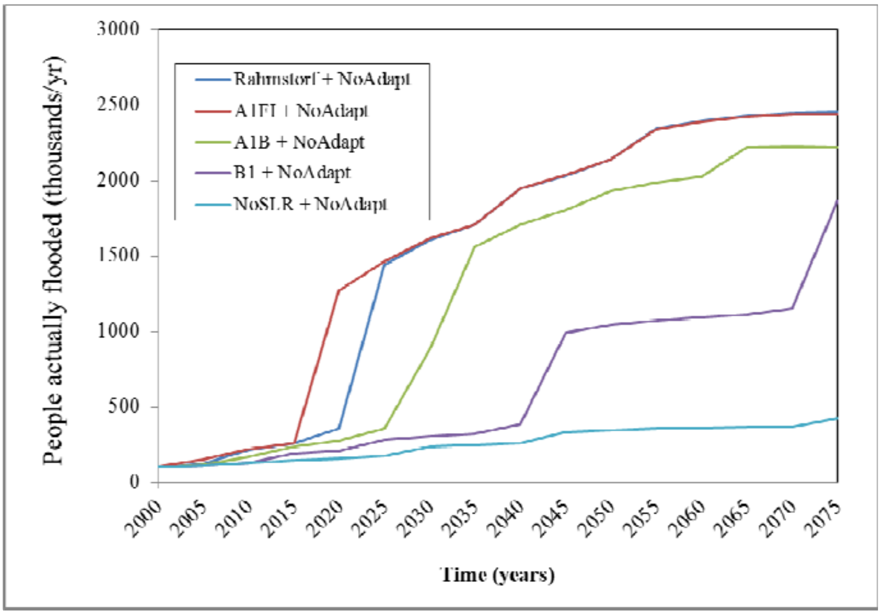


Figure 9. Number of estimated additional people flooded per year (from sea level rise and socio-economic change) - NO adaptation

The analysis has also estimated the total economic costs of sea-level rise, i.e. from land lost, salinisation costs, sea flood costs, coastal river flood costs and forced migration. It also includes the economic costs of loss of coastal wetlands (saltmarshes, mangroves, high and low unvegetated wetlands, mangrove areas and coastal forest areas).

Without adaptation, the total damage costs are estimated between US$26 and US$55 million per year in 2030 (2005 dollars, undiscounted) under the range of sea-level rise scenarios. These costs become greater with time as sea level rises, increasing to US$104 to $210 million/year by 2050 (2005 dollars, undiscounted) and US$408 and US$612 million per year in 2100. However, the analysis shows that Tanzania's coast faces important challenges even without climate-induced sea-level rise.

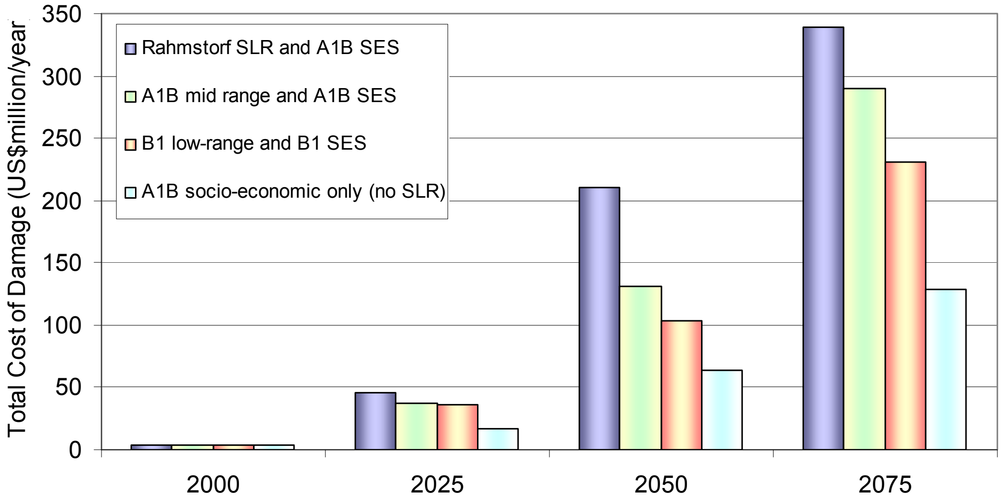


Figure 10. Total Costs of Damage - With No Adaptation
(includes the combined effects of sea level rise and socio-economic change)

To summarise, without adaptation the physical and economic impacts of sea-level rise are estimated to be high under all the scenarios. Even without climate-induced sea-level rise, there are some damages and costs due to natural and locally-induced subsidence and increase in population, population density, and GDP.

Sea level rise could lead to large impacts and economic costs on coastal zones in Tanzania, flooding large numbers of people. The economic costs are estimated to be $26 to 55 million per year by 2030, and rise to as much as $200 million per year by 2050s.

The estimates above are based on regional level analysis. The study has reviewed the monitoring data. The Tanzanian sea level network consists of two operational stations of Zanzibar and Dar es Salaam, and three historic non-operational tide gauges at Mtwara, Tanga and Pemba. The data indicates that the coast of Tanzania has experienced a drop in sea level over recent decades, though, it is stressed that trends of sea-level change obtained from tide gauge records of short durations (< 50 years) can have a significant bias due to inter-annual-to-decadal water level variability (for example, in Mombasa, located within the same region and with measurements approximately over same duration, a 1.1mm/year rising sea level trend is recorded). Therefore, the maintenance (and expansion) of sea level monitoring networks is a key priority. The current data does, however, imply stable or falling sea levels and potentially smaller than global average changes.

The above study, while providing key national level estimates, is still aggregated. Further work on understanding impacts, especially from current as well as future risks, and moving to actual adaptation planning, requires a higher level of resolution. To illustrate this, the study has undertaken a case study on the impacts of sea-level rise and extreme climates in Dar es Salaam, to complement the DIVA work above, summarised in the box below[15]. This raises key issues, not least in relation to the current Dar es Salaam development plan.

Case study. Sea Level Rise and the exposure of population and assets to coastal flooding in Dar es Salaam

The coastal city of Dar es Salaam is the largest city in Tanzania, and one of the largest international seaports in Eastern Africa (handling around 95% of Tanzania's international trade, as well as serving a number of land-locked countries further inland). It had over 2.5 million inhabitants in 2005, and probably well in excess of 3 million people (with some estimates towards 4 million). It has an important role in the national and regional economy. The city and nearby coastal towns have many low-lying areas and include significant population and infrastructure, as well as considerable economic activity (tourism, forestry and fishing, urban agriculture, mining and quarry, and manufacturing). All of these activities are vulnerable to sea level rise. Indeed, Dar es Salaam has been identified as one of the largest coastal cities in Africa highly at risk of sea-level rise (UN-HABITAT (2008). The high vulnerability is largely attributed to poor planning (about 70% unplanned settlement), poverty, and lack of infrastructure (e.g., poor storm water drainage systems).

The potential impacts of sea level rise will be exacerbated by socio-economic drivers as well, i.e. by the rapid and unplanned growth of the city, due urbanisation and coastward migration, and overburdened infrastructure. The current population density is shown in the figure below (left). Most of the city's growth has occurred along the central and northern part of the coastline with a great majority of the population living in unplanned and informal settlements. The Kisutu ward (in the Ilala district) has the highest coastal population density of over 26,000 people per km^2. The city is generally divided into four distinct landforms as upland plateau, inland alluvial plains, coastal plains and shoreline and beach. The coastal topography is shown in the figure below (right), which shows the contour lines (elevation above sea level).

The city has a history of flooding Casmiri (2008), with several areas prone to a combination of coastal or urban flooding. A number of informal settlements are often highly prone to flooding from a variety of mechanisms. Coastal erosion problems have also been reported along much of the mainland coast of the country and around the islands, and including stretches around the city. However, to date, Dar es Salaam has relatively little

[15] A separate report is available on the case study: Population and Assets Exposure to Coastal Flooding in Dar es Salaam (Tanzania): Vulnerability to Climate Extremes by Abiy S. Kebede and Robert J. Nicholls, University of Southampton, School of Civil Engineering and the Environment and Tyndall Centre for Climate Change Research. The full technical report is available at the web-site (http://economics-of-cc-in-tanzania.org/).

protection. Tourist facilities – hotels and roads are partly protected from erosion by groynes and a sea-wall, however, there is a need for much greater protection to address current risks.

A number of previous studies have considered the potential impacts of SLR (Mwaipopo, 2000; 1st National Communication of Tanzania, 2003) which have estimated on average that a 400m landward retreat would occur in the city under a 1-m sea-level rise, with a total of 247 km^2 and 494 km^2 of land might be lost for a 0.5 and 1 metre, affecting infrastructure worth US$48 and US$82 million respectively. Nicholls *et al.*, (2008) estimated population and asset exposure in large port cities to coastal flooding from a 100-year event, reporting Dar es Salaam had the 7th highest risk in Africa for population and 14th in Africa for asset exposure, with over 350,000 people and infrastructure asset worth approximately US$5.3 billion potential at risk to the 100-year coastal flood by the 2070s.

The case study has used an elevation-based geographic information systems (GIS)-analysis to estimate the number of people and assets exposed to extreme water levels, assessing the physical exposure and socio-economic vulnerability under a range of sea-level rise and socio-economic scenarios, for the years 2005, 2030, 2050 and 2070. It also considered future socio-economic changes based on a scenario of population growth, including urbanisation, and rising gross domestic product (GDP) of the city. The analysis looked at the potential worst case exposure, i.e. without defences and other adaptation measures, estimating the number of people and associated economic assets that are located below the 1 in 100 year flood event and extreme water levels. This identifies hotspots of population and assets.

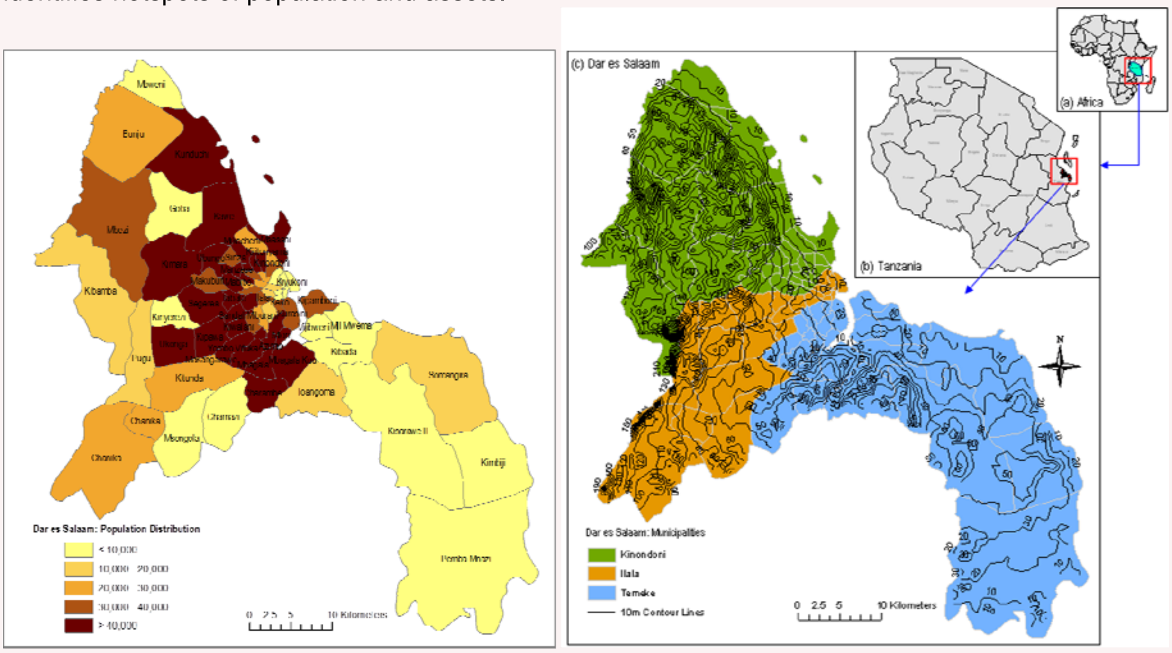
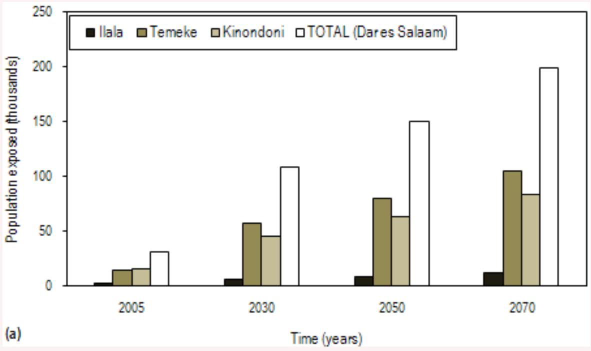


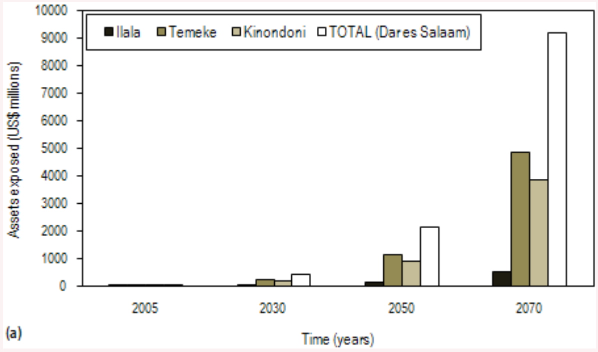
Figure 11. Total Population (left) and Contour map (right) for Dar es Salaam

The results show that about 8% of the land area of Dar es Salaam (distributed across the districts as 4.4km^2 in Ilala, 35.2 km^2 in Kinondoni, and 89.2 km^2 in Temeke) is below the low elevation coastal zone, i.e. within the 10m contour lines, with over 140,000 people located in these vulnerable areas (around 5% of the city population). These areas contain associated economic asset worth more than US$168 million in 2005 (note these estimates do not include the actual value of ports and harbours or tourist infrastructure). More than 31,000 people (in 2005) are currently at risk of the 1 in 100 year return period storm surge flood event.

By 2030, the upper scenario of slr and population growth (worst case scenarios) results in around 110,000 people and over US$400 million assets in the city being exposed to the 1 in 100 year flooding due to extreme water levels. By 2070, the estimate rises to over 200,000 people and assets worth between US$10 billion. The exposure is highest in the Kinondoni and Temeke districts. However, even without climate-induced sea-level rise, exposure is high, demonstrating that future population and asset exposure to flooding are much more sensitive to socio-economic change than climate change. The estimates also highlight the crucial message that, without action today to ensure sustainable development and planned population settlement, economic growth itself will strongly aggravate the impacts of climate change and sea-level rise on coastal flood exposure. Potential adaptation measures are considered in the later section.



Exposed population



Exposed assets

Figure 12. Exposed population (left) and exposed assets (right) in Dar es Salaam in 2005, 2030, 2050, and 2070 to a 1 in 100 year flood event under the A1B mid-range SLR scenario. No adaptation.

The study shows that significant numbers of people in Dar es Salaam are, and will continue to be, vulnerable to flooding due to extreme water levels during this century. It should be recognised that this analysis only provides indicative results. Limitations of the analysis include lack of sufficient and good quality observational local climate data (e.g., long-term sea-level measurements), finer resolution spatial population and asset distribution and high resolution local elevation data, and detailed information about existing coastal defence systems (natural and/or artificial) and current protection levels. As such it should be seen as a first step towards analysing these issues, and needs to be followed by more detailed, city-based analysis.

These issues of future coastal flood risks are raised as a key issue in the current plans towards the Dar es Salaam development plan.

The study has also undertaken contour mapping for Zanzibar. Further work to apply similar analysis to this and other islands is considered a priority.

5.4 Agriculture and Livestock

Agriculture is the dominant sector in Tanzanian economy, providing livelihood, income and employment to over 80% of the population. The Kilimo Kwanza document reports that the sector contributes 27% of the Country's GDP; 30% of total exports; and 65% of raw materials for Tanzanian industries. Other sources give higher values: the NAPA reports that agriculture accounted for 56 percent of GDP and about 60 percent of export earnings in the past three years[16]. Food crop production accounts for about 65% of agricultural GDP, with maize the most important crop (accounting for over 20% of agricultural GDP) and with cash crops accounting for only about 10%.

Agriculture is the main source of employment for the population, an important economic sector for food production, employment generation, production of raw materials for industry and foreign exchange.

Farming in Tanzania is generally small scale (small holder farmers) with most farms 3 hectares or less, and together with pastoralism, these dominate rural subsistence and informal economies, and take up 60 per cent of total cultivated land. Most smallholder producers are rain-fed, which means they are highly affected by climate variability.

The Kilimo Kwanza (United Republic of Tanzania, 2009) reports that Tanzania is endowed with about 44 million hectares of land suitable for agriculture, of which only 23 percent (10.2 million hectares) is utilized. Out of 29.4 million hectares of land suitable for irrigation, only 289,245 hectares (1 percent) was under irrigation by the end

[16] Other studies cite different values – the recent IIED study reports that agriculture accounts for 45 per cent of GDP, 80 per cent of employment, 66 per cent of merchandise exports, and 55 per cent of foreign exchange earnings.

of 2008. It also reports that the agriculture sector in Tanzania is dominated by small scale holders who use very poor technologies; and as a result, the sector has exhibited very low productivity and food insecurity.

The effects of periodic droughts and occasional floods from climate variability are also an issue. Large-scale events, such as the 1997/98 El Niño, illustrate ways in which many communities are already suffering from less predictable and more extreme weather patterns. The 1997/98 El Niño, for example, resulted in cereal deficit at 916,000 metric tons in Tanzania. The livestock sector also underwent severe losses The La-Niña event of 1996/97 was responsible for the severe drought that occurred in most parts of Tanzania: crop failure was widespread and rangelands could not support livestock resulting in large production shortfalls. In 2005 the agricultural sector grew by only 5.2% compared to 5.8% growth in 2004 and GDP was targeted to grow by 6.9% but it grew by 6.8%. This was attributed to severe drought that affected most parts of the country, triggering food shortage and power crisis (URT, 2005).

The NAPA outlines that based on altitude, precipitation pattern, dependable growing seasons and average water holding capacity of the soils and physiographic features, Tanzania has 7 agro-ecological zones: coasts, arid lands, semi-arid lands, plateaux, southern and western highlands, northern highlands, and alluvial plains

However, because of the time-scales being considered here for climate change, it is also important to consider the future nature of the Tanzanian agriculture sector – even in the short term – as these changes must be understood in considering the potential effects of future climate change.

The Vision 2025 (United Republic of Tanzania, 1999) and more recently the Kilimo Kwanza document outlines that the transformation of Tanzania's agricultural sector should be the foundation of the country's socio-economic development, and that the country must achieve food self-sufficiency for its continued stability and development.

Kilimo Kwanza sets out the acceleration of the agricultural sector transformation, with agriculture as an economic priority. While it builds on existing strategy, it has a stronger private sector lead, and sets out a number of pillars, covering financing, governance, production (food crop priorities), tenure, incentives, value addition, resources and infrastructure development.

The National Strategy for Growth and Reduction of Poverty (NSGRP II or MKUKUTA II: United Republic of Tanzania, 2010) reports that the real growth of agriculture sector in the medium-term between 2010 and 2015 is projected at an average rate of 5.3 percent a year compared to average growth rate of 3.9 percent in the 2005 – 2009 period. The sector is expected to recover from a low growth rate of 2.7 percent in 2009 up to 4.0 percent in 2010 before jumping to 6.3 percent by 2015 mainly on the assumption that world economy recovers. The growth in the production of crops is expected to pick up, due to increased productivity due to government efforts of boosting production capacity by providing agricultural inputs such as fertilizers, tractors and technical assistance (under the Kilimo Kwanza initiative).

The Mkukuta interventions (also articulated in Kilimo Kwanza agricultural development strategy) include:

- improving existing and expanding agriculture irrigation infrastructure, and developing rain water harvesting infrastructure, including water for livestock;
- Increasing proportion of small holder farmers using mechanization and improved seeds and implementing contract-based farming model and out-grower schemes;
- Strengthening physical infrastructure to support growth of employment generating and profitable agriculture, including small scale agriculture;
- Introducing and strengthening investment incentives in agriculture, including mechanization, firm level irrigation facilities, and farm level agro-processing, and large scale crop storage facilities;
- Strengthening agro-processing, and service sector and marketing baseline information to support agricultural growth;
- Promoting and adopting the use of science and technology in agriculture, including R&D for quality and nutritious food crop, high value cash crops, as well as ICT to provide information on prices and markets, advisory services;
- Promoting measures to cushioning farmers from famine/droughts impacts, including piloting and scaling up farm crops/livestock insurance;

- Increasing proportion of exported processed agricultural commodities

All of these are important in both future climate risks – as well as for carbon emissions (see later section).

The Key Risks from Climate Change

The study has undertaken an analysis of the impacts of climate change on agriculture. A full technical report is available on this work[17]. This section summarises the analysis and findings.

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 agriculture is currently rain-fed, there are also potentially wide ranging effects from the potential changes in precipitation. Weather-related hazards already present a serious threat to agriculture. 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).

Previous studies

The study has first reviewed previous studies that have assessed the potential changes for agriculture in Tanzania. This includes alternative approaches for assessing potential effects. One of the key changes – as reported in the NAPA – is the likely change in the distribution of the agro ecological zones. This includes a potential reduction in the rangelands which are important for livestock keeping communities in Tanzania.

The 1st National Communication reports studies of changes in crop yields, citing that increases in temperature and reduced rainfall as well as change in rainfall patterns, will reduced maize yields by 33% nationally, but with up to 84% in the central regions, 22% in Northeastern highlands, 17% in the Lake Victoria region, and 10 – 15% in the Southern highland. It also reports that as a result of temperature increases, coffee production is projected to increase by 18% in bimodal rainfall areas and 16% in unimodal rainfall areas. These assessments were based on regression models for coffee and cotton; and the CERES model for maize production. Munishi et al (2010) used these losses (equivalent to 9.5 million tonnes (cumulatively) over the period to 2060 (or 0.2 million tonnes per year), and using average current prices, reported that this was equivalent to $US3.1 billion, or an annual loss of $63 million. The study also uses a more general analysis to look at climate change and agricultural, reporting even larger numbers.

Crop models (e.g. by ILRI as reported in SEI, 2009) have been applied to Tanzania, as part of an East African analysis looking at individual crop varieties using impact assessment based approaches. These reveal mixed patterns in the region and strong differences between areas within the country, with some areas showing higher yields or potential for new crop varieties, whilst other showing negative effects.

Jones and Thorton (2003) also report a decrease in maize yields for Tanzania by 2055, with a reduction in yield falling from 1458 kg/ha (baseline) down to 1246 kg/ha.

IIED (2009) applied climate projections (reporting an increase in rainfall in the north, but a decrease elsewhere) and estimated that the impacts of climate change in Tanzania could reduce yields for some crops, effectively shrinking Tanzania GDP by 0.6 to 1 per cent by 2030. They estimated that climate change would boost productivity in barley, rice, wheat and some other grains, yet would decrease productivity in maize, the country's key crop. They also reported that in later years, the impact of climate change on agriculture could be extreme (citing values of 5 to 68 per cent of GDP, depending on the severity of climate impacts, though this is in the absence of farm level adaptation, and assumes current a continuation of the economic structure). They also highlighted that these figures excluded the informal economy, and that impacts would be uneven across the country, particularly affecting the poor.

[17] The 'Economics of Climate Change for Agriculture Sector in Tanzania: Adaptation Options and their Costs'. S.D. Tumbo, B.P. Mbilinyi, F.B. Rwehumbiza and K.D. Mutabazi. Soil-water Management Research Group, Sokoine University of Agriculture, Morogoro, Tanzania. available at the web-site (http://economics-of-cc-in-tanzania.org/).

It is also important to note that under certain scenarios and models, positive effects are possible. Fischer et al. (2005) has suggested that Tanzania may have increased cereal-production potential by 2080s.

Ahmed et al (2009) used analysis of multiple model ensembles, country specific analysis of climate and yields, and applied these in the context of wider agricultural trade models to look at the effects of climate on poverty. The study reports that changes in climate volatility are likely to render Tanzanians increasingly vulnerable to poverty episodes through its impacts on staple grains production in agriculture. They estimate as many as 90,000 additional people, representing 0.26 percent of the population, could enter poverty in the median case. Extreme poverty-increasing outcomes are also found to be greater in the future under certain climate scenarios, with the highest possible poverty increase equal to 1.17 million people (approximately 3.4 percent of the population). The results suggest that the potential impacts of changes in climate volatility and climate extremes can be significant for poverty in Tanzania.

There are also several on-going studies, for example, a Climate Change Adaptation in Africa (CCAA) research and capacity development program is undertaking work. Project activities include crop modelling to assess future climate impacts, and capacity building through extension and training efforts to reduce the vulnerability maize-based smallholder systems in selected local communities (CCAA, 2009).

Analysis

The current study has also undertaken agricultural modelling analysis to look at the potential order of magnitude of impacts. The projected impact in agriculture due to climate change was investigated by studying the effects of future climate (2030 & 2050) on maize yield, assuming all other parameters remain the same.

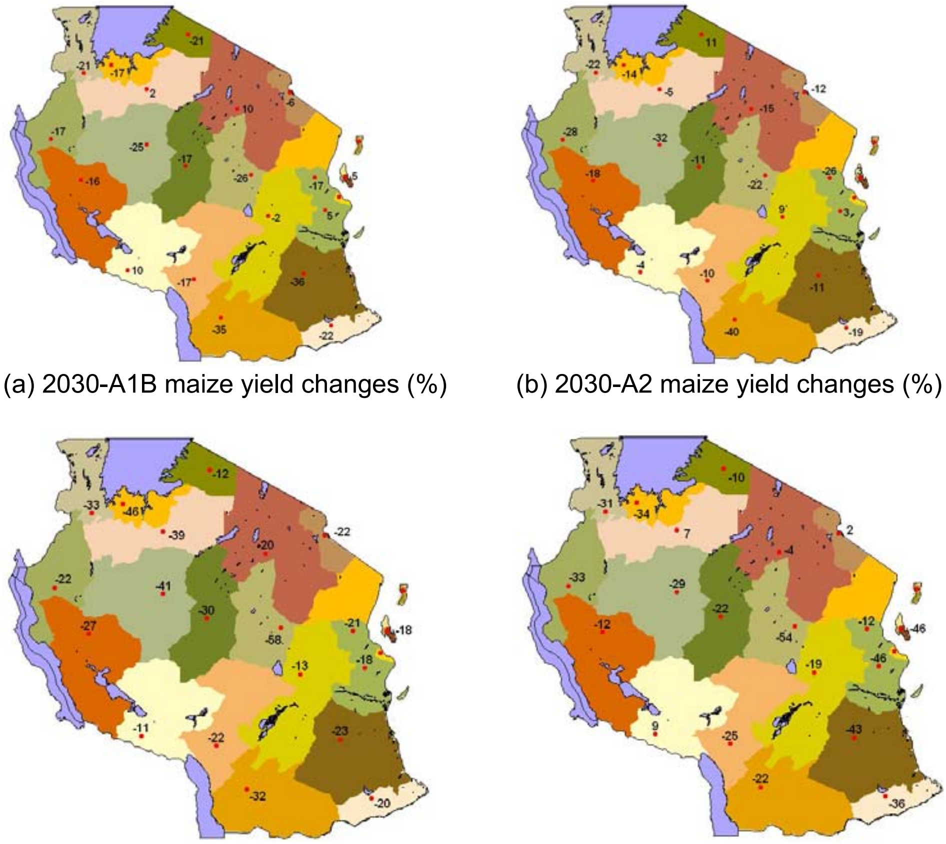
As noted above, any results are strongly determined by the specific climate projections as well as the agricultural models or analysis used. For this part of the work, a pessimistic scenario was used which include higher temperatures and rainfall reductions during the March-April-May period (decreases of up to 15%, with an exception of the Eastern Arc Mountains, South-Eastern Tanzania and portions around Lake Victoria). This implies a shortening of the season and shifting of the planting dates. Therefore, current agronomic management practices will need to be adjusted by changing planting dates and crop types and varieties.

The analysis simulated changes in maize yields under the business-as-usual, i.e. current management practice, using crop simulation model DSSAT. For calibration of the model, maize yield between 1992 and 2001 for different regions in Tanzania were obtained from the FAOSTAT database. Locations in different regions for use in DSSAT were purposefully chosen from the FAO AfriCover database, soil types from FAO soil map, and soil profiles from WISE database and also included planting dates for seasonal crops in Tanzania.

Results

For maize, the projected yield changes were estimated for two existing model emission scenarios, for 2030 and 2050. Note that given the tight time-table for the project, the analysis used existing model data, rather than the specific UCT projections presented in the earlier section, and focused on one model projections (reflecting generally negative changes in precipitation). An additional A1B scenario was also included, as this data was already set-up in the existing model.

With exception of very few regions, the results show that most areas will suffer yield losses of between 10% and 20% by 2030 and between 20% and 40% by 2050. The average yield obtained are 1.3 t/ha for baseline year, 1.12, 1.13, 0.97 and 1.05 t/ha for 2030-A1B, 2030-A2, 2050-A1B and 2050-A2, respectively. This shows that, on average, yields will decline in the future, with a reduction of around 1 million tonnes /year in 2030, rising to a reduction of 2.0 to 2.7 million tonnes / year in 2050, across the two scenarios sampled. Note that reductions would be lower in the later time periods under a low emission or global mitigation scenario. The figure below shows the changes.



(a) 2030-A1B maize yield changes (%) (b) 2030-A2 maize yield changes (%)

(c) 2050-A1B maize yield changes (%) (d) 2050-A2 maize yield changes (%)

Figure 13. Percent change in maize yield by 2030 and 2050 compared to the baseline year: (a) 2030-A1B, (b) 2030-A2, (c) 2050-A1B and (d) 2050-A2 – for the more negative climate scenarios
Note no farm level or planned adaptation

The results estimate that the total cereal yields could decrease in total by 14% by 2030 and 23% by 2050 compared to the baseline year of 2000. This implies a decline of about 1 M tonnes and 2.9 M tonnes per year (using an average simulated yield of 1.3 t/ha) by 2030 and 2050, respectively.

Projected population growth, and change in cereal production due to climate change by 2030 and 2050 – for more pessimistic climate scenarios (no farm level or planned adaptation)

Subject	**2010**	**2030**		**2050**	
	Baseline	**A1B**	**A2**	**A1B**	**A2**
Tanzania population ('000)	45,040	75,498	75,498	109,450	109,450
Maize production (BAU) ('000 tonnes)	4,059	7,047	7,047	10,378	10,378
Maize production (CC) ('000 tonnes)	4,059	6,025	6,079	7,684	8,318
Maize yield (CC) (t/ha)	1.31	1.12	1.13	0.97	1.05
Change		(1,022	(968)	(2,694)	(2,060)
Cereal production (BAU) ('000 tonnes)	5,074	8,283	8,283	11,859	11,859
Cereal production (CC) ('000 tonnes)	5,074	7,185	7,243	8,967	9,647
Cereal production change ('000 tonnes)	-	(1,098)	(1,040)	(2,892)	(2,212)

As a simple analysis of the order of magnitude of these changes, the study has applied the crop prices from Munishi et al (2010), which cites the average price for Maize in East Africa (based on FAO, 2009) as US$332 per tonne. Assuming constant current prices, this is equivalent to around $330 million/year by the 2030s, which would be around 0.3% of projected GDP in 2030 based on growth rates assumed in the Vision. The losses rise to $680 - 980 million/ year by the 2050s (current prices, undiscounted). Of course, these values ignores wider price effects, and assumes that farmers do not react to falling yields, i.e. it assumes no baseline autonomous farm level adaptation, which is unrealistic. Nonetheless, it shows that the potential impacts could be significant in economic terms.

It is highlighted that the estimates above – as well as the previous studies reported - use different climate projections, but also different approaches for estimating impacts. Many are based on crop functions or models, and assume no farm level adaptation, i.e. they are likely to overestimate impacts because they assume that farmers take no action to address falling yields, nor switch from more climate sensitive crops such as maize to alternative for food staples. They also only consider a partial set of possible future effects – both positive and negative, including some major issues such as the effects of extremes, or pests and diseases.

This is highlighted as a key point. It is emerging that the future effects of climate change on the agricultural sector are complex, and only partially understood. Work in this study has also considered a more comprehensive analysis of the interplay of biophysical, socio-economic and decision-choice factors for agriculture, all operating across spatial and social scales of space and time. The 'cloud' diagram below plots these various issues.

A key conclusion from this wider analysis is that given present knowledge, the outcome of future climate change for agriculture in Tanzania remains highly uncertain. Nonetheless, the findings show that the impacts could be potentially very large, i.e. important for the economy and for millions of livelihoods.

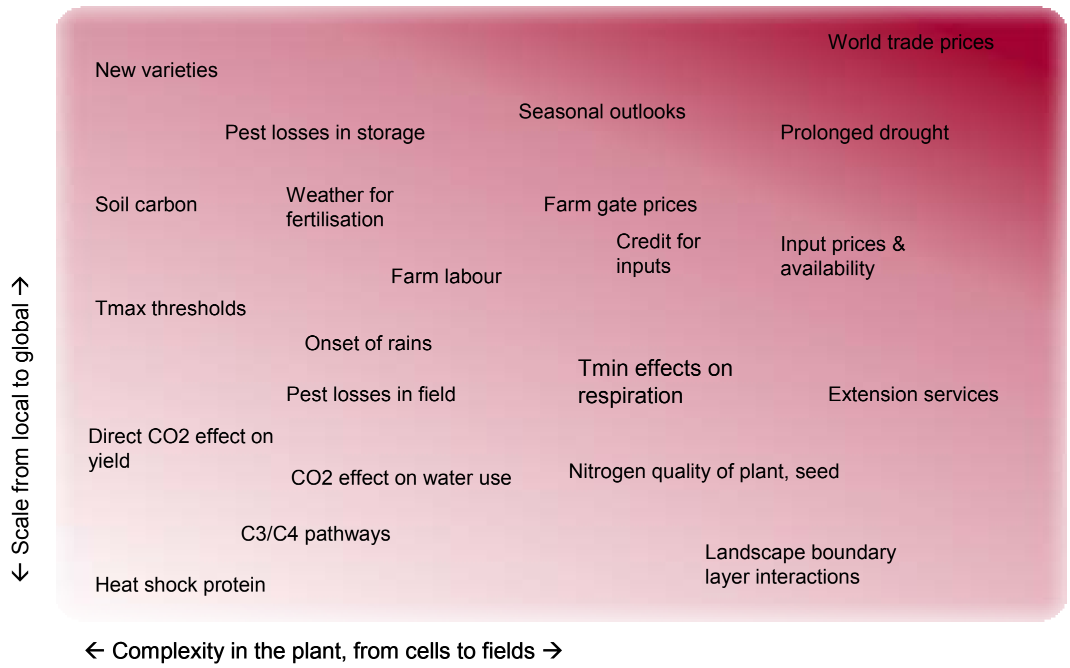


Figure 14. Range of factors affecting vulnerability, impacts and adaptation to climate change

As well as agriculture, the study has undertaken a case study on pastoralists[18]: looking at the vulnerability of these groups to climate change. This is important to capture the non-formal economy, which would otherwise be missed through a sector aggregated analysis. The case study is summarized in the box below.

[18] The Pastoral to Agro-Pastoral Transition in Tanzania: Human Adaptation in an Ecosystem Context. Stacy Lynn. The full technical report is available at the web-site (http://economics-of-cc-in-tanzania.org/).

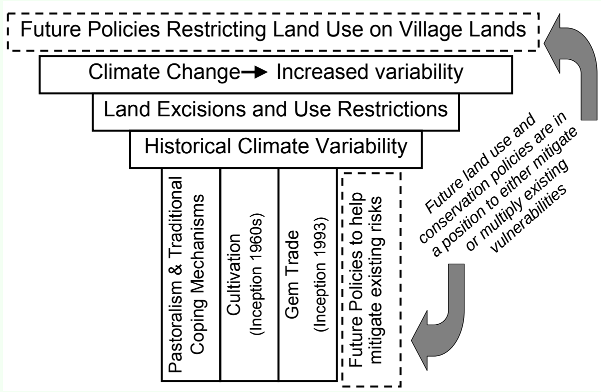
Case study. Pastoralists in Tanzania and Climate Change

Pastoralists have used the arid and semi-arid lands (ASAL) of Tanzania for millennia, with livestock herders making efficient use of the available resources in areas that are too marginal for most other users. These pastoralists have adapted to the inherent and historical risk of climate variability in the ASAL. However, land excisions and other restrictions on resource access present new risks that decrease resilience and system stability. On top of this, the potential risk of climate change has the potential to change the coping capacity of these groups, amplifying the risks of variability.

The study has commissioned a case study to consider these issues. This highlights that current policies are having major impacts on these groups (e.g. wildlife policy, land use policy, land tenure decisions, etc.) as well as from wider livelihood diversification and land use changes (including cultivation). It also considers the impact of the current climate on ASAL land cover and pastoralist activities – the current bimodal pattern of rainfall in ASAL, such as that found in Tanzanian rangelands, favors pastures, woody plants, and pastoral land-use. The study reports on how pastoralists traditionally reduce risk from variations, i.e. through existing adaptation. This includes livestock movement and migrations to track forage and water availability, herd diversification with multiple species to buffer their losses in difficult times (as well as more drought tolerant species of cattle, to spread risk across species), herd management such as increasing stock during good years in anticipation of future losses, reciprocal access rights to common resources / social programs and alliances such as stock associations and wealth re-distribution from wealthy to poor, especially following times of hardship to re-build herds.

Under conditions of increased climate variability, ranging from short-term droughts to long-term climate shifts, the case study considers that the ability of the pastoralists to maintain their livelihoods in their traditional lands using traditional methods is likely to be impacted, particularly when these fluctuations are layered with other livelihood stresses. The existing coping strategies and buffers in place will become less effective. However, these pressures need to be seen in context: and other pressures are likely to be more dominant, such as policy (see above) or landscape fragmentation and loss, particularly when this restricts movement as this reduces necessary resources and buffer zones. As a result, pastoralists may be forced to reconfigure the former functioning and resilient social-ecological systems into less optimal systems that may compromise the long-term sustainability and persistence of all system components (noting the interactions with wildlife as well as the integrity of ecosystems as a whole – see later section). It is also highlighted that the implementation of mechanisms to improve resilience in one sector may actually increase vulnerability in another.

It also reports on an example, considering cultivation, livelihoods and wildlife conservation in the Tarangire-Manyara Ecosystem. The study has considered the Maasai pastoralists of Simanjiro and the layers of risk by relying on three livelihood sectors: traditional pastoralism, cultivation, and gem trading – see figure. If the stability of any of these pillars of support is compromised, the system may destabilize. Future land use and conservation policies may either present an additional layer of risk, further restricting mitigation options (thereby increasing vulnerability), or provide an additional support for pastoral livelihoods by assisting with risk mitigation (thereby increasing resilience).



Future land use and conservation policies are in a position to mitigate or multiply existing vulnerability

Strictly limiting cultivation by pastoralists will remove a subsistence alternative. Negotiating multiple land use options, including the limited use of protected resources during drought, may help communities mitigate risks associated with a highly variable climate and uncertain futures.

Agriculture is a highly climate sensitive sector. Climate change could have a range of positive as well as negative effects, however, under certain future impacts could be large.

An analysis of the more extreme climate projections shows potential reductions in maize of 10 to 20 % by 2030 and 20 to 40% by 2050 (without adaptation), which would have major economic costs, though the actual future impacts will depend on a wider range of factors, not all of which are fully understood as yet.

5.2. Health

Previous work (e.g. McMichael, et al. 2004. Boko et al, 2007: Nkomo et al, 2006: Ebi, 2008) has identified a potentially wide range of health effects from climate change in Africa. These conclude that Africa faces a high relative health burdens from climate change, from a combination of:

- The shift or increase in incidence of malaria, diarrhoea, schistosomiasis, as well as other vector borne diseases such as dengue fever, yellow fever, encephalitis (tick) and Trypanosomiasis (Tsetse fly), noting that these changes could be positive for some regions or time periods.
- Heat related mortality and morbidity.
- Increased incidence of deaths/injuries/disease linked to the coastal and inland flooding, as well as secondary events associated with water borne diseases, e .g. cholera, typhoid, dysentery.
- Indirect effects associated with changes in the risk of under-nourishment and malnutrition, and wider effects between economic and development levels and health.

A number of these are priority issues in East Africa, notably the incidence of malaria, diarrhoea and schistosomiasis. There have also been concerns on the potential resurgence of some diseases such as Rift Valley Fever, as well as the risk of under-nourishment and malnutrition, and wider effects between economic and development levels and health.

Climate change is likely to affect many of these health impacts, 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 extreme events (droughts or floods). Future climate change could mainly act as an amplifier of current health problems, though it is likely to also give rise of new health stresses. There are also a wider set of indirect impacts from climate change on health, linked to other sectors (e.g. water quality, food security). Climate change is also likely to complicate reaching the health-related Millennium Development Goals (MDGs) to eradicate extreme poverty and hunger (MDG 1), reduce child mortality (MDG 4), improve maternal health (MDG 5) and combat HIV/AIDS, malaria and other diseases (MDG 6).

These health changes will also have economic consequences through incurring medical treatment and health protection expenditures, and the potential loss of work productivity. In addition, there are likely to be associated changes in welfare from the pain and suffering associated with adverse health outcomes. These effects can be expressed in economic terms when captured by measures of willingness to pay to avoid them.

However, assessment of these health effects is uncertain, due to the multiple climate parameters involved in many impacts, especially in relation to climate variability. It is also complicated by changing socio-economic factors that will affect health outcomes, including the movement of people and goods, changes in land use and economic development. In considering the future effects of climate change on health, it is therefore also necessary to consider future socio-economic baselines, including how these might reduce (as well as increase) future burdens. For example, at higher per capita levels, the risk of malaria and diarrhoea[19] are likely to reduce significantly.

[19] For example, previous studies have assumed the climate sensitivity of malaria and diarrhoea and found these will decrease with increasing GDP and per capita incomes. However, given the very low per capita incomes in Tanzania at present, and even accounting for the rise in future years, there will clearly still be a high disease burden for some vulnerable groups.

Against this background, the study has undertaken a scoping analysis of the impacts of climate change on health. A report is available on this work[20]. This section summarises the analysis and findings.

Previous studies

Some observations of changes in health status due to climate – as well as other factors – have already been recorded in Tanzania. The NAPA (URT, 2007) reports malaria incidence in areas not previously associated with the disease, such as in some parts of Kagera region on the shores of Lake Victoria with an estimated altitude of about 2,500m above sea level as well as Lushoto and Amani in Tanga region which are part of the East Usambara Mountain Ranges along the North-East coast of the country.

Kibona (for CLACC, 2008) summarised the potential effects of climate change and health in Tanzania, and undertook a case study on the recent impact of climate on malaria in Lushoto (Tanga region). This suggests that climate may affect health in the highlands of Tanzania (possibly affecting malaria transmission by increasing relative humidity and modifying temperature, but also highlighting low statistical associations despite increases in numbers over the past ten years, and raising issues of other factors such as drug resistance, population growth, migration, etc.).

There have been also general assessments for Africa for the potential impacts on health from climate change (McMichael, et al. 2004 ; Ebi, 2008). The Economics of Climate Adaptation Working Group (ECA, 2009) study looked at health impacts of droughts specifically in Tanzania (identified as the impacts of malnutrition, trachoma, dysentery, cholera, and diarrhoea), correlating historic rainfall with numbers of diseases and with crop supply, then simplistically applying these relationships to estimates of future drought episodes from climate change for the short-term. It estimated that by 2030, under a moderate climate change scenario, a 10 percent decrease in average rainfall would cause a 60 percent increase in the proportion of the population under food stress, and significant increases in the number of cases of cholera and dysentery. Trachoma cases were estimated to potentially double in number. A higher climate change scenario would worsen this impact. However, the confidence in these estimates is very low, and the analysis did not take into account development changes (see earlier discussion of drought projections and also socio-economic development).

Analysis

The study has estimated the impacts on climate change on health, focusing on climate sensitive disease (including malaria, diarrhoea (dysentery and cholera), respiratory infections (pneumonia and others)) and nutritional status. The potential range of impacts is summarized below. For sub-Saharan countries with high child mortality and very high adult mortality, malaria, diarrhoea, and malnutrition are projected to pose the largest increases in relative risk for 2030 attributable to climate change (Patz et al, 2005)

Climate Change	Health Impacts
Heat waves	Heat strokes Food insecurity Malnutrition Reduction in labour productivity
Droughts	Diarrhoea (including from cholera) Food insecurity Water-washed diseases Drinking water scarcity Malnutrition
Gradually increasing temperatures	Infectious diseases (faster turn-over rate) Highland malaria Diarrhoea (including cholera) Drinking water scarcity Possible (complex) relations to food insecurity, malnutrition and new/unfamiliar diseases

[20] Health sector assessment by Tom E Downing and Nico Brunner, available at the web-site (http://economics-of-cc-in-tanzania.org/).

Floods	Physical injuries and mental health problems Diarrhoea (including cholera) Malaria Crop failure Respiratory infections Other water-borne diseases Water contamination Malnutrition

Malaria

Malaria is one of the largest health issues in Tanzania (as cited in the NAPA) accounting for about 16% of all reported deaths – the other major health hazards reported are in relation to dysentery, cholera and meningitis. Kibona (2008) reports that every year 14– 18 million new malaria cases are reported in Tanzania, resulting in 120,000 deaths, and 40 per cent of all outpatient attendances. Of these deaths, 70,000 are in children less than five years of age. Other sources cite an estimated 11.5 million malaria cases in 2006, with 10–12 million cases and 15 000–20 000 deaths annually between 2003 and 2006. What is clear is that the impacts are significant: Jowett et al, (2005), estimates that over 1% of GDP is devoted to the disease. The World Malaria Report (WHO, 2009), reports total public expenditure on malaria treatment in Tanzania of at least $25 million in recent years, and in some years on the order of $100 million.

Apart from the high altitude mountainous areas, malaria is endemic throughout Tanzania with highest endemicity in the low-laying areas. Increasing malaria outbreaks have been reported during years of excessive rains and flooding, mainly through prolonging the malaria transmission season.

Recently, special consideration has been put into modeling the emergences of malaria into East African highlands where malaria is restricted by the lower temperature threshold. A number of studies have linked highland malaria epidemics in East Africa over the last two decades to climate variability. While this remains an issue with some controversy, increasing temperatures epidemics are probably more likely to occur in these marginal areas and malaria may eventually even become endemic - recent studies have estimated that the potential effects across the East African highlands from climate change could extend to millions of additional cases per year (Bouma in SEI, 2009).

Diarrhoea

Overall diarrhoea morbidity is known to be affected by weather and climate variability and it is anticipated that the burden of diarrhoeal diseases is likely to increase due to warmer temperature associated with future climate change (McMichael et al., 2004). There are also linkages with climate variability and extremes. These changes can arise from food and water borne disease. The risks of food borne diseases may increase with higher temperatures. An effect of high rainfall on diarrhoea may also arise from flooding and loss of water and sanitation systems and hence to contaminated drinking water, whereas water scarcity may arise from the use of unprotected water sources. A positive link to both very low and high rainfall has also been documented for cholera – and epidemic outbreaks have been reported in Tanzania during recent decades.

Malnutrition

In developing countries, impaired nutritional status associated with food shortages can have significant health and economic consequences since malnutrition is one of the leading causes of morbidity and mortality, especially among infants and young children. Many factors are important, though climate may have a role. As well as direct effects, malnutrition has a far greater impact through complex interactions exist with infectious diseases. According to the National Bureau of Statistics (NBS) in Tanzania, 45% of all under-five deaths are related to underweight with moderate malnutrition being responsible for most of the deaths. However, malnutrition is hardly ever the final cause of death and hence its impact is often greatly underestimated.

Climate related flooding

Inland flooding results from heavy rainfalls (see earlier section). Coastal flooding (see coastal section above) occurs due to storm surges with sea-level rise increasing the risk significantly. As well as direct deaths and injuries, flooding leads to indirect effects, such as on disease burden (see above) but also through indirect effects on wider well-being.

Heat related mortality and morbidity and reduction in labour productivity

While there is little focus on the risks of heat extremes and health in Africa, this has the potential to cause additional health impacts in the form of mortality and morbidity, though this has been the focus in many OECD countries.

Higher temperatures are also likely to affect labour productivity. The increase in outdoor and indoor heat from climate change may impair productivity (as shown by Kjellstrom et al, 2009), who report that workers may need to work longer hours, or more workers may be required, to achieve the same output and there will be economic costs of lost production and/or occupational health interventions against heat exposures.

Analysis

The study has used the approach of Ebi (2008) (the WHO global burden of disease based approach) but applied this to two development and climate scenarios in Tanzania. Both assume population growth, consistent with the UN median variant projection of population growth through 2050 (with population rising to over 100 million). Both scenarios assume warmer conditions and increased climatic variability, with continued or increased threats of climatic hazards. However, the first scenario has continued trends in development, with increased climate impacts representing a more pessimistic view of the envelopes of climate change and impact pathways, whilst the second scenario has enhanced development as expected with the Mkukuta framework and somewhat reduced impacts of climate change, consistent with a more optimistic envelop of climate change. The aim has been to estimate plausible upper and lower bounds of health costs of climate change. The quantified analysis was applied to three climate sensitive diseases: malaria, diarrhea and malnutrition, using baseline assumptions detailed in the health report, and functions from Ebi (2008) applied to Tanzania, noting that this represents only an indicative scoping analysis. The study also assumes declining baseline rates of disease, to account for development and the relationship with health.

Results

The results are shown below for the two scenarios.

Scenario	**Estimated Impacts**
Current trend (pessimistic)	• Malaria: from 3% currently to 10% in 2050 • Diarrhoea: from 9% now to 20% in 2050 • Malnutrition: from 3% now to 10% in 2050
Development vision scenario (optimistic)	• Malaria: from 1% currently to 5% in 2050 • Diarrhoea: from 5% now to 10% in 2050 • Malnutrition: from 1% now to 4% in 2050

These are valued using treatment costs, reflecting African data. The treatment costs are adjusted downwards in the more optimistic scenario in future years. Note that this uses a similar value to estimating the full welfare costs (medical costs, lost time of individuals, costs for pain and suffering) of the increased disease burden, at least as estimated by SEI, 2009.

The results are shown below, indicating the potential for significant health costs related to climate change. Malaria is the major cost, at over 60% of the total in all of the scenarios and years, followed by malnutrition (at around 25%). The trend scenario, with high costs and additional sensitivity to climate impacts, would cost in the region of $100 million in 2030, representing a significant, additional burden for public finance. However, under the development vision scenario has much lower costs, at less than $20 million in 2030.

Summary of health sector costs for three climate-sensitive diseases in Tanzania (no adaptation)

	Annual treatment costs (US$ Million/year)	
Scenario	**2030**	**2050**
Current trend (pessimistic)	US$97.8 M/yr	$157 M/yr
Development vision (optimistic)	US$18.3 M/yr	$36.0 M/yr

In addition, the study has undertaken a qualitative assessment of the potential effects of more extreme high temperatures, looking at the projected number of days exceeding 32°C, an indication of extreme temperature and heat stress on human populations – though the existing warm temperature of Tanzania and low temperature variability are important factors (Jack, 2010).

The results show high exceedence in warmer locations such as Dar es Salaam – with the results shown below for the B1 and A2 scenarios. There are increases in the number of extreme temperature days in summer, but also an extension into the shoulder seasons. Cooler locations such as Mbeya and Mwanza show almost no exceedence throughout the year. The increase in temperature in major areas has implications for direct health effects, but also is likely to impact on labour productivity and associated economic costs.

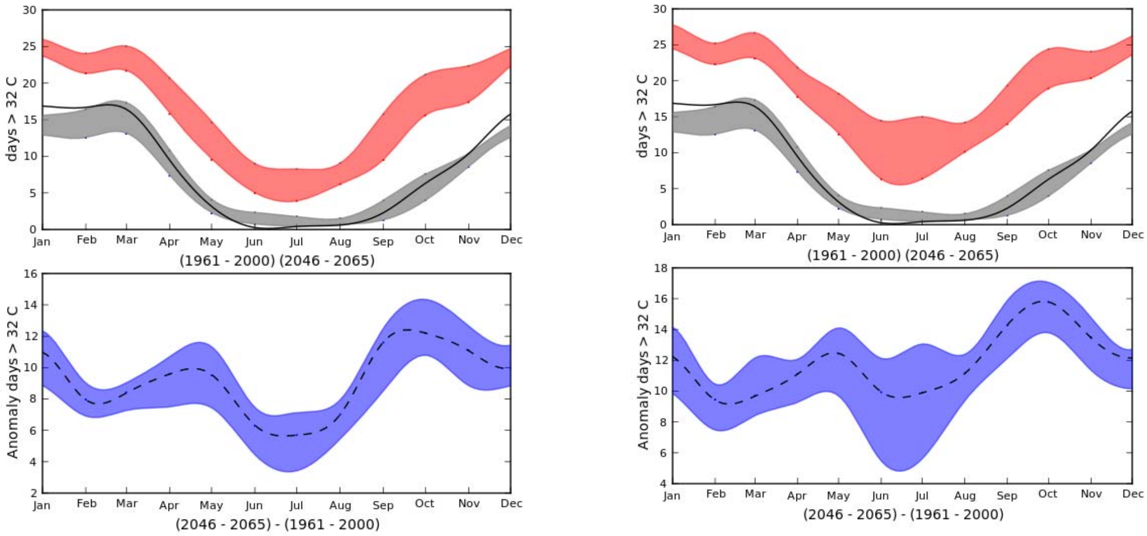


Figure 15. Projections and anomalies of monthly days exceeding 32°C (2046 - 2065) B1 (left) and A2 (right) Scenarios for Dar es Salaam

For each station, the top box presents the modeled baseline (in grey) and the future period (2050s) with climate change (red). The bottom graph (blue envelope) shows the increase from the modeled baseline, i.e. the marginal increase.

Finally, it is recognized that the analysis above only includes a sub-set of potential health impacts. For example, the health impacts of heat waves and other diseases such as trachoma are not included. Further work is needed to increase the spatial dis-aggregation, consider the climate projections in detail, and consider a wider set of possible health burdens.

Climate change could have large health impacts in Tanzania, on top of the existing high burden. The impacts and economic costs depend on future projections and development scenarios, but initial estimates for a limited number of health endpoints indicates that climate change could lead to additional treatment costs of $20 to 100 million by 2030, and $36 to 150 million a year by 2050.

5.3 Energy

Climate change is expected to have a direct effect on both energy supply and demand, as well as on energy related infrastructure. This is a key sector and also links with the low carbon analysis.

Energy Supply

Tanzania has diverse potential energy resources, including renewable energy, as well as some fossil fuel reserves. However, energy is primarily met through biomass (fuel-wood and charcoal), because of low cost and accessibility in rural and urban areas, contribution around 90% of final energy consumption.

In terms of electricity, the dominant source of generation is hydropower. In 2007, the capacity of the electricity generation system was approximately 1000 MW, over 50% being from hydro generation plant, with the remainder broadly split equally between gas and oil. In terms of generation, over 60% of electricity was provided by hydro power, and 37% from gas generation. Of the total hydro generation, over 80% of hydropower is generated in the Rufiji basin, with nearly all the rest generated on the Pangani River in northern Tanzania.

Historically, electricity generation levels have been relatively low although they have increased rapidly post-2000, and distribution losses have also been historically high, at over 20%. The low levels of generation (and therefore consumption) are reflected in Tanzania's per capita consumption levels. In 2007, the level was 81 kWh / capita compared to 151 kWh in Kenya and 4985 kWh in South Africa.

Prior to 2005, the system was almost totally reliant on hydro generation, leaving it highly vulnerable to outages during low rainfall years. This was seen particularly in the mid-1990s and in 2003, but also occurred in 2006 when serious load shedding problems arose. Post-2005, significant additional thermal generation capacity has come online, reducing (but not removing) vulnerability in dry periods. Several studies have estimated the economic costs of these outages. Following 2003, additional gas turbine units were brought on the system (with monthly fuel costs of US$8 million, the costs of incremental thermal generation due to the drought was of US$67 million from January 2004 to February 2005, see World Bank, 2004).

There have been other energy-related impacts on the economy due to drought. The Central Bank of Tanzania estimated that in 2007 that economy grew 1.1% slower than expected due to electricity shortages (NAPA, 2007), while a 2006 World Bank reported that power rationing was costing the economy $1.7 million per day (World Bank, 2006). While the introduction of fossil generation has diversified the mix, there remains severe power outages and load shedding, which has resulted in the growth of small diesel generators for self-generation: recent analysis (World Bank, 2010) indicating the economic cost of power shortages, running backup generators and losses from foregone production; at over 4% of GDP annually for Tanzania.

Tanzania has significant hydropower potential, estimated at 4.7 GW (compared to a current level of about 0.55 GW), as well as fossil resources include coal reserves, with 304 million tonnes proven, and natural gas, estimated at 45 billion cubic metres (from Songo-Songo and Mnazi Bay as well as other potential areas). It also has extensive renewable resources such as wind, solar and geothermal. The evolution of the energy system is set out in the National Energy Policy of Tanzania (United Republic of Tanzania, 2003) and more recently the Power System Master Plan Study (United Republic of Tanzania, 2008), which includes near term additions of coal, wind, gas and hydro, as well as small-scale renewables, see the later low carbon section. Based on the projections in the Master Plan, the system becomes much more diversified. Although hydro remains a critical generation source, there are significant increases in domestic gas and coal-based generation.

The Key Risks from Climate Change

Clearly the priority risk for the energy (electricity) sector is the effects of climate change on hydro-electricity stations, from a combination of changes in precipitation, run-off and river flow, surface water evaporation, various impacts from changes in variability (reduced run-off due to droughts and increased run-off due to floods) and secondary effects such as impacts of siltration deposits and sedimentation. These feed through to key issues of storage levels as well as generation. Note that the impacts do vary with the type of scheme: storage based projects (dams) are subject to differences to run-of-river schemes.

The potential impacts of climate change on thermal generation, as a results of impacts on cooling water availability, is also highlighted as a potential issue, which may reduce the resilience of electricity diversification. Higher temperatures may also reduce the efficiency of transmission or some thermal station efficiency. There may also be other risks to energy supply stations and transmission infrastructure, from flooding or from temperature extremes. Finally, climate change will have potentially large impacts on biomass energy, discussed in later sections.

Previous studies

Tanzania's 1st National Communication identified damage to hydropower installations due to flooding on the Rufiji River as a possible impact of climate change (URT, 2003), and that there were also potential risks from flooding on sedimentation.

There has been detailed assessment of the potential effects of climate change on future hydro potential in the East Africa region, included Tanzania, as part of the Nile Basin Initiative (Stratus, 2006). This considered a number of extensions or new sites[21]. The study also looked at run-off and storage-yield. The analysis used a hydrological model and considered two future scenarios, to represent a central and high projection, sampling across a large number of GCM outputs. Consistent with the earlier reported scenarios, this study highlights that while all models show warming, there is a wide range of model projections of precipitation, including projected increases and decreases across the models (with annual and seasonal variations) though for most of the study areas, the models generally reported increases in precipitation and run-off. The study looked at storage-yield curves (as well as run-off), to show the amount of water storage necessary to provide a reliable amount of water in each time period. For the Tanganyika region, the study found increases in runoff for most regions in the 2050s and 2100s, thus indicating increased average yields. However, the seasonal changes lead to different impacts on storage-yields, such that for reservoirs with relatively small storage, firm yield would be reduced (even though average yield would increase). This highlights the risk of increases in climate variability. It also suggests that larger reservoir capacity can better cope with increased variability. The changes in variability were potentially greater in the southern Tanzania region. For the main Tanzanian projects there was some potential for average annual runoff reduction, under the driest models, thus these projects could be vulnerable (under this scenario). The study also highlighted the potential for increased flood flows in all regions.

Other studies have applied a simpler approach, for example, ECA (2009) looked at GCM outputs to project extreme events (drought periods) for the central region of Tanzania (the Rufiji River) for the year 2030, looking at central and high scenarios of precipitation and variability. It used this to assess the potential impact of droughts on power generation, by correlating historical rain with historical power production at Kidatu, and looking at reserve margins. The study reported that in the high climate change scenario the expected losses would lead to a 1.7% decrease in national GDP in 2030 – and in the moderate climate change scenario, GDP would decrease by 0.7%, as a result of the climate-change induced droughts. However, the confidence in these reported results is very low, due to the uncertainty associated with the projection of extreme events from the models in the short-term, see earlier, but also because of the method used to derive impacts and economic costs, which do not take account the greater diversity in the current (and future) electricity system).

Analysis

The study has considered the current and potential siting of hydro stations in Tanzania, shown on the map below. These have been combined with the climate projections, outlined earlier.

The impact would be expected to come from changes in precipitation and run-off, as well as increased evaporation of water from reservoir surfaces due to higher temperature, as well as impacts associated with climate variability.

The study has considered the information from the climate projections reported earlier. The current level of large-scale hydro capacity in Tanzania is significant, currently at 560 MW. In terms of the future projected potential, there is approximately between 3-4,000 MW that has been subject to feasibility studies.

[21] The study considered the 62 MW proposed (2012) Rusumo Falls project on the Kagera river Burundi/Rwanda/Tanzania) and Ruhudji river project (358 MW, planned 2015) and Rumakali river project (222 MW, planned 2020) in Tanzania.

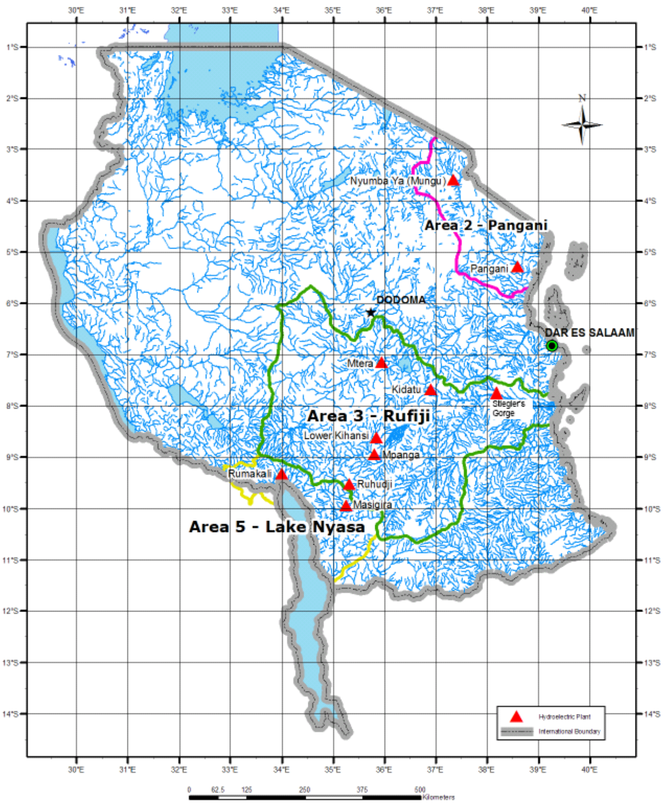


Figure 16. Map of current and potential hydro sites.

In the projections for this work, an upper limit additional 2000 MW of large hydro by 2030 has been assumed, as per the TANESCO Master Plan (United Republic of Tanzania 2008b). Hydro would comprise 47% of capacity (MW) and is estimated to meet 37% of supply (kWh), see below.

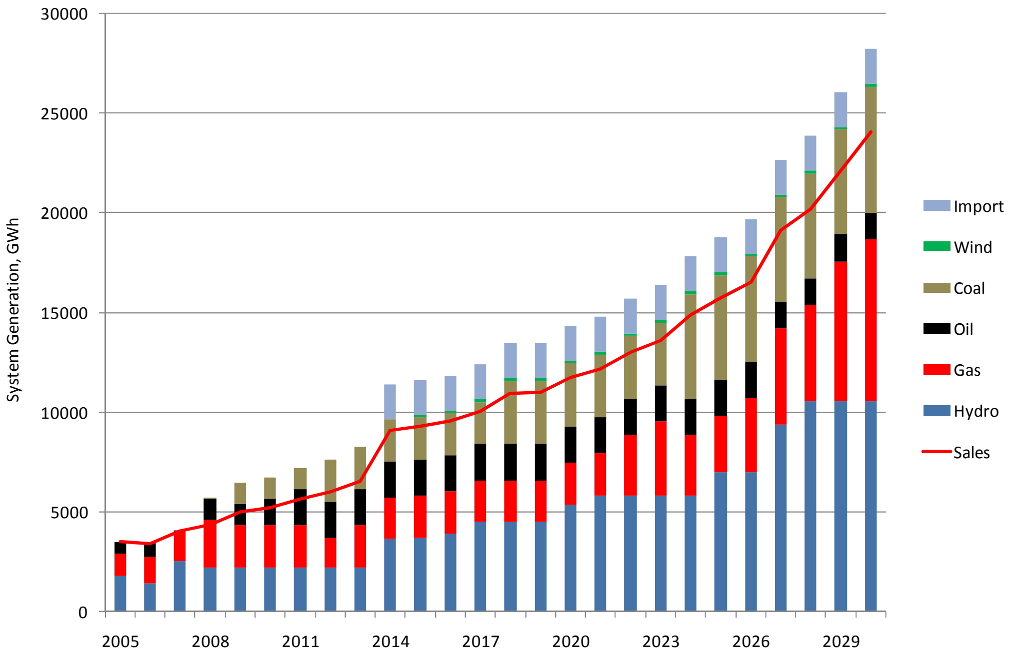


Figure 17. Forecast electricity generation (GWh) for Tanzania, 2008-2030

Source: GoT 2008b

The next stage in the analysis has been to consider the potential threats to hydro indicated by the climate model projections. This has been challenging, because of the wide range of model projections, reported earlier, and there is considerable uncertainty. There are potential threats from increased evaporation: the largest dam in Tanzania is Mtera, with surface capacity of 605km^2 at full supply level. Previous studies have assumed a 5% evaporation rate, and increased temperatures from the projections would increase this. The changes in precipitation and run-off are more complex to assess, and really require basin level analysis to be meaningful. These changes also need to be seen against a future of socio-economic demand for water, from rising population, but also from other sectors, notably agriculture.

In addition to the changes in average projections, it is also necessary to conside extremes, which have potentially more impact in relation to major events. The model variation here is much greater (see Shongwe et al, reported earlier), where the sign of the changes are very uncertainty in the short-term (next 30 years) and highly variable across the model projections in the longer term where the climate signal should be more robust i.e. towards 2100). Moreover, the models cannot yet consider (with any degree of confidence) the potential changes in the ENSO cycle.

In many models, in northern region, the potential for greater intensity of heavy rainfall exists, which represents a risk for hydro operation, as well as siltation. Note that risks are different for dam based schemes compared to run of river schemes. Moreover, while the stations themselves should be protected by overflow, not necessarily so for transmission lines, service roads, small barrages etc. In many models (but not all), there are potential increases in southern Tanzania for droughts.

This increases the potential risks to hydro for Tanzania. While there is some diversification of the mix planned, hydro is still likely to comprise a high % of future capacity and supply. Further, the high demand projections for Tanzania are likely to mean there is a fairly low level of plant margin on the system, and thus any events from extremes could be associated with high economic costs from lost load.

Thermal plant efficiency and transmission

Climate change has the potential to reduce thermoelectric generation by decreasing plant efficiency and by affecting cooling capability. Studies have identified a potential fall in thermal (fossil) power station efficiency with temperature (Linnerud et al.(2009), Mideksa and Kallbekken, 2010), which imply that for a temperature increase of 1°C, coal and gas power output decreases by 0.6% due to the thermal efficiency loss.

By 2030, the electricity Master Plan (see above) anticipates annual generation of just over 28000 GWh/year, of which 55% is fossil generation (coal at 22% and gas at 29%, the rest diesel). Applying this simple efficiency function to the climate projections, and the future electricity mix projected in the Master Plan (see above), would to a loss of almost 100 GWh, at current prices, around $10 million / year. By 2050, the rise in temperature would increase these potential losses, particularly given the likely continued rise in electricity supply, though the level of impacts would be determined by the level of fossil (and the technology) in generation mix.

Other effects

Some studies (Eskeland et al (2008)) also report there could be a loss in electricity transmission efficiency with higher temperature due to increased resistance on power lines. There are also potential effects on wind, though the impacts are unclear, and levels of generation anticipated to be relatively low (see low carbon study). There are also potential impacts on bio-energy, discussed in later sections.

The costs of current climate variability on electricity generation already have macro-economic costs in Tanzania. Under some scenarios, climate change could increase these problems for hydro stations, especially for some regions. However, changes in water availability and variability may also affect coal and gas plants by affecting cooling water availability. Finally, rising temperatures will reduce fossil plant efficiency, with potential costs of $10 million/year by 2030s.

Energy Demand

As well as energy supply, climate change also affects energy demand, as outside temperature drives heating and cooling requirements. Energy demand increases with colder temperatures (heating in homes, offices and factories) and with higher temperatures (cooling), though these are conditional on technology penetration rates. 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). Finally human-induced pressures (growing population, water abstraction, etc.) will also exacerbate the effects on energy demand – though these would arise even in the absence of climate change.

The Key Risks from Climate Change

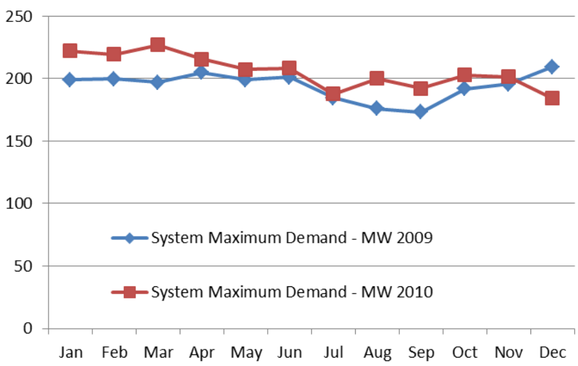
The average temperature increases associated with climate change will, in general terms, decrease the demand for heating in colder months and regions (a benefit), but increase the demand for cooling in hotter months and regions (an impact, itself an adaptation), though the scale of these effects is strongly determined by the climatic zone and socio-economic conditions. Energy consumption for cooling is also affected by-appliance ownership.

The likely effect is an increase in average electricity use, with associated costs, and as highlighted above, potential mal-adaptation in the form of increased emissions (when fossil generation delivers cooling). However, the same time, the rise in air conditioning demand will also increase the peak demand on the system, requiring new capacity (or else other measures such as demand management). It will also increase any emissions associated with fossil generation on the system.

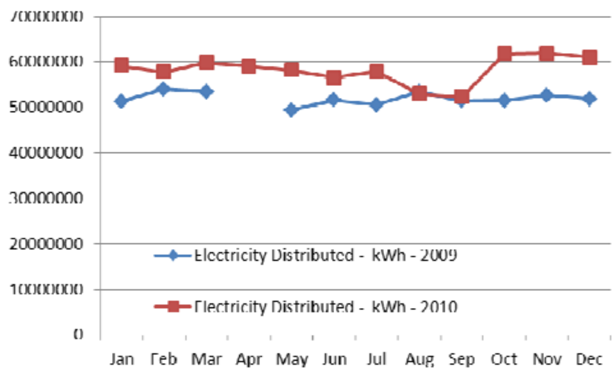
On top of the pattern of average warmer temperatures, climate models also project increases in the number of heat extremes (heat-waves), which may be an important driver of penetration uptake, but also exacerbate peak demand problems, potentially through loss of supply and outages.

Analysis

The study has considered a number of approaches to assess potential effects on energy demand. First, it has investigated whether it is possible to correlate current daily generation demand with daily temperature. Unfortunately it has not been possible to obtain such detailed data for the study. There is no available data (that the study could find) that estimates how much of the current demand (3300 GWh consumed [2007]) is used for cooling, and the projections of future demand (in the Power System Master Plan Study) do not separate out cooling demand (current or projected). Further work to investigate this is an obvious next step. However, it has been possible to obtain some district level data for Dar es Salaam, where air conditioning would be expected to be concentrated. Data on monthly maximum demand and electricity distributed has been collected from TANESCO for 2009 and 2010 for the Iala district in Dar es Salaam below.



System Maximum Demand



Electricity distributed

Figure 18. Forecast Monthly electricity demand (maximum – left and distributed – right) for the Ilala region of Dar es Salaam.

Source: TANESCO

This can be compared against the current climate data, as reflected in the climatology of monthly mean maximum temperatures for Dar es Salaam (Jack, 2010), showing the warmer months of the year.

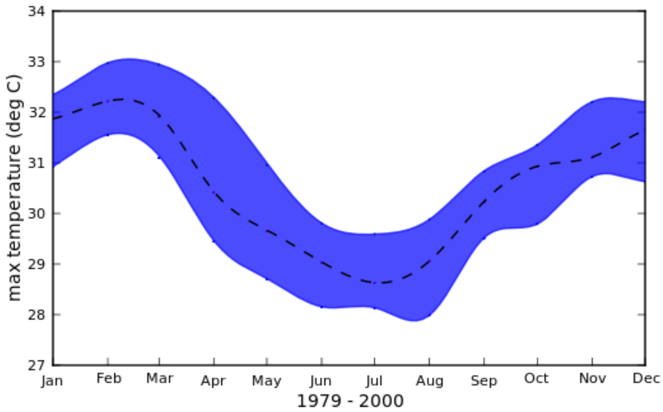


Figure 18. Climatology of monthly mean maximum temperatures Dar es Salaam

Source CSAG.

The number of years of data is not robust enough to undertake a regression analysis, and ideally daily demand and average daily temperature would be needed for this. Therefore caution is needed in interpreting the general trends. There appear to be minor trends of lower peak (maximum) demand during colder months in 2009 (June July Aug) and higher peak demand during hotter months in 2010. However, in many ways it is surprising there isn't a greater trend visible – but one of the problems in interpreting this data is the large number of outages, load shedding and unmet demand in the electricity supply system, as well as the use of back-up generation (for example in the hotel sector).

Looking forward, the main issue is how much future cooling demand might increase in the future, noting that cooling can be seen as an impact or an autonomous adaptation.. The study has first used the climate model outputs to consider current and future cooling degree days (CDD) (Jack, 2010)[22]. Cooling degree days (CDD) are used as a proxy for the amount of energy required to cool buildings when the temperature rises above a certain level. They can therefore be used to estimate the exposure (burden) of temperature on cooling demand and electricity generation, and in turn the economic costs of higher temperatures. Note that these are an 'exposure' metric, i.e. they present the burden as opposed to the actual impact.

CDD are calculated as annual measure of the frequency and extent to which days have a mean temperature above a set threshold (ºC), above which comfort levels would potentially lead to cooling demand, e.g. the use of air conditioning[23]. In the analysis here, because of the existing warm climate, and because of data availability, the study has used a high CDD threshold level of 22 °C.

The study first considered the historic data sets. Unfortunately, due to meteorological data availability, the study has had to use a simpler version of the calculation, looking at the difference between the daily maximum temperature and the threshold temperature[24]. It is highlighted that this approach is only indicative, and a more comprehensive analysis is recommended for the future. The data for all met stations considered in the study are shown in the underlying report. Most the results are as expected with higher exposure (i.e. potential cooling

[22] To derive CDD, the number of degrees Celsius that the mean temperature is above a given threshold (ºC) has been calculated for every day of the year and this is summed for all days of the year. Thus Σ(daily mean temperature – threshold) for Tmean > threshold. The threshold temperature used varies between studies, which has a large effect on the cooling demand. In many global studies, a daily mean temperature of 18 °C is used. However, studies in the US have worked with 21 °C based on observational information, and UK analysis often uses 22 °C.

[23] Noting that the use of AC is conditional on having the technology installed, the availability of energy supply, and the financial resource to afford to use it. There are therefore very large differences between the potential effect, as measured in cooling degree days, and the actual impacts, measured in additional kWh of energy use. Note however that if future cooling demand is unmet, then it leads to alternative economic costs in the form of reduced comfort levels, loss of productivity, risks of health impacts, etc.

[24] It is stressed that the use of the daily maximum temperature is not accurate and other more sophisticated methods can be used given more data for the location. Minimum temperature is available for locations in Tanzania, but the timing of the measurements is suspect and hence the values are not reliable. The method used here primarily provides a baseline climatology with which to compare future projections. Note these temperature-based indices do not take into account secondary variables influencing the need for cooling notably humidity.

demand) in warmer locations such as Dar es Salaam and Kilimanjaro. Cooler locations such as Mbeya and Mwanza show much lower levels throughout the year.

Results

The study has then considered the future cooling degree day with climate change. This is shown below for Dar es Salaam for the 2050s, using downscaled data. Other met stations and later time periods are included in the underlying report. In each case, the top figure presents the CDD over the year for the modeled baseline of 1960 -1990 (in grey) and with climate change during the period 2045 – 2065 (in red). The bottom graph (blue envelope) shows the change between the two, i.e. the absolute level of increase. Note that the high threshold level for cooling used in the analysis means the absolute CDD changes are less than in other global studies[25].

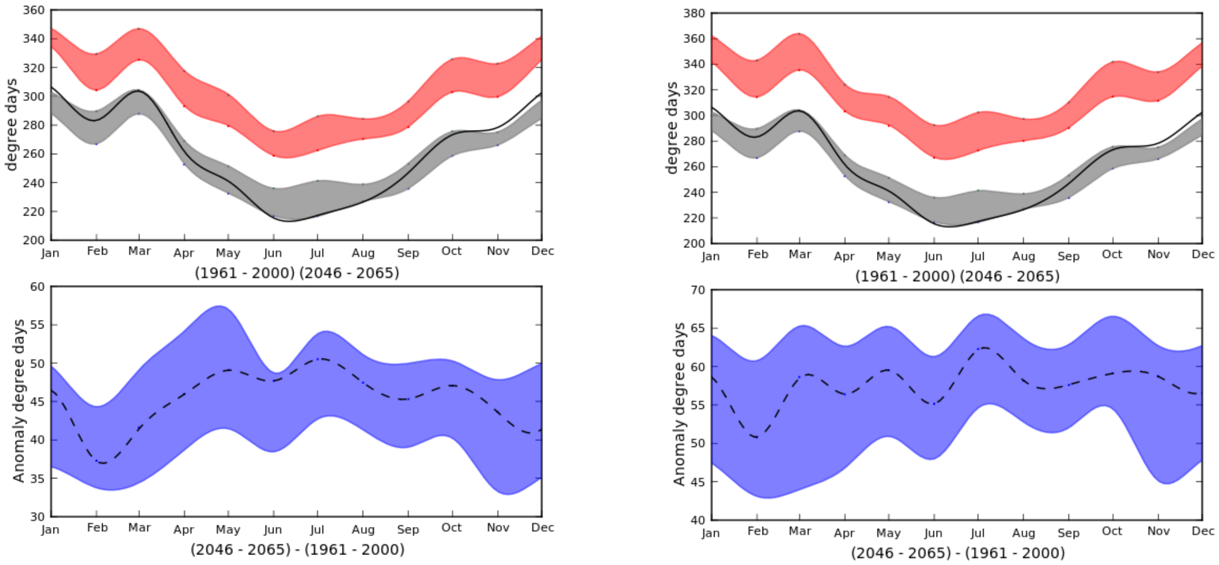


Figure 19. Projections and anomalies of monthly cooling degree days (2046 - 2065) B1 (left) and A2 (right) Scenarios using a high cooling demand threshold for Dar es Salaam.

For each station, the top box presents the CDD over the year for the modeled baseline (in grey) and the future period (2050s) with climate change (red). The bottom graph (blue envelope) shows the increase from the modeled baseline, i.e. the marginal increase. Note the results presented are for a higher cooling threshold.

The results show relatively consistent increases through all seasons in Dar es Salaam, because of the relatively high (22°C) threshold used, and because of the high constant temperatures in the city. The analysis of other met stations shows similar patterns, where the increase in CDD broadly matches temperature increases, with the exception of cooler locations such as Mbeya and Mwanza.

The study has considered the potential implications and costs of the rise in cooling demand on the electricity sector. In terms of energy, the rise in cooling demand will increase average generation demand. However, it will also alter the demand curve, and increase the capacity needed on the system to cope with the marginal increase in peak demand.

A comprehensive approach to do this would be to follow the approach of McNeil and Letschert (2008) as applied in studies such as Isaac and van Vuuren (2009). This estimates future air conditioning demand based on a series of equations, that take account of future CDD, population (households), per capita income (and related technology penetration, which rises rapidly about a per capita threshold), average consumption and efficiency. The CDD data (see above) is not in the correct form to allow the estimation with these equations.

However, this literature does provide some key pointers. First, air conditioning is highly income dependent, with penetration levels rising above a threshold of around $10,000 per capita (note PPP adjusted). This is higher

[25] Isaac and van Vuuren (2009) project that average CDD in Africa will rise from around 2000 CDD currently to 3600 CDD by 2100 with climate change, but with a threshold of 18C.

than average per capita incomes in Tanzania – now – or in the immediate development future. Analysis of penetration curves with income (from Isaac and van Vuuren, 2009) suggests that availability (% of maximum saturation) in Tanzania would therefore be very low even in 2030. The current penetration – and future increase in air conditioning - are likely to be constrained to higher income households, some parts of the service sector notably tourism. However, the lack of cooling across the rest of the population and economy will mean that there are impacts from unmet cooling demand, in the form of comfort levels, health effects, and reduced labour productivity, etc.

To explore these potential costs, the study has looked at other literature sources. The IPCC reports that space cooling is already a major concern in tropical and subtropical cities, accounting for in excess of 50% of total electricity use in medium income countries – this is important in terms of the growth objectives outlined in the Vision. As a very indicative analysis, the study has assumed 10% of current demand supplies cooling (which seems plausible based on the earlier supply data), and that this proportion will increase in line with electricity growth in future years (a tenfold increase in the master plan) in line with rising GDP and per capita income. It has then assumed a 25 - 50% increase in demand by the 2030, rising to 25 – 100% by the 2050s (consistent with the range of CDD data above) in electricity generation for cooling. Even with these assumptions, this leads to significant increase in demand on the system for cooling, of around 600 to 2300 GWh by 2030 (i.e. at least several large stations, and potentially much more than this). With rising per capita growth and rising temperatures, these would increase significantly by the 2050s.

There are complex issues in predicting future energy demand and prices, not least because of the need to predict future energy and electricity prices (under socio-economic conditions and future mitigation scenarios) and technological efficiency. TANESCO currently sells power at about $0.10 per unit (kilowatt hour/kWh), which is broadly in line with the Master Plan price projections. Applying these current prices to the additional generation leads to an indicative cost of $60 million a year by 2030 (current prices), though in practice the marginal cost on the system would be different to this. This very simplistic analysis therefore shows that the additional costs of climate change easily be in the range of $ 60 - 120 million per year by the 2030s, and if electricity demand rises at the same rate in future years, potentially $200 – 800 million / year by the 2050s. This highlights that the issue could be a key issue and warrants further investigation.

In some sectors, such as high value tourism, it would be expected that these future cooling burdens would be met through mechanical (electric) air conditioning. This will increase costs to this sector. It will also be an important factor in the service sector.

However, while this increases average demand, it also has the potential to increase peak demand on the system, as cooling demand rises during particularly hot spells. This is a key concern for Dar es Salaam, as shown in the early projections of number of days exceeding 32 degrees. This will lead to much higher marginal costs, as well as having implications for the overall system security of supply, i.e. there will be a need for electricity planning to consider much higher potential peak capacity levels because of climate change.

At the moment, the current electricity planning in Tanzania (e.g. Master Plan) does not take account of the effects of climate change on demand forecasts (average and peak). Furthermore, the effects of climate change on energy demand is not factored into key national planning (e.g. in the NAPA or NC). This is highlighted as a key omission, and the study recommends the need for energy demand to be added as a key risk for Tanzania, especially given the current economic costs associated with unmet demand (see earlier) at present.

It is also highlighted that given the existing high levels of own-generation (diesel back-up) in Tanzania, there is a danger that climate change will increase demand, leading to much higher energy requirements on such systems (e.g. for hotels). As this self-generation is primarily supplied by high cost, high polluting generation, the increased energy demand from climate change will lead other impacts, such as air pollution.

For the more vulnerable, lower income groups, there will not be access to cooling, 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.

Higher temperatures and rising incomes will increase <u>cooling demand</u> leading to increased electricity use and economic costs, perhaps by 25 to 100 % by the 2050s. The associated economic costs could be large – an indicative analysis indicates easily $ 50 million per year by the 2030s and potentially much more by the 2050s. The demand for cooling will also increase peak demand, putting extra pressure on the system. The impact of climate change on future electricity demand is not yet accounted for in energy master plans. This is highlighted as a key issue.

The net changes in energy demand will vary with location across Tanzania. These effects are likely to be particularly important at the city scale, due to the concentration of population and industry, and because of the potential urban heat island effects in future years with urban development. 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.

There is also another potential adaptation-mitigation linkage emerging, with the potential increase in energy use for increasing water supply (pumping, desalination, recycling, water transfers) in areas where water availability is declining due to climate change. There is little information about these effects as yet, but they are strongly related to other sectors (cross-sectoral linkages between water availability, domestic supply, agriculture, tourism, etc.) and are a major evidence gap.

5.5. Water Sector

Water is a critical sector and underpins much of the Tanzanian economy. It supports the agriculture sector and is also an input into industrial production: for example, mining, a key sector in Tanzania's Development Vision 2025, depends on reliable water. Water - through hydropower - provides 55% of the country's power generation. Water flows also support Tanzania's forests, grasslands, and coastal resources, which provide provisioning services (such as food, fodder, fuelwood, timber and other products) and other services (water purification, climate regulation, cultural and supporting services), including for national parks and protected areas support the tourism sector, a key foreign exchange earner. The study has undertaken an analysis of the impacts of climate change on water. A full technical report is available on this work[26]. This section summarises the analysis and findings.

Tanzania has nine major river basins: Rufiji, Pangani, Ruvu, Great Ruaha, Malagarasi, Kagera, Mara, Ruvuma, and Ugalla River Basins. These are economically significant and support livelihoods through fishing and traditional farming irrigation systems. It also has three of the largest freshwater lakes in Africa - Tanganyika, Victoria and Nyasa - which represent a huge natural storage capacity for Tanzania. About half of the country's surface runoff comes from rivers flowing into the Indian Ocean, part of the rest drain into the lakes Victoria.

The second Vulnerability Assessment Report of Tanzania reports that the majority of households use more than one source of water supply, although (62%) depend on traditional sources of water supply, with wells (26%), rivers (24%) rain harvest (9%) and lakes (6%). Two thirds of the households depend on underground water wells, rain water and lakes for water supply while only one third is served by piped water.

The sources of drinking water are very different between urban and rural locations: for example, almost 70% of urban households have access to piped water either within their household plot or through a shared tap, whereas less than 7% of rural households have this level of access. However, there have been concerns over declining access to improved sources of water in recent years, including for Dar es Salaam (van den Berg et al., 2009) due to rapid urbanisation, as well as issues of over-abstraction upstream, catchment degradation and salt water intrusion in groundwater. It is also noted that there is an increasing gap between water connection and water service supply, as evidenced by recent rationing in 2010.

[26] The Economics Of Climate Change In Tanzania: Water Resources. Stacey Noel, Stockholm Environment Institute, SEI-Africa Centre, Institute of Resource Assessment, University of Dar es Salaam, available at the web-site (http://economics-of-cc-in-tanzania.org/).

In rural Tanzania, access to improved water sources has increased, from 35% in 1991 to 42% in 2007, mostly due to increasing dependence on other improved water sources, especially groundwater (van den Berg, 2009). Currently, about 50% of Tanzanians living in rural areas have access to clean drinking water. A total of 31.7% of the rural population rely on ecosystem sources (springs, streams, rivers, ponds and lakes) and 28.5% access domestic water from open public wells. However, there are major challenges over the sustainability of rural water supplies, with a number of recent studies highlighting problems with waterpoints.

These issues also need to be seen in the context of socio rapidly changing socio-economic change, notably population growth, agricultural irrigation extension, land-use change, etc. To illustrate, as highlighting earlier, the country has a very varied rainfall regime, which varies with region and season. In 2007, Tanzania's renewable water resource per capita was 2,290 m^3 (WRI, 2010). However, due to demographics, the rise in the population to over 50 million by 2015, would tip the country's per capita water resources to below 1,700 m^3 per person, the definition of water scarcity (using the Falkenmark Water Stress Indicator). By 2030 the population is expected to be around 75 million and by 2050 it is projected to reach over 100 million, further lowering per capita water resources. Moreover, water resources are unevenly distributed, with some regions receiving high rainfall (e.g. the southern highlands) while major parts of the country receiving very low. These changes also have to be seen in the context of rapid urbanisation. However, these future projections – and the supply demand balance – are conditional on a lack of future action. It is possible to address future deficits, though it is clear this will take major investment.

Given these underlying drivers, there is likely to be considerable resource pressures on water in future years. Climate change – and the potential changes in precipitation, variability, run-off, salt water intrusion, etc. - has the potential to exacerbate any water deficit. Indeed, as a highly climate sensitive sector, climate change has the potential to impact on water resources, affecting the whole water cycle and water ecosystems. This could include changes in river flow and groundwater systems, that would 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), as well as energy supply, agriculture, tourism, industry, etc. across the economy. Ancillary stresses of pollution, salinisation, sedimentation and over-extraction of groundwater exacerbate vulnerability to current and future climate risks.

Previous studies

Mwandosya *et al* (1998), as part of the US Country Studies Programme, considered changes across a range of impacts, including on river runoff using a Water Balance (WATBAL) model, The study projected the changes in the annual river runoff changes for Ruvu River (decrease of 10%), Pangani basin (decrease of 6-9%) and Rufiji basin (increase of 5-11%). These values have been very widely cited and used in assessments in Tanzania. However, the analysis only considered climate drivers, and also did not report the range of modeled projections, as discussed earlier.

Munishi et al (2010) took the values from Mwandosya et al above, assessing water flow loss for each river, and applied water prices based on urban water supply (TSH 500 m^3). While this approach is problematic, the reported losses were estimated at $63 million/year.

There have also been a number of economic reports, particularly focusing on the Pangani basin (notably Turpie et al (2003: 2005). This highlights the very high value of water across users (domestic users, agriculture food and cash crops, energy generation, livestock, etc.) and the estimate value per m^3: it also highlights the value in terms of environmental goods and services, including aquatic food sources and wider provisioning services, and reports on the total value per household this generates. These provide much more comprehensive analysis to assess the potential economic costs of future climate change against.

Discussion

The water analysis has considered the potential changes across the projected climate model outputs, noting the wide range of possible outcomes. Within the time and resources of the study, it has not been possible to undertake detailed catchment analysis and build up an assessment of potential impacts and economic costs on the supply demand deficit. However, it is highlighted that given the socio-economic drivers outlined above, any negative effects from climate change could have potentially high economic costs. Following on from this, the challenge for Tanzania in terms of water strategies will be the need to consider the high degree of uncertainty in future climate. While temperature change predictions are fairly consistent, rainfall patterns and water flows projection vary widely, including both spatially and temporally within seasons. Factors such as land use change, ENSO (variability) and population growth also have the potential to change the level of water resources available, further complicating the divergent scenarios. This is considered further in the adaptation section.

However, even if the projections of future models were more certain, a finding of the study is that there is a lack of systematic studies of the integrated risk in the water sector in Tanzania. This constrains the ability to judge potential impacts and response options. This is a major gap requiring urgent attention.

The future impacts of climate change on water depend on the nature of managed supply and demand, related to a wide range of factors including socio-economic development and operational management as well as climate outcomes.

The lack of systematic studies of the integrated risk in the water sector in Tanzania constrains the ability to judge potential impacts and response options. This is a major gap requiring urgent attention.

Extreme Events and Infrastructure

As highlighted above, Tanzania already is 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.

The review material has considered the earlier reported results on the economic costs of floods and droughts, and the climate projection results reported in the IPCC AR4 and recent comparison of results from Shongwe et al (2009).

Many of the projections indicate an increase intensity of extreme rainfall events in much of East Africa, including in Tanzania by the end of the century (i.e. 2100).These are associated with higher flood risks. 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.

While many of the models predict increases in rainfall on average in many (but not all) regions, 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 Tanzania. Other models project a potential intensification of these events, particularly in Southern and central regions. However, the fact that changes are likely makes this a priority area.

Against this background, there is a need to enhance the resilience of existing infrastructure to a changing climate and to potentially more extreme weather conditions, taking into account the social and economic costs of infrastructure failure. The need to build resilience to droughts and floods is therefore a key priority for Tanzania.

5.6 Forests, Biodiversity and Ecosystem Services

Tanzania has very diverse and rich ecosystems that range from coral reefs and mangroves along the Indian Ocean coast - to dense mountain forests - to the shores and waters of Lakes Victoria. The specific ecosystems include freshwater rivers, mountains, drylands, wetlands, savannah, coastal and marine ecosystems, many of which are trans-boundary in nature.

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' (MEA, 2005) 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), see below.

Ecosystem Services

It is now widely recognised that ecosystems provide multiple benefits to human society, known as 'ecosystem services' that are much wider than just biodiversity. These include

- Provisioning services: include the production of basic goods such as crops, livestock, water for drinking/washing, industry, hydro-power and irrigation; fodder/or pasture/grazing, timber, biomass fuels, fibers such as cotton and wool; minerals for energy, construction, transport; and wild plants and animals used as sources of foods, hides, building materials, and medicines
- Regulating services: include benefits obtained as ecosystem processes affect the physical and biological environment around them; these include water storage, flood protection, coastal/tsunami protection, regulation of air and water quantity/quality, regulation of water flow, absorption/bio-degradation of wastes, absorption of carbon dioxide, control of disease vectors, and regulation of climate
- Cultural services: include non-material benefits that people derive from ecosystems through spiritual enrichment, recreation, tourism, outdoors-related sports, education, heritage, bequest value and aesthetic enjoyment. These services also include societies whose cultural identities and religions are tied closely to particular habitats or wildlife
- Supporting services: these services are necessary for the production and maintenance of the three other categories of ecosystem services. Examples are water cycle, nutrient cycling, production of atmospheric oxygen, soil formation, and primary production of biomass through plant photosynthesis

The human species – and economies - while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of these ecosystem services.

As an example, SWMP (2010) highlight the services provided by wetlands to the economy and livelihoods in Tanzania:

• 95% of electricity is from wetlands from hydro-electric power (HEP) (eg. Usangu)
• 95% of domestic, irrigation, industrial and livestock water is from wetlands
• 80% of irrigation is traditional schemes in wetlands
• 95% of rice is grown in wetlands
• 95 % of vegetables are grown in wetlands
• 850 000 ha of wetlands have potential for future rice irrigation conversion
• 95 % of wildlife depend on wetlands for grazing and water
• 95 % of all game corridors/wildlife migration routes are between wet and dry season wetlands
• 95% of the 25 million livestock is maintained through dry season pastoralism in wetlands
• 50% of non-forest products, medicines, clays, coral lime, salt and sand mining, house building materials, fibres for mats, etc. is from wetlands
• 90 % of wetlands are susceptible to climate change & catchment degradation
• 95% table salt is from 197 salt works in coastal and inland modified wetlands
• 95% of tourism (coastal and wildlife) depends on wetlands

Similar examples exist for coastal ecosystems (coral reefs and sea grasses), mountain regions, etc.

Ecosystem services are integral to the Tanzania economy and underpin a large proportion of GDP (over 50%), as well as foreign revenue and export earnings, for example, nearly one-third of Tanzania's national revenue is derived from wildlife tourism. There are also important fishery resources in Lake Victoria, Tanganyika and Nyasa and other small lakes and rivers. These areas also sustain a very large proportion of the population and a large proportion of livelihoods. A specific example is included in the box above. While the definition of ecosystem services includes consideration of agriculture and water, these are included in a separate sectoral analysis, and thus omitted from this section. The consideration of coastal ecosystems is also discussed in the coastal sector.

A large proportion of Tanzanians 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. In addition to agriculture, nature-based tourism, fishing, timber and charcoal production are other important sources of income in the country. It is also highlighted that the MKUKUTA's aim is to stimulate growth and reduce poverty are largely dependent on multiple ecosystems and the services and resources these provide.

Forests

The study has undertaken a detailed baseline analysis of forests, as part of work on REDD (see later section). This section summarises the background information. A full technical report is available on this work[27].

Tanzania has extensive forest and woodland resources, reported at 35 million hectares in 2002 (UNREDD, 2009), or around one third of total land. These forests have a major role in the Tanzanian economy, including directly but also in the provision of wider ecosystem services. The total monetary value of Tanzanian forest (standing timber) was estimated at US$ 228 trillion (Munishi et al, 2007).

However, there are extensive deforestation pressures due to clearing for agriculture and settlement, overgrazing, wildfires, demand for biomass and charcoal burning and over-exploitation of wood resources for commercial purposes. Note that these also increase of CO_2 in the atmosphere as the carbon sink is progressively lost Estimates of forest losses do vary, but it has been estimated that Tanzania lost an average of 412 thousand ha of forests per year in the 1990s and early 2000s, amounting to a loss of 15% of forest cover in the period 1990-2005 alone (UN-REDD, 2009), with the underlying reasons for the deforestation due to population dynamics, poverty among rural communities, inadequate energy substitutes and limited technology to utilise the available natural and energy resources and opportunities.

Forests provide over 90% of the national energy supply through wood fuel and charcoal, and 75% of construction materials, and the demand for energy in particular is a key factor in deforestation, particularly in areas adjacent to major cities and towns, notably as Dar es Salaam, but also in rural areas where access to electricity is very low. This forms a key linkage with the later energy sector and low carbon analysis.

These issues are now recognised, and there are Government tree planting programs and land being set aside for forestry and national parks to address the problem. Similarly, there are policies emerging, including participatory forest management[28]. More recently, there has been considerable interest in REDD – in which Tanzania is a key stakeholder. Nonetheless, there remain many pressures on forests and climate change poses an additional threat.

Impacts of climate change

The potential impacts of climate change on forests are complex, but forests are potentially very vulnerable to climate change, because of the long life-times of trees, and the fact existing stocks have evolved to the current climate, gradually shifting their composition and structure as climate over millennia. They also have low capacity to adapt to changing ecological conditions through migration (in the way that other natural ecosystems can).

While tree growth may be enhanced by some processes related to climate change (including CO_2 fertilisation, longer growing seasons), forests are potentially impacted negatively by others, notably in relation to changing ecological zones, and the potential for high temperatures, reduced rainfall and increased variability including extreme events such as drought (under some projection). Indeed, forests are likely to experience general stress caused by changing climatic conditions to which they are poorly adapted, affecting growth, forest health, wider biodiversity and system stability. There are also potential effects to forests through changes in soil conditions and hydrology, pests and diseases, the greater risks of fires, etc.

[27] Reducing Emissions: Low carbon and forest management in Tanzania, by Dr Pius Z. Yanda, IRA. The full technical report is available on the web-site (http://economics-of-cc-in-tanzania.org/).
[28] Participation of communities operates in two major forms; Joint Forest Management (JFM) and Community Based Forest Management (CBFM). Community Based Forest Management concerns forests situated on village or general land whilst Joint Forest Management, takes place on reserve land.

The current ecological conditions in which current forests exist will change with increasing temperature, i.e. the suitable conditions for species will change in area over time, either over wide geographical areas, or if available, by elevation. Forests may not be able to make these shifts due to slow growth rates, and/or there may not be suitable natural areas to expand into. However, the changes in precipitation and variability may be even more important. Any changes in floods, or the intensity or severity of droughts, has much greater potential to impact on forests: given the slow growth rates, losses may be irreversible. Any impacts will have wider effects on forest reliant communities, as well as wider ecosystem services that forests provide (e.g. soil protection, flood prevention, natural resources, etc.).

In Tanzania, the 1st National communication reports on modelling studies which look at the projected changes in forests with climate change. This reports that climate change will shift forests across Tanzania towards drier regimes: from subtropical dry forest, subtropical wet forest, and subtropical thorn woodland to tropical very dry forest, tropical dry forest, and small areas of tropical moist forest respectively. The analysis predicted that subtropical thorn woodland would be completely replaced. Subtropical dry forest and subtropical moist forest will decline by 61% and 64% respectively. Munishi et al (2010) attributed this loss to a total economic value of $144 trillion, though some care must be taken in applying total economic values in this way. Nonetheless, the analysis highlights the potentially high value of losses from climate change to Tanzanian forests. The NAPA also reported an increase in tropical very dry forest, tropical dry forest and tropical moist forest, which are likely to replace the current zones. The analysis highlighted some species will be more vulnerable to climate change particularly those: that are drought/heat intolerant; with low germination rates; with low survival rate of seedlings; and with limited seed dispersal/migration capabilities.

The OECD (2003) study reports on the risk of enhancement in the intensity and risk of forest fires on Mount Kilimanjaro, as a consequence of the increase in temperatures and a concomitant decline in precipitation. Continuation of these trends could result in the loss of most of the remaining subalpine Erica forests in a matter of years and the effective water catchment.

The study has not undertaken new modelling analysis on forests and climate change, and it is highlighted that the modelling of these effects is extremely challenging, given the wide range of model projections, but also the very large number of complex factors (and their interaction) that are likely to arise (e.g. including climate variability, pests and disease, as well as general climate change, in predicting ecosystem envelopes associated with suitable ecological zones). However, the potential effects are highlighted as one of the key concerns for future work.

It is clear that any large-scale losses would have a very large impact on the Tanzanian economy from the direct loss of timber values, provisioning services (fibre, building resources, food), regulatory services (soil protection) and cultural and tourism value. It would also have a detrimental effect on carbon storage and Tanzanian's net carbon emissions, which would have an important economic value (in global terms, but also in relation to possible emerging mechanisms).

It is also highlighted that there is the potential for climate change to affect the UN Reduced Emissions from Deforestation and Forest Degradation (REDD+) scheme. The limited indicative studies that are available indicate large threats to current ecological zones, which would affect the viability of current afforested areas and thus the viability and revenues associated with the scheme. This issue is highlighted as a priority for consideration in the context of REDD development.

The potential impacts and economic costs of climate change on forests are potentially high, affecting the services and economic value that they provide, including timber, fuel wood, building material, soil and flood protection, carbon storage and tourism value.

Climate change also has the potential to affect the UN Reduced Emissions from Deforestation and Forest Degradation (REDD+) scheme, in terms of the future viability of current afforested areas and thus revenues. This issue is highlighted as a priority for consideration in the context of REDD development.

Biodiversity and Ecosystem services

The study has undertaken an initial scoping analysis on the impacts of climate change on biodiversity and ecosystem services in Tanzania. A technical report is available on this work[29]. This section summarises the analysis and findings.

There are many stresses on ecosystems already, such as: agricultural expansion; destruction of habitat; pollution; high rates of land use change; recent population growth, etc. Many of the ecosystems of Tanzania are under threat or over-exploited already. Future socio-economic drivers will also increase these pressures, notably the very high population growth forecast for Tanzania, which could double the population over future decades. While Tanzania does have a network of national parks, reserves and conservation and wildlife areas, as well as marine protected areas, these are under pressure.

Climate change will add to these existing issues. Indeed, climate change is likely to have major effects on managed and natural ecosystems and associated ecosystem services. These impacts are complex but potentially arise from temperature increases, changes in precipitation, shifts in climatic zones, sea level rise, droughts, floods and other extreme weather events. Particularly vulnerable areas in Tanzania include arid lands (from water scarcity and heat stress), coastal zones and mountain regions.

Climate change could lead to shifts in: species distributions; changes in phenology; a potential decoupling of coevolved interactions, such as plant–pollinator relationships; effects on demographic rates, including as survival; changes in population size; and in some cases extinction. There may also be effects from direct loss of habitat due to sea-level rise, increased fire frequency, altered weather patterns, glacial recession, and direct warming of habitats. This can be compounded by other indirect effects such as changes in the distribution or spread of wildlife diseases, parasites; changes in invasive or non-native species, including plants, animals, and pathogens.

Many of these potential impacts are uncertain, and highly complex to predict. What is clear is that climate change could cause bio-climatic zones (and their ecosystems) to move, potentially by tens to hundreds of kilometres by the end of the century. The success of ecosystems to move 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. There are also many indirect effects of climate on ecosystems, for example in relation to water resources and availability, land-use pressures (e.g. in relation to other sectors), pest and disease, etc.

There are already observational changes of climate in Tanzania, the most obvious being the decrease in the ice cap of Mount Kilimanjaro, which has reduced between 50-80% over recent times. While glaciers on the mountain have been in a general state of retreat for over a hundred and fifty years, the recent decline in precipitation coupled with a local warming trend in the second half of the twentieth century (plus potentially other complex factors) has accelerated this. Kilimanjaro's ice cap is now projected to vanish entirely by as early as 2020 (OECD, 2003).

Other climate related episodes include the coral bleaching that occurred from warmer temperatures associated with the 1998 El Nino, which reduced coral cover in most reefs of the country, with mortalities of up to 90% in many shallow areas.

The NAPA reported on the potential important shifts in Tanzania's ecological zones. This includes potentially major shifts in forests (see earlier section).

Climate change is expected to put Africa's and Tanzania's ecosystems and biodiversity at severe risk, with the IPCC AR4 (2007) reporting that potentially 5,000 African plant species and over 50% of bird and mammal species could be seriously affected or even lost by the end of this century. It also reports on studies that estimate that by 2100 the productivity of Africa's lakes could decline by 20 to 30%, a key factor for Tanzania. These changes will have large economic consequences through the ecosystem services provided, whether this

[29] Ecosystems Report for the Economics of Climate Change in Tanzania – and Ecosystems Based Adaptation in Tanzania by Tahia Devisscher (SEI), available at the web-site (http://economics-of-cc-in-tanzania.org/).

is the provision of food, the tourism potential of key areas, etc. the previous studies and literature on the possible effects for East Africa – noting many ecosystems are trans-boundary - projected by different studies, are summarised below.

Effects of Climate Change on East African Ecosystems for Varying Temperature Increase

(°C)	*Possible Impacts*
<1.5	Up to 15% of Sub-Saharan species could be at risk of extinction (IPCC WGII 2007).
1.5	Widespread bleaching of up to 97% of coral reefs of East Africa (Hoegh-Guldberg 1999).
<1.5	Glaciers on Mount Kilamanjaro, Mount Kenya could be lost by 2015 (Thompson et al. 2002)
1.5	10-15% of sub-Saharan species could be at risk of extinction (IPCC WGII 2007).
1.7 – 3.2	8-12% of 277 med/large mammals in 141 national parks at risk (Thuiller et al. 2006).
2.4	Bio-climatic range of 25-57% (full dispersal) or 34-76% (no dispersal) of 5,200 plant species exceeded in Sub-Saharan Africa (McClean et al. 2005).
>2.0	At least 40% of sub-Saharan species at risk of extinction (IPCC WGII 2007).
2.3 – 4.6	Cloud forests lose hundreds of meters of elevational extent, potential extinctions at 2.5 °C for Africa (Still et al. 1999).
2.6-3.7	30-40% of 277 mammals in 141 parks critically endangered (Thuiller et al. 2006).

Sources: IPCC AR4, PA 2009. ΔT above pre-industrial.

Of course, while these future effects are influenced by climate change, they are also heavily affected by socio-economic factors, including the growth and movement of people and goods, changes in land use and economic development. The consideration of future baselines and the potential for economic development to reduce future burdens is therefore a key consideration.

The valuation of ecosystem services has progressed in recent years (TEEB, 2009), and several studies have been conducted to value different ecosystem services attributable to protected areas in the context of Africa, such as tourism value, genetic prospecting, wildlife viewing, community uses, etc.

Provisioning services can be valued at market prices. Other services, such as regulating and cultural services, such as the ability of an ecosystem to provide natural habitat for flora and fauna and biodiversity loss, have no direct market price, though it is possible to approximate the value of these functions by the use of direct or indirect valuation methods. Similarly, as these services have an economic value, loss or degradation of such ecosystem services has economic costs

The majority of the studies have been based on contingent valuation methods. Other economic valuation studies have estimated services provided by mangrove ecosystems at US$4,290 annually per hectare, benefits from lagoons and seagrasses at around US$73,900 per year per hectare, and services provided by coral reefs at US$129,000 per year per hectare (TEEB 2009). There are some older estimates for East Africa and Tanzania, including estimates for the Tarangire national park (Clark et al 1995), which estimated WTP values of $ 3.4 per hectare, as well as examples from other East African countries for Kenya (tourism and CV studies), Rwanda (mountain park / gorilla tourism), and Uganda (rainforest and pharmaceuticals).

There has also been an assessment of the market revenues (activities such as tourism, hunting, fishing), and non-market earnings (i.e. unmeasured, unmanaged and under-valued activities) generated in Tanzania by wildlife, ecosystems and nature-related sectors and industry between 2005 to 2007 (MNRT 2008, TRAFFIC 2008).

However, more work needs to be done to account for the range of services that ecosystems can provide. Further, it is often difficult to predict the change in ecosystem services that will arise from climate change (i.e. the marginal reduction in services). To date studies have focused on current pressures, rather than climate change.

Discussion

The analysis of climate change on biodiversity and through to ecosystem services (and valuation) is extremely challenging. It is possible to assess the change in ecological zones, through mapping future climate envelopes, but such approaches remain highly uncertainty, due to the climate projections as well as the much wider and complex range of direct and indirect climatic and socio-economic effects.

Given the resource and time constraints of the current study, the analysis has undertaken a qualitative mapping of key ecosystems services and the potential effects of climate change in Tanzania.

The study has considered the baseline contribution of ecosystem services to the economy, and considered the existing and future pressures on the most important of these. This finds that the growing population is likely to be the most important pressure on future ecosystems, the potential to exceed ecosystem carrying capacity, unless natural resources are managed more sustainably.

For example, the pressure on water resources will most likely exceed the carrying capacity of wetland ecosystem leading to a possible collapse of wetland functions and services.

The scoping study prepared by the International Institute for Sustainable Development for the United Nations Environment Programme in 2005 identified four human induced critically stressed ecosystem services in Tanzania that need immediate attention: 1) maintenance of biodiversity; 2) food and fibre provision; 3) water supply, purification and regulation; and 4) fuel provision. The latter three are covered in earlier section. The remaining priority area is around biodiversity.

While there is extremely large and diverse biodiversity in Tanzania, the primary ecosystem service (in economic terms) is through the country's tourism sector, which is primarily based on wildlife and wetlands tourism. Currently, the tourism sector is valued at USD 1.3 billion, accounting for 33% of the GDP (MNRT 2008). The main tourist attraction in Tanzania is associated to the natural assets of the country.

The study has undertaken some case study work, looking at the potential threats of climate change on some key areas, considering climate envelopes and potential impacts on the Kenya-Tanzania Borderlands. Given the average climate projections in these areas (higher temperatures, but potentially also increases in rainfall), the immediate effects may be modest, however, there could be significant shifts in species and habitats over time, with increasing conflicts between rapidly expanding agriculture into previously marginal areas, and pastoral communities and biodiversity. However, other factors arising from climate variability that may be more important.

It is considered that the challenges will be most acute for narrow ranged species and those confined to highland areas. A key issue for impacts is the flexibility / mobility that national parks and reserves have in the face of projected changes in climate, especially given the uncertainty in the model projections, therefore early adaptation measures to allow connectivity are still needed.

There are also potential other impacts of relevance to tourism – and wider food provision (fisheries) - from the potential impact of rising temperatures, and rising ocean acidification, on coral reef ecosystems. There are some recent assessments of the economic costs of coral bleaching along the East African coast (see SEI, 2009).

Another focus has been to consider the implications for wetlands. Recent work (SWMP 2009: 2010) highlights the importance of wetland ecosystems, which occupy 10% of Tanzania's territory, and play a crucial role in the economy, livelihoods of people and livestock, fish and wildlife in Tanzania: these are one of the most productive systems, supporting agriculture, providing water, food, energy (including hydro), utensils, construction materials, economic and habitat security, and providing the feeding, breeding and nursery areas for prawns, shellfish and many other commercial fish species. Wetlands are also key to wildlife habitats and serve as important wildlife corridors. They also provide flood control, water storage, water purification and waste management. As highlighted in the water sector above, while the impacts are uncertain, these remain potentially at risk from climate change.

Finally, it is stressed that the impacts of climate change on ecosystem services will not be felt equally across Tanzania, both in terms of by region, but also across groups: large portions of the population are particularly vulnerable to climate change because of their limited livelihood base, poor access to markets and services (notably economic dependence on nature for food, water supply, energy, transport, healthcare and social welfare), and weaknesses in the institutions that govern them. Further analysis in this area – including the economic valuation of potential reductions in ecosystem services – is considered a priority.

Ecosystems provide key economic benefits (services) to Tanzania and underpin more than 50% of the economy. They are also underpin the MKUKUTA, as the stimulation of growth and poverty reduction are largely dependent on multiple ecosystems and the services and resources these provide. There are many stresses on these systems already and climate change will add to these pressures.

5.7 Summary of Sectoral Analysis

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 agriculture, coastal zones, electricity and health alone indicate future economic costs could be almost a billion dollars by the 2030s and well in excess of this by the 2050s under some projections. The figures are summarised below. The numbers broadly support the early aggregate analysis: for the 2030s, the analysis indicates costs for these sectors alone could be around 1% of GDP equivalent per year (forecast future GDP, assuming Vision growth rates).

There are also potential effects on ecosystem services, which whilst difficult to estimate at present, could be very large in economic terms. Finally, there are some possible scenarios of climate change on the water and indirectly on other sectors which would lead to high economic costs.

It is also highlighted that as well as economic impacts, there will be impacts 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 (as well as affecting livelihoods). There is also likely to be a strong distributional pattern of effects, with some sub-regions and some groups affected more than others.

Finally, there are a number of early next steps which are highlighted. The most important of these is to further understand these potential impacts and economic costs of climate change. There are recent studies which have started which will help address the gaps. However, a number of specific issues are highlighted.

- There is a need to need to address the current economic costs of existing climate variability in Tanzania. One way to advance this might be through a more detailed economic study on current costs and how this affects GDP. This information could also be presented in a way that communicated the impacts on individual Government budget lines, to help mainstream actions to address the current adaptation deficit.

- There is a need for a broader consideration of additional risks not yet covered, e.g. within existing sectors (such as assessing additional health risks), and in particular additional sectors yet covered (e.g. tourism and industry), as well as cross-sectoral issues and indirect effects.

- There are a number of priority impacts that need consideration in Government planning, notably in relation to the effects of climate change in relation to coastal development plans (especially for Dar), future energy planning and forest schemes (REDD), as well as more general sector policy for agriculture, water and health.

Indicative Economic Costs of Climate change (no adaptation)	
Coasts	US$26 to 55 Mill / year in 2030 US$104 to 210 Mill / year in 2050 US$408 to 612 Mill / year in in 2100. [1]
Agriculture (crops only)	Maize : from potentially positive through to worst case scenarios (no autonomous adaptation) of $US330 million/year by 2030s and possibly several times this by the 2050s[2] Note potential additional impacts on cash crops, horticulture and livestock
Health	Indicative (scoping) estimates of treatment costs for malaria and diarrhea only US$18 - 98 Million / year in 2030 and US$36 - 157 Million / year in 2050[3] Note potential additional health impacts for a range of direct and indirect outcomes, as well as impacts on labour productivity
Energy	Supply – Hydro – potentially large under some drier scenario Indicative estimates of efficiency loss for thermal plant ~$10 million / year by 2030s[4] Indicative (scoping) estimate of increase in electricity costs for cooling demand = $60 - 120 million / year by 2030s and several times larger than this by the 2050s[5]
Water supply and quality	Not quantified, but potentially large additional cost under drier scenarios from reduction in water supply (or costs of addressing water supply deficit)
Forests, Biodiversity and ecosystem services	Not quantified, but possibly large ecological shifts and loss of ecosystem services, including provisioning, supporting, regulating and recreational, with potentially high costs

Values in 2005 dollars, undiscounted.

1 Modelled using the DIVA model. Includes combined effects of climate and socio-economic change, with no adaptation. Values reflect range of low to high levels of sea level rise and range of linked socio-economic scenarios.

2. Modelled using crop based models, considering high emission scenarios and the more negative range of modelled change. No autonomous adaptation (i.e. no farm level or planned adaptation) assumed, and costs simply estimated using current prices, with no linkage to wider prices or markets.

3 Indicative estimates using relative risk estimates, combining climate and socio-economic scenarios to provide a bounded range (high climate low development and vice versa). Costs based on treatment costs, not WTP.

4 Indicative (scoping) analysis based on reported efficiency losses and based on current forecast prices.

5 Indicative (scoping) analysis based on assumptions of current level of AC, planned future demand levels, and indicative rise in cooling degree days.

6. Aggregated Estimates of Adaptation to Climate Change in Tanzania

6.1 Background

Adaptation can reduce many of the impacts outlined in the previous chapter, however, while it provides benefits, it also has a cost. The study has assessed the costs and benefits of adaptation for Tanzania, starting with the existing priorities and cost estimates in the NAPA.

The Tanzania NAPA

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

The Tanzanian NAPA (URT, 2007) initially proposed 72 project activities. 11 were in the agriculture sector; while water, energy, forestry, health and wildlife sectors had 7 project activities each. Industry and coastal and marine resources sectors had 6 project activities each; human settlements had 9 and tourism had 5. Using a list of agreed criteria that best suited Tanzania conditions and local environment, these were later narrowed down into 14 priority project activities. These were further ranked in accordance with their importance regarding impacts, poverty reduction and health, reliability, replicability of the technique and sustainability.

The 14 selected projects activities were:
1) Water efficiency in crop production irrigation to boost production and conserve water in all areas
2) Alternative farming systems and water harvesting
3) Develop alternative water storage programs and technology for communities
4) Community based catchments conservation and management programs
5) Explore and invest in alternative clean energy sources e.g. Wind, Solar, bio-diesel, etc. to compensate for lost hydro potential
6) Promotion of application of cogeneration in the industry sector for lost hydro potential
7) Afforestation programmes in degraded lands using more adaptive and fast growing tree species
8) Develop community forest fire prevention plans and programmes
9) Establishing and Strengthening community awareness programmes on preventable major health hazards
10) Implement sustainable tourism activities in the coastal areas and relocation of vulnerable communities from low-lying areas.
11) Enhance wildlife extension services and assistance to rural communities in managing wildlife resources
12) Water harvesting and recycling
13) Construction of artificial structures, e.g., sea walls, artificially placing sand on the beaches and coastal drain beach management system
14) Establish good land tenure system and facilitate sustainable human settlements

Following further prioritisation, six key areas were submitted to the UNFCCC NAPA database, along with cost estimates, as follows.

1 Improving food security in drought-prone areas by promoting drought-prone tolerant crops 8,500,000

2 Improving Water availability to drought-stricken Communities in the Central part of the country 800,000

3 Shifting of Shallow Water Wells Affected by Inundation on the Coastal Regions of Tanzania Mainland and Zanzibar 3,300,000

4 Climate change adaptation through participatory reforestation in Kilimanjaro Mountain 3,300,000

5 Community Based Mini-hydro for Economic Diversification as a result of Climate Change in Same District 620,000

6 Combating Malaria Epidemic in Newly Mosquito-infested areas 650,000

The estimated total project costs for these projects were $17.2 million.

However, the priorities outlined in the NAPA only reflect a small part of the adaptation needs for Tanzania.

Further, the challenges of climate change have to be seen in the context of wider vulnerability. As set out in the NAPA –adaptation in Tanzania is constrained by several factors, including (i) extreme poverty of the most vulnerable groups, (ii) poor infrastructure , especially poor rural roads making it difficult to access rural areas, hence difficulties in delivering farm inputs and accessing markets (iii) limited credit opportunities for rural communities to allow family house-holds easily access farm inputs, (iv) the impact of HIV/AIDS creating a major drain on family energy, cash and food,(v) poor health conditions of resource-poor rural communities and (vi) Limited analytical capability of local personnel to effectively analyse the threats and potential impacts of climate change, so as to develop viable adaptation solutions.

There is urgent and significant investment needed for building capacity for adaptation, piloting early action, and moving to climate resilient growth (including 'climate-proofing' new investment), in line with the economic growth plans outlined in Vision 2025, and taking account of projected population and urbanisation trends.

To progress this, the study has undertaken a number of approaches to explore these potential needs, including top-down and bottom-up analysis.

6.2 Top down analysis of Adaptation

A top-down analysis has reviewed the existing estimates of adaptation costs for Africa and scaled these to East Africa and in turn to Tanzania.

To do this, 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 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 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, i.e. the marginal additional costs above current. 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.

Results

Based on this top-down analysis, the study estimates:

Urgent needs, for <u>2012</u>:

- 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 and accelerated development (overcoming the historic adaptation deficit) potentially of the order of $500 million a year, but possibly much more.

Benchmark costs for <u>2030</u>:

- 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 of the same order of magnitude as above and additional funding to accelerate development investment to ensure climate resilience, possibly of the order of $500 to $1000 million a 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 directly attributable to climate change). However, while they are associated with development and addressing the current adaptation deficit, they are essential to reduce future impacts of climate change.

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.**

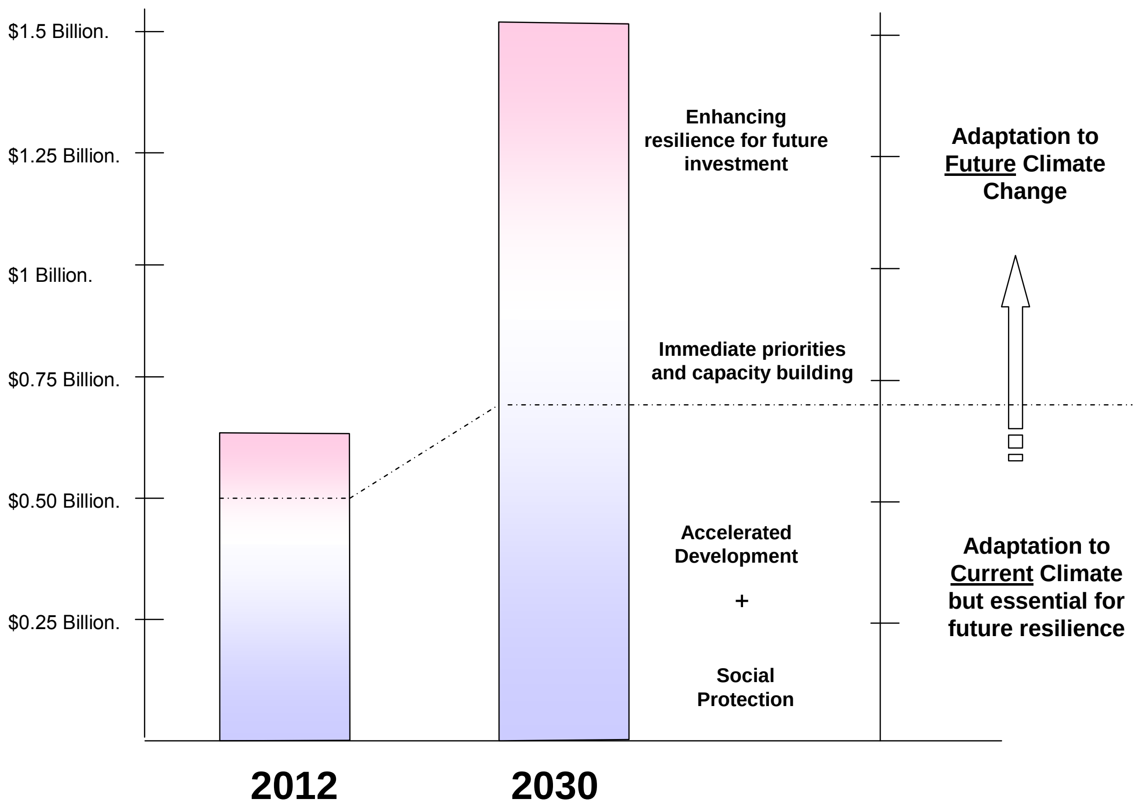


Figure 20. Indicative costs of adaptation to current and future climate in Tanzania $ billion/year

The top-down analysis indicates immediate needs for building adaptive capacity and enhancing resilience against future climate change at US$100 – 150 million per year. This is an order of magnitude greater than the current NAPA.

However, additional funding is needed to address current climate risks, and a conservative estimate is that US$500 million per year (but probably more) is needed. Addressing the current adaptation deficit is essential in building resilience and reducing the future impacts of climate change.

The adaptation needs increase rapidly in future years. By 2030, the estimated costs are estimated to be up to US$1 billion per year for climate change, but again potentially more if further accelerated development is included.

6.3 Discussion of Adaptation and Uncertainty

The methods for assessing the costs – and benefits – of adaptation are still evolving. The review has reviewed the methodological issues, and highlighted a number of key themes for the current study:

- 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 therefore inappropriate to design adaptation strategy against a single future projection of modelled climate. To address this, the study has adopted a greater focus on decision making under uncertainty, emphasizing 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.
- 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 adaptation actions over different 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 Tanzania. 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.
- These are also 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 for early adaptation focus to be on:
    - 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 this set of adaptation responses as a series of steps, together forming an 'adaptation signature'. These identify actions in each of the areas above 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.

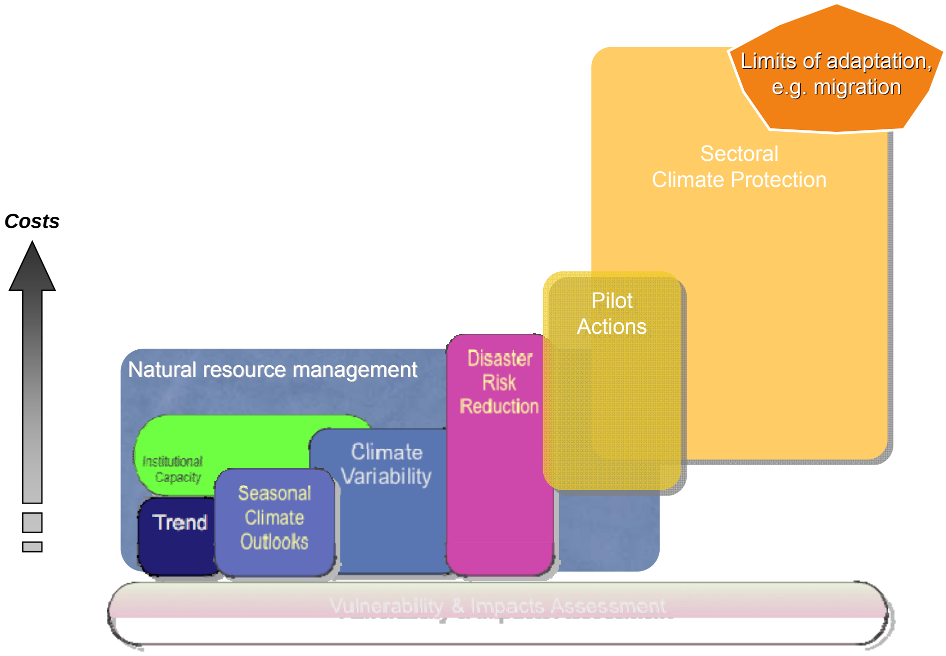


Figure 21. An ensemble of adaptation strategies is required

An example of how this has been applied is outlined in the figure below. Those areas in 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.

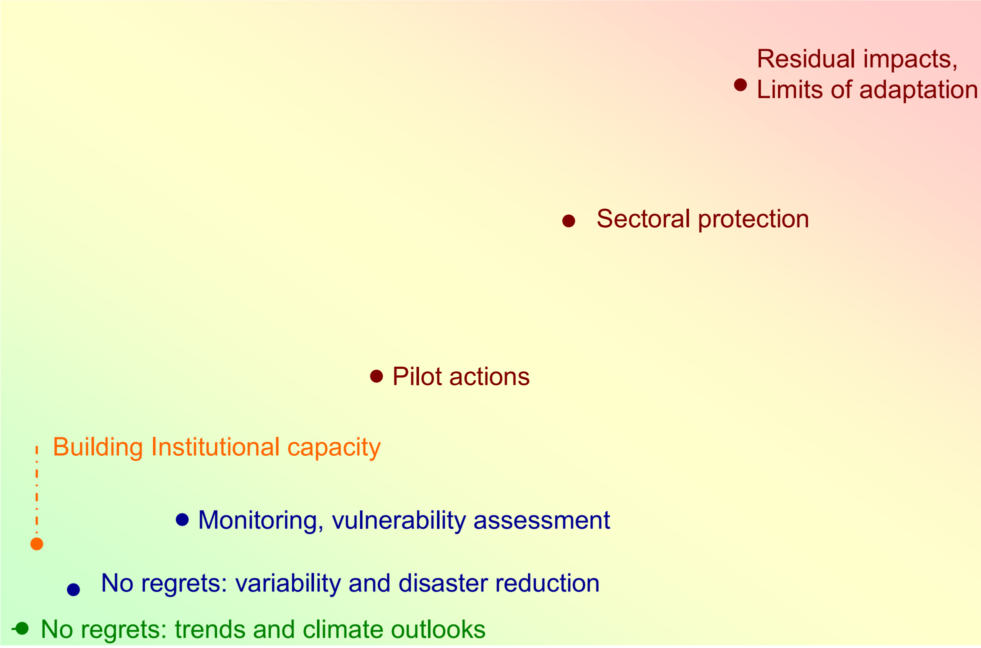


Figure 22. Examples of an adaptation signature (adaptation strategies)

However, while adaptation reduces damages, it does not remove the impacts of climate change entirely. Residual impacts in Tanzania, 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.

The uncertainty involved in future climate change means adaptation needs to work within a framework of decision making under uncertainty.

This can be advanced in an economic framework by building capacity and focusing on no regret and flexible options, working within an iterative framework which considers portfolios of options, rather than trying to predict and optimise.

7. Sector Estimates of Adaptation to Climate Change in Tanzania

7.1 Coastal Zones

In order to address the potential risks of climate change to existing assets and people, some form of protection or other policies are required for 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 to address these risks, 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.

Planned adaptation options to sea-level rise are usually presented as one of three generic approaches, i.e. retreat, accommodation or protection (Nicholls et al 2006).

- For planned retreat – the impacts of sea-level rise are allowed to occur and (human) impacts are minimised by pulling back from the coast via appropriate development control, land use planning, and set-back zones, etc.
- With accommodation – the impacts of sea-level rise are allowed to occur and human impacts are minimised by adjusting human use of the coastal zone to the hazard through early warning and evacuation systems, increasing risk-based hazard insurance, increased flood resilience (e.g., raising houses on pilings), etc.;
- For protection – the impacts of sea-level rise are controlled by soft (e.g., beach nourishment) or hard (e.g., dikes construction) engineering, reducing human impacts in the coastal zone that would be impacted without protection. However, a residual risk always remains, and complete protection cannot be achieved even in the richest and more developed countries, such as The Netherlands. Managing residual risk is a key element of a protection strategy that has often been overlooked in the past;

These lead to a range of options, e.g. as below (Nicholls and Tol 2006; Nicholls 2007).

Adaptation Options and Responses to Sea-Level rise.

Physical Impact of Sea-Level Rise		**Some Examples of Potential Adaptation Responses**
Direct inundation, flooding and storm damage	➢ Storm Surge (sea) ➢ Back water effects (river)	▪ Dikes/surge barriers (P) ▪ Building codes/flood-wise buildings (A) ▪ Land use planning/hazard delineation (A/R)
Loss of wetland area (and change)		▪ Land use planning (A/R) ▪ Managed realignment/forbid hard defences (R) ▪ Nourishment/sediment management (P)
Erosion (both direct and indirect)		▪ Coastal defences (P) ▪ Nourishment (P) ▪ Building setbacks (R)
Saltwater intrusion	➢ Surface Waters	▪ Saltwater intrusion barriers (P) ▪ Change water abstraction (A)
	➢ Ground Waters	▪ Freshwater injection (P) ▪ Change water abstraction (A)
Rising water tables and impeded drainage		▪ Upgrade drainage systems (P) ▪ Polders (P) ▪ Change land use (A) ▪ Land use planning/hazard delineation (A/R)
Note: P – Protection; A – Accommodation; and R – Retreat		

Source: Nicholls and Tol, 2006; Nicholls, 2007.

Note that the choice and use of these adaptation strategies depends on the nature of the coastal zone and the type and extent of impacts, i.e. adaptation requires a site specific context. There are also differences when considering wider impacts on coastal ecosystems as well as humans: for example, accommodation and retreat options reduce or avoid the problem of 'coastal squeeze' (preventing onshore migration of coastal ecosystems) which can occur when fixed coastal defences (protection) are introduced. There are also differences between technical (hard) and non-technical (soft) options. A key emerging theme is the recognition of the benefits of applying portfolios of adaptation strategies, e.g. flood warning and protection systems.

The study has undertaken a detailed analysis of adaptation for coastal zone (for reference, see previous coastal section) and this is included in the technical report. This section summarises the analysis and findings.

Previous Studies

The NAPA highlighted two relevant adaptation projects for coastal areas. First, the construction of artificial structures, e.g., sea walls, artificially placing sand on the beaches and coastal drain beach management system as one of the initial short-list of priority projects. Second, to implement sustainable tourism activities in the coastal areas and relocation of vulnerable communities from low-lying areas. However, neither project was included as one of the final six projects that were included in the costed analysis.

There has been some previous work on coastal protection in Tanzania. Tourist facilities such as hotels and roads in Dar es Salaam are partly protected from erosion by groynes and a seawall. The cost for building seawalls to protect important vulnerable areas of the city against a 1m rise in sea level has been estimated at US$337 million (Mwaipopo, 2000).

Moreover, different response measures (such as introducing a range of management and conservation initiatives) have been taken over the last two/three decades including traditional management systems, enforcement of policies and laws through regulatory mechanisms and collaborative management arrangements (Julius, 2005). Existing adaptation activities such as:

(1) Coastal and marine environment management programmes and projects,

- *e.g.*, Tanga Coastal Conservation and Development Programme (TCCDP), The National Integrated Coastal Environment Management Strategy, Rural Integrated Project Support Programme (RIPS), Mangrove Management Programme (MMP), Rufiji Environment Management Project (REMP), Conservation of Lowland Coastal Forests Project, Zanzibar Coastal Zone Management Programme, Sustainable Dar es Salaam Project, Kinondoni Coastal Area Management Programme;

(2) Conservation of marine and coastal resources measures,

- *e.g.*, Mafia Island Marine Park, Mnazi bay Marine Park, Menai Bay Conservation Area, Misali Island Conservation Area, Chumbe Island Coral Park (NAPA, 2006).

However, there is clearly a need for increased strategies due to the threat of sea-level rise. The study has therefore considered the potential costs of adaptation for coastal zones in Tanzania.

Analysis

The DIVA model has been used to extend the analysis of impacts and economic costs, to consider the costs and benefits of adaptation. Under the model, adaptation costs are estimated for two planned adaptation options: (1) dike (sea or river) building and upgrade, and (2) beach/shore nourishment. The model assesses the costs for planning, preparing, facilitating and implementing adaptation measures, and the benefits are expressed in terms of avoided damage costs. These are introduced on the basis of a demand function for safety (for dikes, maintaining acceptable levels of risk) linked to population density, and cost-benefit function for beach nourishment (in terms of avoided damages).

Therefore the model assesses the total impacts and economic costs with adaptation (and can compare to the case without adaptation, thus giving the benefits of adaptation), and also estimates the total adaptation costs (in monetary terms): comprising beach/shore nourishment costs, basin nourishment costs, wetland nourishment costs, sea dike costs, and river dike costs. Values are presented in $2005 with no discounting of values in future periods.

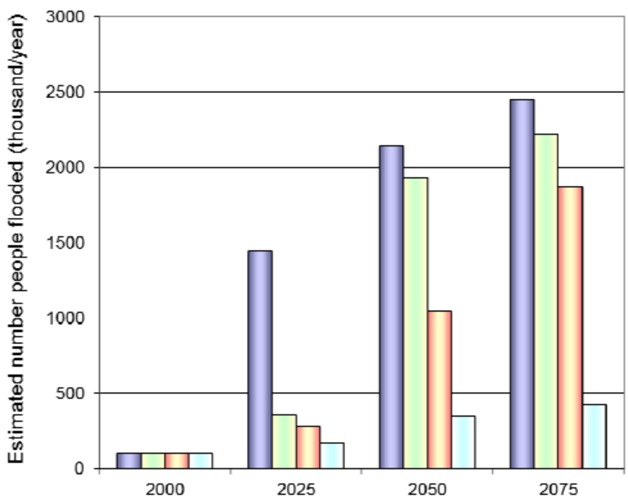
Results

The study demonstrated that when adaptation measures are applied, the potential impacts and economic costs can be significantly reduced. It shows that adaptation has large potential benefits in reducing coastal erosion and inundation, which can be expressed in terms of avoided damage costs. The results are summarised below.

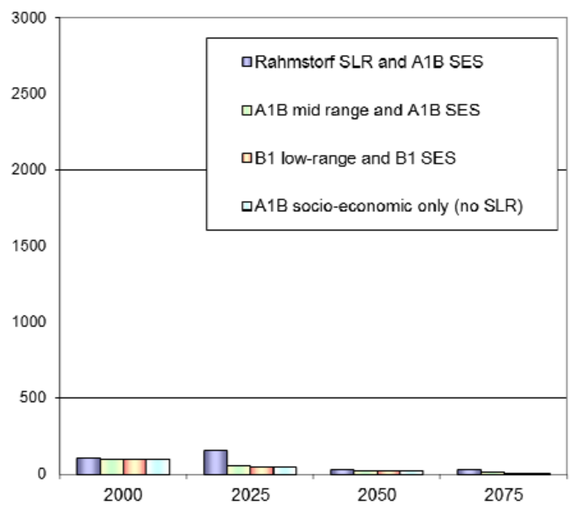
- Cumulative Area of Land lost. With adaptation, the cumulative land loss is estimated to fall from between 1924 and 7624 km^2 in 2030 (no adaptation) to 1.3km^2 in 2030.
- Land loss due to erosion. With adaptation (beach/shore nourishment), the loss of land due to erosion is estimated to fall from 12 km^2 in 2030 (no adaptation) down to 1.3km^2 in 2030, with an estimated annual nourishment cost of US$27 million per year in 2030.
- Land loss due to submergence. With adaptation, the land lost to submergence falls from between 3576 and 7614km^2 in 2030 down to effectively no loss under all the sea-level rise scenarios
- People Actually Flooded. With adaptation, the expected average number of people subjected to annual flooding falls from 0.3 to 1.6 million in 2030, down to 0.04 to 0.1 million. The benefits in later years are even greater from 1.0 to 2.1 million in 2050 (no adaptation) to 0.02 to 0.03 million per year (with adaptation) if protection is applied. This is shown in the figure below.
- Forced migration. With adaptation, it is assumed that the forced migration reduces from 67,000 to 852,000 people in 2030, down to almost negligible numbers

The DIVA results therefore suggest that protection via building and/or upgrading of dikes and beach/shore nourishment could be an effective response to significantly reduce these impacts. However, it is important to note that even with adaptation measures, there are some residual damages. Nonetheless, coastal protection appears to substantively reduce the threats imposed by sea-level rise, and the benefits of adaptation outweigh the costs.

With adaptation, the total residual damage costs reduce down from US$26 and US$55 million per year in 2030 to US$20 million (with adaptation). The benefits are even larger in the longer-term, and in 2050, adaptation reduces impacts from US$104 to 210 /year (no adaptation) down to around $60 million / year (with adaptation).



No Adaptation



With Adaptation

Figure 23. Number of people flooded (thousand per year) – no adaptation (left) and with adaptation (right) (for sea level rise and socio-economic change)

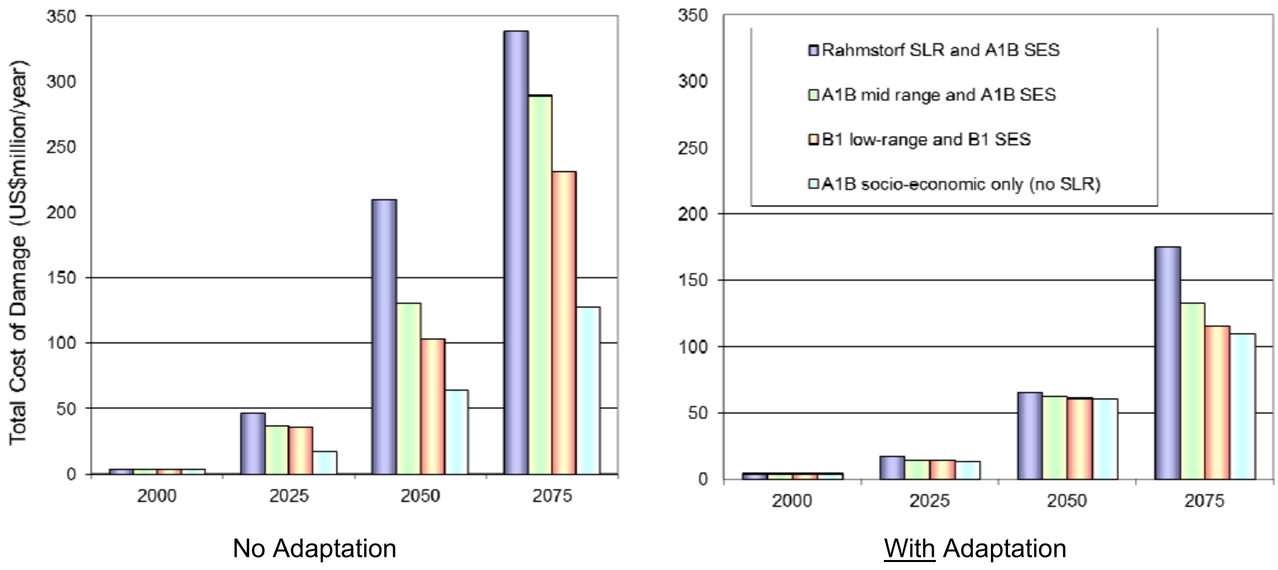


Figure 24. Total Costs of Damage ($million/year) – no adaptation (left) and with adaptation (right) (sea level rise and socio-economic change)

Nonetheless, the costs of adaptation are still relatively high. The cost in 2030 is estimated at $32 to 81 million / year (2005 dollars undiscounted) depending on the sea level rise scenario. These costs could rise to $ 34 to 118 million / year by 2050 and would be much higher in future years. By 2100, these costs could reach as high as US$300 million per year due to the combination of flood protection and beach nourishment (to address erosion). Note that even under a case of no climate-induced sea-level rise, costs of protection would need to rise to address rising population and assets – with costs estimated at about US$21 million per year in 2030.

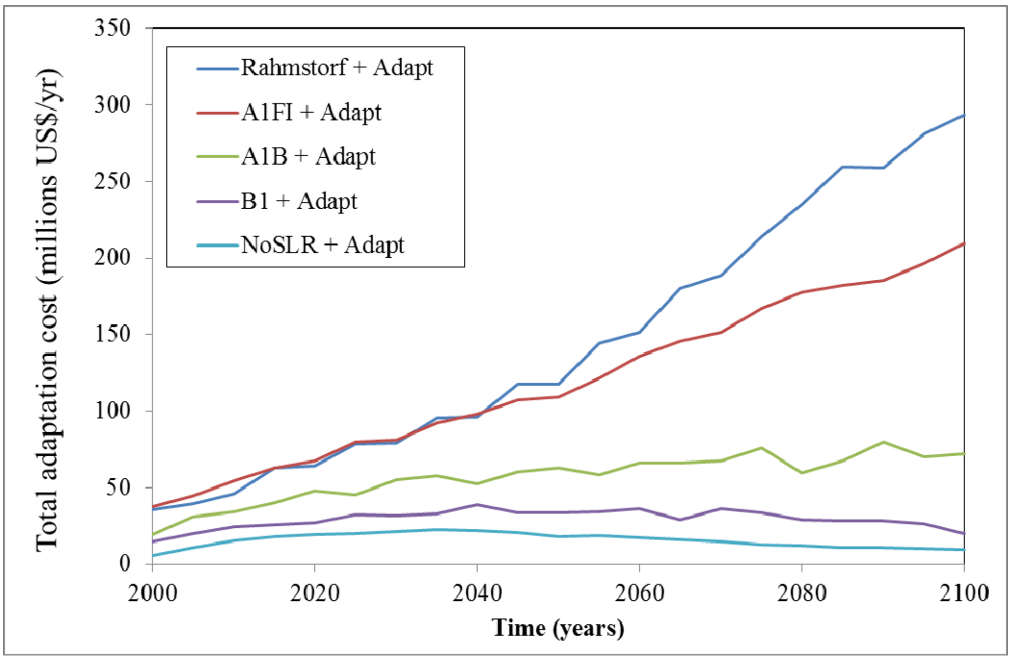


Figure 25. Total adaptation cost per year from 2000 to 2100 for Tanzania under scenarios with adaptation (note includes adaptation to the combined effects of socio-economic change and sea level rise)

The results demonstrate that these impacts and economic costs of sea level rise can dramatically be reduced if standard protection measures of adaptation (in terms of beach/shore nourishment and dike construction and upgrade) are employed. However, protection (defence) will not completely avoid all impacts (there will still be residual impacts) and may even exacerbate some impacts such as degradation of mangroves and other wetlands. Moreover, while it is possible and probably desirable to protect many areas of coasts through adaptation, this does not address all coastal threats. Coastal ecosystems would be highly threatened. These habitats could be severely reduced or disappear during the 21st century. These highlight that future planning and responses to climate change will need to address more than just climate change

The results also show one possible approach for addressing beach nourishment to address coastal erosion, which is a major challenge in the coastal zone of Tanzania. However, in addition to the options considered in the model, building setbacks could be considered as a low cost planning local approach to retreat, although enforcement may be problematic.

The study also shows there is a need to focus on existing disaster risk reduction planning, and risk prevention, as well as to start planning for future change now. This includes the need for forward planning to focus population and economic growth in less vulnerable areas. There is also a need to control the overall growth in the coastal zone, which could significantly reduce exposure, and hence damages and costs. This would apply, for example to future economic zones. This necessitates a need for spatial planning. This could be implemented through development and planning policy. To advance such a policy will require further work on detailed vulnerability mapping for the city. It is also recognised that such a policy could be challenging in the context of the rapidly growing population and informal settlements.

Delivering adaptation in practice will be challenging, and could be more costly and difficult than suggested by the analysis above. The costs assume a well-developed adaptation infrastructure which can be incrementally upgraded. As already noted, this is not the case and addressing this adaptation deficit is a major issue. However, Tanzania is not adapted to the current climate, and there is an urgent need for coastal adaptation to address current risks – and countries such as Tanzania have high existing 'adaptation deficit' (Parry *et al*., 2009). This analysis here does not consider this deficit, which implies the need for more investments to meet the adaptation needs of today climate, before addressing the future marginal impacts of sea level rise: failure to address this underlying adaptation deficit therefore means the total adaptation costs will be higher. These challenges also have to be seen in the context of other coastal issues including loss of habitats, industrial and domestic-based pollution, declining resources and conflict between users, low levels of planning and decision making, greater dependency of coastal community on natural resources, and additional pressures due to increasing trend of coastward migration and population growth. Additional difficulties to adaptation also exist due to the low adaptive capacity, and even if sufficient funds for adaptation were available, the need to strengthen other capacities (such as monitoring, disaster risk reduction and prevention, technology).

Conventionally, many coastal management practices have been more sectoral focused on single-goal management practices, rather than addressing the multifaceted pressures that affect the coastal zone, as outlined above. These highlight that future planning and responses to climate change (at a local, regional and national scale) will need to adopt a diverse and integrated cross-sectoral approach to address the impacts of climatic and other non-climatic drivers of change, with Integrated Coastal Zone Management (ICZM or ICM). A key issue is therefore to develop the institutional capacity to allow such policies.

In addition, as the country continues to look at the available coastal resources for future economic development, sustainable management of resources should be given a priority and coastal activities need to be more coordinated and coherent for a more predictable, sustainable and equitable future socio-economic development in the coastal zone, and hence in the country.

Future planning should also incorporate accurate monitoring in the coastal zone, including sea-level rise, to assess where and by how much the coast is changing with time. Although the available sea-level change measurement records show a declining trend, it is difficult to interpret this as a long-term trend as the duration of measurements are very short and could simply reflect inter-annual-to-decadal water level variability. Hence, it is important that measurements are collected and analysed as sufficiently long (*e.g.*, > 50 years) and good as possible in order to be able to have a maximum insight into the future and to plan to prepare and adapt for future impacts as appropriate.

A key element of long-term planning will be to ensure flexibility, and hence forward planning to focus population and asset growth in less vulnerable areas could be an important part of a strategic response to sea-level rise.

The analysis also highlights consideration of future thresholds for flooding, to allow decision pathways to be developed.

Adaptation can reduce down the impacts of sea level rise significantly and has high benefits compared to costs. Nonetheless, the cost of adaptation in 2025 is estimated at $30 to 80 million / year by 2030, rising up to potentially $120 million / year by 2050.

The future options are brought together in the adaptation signature below.

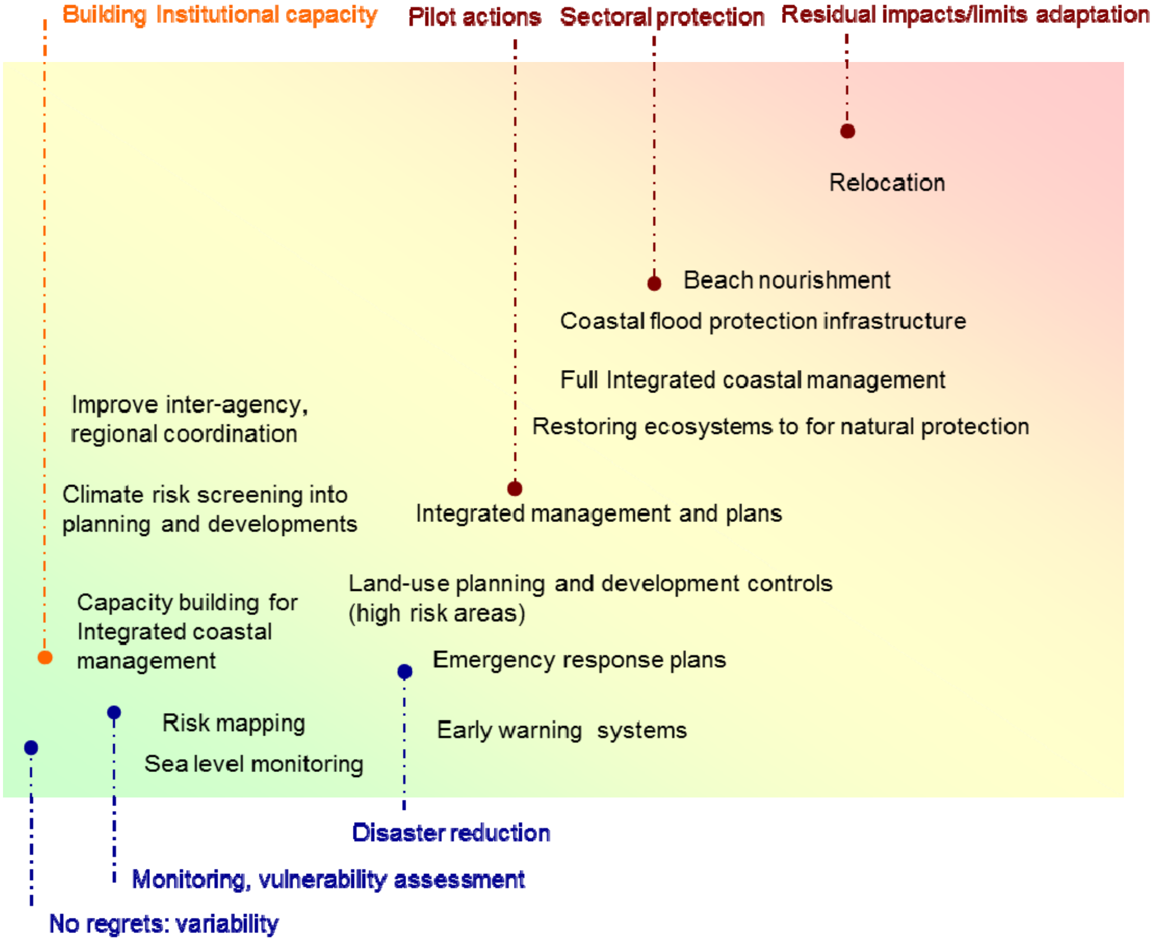


Figure 26. Adaptation signature for coastal zones.

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. This is a key step in building adaptive capacity, to allow more detailed studies to be carried out.

The potential for adaptation has also been investigated in the case study in Dar es Salaam, outlined in the box below. The results show that the risks of sea-level rise in the city could be significantly reduced using a sustainable spatial planning for population settlement and economic activities in the coastal zone and by steering future development away from low-lying zones to alternative areas that are not threatened by current or future sea-level rise.

Case study. Sea Level Rise and the exposure of population and assets to coastal flooding in Dar es Salaam

The case study (see previous box) has used elevation and population data to assess the people and economic assets at risk in Dar es Salaam to a 1 in 100 year coastal flood event.

Very little protection has been made around Dar es Salaam. Tourist facilities – hotels and roads are partly protected from erosion by groynes and a sea-wall. The cost for building sea walls to protect important vulnerable areas of the city against a 1-m rise in sea level has been estimated as US$ 337 million (Mwaipopo, 2000).

As highlighted earlier, around 8% of the land area and 140,000 people are below the 10m contour line, with associated economic assets worth more than US$168 million in 2005. More than 31,000 people are considered currently at risk of the 1 in 100 year return period storm surge. The analysis has identified the hotspots of population and economic assets that are exposed in the future, under a scenario of no adaptation or changes to spatial policy. By 2030, more than 100,000 people and over US$400 million (2005 values) assets in the city are exposed to the 1 in 100 year flooding due to extreme water levels. A strong spatial planning policy, assuming potential future population and economic growth occur outside the vulnerable areas, would significantly reduce exposure to about 30,000 people and US$35 million assets in 2030 (2005 values, no discounting). The benefits are even greater in later years, due to the combination of rising population and greater vulnerability due to sea level rise.

The results show that steering development away from low-lying areas, to other parts of the city (or outside the city) that are not threatened (or are less vulnerable) to sea-level rise and extreme climates, would be an important part of a strategic response to significantly reduce the future growth in exposure. It is noted, however, that enforcement of such a policy will be challenging where informal settlements dominate urbanisation.

As a minimum, there is a need to focus on the key spots (the wards at most risk) and try to tackle these through awareness raising and planning policy. Potential policy choices and/or responses for managing encouraging future population and economic growth to happen outside the most threatened areas would lead to very significant reductions in future exposure.

In addition, appropriate adaptation measures (e.g. protection in terms of beach/shore nourishment and flood defence structures such as dikes) could also be considered in order to keep risks at an acceptable level, but this will require higher costs associated with capital investment and subsequent maintenance. Port and harbour infrastructure would also require upgrade.

Further work to address spatial planning policy for current and future flood risks is identified as a priority area for immediate consideration and it is recommended that it is followed up by a more detailed, city-based analysis. This would need to include good quality observational local climate data (e.g. long-term sea-level measurements), finer resolution spatial population and asset distribution and higher resolution local elevation data, as well as detailed information about existing coastal defence systems (natural and/or artificial) and current protection levels.

Overall, this study shows that significant numbers of people in Dar es Salaam are, and will continue to be, vulnerable to flooding due to extreme water levels during this century. The study 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, showing these issues are importantly in terms of livelihoods and economic activity. Forward planning to address projected population growth can reduce exposure levels to a significant degree. The estimates also highlight the crucial message that, without action today to ensure sustainable development and planned population settlement, economic growth itself will strongly aggravate the impacts of climate change and sea-level rise on coastal flood exposure.

7.4 Agriculture

The study has undertaken a detailed analysis of adaptation for agriculture (for reference, see previous section) and this is included in the technical report. This section summarises the analysis and findings.

Adaptation to climate variability and change usually include measures such as risk management practices aimed at addressing the existing “adaptation deficit”, better preparedness such as application of climate forecasts by farmers; strengthened institutions and capacities that contribute systematically to enhanced resilience, and awareness raising campaigns to prepare all the stakeholders for appropriate actions.

Background and Previous Studies

Empirical information on the costs associated with climate change impacts and adaptation in the agriculture sector is limited. Some costing estimates of adaptation options are presented in the NAPA (URT, 2007). It is estimated that a 3-year project to improve food security in drought-prone regions of Shinyanga, Dodoma and Singida through promotion of drought-tolerant crops would cost US$ 8,500,000. And that of improving water availability to communities in the same regions would cost US $ 800,000.

Munishi et al (2010) outlined a number of options (and costed these, estimating total costs at $21 million) including, crop diversification, increased irrigation and technology improvement, improvements in soil fertility, strengthening climate information, research and training, agricultural extension improvements, building adaptive capacity, rain water harvesting and increased water storage, vulnerability assessments, and improved pest management.

Analysis and Results

In this section, some of the key adaptation strategies in agriculture, i.e. irrigation expansion, use of soil and water management, research and extension, are discussed and complemented with case studies. These strategies have also been identified in the Tanzania NAPA (URT, 2007) and form a basis for costing adaptation in agriculture in Tanzania.

These investment areas are strongly emphasized in the agricultural development policies, strategies, and programmes at national, regional and global levels

The costs of adaptation to climate change have been computed based on the four components that have been identified as potential for adaptation by various studies (IFPRI, 2009a; McCarl, 2007).

1) Increase investments in smallholder farmers’ irrigation development beyond that in the National Irrigation Master Plan.

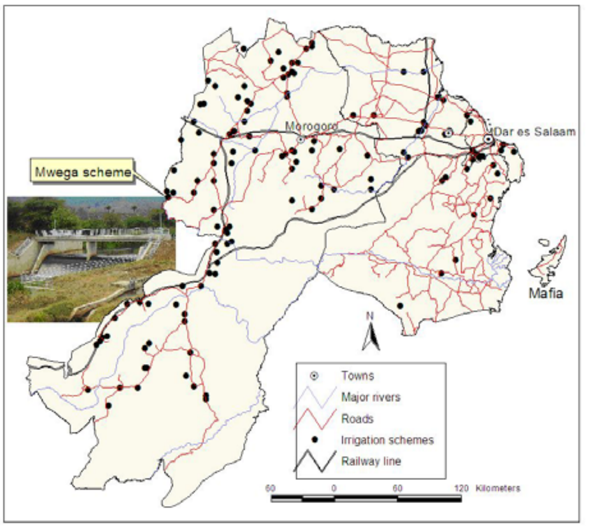
The current investment in irrigation infrastructure is just sufficient to meet the requirement set in the National Irrigation Master Plan (NIMP), which translates to 5.4% area growth rate per annum using 2006 irrigation area (273,945 ha) as a baseline (the area growth was 7.4% in 2008/09 but 3.4% in 2006/07). To achieve goals set in the “Kilimo Kwanza” policy declaration of 7,000,000 ha by 2025, which translates to 129% area growth rate per annum. May be the percent increase under Kilimo Kwanza is too high but also the percent increase under NIMP may be is too low, therefore the government should continuously strive to either increase the investment in irrigation development to reach at least 15% area growth rate per annum. The increase is necessary to address the yield losses expected in cereal production to 2030 and 2050, which will be caused by climate change. The study found that in order to compensate for the loss in production the area under irrigation will have to double the NIMP targets.

Case study of Mwega smallholder irrigation project

Mwega smallholder irrigation project is located in Kilosa district, Morogoro region. The construction work commenced on November 17, 2000 and was completed in March 2002. It covers about 580 hectares cultivated by 740 households benefiting approximately 7000 people from Malolo A and B, Mgogozi and Nyinga villages. Main crops grown are paddy and maize during rainy season and onions, cabbage, potatoes, and pulse during dry season. The main objectives of the project were to increase productive capacity, improve both household food security and income of farmers; and hence alleviate poverty. The project involved construction of Mwega headwork, irrigation canals works, road improvement and river improvement works.

The project cost translates to USD 15,700/ha, which is expensive compared to many smallholder irrigation schemes in Tanzania. The cost for developing a 400 ha Magoza village irrigation scheme (located in Mkuranga, Pwani region), for example, is estimated at about USD 2,470/ha. In most of the irrigation projects beneficiaries do usually contribute cash or labour. For example, in the Magoza scheme farmers are expected to contribute their labour (bush clearance of farm service roads route and canals, spreading of soil material on the service road, and excavation of drainage canals) estimated at about USD 135,000.

After the rehabilitation of the irrigation infrastructures, scheme management, including Operation and Maintenance (O&M) activities, was subsequently entrusted to farmers under the auspicious of Mwega Irrigation Primary Cooperative Society called "CHAUMWE".



Extent of use of smallholder irrigation practice in the Eastern zone of Tanzania (scaling up potential).

The main channels are cleaned by community based labour, locally known as "Msalagambo". Farmers clean secondary and distribution channels from which they get water for irrigation.

As a result of the rehabilitation of the scheme, tenants in Mwega benefited from a more reliable supply of water to their fields. Consequently, food security, household income and employment opportunities to the nearby communities have been improved significantly. Paddy production has increased from 2 t/ha in 2005 to 5.0 t/ha in 2008. Other benefits include increase in the value of land through an increase in rental prices, improvement in water use efficiency, improved farming practices, and reinforcement of farmers organization. The improvements have been largely contributed by the trainings provided by Kilimanjaro Agricultural Training Centre (KATC) on paddy rice agronomy. More than doubling rice yield per ha reduces the need to expand the cultivated area consequently reducing GHGs emissions and particularly of methane.

2) Special programmes should be started in soil and water conservation in order to maintain the productivity in the highlands.

As of 2004 about 35% of population in Tanzania was living in the highlands, which occupies 37% of the total area in Tanzania. However, while these areas are one of the main sources of food and water the investments in soil and water conservation (SWC) in these areas are extremely low compared to investments in other areas. This study found that the funding for SWC is merely 0.3% of the total funds allocated to DADPs. The move by the Ministry of Agriculture and Food Security to upgrade the status of the Land Use Planning Unit to full directorate is commendable but that should be in line with increase funding which is currently very low (0.50 and 0.04% for recurrent and development expenditures, respectively). Either, SWC experts should be employed and deployed to the Districts so as to provide the necessary technical backstopping. This study recommends that the government should spend between 11.4 and 26.1 M 2010-USD per annum on the ground to address the development deficit in this area.

Case study of soil and water conservation (SWC) measures in the Western Pare Mountains, Tanzania

The Western Pare Mountains are located within the semi-humid areas stretching south-eastwards. The area has a very long SWC history dating back to the pre-colonial period; it was one of the nine districts targeted by the government for SWC works since the 1930's; and represents other highland areas in terms of farming system, soil degradation problems and upstream - downstream water use relationship. Agriculture is the major economic activity in the area. Agricultural production in this zone is only possible through rainwater harvesting (RWH) using supplementary water mainly from ephemeral flows during the rainy season. Soil and water conservation measures are needed to control soil erosion and sustain agricultural production on steep slopes of the mountains. Important SWC measures include stone terraces, bench terraces, contour terraces, fanya juu and grass strips.

The investment costs necessary to establish the SWC measures include labour, equipment and materials, and maintenance. Benefits include all gains in current and future production as a result of implementing the respective SWC measure. This includes effects of SWC measures on retention of soil nutrient and water reflected in an increased crop yields and other outputs, such as fodder for livestock.

Evaluation of the efficiency of bench terraces, *fanya juu* and grass strips done by Tenge, et al (2007) in the Western Usambara Mountains, which are not far apart with the Western Pare Mountains, showed that all the three SWC measures were effective in retaining soil moisture and reducing soil loss compared to the without conservation situation. Bench terraces were more effective by retaining more moisture than *fanya juu* and grass strips. The fields with SWC measures also produced a significant increase in maize and beans yield in comparison to the without conservation situation.

Bench terraces were found to be more costly to establish than fanya juu and grass strips, but with highest financial returns in the long run. For the establishment of bench terraces a total of US$ 215 ha-1 was required compared to US$ 165 ha-1 and US$ 84 ha-1 for fanya juu and grass strips, respectively. However, even after overcoming the initial investment costs, the cash flow from grass strips was still lower than the other two SWC measures. Bench terraces had the best internal rate of return (19%) followed by fanya juu (14%) and grass strips (6%). These results suggest that, farmers who are able to invest in bench terraces, will be able to recover their investment faster than from the fanya juu and grass strips.

Bench terraces with high value crops in the Western Pare Mountains.

3) Strengthen the capacity of agricultural research institutes to conduct basic and applied research.

The government should reverse the recent trend of declining funding of agricultural research and minimize research projects that are directly channeled to agricultural research institutes from outside. The national agricultural research policy, strategy and programme should be developed, which could be reviewed after several number of years. All programmes and projects should thereafter address components under the national agricultural research programme. The 2010/2011 budget commitment for research through the Ministry of Science, Technology and Communication is just sufficient to address research deficit in agriculture alone. Therefore, the government should strive to increase its research spending to reach 1% of country GDP (about 58.8 M 2010-USD) per annum. Beyond the 2010/2011 impressive budget commitment, Tanzania needs additional funds between 7.6 and 8.0 M USD annually until 2030 for research in climate change adaptation.

4) Institutionalize climate information data collection, analysis and dissemination in the District Agricultural Development Plans.

Timely and focused dissemination of weather forecasts to end users is extremely important to Tanzania's farmers because about 90% of agricultural production is rainfed. TMA has the scientific skills and the mandate for weather forecast generation and dissemination. However, they have limited capacity in terms of reaching end-users. The District Agricultural and Livestock Development offices have the reach because of their extension workers distributed in almost all wards and in some villages. Informally, the agricultural communities in rural areas mainly use indigenous knowledge in guiding their agricultural calendar. As a climate change adaptation programme, this study recommends that the three components be integrated to improve data collection, knowledge integration and information dissemination. Data collection will be improved through installing weather monitoring devices in almost all villages. Integration of scientific and local forecast will improve weather forecast and make more area specific. Village/ward extension workers could act as important channel in the dissemination of climate and weather information. This study recommends additional spending in agricultural extension of about 18.7 M USD on annual basis to 2050 and should be institutionalized in the District Agricultural Development Plans.

5) Additional investment is required in rural road infrastructure to address development deficit and future climate change.

Better roads, agro-processing and improved markets are critical in improving market access and maintaining reasonable prices for agricultural goods. The differentiation of rural roads and other types of roads (district, regional and trunk roads) is somehow complicated taking into account that 80% of Tanzanians are engaged in agriculture. Therefore, almost all roads are somehow servicing the farmers. However, increased investment in rural roads is first required for feeder roads. This will require a shift in DADPs budgeting such that more funds are allocated to improving or building feeder roads. Also, as more trunk and regional roads are surfaced to tarmac level, regional and trunk roads funds should be shifted to fund roads where the irrigation infrastructure are expected or have been built. This study estimates an investment of 31.6 M USD in rural roads to address the current development deficit. Current investment in rural roads stands at 7.8 M USD. The additional area that will be put under irrigation will also require road infrastructure. This study estimates an investment of around 14.0 M USD per annum up to 2030 for adapting to climate change.

The study has brought the estimates together to estimate the potential costs of adaptation – over and above the current spending. Note that this requires a different costing method, based around the costs of investment (effectively an investment and financial flow analysis). This effectively estimates the total funding needed over time to implement the measures. Note this is different to the economic costs of adaptation presented for coasts, which looks at annual additional costs to address increased risks (and was presented as the increase in annual costs, presented in current prices with no discounting).

In the analysis below, the total costs of investment are presented as a discounted equivalent annual cost. Again, note that these values are not directly comparable with the annual costs from the coastal analysis above. The results are presented below. Note that in the analysis below, social discount rates based on the stern analysis have been used. Different discount rates would significantly affect the equivalent annual costs.

In producing the estimates, the study first takes account of the fact that Tanzania still faces a deficit in most of its development investments including irrigation. This is referred to as “development deficit” (DD).

Table 2. Annualized and projected investments under BAU and DD perspectives (‘000,000 of 2010-USD, with discounting)

Components	**Annual**		**2030**		**2050**	
	BAU	**DD**	**BAU**	**DD**	**BAU**	**DD**
Irrigation	25.5	62.4	468	1,095	803	1,915
SWC	0	26.2	0	480	0	480
Research	31.1	58.8	571	980	1,038	1,811
Extension	187.3	211.4	3,435	6,135	5,895	11,752
Rural Roads	7.8	31.6	143	580	245	996
Total	**251.7**	**379.1**	**4,617**	**9,073**	**7,981**	**16,609**

SWC=soil and water conservation, BAU=Business-As-Usual, DD=Development Deficit

The analysis has then considered the additional funding needed with climate change, comparing two future scenarios of medium-high (A1B) and high emission (A2) scenarios for the 2030s and 2050s.

Table 3. Annualized and projected investments under selected emission scenarios ('000,000 of 2010-USD, with discounting)

Components	Annually		2030		2050	
	A1B	A2	A1B	A2	A1B	A2
Irrigation	51.8	39.6	950	727	1,631	1,247
SWC	11.4	26.1	210	480	231	480
Research	8.0	7.6	147	139	431	337
Extension	21.1	21.1	614	614	1,175	1,175
Rural Roads	14.0	13.2	274	253	745	580
Total	**106.3**	**107.6**	**2,195**	**2,213**	**4,213**	**3,819**

The analysis highlights the issue of the existing adaptation deficit and the fact that the costs of addressing this are very high. This supports the earlier top-down findings.

The analysis shows that the additional costs to address climate change would require an extra 107 M USD per year (of investment funding, expressed as an equivalent annual cost) – on top of the existing development deficit - to cover adaptation costs in agriculture for all five adaptation components under A1B and A2 emission scenarios.

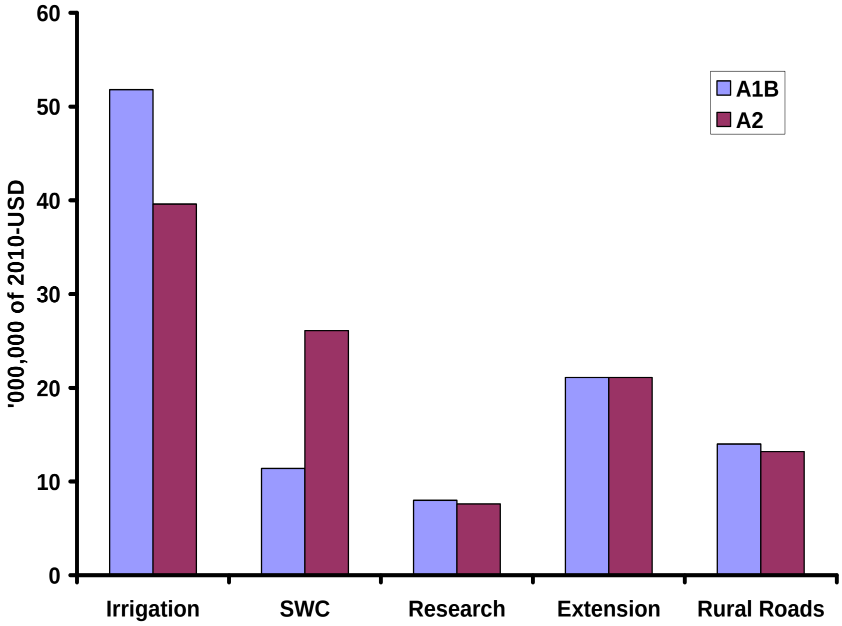


Figure 27. Projected adaptation costs per annum for Agriculture in Tanzania. Source Sokoine University Note costs are total investment costs, expressed as equivalent annual cost.

A key conclusion is that mainstreaming climate change in development policies and investment plan is critical. This would strategically guide investments to build resilience in the agriculture sector, for example in relation to current investment in irrigation, which is likely to be potentially affected by climate change.

The study has recommended five policies for adaptation for crop production: 1) Irrigation expansion, 2) Soil and Water Conservation, 3) Agricultural research, 4) Extension, and 5) Rural roads, with an estimated cost of $US 100 Million per year (equivalent annualized cost) above the current development spending.

The study has also considered adaptation in the case study on pastoralist, presented in the box below.

Case study: pastoralists and adaptation

The case study on pastoralists has considered the potential issues of climate change and adaptation. A clear finding is that these have to be set in the context of more general issues, notably in relation to wider pressures from contemporary changes to Tanzanian pastoral livelihoods, such as over boundaries, access to resources, conservation policy and land tenure, cultivation pressures and landscape fragmentation, and population growth. It also highlights that traditional knowledge is not enough to address the contemporary risks, nor the additional potential risks of climate change.

The case study highlights that many of the options (including options to help address risks from future climate change and variability) centre around non-technical options such as effective dialogue between conservation and land-use decision makers and the land users. It also highlights the need for research – a key component of capacity building – to build baseline information (to allow subsequent decision making and targeted support) to investigate perceptions of risks and options for adaptation as well as the most vulnerable areas, and to identify stakeholders and to introduce processes that encourage collaboration and dialogue.

In terms of specific policies, the study highlights the potential use of negotiated flexibilities in protected area access during extreme droughts, as well as explicit local control over natural resources located on village lands and the financial benefits of these resources, including wildlife. It highlights such measures are more likely to succeed as they help local people see the value of wildlife and increase their tolerance of the costs incurred for sharing the landscape.

The study also highlights that land conversion is being concentrated in known wildlife corridors, which will have negative consequences for wildlife, and threaten the sustainability of the livestock sector of Maasai pastoralists. The study highlights that land use planning at the local level, using up-to-date and relevant research, is needed to address this, but also highlights that land tenure insecurity is leading to cultivation to secure land rights despite a recognized potential for negative consequences, and that these underlying casual factors need to be addressed..

A key factor is therefore recognizing the need to address existing pressures and vulnerability as well as building resilience for the future. The study highlights the role that organization such as Maasai Women Development Organization (MWEDO), which works with Maasai pastoral women, has had by helping to reduce vulnerability by promoting sustainable livelihoods through women's education, economic development and public health. A key part of this includes a greater focus on education. These community based actions increase adaptive capacity by presenting options to children. While this does not directly address the uncertainties presented by a changing climate, land tenure insecurity and conflicts with natural resource conservation, it does indicate that people are aware that circumstances are changing (see Biermann 2010) outside the realm of historical experience and that new approaches must be developed in order to adapt to this new context.

Finally, the case study on the Tarangire-Manyara Ecosystem, and the Maasai pastoralists of Simanjiro highlights that to reduce pastoral vulnerability to change, policymakers need to give local pastoral stakeholders the authority to make land use decisions, incorporate objective predictions of both wildlife and human impacts to best maintain system resilience, and assure benefits from management of natural resources to local people.

7.2 Health

A wide range of measures have been identified in the health sector to adapt to climate change impacts. Most of these build on well-established public health approaches and are therefore theoretically easy to implement. They include general measures such as:

- 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.

Examples of more specific measures include:

- Behavioural strategies to accompany physiological acclimatisation.
- Vaccination programmes.
- Technical measures, including control of disease vectors.
- Institutional mechanisms, including early-warning systems and emergency planning / disaster preparedness schemes, training, communication, monitoring and surveillance, and research

Of course, all of these have associated costs, which include (Kovats, 2009):

- 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 (though this can also be considered as 'damage' or impact costs, rather than adaptation costs).

The study has undertaken an indicative analysis of adaptation for health (for reference, see previous section) and this is included in the technical report. This section summarises the analysis and findings.

Previous studies

The NAPA considered health was a high priority, ranked on 5th position out of the nine national sectors chosen. This was due to the direct impacts, but also the close inter-linkages between "Health" and other sectors such as "Agriculture and Food security" (ranked highest priority) and "Water" (ranked second highest priority). As part of the short-list of projects, the NAPA process identified 'establishing and strengthening community awareness programmes on preventable major health hazards' as one of the 14 selected areas. Further, as part of the costed NAPA plan, submitted to the UNFCCC, there was $0.65 million allocated for one of the six priority projects, Combating Malaria Epidemic in Newly Mosquito-infested areas.

There has also been previous work on other health outcomes. The Economics of Climate Adaptation Working Group (ECA, 2009) undertook a case study on the costs of adaptation for drought related health impacts in the central region of Tanzania, applying historical relationships to short-term projections of extreme events (2030) from climate change. As highlighted in the earlier health section, the confidence in these estimates is very low, as they do not account for the model confidence or for the greater resilience from socio-economic development). Of more interest, the study considered the costs of alternative options for addressing drought related health risks, including prevention, vaccination or treatment, and this was used to rank the cost-effectiveness of options. The most favourable options were considered to be educational programmes (good hygiene, sanitation and breastfeeding) and water quality improvements. It is stressed that these are primarily primary development activities associated with the current adaptation deficit, rather than future climate change – but this does re-enforce the earlier discussion of the need to address this deficit (and the associated costs) as well as preparing for future climate change.

Munishi et al. (2010) provided costs for health based adaptation strategies (though without details on time periods, i.e. whether these are investments or annual costs), which included $2 million for integrated disease surveillance response systems (IDRS), $3 million for malaria and other climate related diseases, $4 million for efficient and well co-ordinated early warning and emergency systems, $10 million for capacity building and $15 million for preventative and curative health services, thus a total of $34 million.

Discussion

The study has not undertaken a detailed assessment of health adaptation costs. However, the study has reviewed the potential adaptation options for malaria.

Kibona (CLACC, 2008) in the discussion of malaria and climate change, reports that the existing approach in the Ministry of Health provides much of the basis for enhanced future resilience, citing the existing four pillars of:

i) improved case management,

ii) vector control using insecticide treated mosquito nets,

iii) prevention and control of malaria in pregnancy and;

iv) epidemic preparedness, prevention and control.

However, the study also highlights the challenges of existing capacity levels and health education, lack of effective disease surveillance systems; existing health service system levels, i.e. highlighting the existing high adaptation deficit. It also highlighted the need for weather and climate forecasts and early warnings systems, as well as wider preparedness plans. Finally, general malaria control strategies were highlighted including early diagnosis and prompt treatment, selective and sustainable preventive measures, including vector control, early detection, and containment or prevention of epidemics, as well as local capacity building for basic and applied malaria research .

Other work, looking at health adaptation costs to malaria in the East African highlands (SEI, 2009 has highlighted a number of potential options exist for addressing malaria – some of which are already in place or planned in Tanzania. These include:

- Enhanced monitoring and surveillance, including to track changes in new areas, as well as Early Warning Systems, monitoring environmental risk parameters and early detection.
- Preventative treatment of pregnant women in endemic, low endemic and epidemic areas.
- Rapid Diagnostic Tests (RDT), noting treatment is often on a presumptive basis (noting false positive clinical malaria diagnosis increases costs).
- Indoor Residual Spraying (IRS), e.g. in highland areas, to control malaria in low endemic areas and to prevent epidemics.
- Distribution of bednets for the additional population at risk

It is noted that in areas of aggravated malaria there would be additional infrastructure and staff 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 established and new staff trained and employed.

Finally, these health based options need to be seen in the context of broader development. 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 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 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.

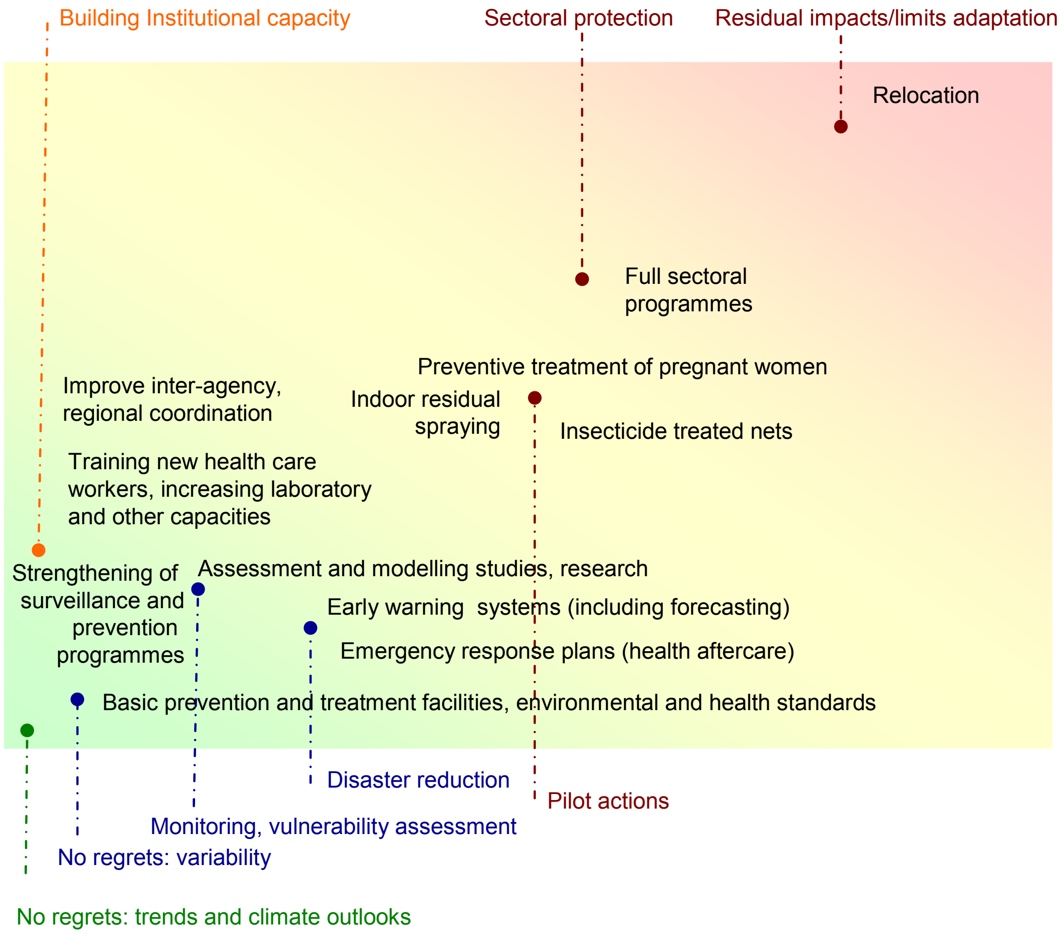


Figure 28. Adaptation signature for health (malaria).

Similarly, adaptation measures to improve overall health must include options for long-term food security and diversity, reducing communicable diseases and improving hygiene and safe drinking water even under conditions of extreme weather events. These constitute measures that fundamentally address the existing adaptation (and development) deficit.

Other key issues that are highlighted is the need for detailed, site-specific analyses, to understand the direct effect of weather and climate on both nutritional health and disease prevalence.

Previous studies (SEI, 2009: World Bank, 2009) have shown that health adaptation measures do seem highly cost-effective, delivering high benefits for relatively low costs. Even so, given the potential scale of risks outlined, under some future scenarios, the total costs of health adaptation for Tanzania could be high (noting that it will also depend strongly with economic growth, per capita incomes, and the success of underlying development strategy).

Finally, as with other sectors, there is clearly an existing adaptation deficit in Tanzania. The Government Health Research Priorities are set out in NIMR (2006) and include improved community access to safe, clean water and environmental sanitation in the rural and urban areas, nutrition and Integrated Disease Surveillance. However, a significant increase in current plans is needed to fully address the development shortfall and to build the necessary resilience for future climate change.

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

7.3 Energy

Energy supply

A number of potential adaptation options exist for addressing the potential risks of climate change on energy supply. These include options to involve hydro-electric supply availability (linked to water options – see below), options to build greater resilience into the system, power source diversification and energy demand reductions.

Previous Studies

The NAPA included a number of water related options, which would have indirect potential benefits of hydroelectricity generation (including water storage, catchment programmes, etc.). It also included a short-listed project to explore and invest in alternative clean energy sources e.g. wind, solar, bio-diesel, etc. and a separate project on the promotion of application of cogeneration in the industry sector, both to compensate for lost hydro potential. As part of the final costed project plan, one of the six priority project was for 'Community Based Mini-hydro for Economic Diversification as a result of Climate Change in Same District', with an estimated project cost of $0.62 million.

There have also been a number of specific studies looking at future climate change and adaptation.

As highlighted in the Stratus (2006) study, there is also the potential for increased flood flows in all regions, thus the need for enhanced designs for flood discharge during construction and over a permanent spillway should take this potential into account. Project costs would also be affected. Similarly the identified trend towards larger floods, suggests that project planning and environmental assessments for multipurpose specifically take into account this hydrologic risk in assessing project benefits from flood control.

The EAC study (2009) study used a marginal abatement cost (MAC) curve for the power sector to look at adaptation – looking at the options for meeting the shortfall projected under the study (note this is not a full energy sector wide MAC curve). This showed that most of the expected shortfall in power production could be met with energy efficiency measures, including demand reduction (residential and commercial sectors), which were actually negative cost (no regret). It also identified reducing spillage at hydro stations and improving the load factor of hydropower could increase power supply for almost zero cost. Finally, it identified building new power plants and reducing losses associated with the transmission, though these were higher cost options.

Munishi et al. (2010) provided costs for adaptation strategies (though without details on time periods, i.e. whether these are investments or annual costs), citing development of energy sources and energy use efficiency ($5 million), management and protection of water catchments and sources ($4 million), increasing availability of biomass and efficiency of use ($3.5 million) and promotion of cogeneration in industry ($2.5 million), thus providing a total estimate of $15 million.

Analysis

In additional to the water adaptation options below (demand-side management, supply-side management and ecosystem protection) there is an 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 that affect Tanzania. This is explored through the marginal abatement cost analysis in the low carbon section below. It is stressed that some caution is needed in any diversification plans. Climate variability can affect thermal plants as well as hydro, due to cooling water demands, thus a move to fossil generation may actually not improve the capacity of the generation system to cope with current and future climate variability. This highlights that a greater focus on renewables may be a more attractive option.

Another obvious area of focus is on demand management. As highlighted earlier, the Tanzanian transmission system has high losses, and there is the potential for end-user demand reduction (see also the energy demand section below). Indeed, given the current power deficit and frequent load shedding, which results in large economic losses to the Tanzanian economy, demand management would appear a no regrets strategy. However, there are a number of additional factors. First, there is already a very large unmet demand on the system (see earlier section): thus, while measures to reduce demand in domestic, service and industrial sectors is still beneficial, it may not necessarily produce greater resilience in the system. Second, the update to the Power System Master Plan (PSMP) did consider such measures, but reported that demand side management would be challenging and require a lengthy process and technical and financial resource: it did not considerate was a realistic option for reducing plant equivalent reductions in the mid-term, though it did note that a loss reduction programme to address the 12% losses in the sector might provide some benefits.

For hydro generation, there are a range of options to help manage current and future water sources, including integrated basin catchment management, as well as upstream land management, which also has the advantage of improving water availability and addressing sedimentation and siltation in flows (note also cross sectoral linkages to agriculture and water sector adaptation). There is also a need for capacity building to support these options, for example in strengthening basin water offices to balance hydropower requirements with other demands for water. There are also options in terms of ecosystem protection, e.g. sustainable land management (SLM) interventions in upstream agriculture to reduce soil erosion and dam siltation, improve electricity production efficiency, etc.

Other options include building greater coping capacity and resilience into the system, noting this has benefits for current issues as well as future climate change. One way to do this is through grid interconnection with neighboring countries. Currently, the country is considering a 330kV transmission line that would run from Zambia across Tanzania to Kenya, linking East Africa to the Southern African Power Pool (SAPP). Tanzania currently has high costs of generation and high tariffs (see low carbon section). The returns to cross-border transmission for the SAPP have estimated as high as 120%, with an average cost of production of only $0.07 in southern Africa (World Bank, 2010). Thus, the interconnection could potentially provide greater resilience and possible even reduced cost per kilowatt-hour. Similarly, the development of regional power trading, such as through regional hydropower schemes (as already planned, for example with Burundi) would produce greater resilience.

Energy demand

For energy demand, the autonomous response to higher cooling demand will be towards greater penetration and use of air conditioning, especially set against a background of rising per capita incomes as reported in the impacts section. However, there are a number of adaptation options that can help reduce or avoid such changes.

There is some potential to reduce down demand increases through energy efficiency improvements, i.e. by increasing the efficiency of AC units. Many current systems are extremely inefficient, and in many cases, replacing these with more efficient units might be a potential no regret measure (as the reduction in energy running costs offsets the capital cost of replacement).

There are also a large number of alternatives to mechanical air conditioning, through passive ventilation, building design, green roofs, etc. However, these require a greater planned response (including e.g. building regulations) and are most cost-effective (or only applicable) at the construction stage. They are important given the long life-time of some buildings.

The wider regional economics study undertook surveys on energy use and air conditioning found some recognition by environmental designers/architects in East Africa, who are already considering the following options:

- 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 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, which is common across the region

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 – or address cooing demand - will increase air conditioning demand 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.

Finally, the most immediate need is a capacity building one, to measure and monitor current usage (linking AC to temperature and demand). There is currently insufficient information on the importance of current AC to electricity demand, and this is not built in explicitly to current electricity sector planning.

7.5 Water

The study has undertaken an initial analysis of adaptation for water (for reference, see previous section) and this is included in the technical report. This section summarises the analysis and findings.

Of course, as with many of the sectors above, this is a sector where there is an existing adaptation deficit, which has the potential to increase sharply in future years with population growth.

Previous Studies

The NAPA had a considerable focus on water. A large number of the (14) selected projects were water based, including water efficiency in crop production irrigation to boost production and conserve water in all areas, alternative farming systems and water harvesting, the development of alternative water storage programs and technology for communities, community based catchments conservation and management programs and water harvesting and recycling. In the final selected six projects, the costed programme submitted to UNFCCC included improving water availability to drought-stricken Communities in the Central part of the country ($0.8 million) and the shifting of Shallow Water Wells Affected by Inundation on the Coastal Regions of Tanzania Mainland and Zanzibar ($3.3 million).

Meena and Raphael (2008) briefly considered impacts and adaptation, and outlined possible conversation measures.

Munishi et al. (2010) provided costs adaptation strategies (though without details on time periods, i.e. whether these are investments or annual costs), citing strengthening integrated water resources and management /community based catchment conservation ($6 million), development of alternative water storage programs and water harvesting technologies ($5 million), development of surface and subsurface water reservoirs ($3.5 million), promotion of new water serving technologies in irrigation, recycle and reuse facility ($ 2 million) and development of new infrastructure for distribution ($4 million), , thus providing a total estimate of $20 million.

Of course, many of the options that are relevant for adaptation are existing development or water enhancement projects, and by doing so, many (but not all) of these provide resilience for the future. There are costs that exist for such options, for example, with analysis of the economic benefits of rainwater harvesting in Tanzania for agriculture (Senkondo et al, 2004) and in Zanzibar. The latter reports that Zanzibar needs to invest US$ 6.4 million(over eight years), but by doing so would create annual water storage per capita of over 1600 m^3 – exceeding the minimum international bench mark – and also improving policies on integrated water resources management.

Discussion

The key challenge for Tanzania in terms of planning adaptation strategies for the water sector will be the need to consider the high degree of uncertainty of its future climate. While temperature change predictions are fairly consistent, rainfall patterns and water flows projection vary widely, including both spatially and temporally within seasons. Factors such as land use change, ENSO and population growth also have the potential to change the level of water resources available, further complicating the divergent scenarios.

The other key issue – from the earlier discussion - is that the sector is already challenged by the existing adaptation deficit. In view of this situation, the projected climatic change impacts - possible increased in intra-seasonal variability of rainfall and/or lower river flows – will exacerbate those problems and substantial new investment will potentially be needed.

The study has considered a number of potential options, focusing on no regret options.

An adaptation strategy that would be effective for both the urban and rural sectors is investing in catchment management. This can secure water resources of sufficient quantity and quality for domestic supply. This would also help to ensure groundwater resources – which are important for domestic supply in many areas, particularly during low rainfall periods - are used sustainably and not subject to pollution.

Shifting away from shallow dug wells – which are vulnerable to contamination, especially in urban areas – and hand-pumps – which tend to have poor reliability – would also be a sound strategy for both urban and rural areas (see also Foster et al., 2006).

Piped water systems in the largest cities in Tanzania source their water from the country's rivers: the Wami-Ruvu river basin supplies water to Dar es Salaam, Morogoro, Kibaha and Dodoma, while the Pangani supplies drinking water to the Kilimanjaro District, which includes the city of Arusha (population of 1+ million). As described above, future rainfall patterns and streamflows are uncertain: one study predicts less rainfall in both of these basins while results from other studies indicated a trend toward more rainfall. However, the studies do suggest a seasonal shift of rains, with possibly less rain earlier in the wet season.

Under cases where there are projected reduced river flows, there may be problems with meeting future water demand in these cities, particularly in the face of population growth and urbanisation. There are high cost options possible, for example, increased storage capacity including the construction of a reservoir in the Ruvu basin to store water for Dar es Salaam, shifting Dar's source of drinking water to the lower Rufiji river basin, or even the introduction of coastal desalinsation plants. However, such options would only be justified if reduced flows in the Wami-Ruvu basin occurred, and/or Dar's population growth exceeded the basin's capacity. Such issues can be addressed through adaptive management plans, developing iterative plans that combined with monitoring and evaluation can be reviewed and amended as more information is available, and greater clarity emerges on future needs.

There is also the potential for demand management, including the control of illegal connections and leaks, noting these are obvious no-regrets strategies. Dar es Salaam's provider, DAWASCO, is estimated to lose over 50% of the water it pumps due to leaks and illegal connections (URT, 2010b) and less than 30% of households served have meters. As irrigation expands, there will also be a need to ensure demand side management and efficient use applications.

In rural areas, adaptation options include development of groundwater wells and rainwater harvesting structures. It is possible that due to socio-economic pressures, and climate change, some aquifers may subside or dry up due to high utilisation rates and slower rates of recharge. One way to address this is to replace shallower with deeper wells, noting that these are more expensive, for example de Waal and Nkongo (2005) estimate costs of US$25 per capita for shallow wells and springs and US$50 per capita for small piped schemes from boreholes of springs.

Rainwater harvesting systems are an alternative, and these systems could be used for domestic water supply as well as a source of agricultural water and could serve to provide storage as a buffer against greater intra-seasonal rainfall variability.

Finally, given the large number of water-points that are non-functional, the need to map rural water-points to serve as an input into district-level planning has also been identified as a necessary tool to ensure sustainability (Taylor, 2009) and thus could help Tanzania cope with climate change-induced stresses on rural water sources. More generally, there is also a lack of systematic studies of the integrated risk in the water sector in Tanzania.

This constrains the ability to judge potential impacts and response options. This is a major gap requiring urgent attention.

Adaptation Options for Water Supply

Subsector	Recommended Actions
General	• Catchment management is the appropriate response to increasing water scarcity: it will help policymakers make rational choices in committing limited water resources to competing sectors. • Catchment management is an effective strategy for all subsectors of water: water supply and sanitation; water for energy; agricultural water; and water for ecosystems.
Urban water supply	• Demand management (controlling illegal connections and leaks) will be the most effective adaptation strategy. • Additional water storage, including possibly the construction of a reservoir on the Ruvu for Dar es Salaam's water supply, will be needed to meet demand.
Rural water supply	• Adaptation measures include a shift from shallow wells and surface water sources to deep boreholes and increased rainwater harvesting structures. • Mapping of rural waterpoints as an input into district-level planning is needed to increase sustainability of water infrastructure in rural areas, • Standardization of technologies may also help boost sustainability of water infrastructure in rural areas.

7.6 Forestry, Biodiversity and Ecosystem Services

Climate change presents a major threat to ecosystems, their functions and services. Autonomous adaptation of natural ecosystems will not be enough to withstand the future combined impacts and climate change, and human planned adaptation is essential for adaptation of socio-ecological systems.

A number of potential adaptation (planned) measures are available, which include:

- To maintain and increase ecosystem resilience: enhancing the ability of ecosystems to absorb and recover from change whilst maintaining and increasing biodiversity.
- To accommodate the potential impacts of climate change: considering both gradual change and extreme weather events.
- To facilitate knowledge transfer and action between partners, sectors and countries: successful adaptation requires that ecosystem and biodiversity conservation is integrated with other sectoral 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 socio-ecological systems to adapt.
- To use adaptive management: relates to the use of a flexible approach for effective conservation and adaptation planning.
- To enhance vulnerability assessments and monitoring systems: 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 based on iterative processes of learning by doing, reviewing, and refining, because the future effects on ecosystems are particularly uncertain.

However, the uncertainties of the precise nature of future climate change and its impacts on ecosystems and biodiversity must not delay practical action.

For some of the provisioning services, notably forestry, there is a range of specific planned adaptation options available.

For general unmanaged or semi-managed ecosystems, there is 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 as a means to ensure healthy and genetically diverse populations able to adapt to climate change;
- Increasing the size and/or number of reserves;
- Increasing habitat heterogeneity within reserves and between reserves by including gradients of latitude, altitude and soil moisture and by including different successional states;
- Building in buffer zones to existing reserves;
- Increasing connectivity, for example with the use of biological corridors or stepping stones to link areas, removal barriers for dispersal, linking of reserves and refugia;
- Increasing landscape permeability through reduction in unfavourable management practices and increasing area for biodiversity dispersal e.g. through agri-environment schemes;
- Increasing and maintaining monitoring programs to study response of species to climate change (physiological, behavioral, demographic) and socio-ecological dynamics;
- Integrating climate change into planning exercises and programmes;
- Assessing, modelling, and experimenting at different spatial scales for improved predictive capacity and outcomes;
- Improving inter-agency, regional coordination;
- Conducting restoration and rehabilitation of habitats and ecosystems with high adaptation value;
- Intensive conservation management to secure populations, including for threatened and endangered species;
- Translocation or reintroduction of species at risk of extinction to new areas that are climatically suitable for their existence;
- Ex situ conservation e.g. seed banks, zoos, botanic gardens, captive breeding for release into wild.

These options also need to be considered alongside other options for enhancing ecosystem services. These include flexible mechanisms such as:

- Regulation
- Economic Instruments
- Integration,
- Market-based Mechanisms,
- Green Investment

And means and adaptive processes, including:

- Research Capacity,
- Knowledge Sharing,
- Technology and Innovation,
- Adaptive Governance,
- Socio-institutional Change.

Previous studies

The NAPA had a considerable focus on forests and ecosystems. The (14) selected projects included three relevant projects: afforestation programmes in degraded lands using more adaptive and fast growing tree species; the development of community forest fire prevention plans and programmes; and enhanced wildlife extension services and assistance to rural communities in managing wildlife resources. In the final costed submission to UNFCCC, one of the 6 priority projects was for climate change adaptation through participatory reforestation in Kilimanjaro Mountain (at a cost of $33 million).

Munishi et al. (2010) provided costs for forest ecosystem adaptation strategies (though without details on time periods, i.e. whether these are investments or annual costs), which include forest ecosystem conservation and restoration ($5 million), awareness creation, training and capacity development in climate change knowledge ($4 million), participatory forest management to build local community capacity and empowerment in managing and conserving forests ($3.5 million), research and detailed assessments of the response of different forest component species ($ million), alternative sources of energy and efficient technologies to reduce use of wood ($3 million), forest management for future economic opportunities from carbon finance markets ($ 3million), thus providing a total estimate of $24.5 million.

Discussion

For forest, the most immediate response needed is to increase monitoring programs to study response of forest and tree species to climate change, along with research into the potential shifts in ecological zones. The additional stress of climate change is also likely to mean a greater focus on reducing and managing existing stresses, such as fragmentation, pollution, population encroachment, habitat conversion, etc. Finally, specific additional measures are likely to be needed, which include creating forest buffer zones, increasing ecological zone connectivity. Given the irreversibility of land-use changes, and the long life-times of forest stock (and growth times), these are highlighted as an early priority.

The range of other ecosystems – and ecosystem services – makes the analysis of adaptation challenging, though the need to progress this is key, given the generally low adaptive capacity of ecosystems.

However, in general terms, there is now a move to combine the principles of adaptation and the consideration of ecosystem services under the concept of **Ecosystem-based Adaptation (EbA)**.

Ecosystem based adaptation relates to the management of ecosystems within interlinked social-ecological systems. The aim is to enhance ecological processes and services that are essential for resilience to multiple pressures, including climate change. EbA therefore integrates the management of ecosystems and biodiversity into an overall strategy to help people and ecosystems adapt to the adverse impacts of global change, such as population pressures or changing climate conditions. An optimal overall ecosystem-based strategy will seek to maintain ecological functions at the landscape scale in combination with multi-functional land uses and multi-scale benefits.

At the core of this approach lays the recognition of dynamic interactions and feedbacks between human and ecological systems and the need to understand these to enhance benefit flows from the system, and to ensure sustainable management of natural resources.

One of the major themes is to manage ecosystems as part of a larger landscape, of which human activities are a part. This involves multiple land-use and conservation of natural capital[30], to provide the flexibility to allow the ecological and social systems to adapt to many stresses, including climate change.

The approach uses an iterative approach to look at pathway that can be adapted over time, recognising that not all decisions are needed now. It also has a focus on learning and adaptive management, not least because the options involved are often 'soft' non-technical options, that reliance on addressing institutional and governance challenges. It is also linked strongly to the focus on no regret options, and so fits within the economic framework outlined in this study. However, the focus on soft adaptation measures makes estimation of costs more challenging.

There are some studies of costs associated to local initiatives that are relevant to EbA in Tanzania. This includes wildlife migration corridors, mangrove restoration, mountain tourism, and payment for ecosystem services. Some examples are included in the box below.

[30] 'Natural capital' refers to the components of nature that can be linked directly or indirectly with human well-being. In addition to traditional natural resources, it also includes biodiversity and ecosystems that provide goods and services (TEEB 2009).

Case Studies Ecosystem Based Adaptation in Tanzania

As part of the case study work, two case studies have been undertaken on ecosystem based adaptation.

Coastal buffer zones: No-regret EbA Measure for Zanzibar and other Coastal Areas in Tanzania

There are numerous no-regret EbA measures that are applicable in Tanzania. One such measure was identified recently through a participatory process from a pool of adaptation options for the Zanzibar archipelago. The option is to restore natural coastal vegetation to enhance the coastal forest buffer zone along the coast. The no regret characteristics arise because the option provides multiple current benefits (even without future climate change), as well as enhancing future resilience. First, it would function as shoreline protective barrier, for instance, against storm surge. Second, it would help prevent excessive erosion by stabilizing beach sand and absorbing wave energy. Finally, it would help maintain the ecosystem services to support local livelihoods and essential goods such as firewood, building poles and sawn timber, herbal medicines, edible fruits, mushrooms, plant-derived oils, leaves and beverages, fodder, fibre, honey, ornamental plants, household utensils and handicrafts, tourism and the fishery, providing a vital, inter-tidal purification function, a feeding, breeding and nursery ground for fish and shellfish. Although costs for enhancing coastal forest buffer zones have not been estimated, there are clear no-regret benefits. The approach is also relevant for many other areas along the coastal wetland forest area in Tanzania. The case study also reports on the issues in progressing such a zone, highlighting that it would require a combination of measures to address the causes of current coastal deforestation, benefits to affected communities, etc.

Piloting Payment for Ecosystem Services to promote Community-based Conservation in the Simanjiro Plains of Tanzania

A second case study reports on a recent study that analyzes a novel payment for ecosystem services scheme (PES) implemented in Simanjiro plains to support community-based conservation outside state protected areas in Tanzania. This approach could also be used to develop an alternative financing arrangement for ecosystem services that are valued for climate change adaptation but not directly consumed in the market.

In general terms, the concept of ecosystem based adaptation 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.

Adaptation is being brought into the ecosystem services concept through Ecosystem Based Adaptation (EbA). The approach integrates the management of ecosystems and biodiversity into an overall strategy to help people and ecosystems adapt to the adverse impacts of various changes, including population growth and climate change.

It is therefore key to ensure Tanzania's economy continues to benefit from ecosystem services in the future.

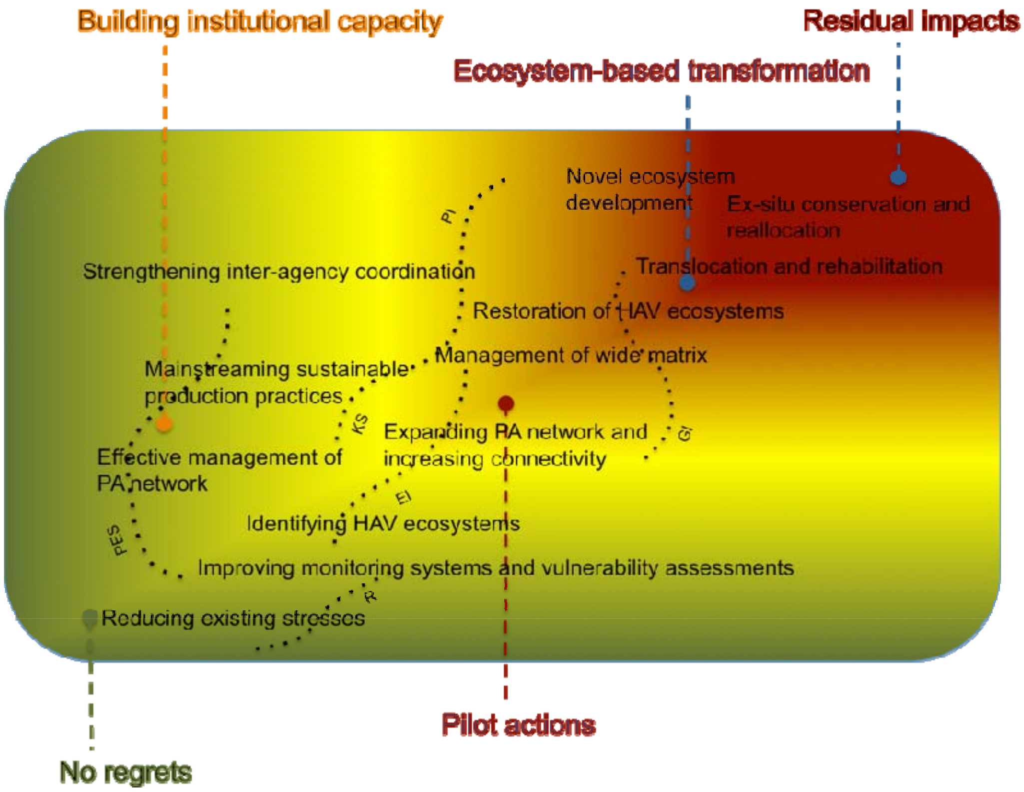


Figure 29. Illustrative matrix of ecosystem-based adaptation pathways following a step-based approach.

Note: R=Regulation; PES=Payment for ecosystem services; PI=Integration into planning processes; EI=Economic Instruments; KS=Knowledge Sharing; GI=Green Investment.

7.8 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 Tanzania, shown below.

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.

Adaptation Strategies	Adaptation needs 2012	Adaptation needs 2030
Development related **1)** Accelerating development **2)** Increasing social protection	$500 million / year though probably considerably more	$500 - 1000 million / year
Climate change specific **3)** Building adaptive capacity **4)** Enhancing resilience	$100 - 150 million / year	$250 - 1000 million / year

The study has also assessed the costs of adaptation for Tanzania using a sectoral bottom-up approach. This tests the estimates above and gives greater insight into sectoral planning. Estimates for the coastal sector indicate adaptation costs to address future climate change of up to $80 million a year by 2030, and current investment needs for agriculture (expressed as an annual equivalent cost) have been estimated at over $100 million per annum. These numbers re-enforce the estimates above, perhaps indicating that for future climate change (3 and 4), when health, water, energy and ecosystem adaptation costs are included, the upper estimate is more plausible.

The study also has advanced a framework to prioritise early adaptation in the sectoral analysis, which considers uncertainty within an economic framework of decision making under uncertainty. 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 Tanzania, 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 Tanzania 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.

Specific actions are set out below:

- Improving the estimates. Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis of adaptation. While there are recent studies which have started which will help address the gaps, a number of specific issues are highlighted.
    - For adaptation, further work is needed on the costs and benefits, including to government, the sector and individuals. This step could provide adaptation costs in detail 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.
    - Further work should also be undertaken on the potential macroeconomic and distributional (equity) effects of adaptation, and more detailed assessment of the costs and benefits to different sectors / stakeholders.
    - Taken together, this analysis could form the basis of an expanded national 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 Tanzania, that include but go beyond those identified in the NAPA. This includes a focus on early no regret options, but also fast-tracked monitoring, forecasting and information provision (as these underpin future prediction and analysis), strengthening early warning systems and disaster risk management and sectoral focal points and cross Government collaboration.

- Building Capacity. Access to substantial adaptation funds must be assured. However, mechanisms, institutions and governance systems for effective use must be developed to allow Tanzania to access these funds. This requires early and concerted action to build capacity across stakeholders and with the affected communities themselves.
- Risk screening through to building climate resilient growth. There are already plans in Government to mainstream climate change, and this reflects the need to build future climate change risk screening into all development and planning, at a sectoral and regional level. However, there is a need to further consider and adapt to climate change, looking not just at the project level, but up to the macro-economic level. Specifically, i) climate resilient plans should cut across all sectors and mainstreamed into sector plans (noting actions are already underway to start this within Government), ii) areas of development that increase future threats to climate change should be identified, iii) linkages between adaptation and low carbon development (especially in relation to opportunities for finance) should be further explored.
- National policy and Vision documents. Planned revision of national policy should examine the potential effects of climate change and the potential for adaptation. There is also a need to build on existing government and donor activities. There could lead to a new strategic vision for Tanzania that addresses these areas, for example, with further development of the Vision 2025 document, as well as supporting intermediate indicators and targets.
- Regional collaboration. There is also a need for regional collaboration and co-operation across the areas of adaptation, to benefit from economies of scale and to enhance regional resilience. Given the many trans-boundary impacts of climate change, the need for international co-operation to address these, and the potential for regional opportunities, this is a key area. There is also a need to examine the potential international dimension of climate change and how this might affect Tanzania.

A summary of key steps for adaptation and sustainable / low carbon growth are presented in the tables below.

Adaptation	Recommended Actions
Immediate needs and capacity building	• Early capacity building (institutions and organisations). • Early warning systems, meteorological capability, and post-disaster coping mechanisms. • Enhanced monitoring of key impacts. • Expanded research into impacts, adaptation and economics. • Extend national climate change plans into major national climate change strategy, including analysis of costs and investment plans (investment and financial flow analysis). • Extension of existing screening of sector and regional plans for climate risks and adaptation opportunities, including in national policy and into long-term vision (Vision 2025) • Build on existing national adaptation authority, expanding capacity and looking to enhance sectoral co-ordination, link to international finance and support private sector. • Enhance links between adaptation and low carbon development.
Climate resilience	• Climate resilient strategies, objectives and targets for immediate concerns. • Screening for new projects, policies and programmes • Develop prototypes of sectoral actions and demonstrate with pilot, to allow later scaling up.
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 and to reduce climate risks, and opportunities to develop adaptive capacity • Scale up successful prototypes to sectoral development plans

8. Sustainable Growth and Low Carbon Opportunities in Tanzania

8.1 Introduction

The final part of the study has focused on the potential benefits of sustainable energy use, aligned to low carbon growth and the emerging opportunities under the various international mechanisms. The main focus is a technical assessment of the near and medium term potential of Tanzania to invest in more sustainable, lower carbon projects and programmes, which have economic development and growth benefits, as well as conserving the natural resource base. This leads to the concept of a more sustainable and low carbon growth path. A full technical report is available on this work[31]. This section summarises the analysis and findings.

Current baseline: economic growth and energy use

Forests provide over 90% of the national energy supply through wood fuel and charcoal. This reflects a lack of affordable and reliable energy alternatives. However, the current rate of wood use is unsustainable, and combined with land-use pressures, it is leading to high rates of deforestation. The growing use of fossil fuels also has wider economic, social and environmental impacts, for example, the growing dependence on fossil fuels is leading to fuel price shocks and inflation (during periods of recent high oil prices), affecting the balance of payments, as well as leading to air pollution (indoors and outdoors). Future socio-economic trends, not least growing population and urbanisation, will exacerbate these existing energy access issues and associated impacts. Furthermore, Tanzania's economy is heavily based on natural resource use. The annual levels of growth needed to match the development objectives in the Vision document (8% annual GDP growth) may be restricted by unsustainable resource use, and an increasing reliance on inefficient use of fossil fuels.

The current and emerging issues are summarised below.

- **High rates of deforestation.** Tanzania has an acute deforestation issues, with significant reductions in forestry cover. Several different estimates exist, but the FAO (2006) estimated deforestation rates of 412,000 ha per year since 1990. In 2005, this deforestation rate translated to an annual loss of forest stock of 1.2%. In terms of annual net loss of forest, Tanzania is ranked globally at 6th (and 3rd in Africa after Sudan and Zambia). Whilst there is some uncertainty over the exact rates are of deforestation, it is clear that extensive fuel wood use for energy (accounting for over 90% of primary energy needs), and the clearance for agricultural land, is leading to the depletion of natural resources. Rising populations, high land dependence, and limited opportunities for economic diversification are likely to reduce forest area further. While there are Government tree planting programs and land being set aside for forestry and national parks to address this problem, this remains a key concern.
- **Inefficient use of biomass**. Related to above, biomass fuel production (for charcoal) and consumption is extremely inefficient, further exacerbating the problem of unsustainable consumption. The technology is use for production and use (in homes) tends to be extremely inefficient, with the latter also leading to high levels of indoor air pollution, which is extremely damaging to health. There are also wider socio-economic impacts through additional time spent sourcing wood due to high consumption levels.
- **Unreliable and limited access to electricity**. The access to electricity is limited and subject to many outages, which disrupt business activities and reduces economic growth. The World Bank (2008) estimates that businesses in Tanzania experience outages equivalent to 63 days of the year. Costs are incurred due to equipment damaged by outages but also the need to switch to higher cost own generation (diesel). The World Bank (2008) estimated that the value of lost load or unserved energy costs the economy 4% of GDP. In addition, emergency capacity required due to near term shortfalls following the 2003 drought events are estimated to have cost 1% of annual GDP in Tanzania. The higher costs of generation and lower revenues for TANESCO reduce investment. The situation is compounded by high system losses and inefficient tariff structures. Moreover, current access to grid electricity is very low in Tanzania, reducing the availability of modern energy services for households and businesses. The access rate is about 12% of the population overall, and 1% of the rural population.

[31] Low Carbon Growth in Tanzania by Steve Pye, Paul Watkiss, Matthew Savage, Justin Goodwin (GCAP), Jillian Dyszynski (SEI), Alex Hendler (CAMCO). The full technical report is available on the web-site (http://economics-of-cc-in-tanzania.org/).

- **Increasing reliance on fossil fuels.** Tanzania's reliance on fossil fuels is increasing, as the energy system diversifies away from dependency on hydro generation for electricity, and diversifies from biomass for non-commercial sector energy needs. There is also high growth in fossil intensive sectors grow, in particular transport, which result in increasing energy security issues and exposure to market price fluctuations: in 2007, high oil price increases led to a significant increase in the value of imports (by over 26%) (United Republic of Tanzania, 2008). In addition to the economic impacts, adverse environmental impacts also arise from increased use of fossil fuels, in particular air pollution. The increasing reliance on fossil fuel use is compounded by inefficient use of energy.
- **Rapid urban expansion and transport sector growth**. High population growth and the continuing rapid rate of urbanisation have put significant pressures on existing urban infrastructure and resulted in significant unplanned development, notably in Dar es Salaam. The problem of urban road congestion are now extremely severe, as the number of vehicles exceed road capacity – the city's roads have a holding capacity for 15,000 cars, while at the moment there are more than 135,000 vehicles travelling on the same infrastructure on daily basis (even though per capita vehicle ownership remains low). A study by the Centre for Economic Prosperity (CEP) indicates vehicles often spends up to two hours to cover a 16- kilometre trip, a distance which could have been reached in 15 minutes if there was no traffic congestion. The cumulative costs of lost travel time is extremely large, A survey conducted by the Confederation of Tanzania Industries (CTI) has estimated that traffic jams in Dar es Salaam costs about 20% of annual profits of most businesses (DN, 2006).

A more sustainable, low carbon growth pathway has the potential to address the issues above, whilst also providing Tanzania with additional carbon finance to help facilitate sustainable economic growth by providing funding for projects and programmes.

In addition to reducing carbon, these options could lead to more sustainable growth through protecting natural resources, improving environmental quality, delivering economic opportunities and reducing reliance on fossil imports.

The issue is illustrated below.

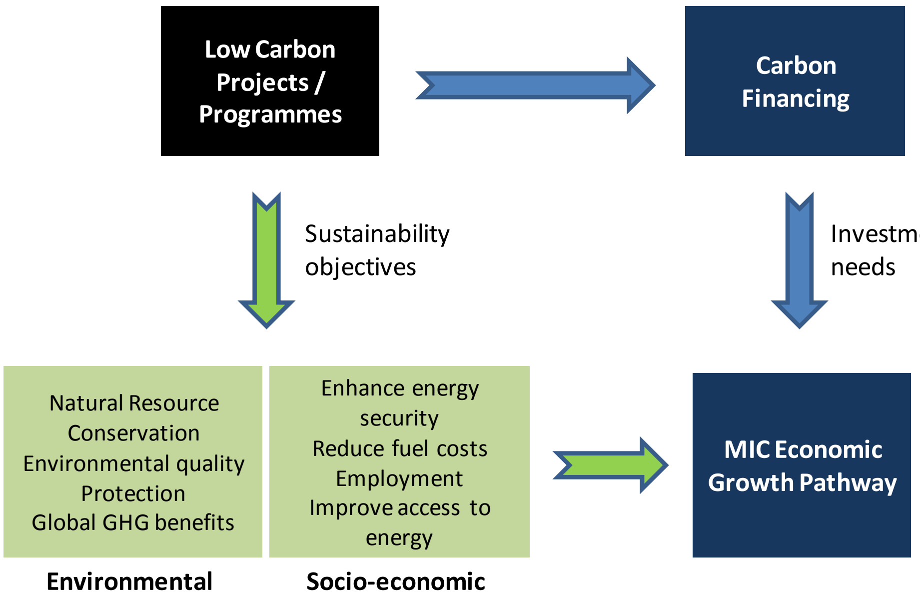


Figure 30. Low carbon opportunities can help deliver more sustainable growth

Some of the key synergies are listed in the table below.

Potential synergies between lower carbon and broader development objectives

Benefits of Low Carbon Investments	Policy Objective Supported	Description
Access to finances	Raise capital for investment in economy	Low carbon projects provide the potential to raise carbon finance, and much needed capital for investment. This could reduce donor-dependency.
Reduce energy costs	Increase competitiveness of economic sectors	Reducing energy intensity of economic production through energy efficiency can reduce energy costs, thereby increasing competitiveness.
Enhance energy security	Reduce reliance on fossil fuel imports	By improving efficiency or switching to renewables / alternative fuels, reliance on oil imports can be reduced, improving energy security and reducing foreign exchange payments.
Promote renewable decentralized energy technologies	Enhance access to modern energy services, particularly in rural areas	Renewable technologies provide significant potential for delivering modern energy services to rural populations.
Developing 'green' sector	Economic development and job creation	A low carbon focus could hold opportunities for developing sustainable energy technologies, and establishing a strong regional position in associated markets
Improve environmental quality	Reduce health impacts from indoor and outdoor air pollution	Reducing reliance on or use of fossil fuels in transport sector and biomass in rural areas could significantly reduce impacts on health.
Habitat protection	Safeguarding forest areas and associated economic sectors	Opportunities for carbon finance through REDD+ provide an incentive for safeguarding forests, in turn protecting important economic sectors e.g. wood products, tourism and maintaining important ecosystem services.
Promoting regional co-operation	Improving regional economic links, and co-operation	Linking up energy infrastructure could have significant benefits for energy security and the supply of clean, reliable electricity.

Low Carbon Options can help deliver more Sustainable Economic Growth, and provide access to finance to fund this transition.

8.2 Future emission projections

To assess low carbon investment opportunities, current and projected emissions first need to be estimated, providing a 'baseline' from which to estimate opportunities for emission reduction potential. The types of low carbon opportunities are then assessed by sector, including current projects, and future potential in the medium to longer term. The analysis then considers how to overcome the potential barriers to accessing financing. Finally, it considers the linkages to the early sections on impacts and adaptation (climate resilient growth).

The analysis has first considered current emissions. Tanzania currently has relatively low emissions of greenhouse gases (total and per capita).

- Current year emissions are dominated by the forestry and agriculture sectors, illustrating the importance of these sectors to the economy but also the very low fossil energy use. Emissions from the forestry sector, due to deforestation and degradation, and agriculture, primarily from livestock (CH_4 from enteric fermentation) and agriculture soils (N_2O from fertilisers, animal manure etc.) accounted for 93% of emissions in 1994 (forests 70%, agriculture 23%).

- Emissions from the energy system are low due to the very high prevalence of biomass, accounting for up ~90% of final energy consumption. However, this biomass is not carbon-neutral because it is sourced from unsustainable resources, the emissions of which are captured in the forestry sector estimates, accounted as removals.

- Per capita emissions are estimated at 1.2 tCO_2e per capita (all GHG, but excluding forestry) and 2.7 tCO_2e per capita, where forestry emissions are included (under category land use change and forestry, or LUCF) – though it is noted that specific CO_2 emissions per capita are very low.

- Tanzania has also 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. These provide practical demonstrations of the benefits of such policy.
- However, emissions are rising rapidly and will continue to do so. The study has estimated future emissions in line with planned development as set out in the Vision 2025, and based on population forecasts from the UN. The results show that future total and per capita GHG emissions will rise significantly, even though Tanzania is already initiating many low carbon options.
- Under this future 'business as usual' scenario, the study estimates that total emissions of greenhouse gases will more than double between 2005 and 2030. Excluding LUCF emissions, emissions are set to rise by 2030 from 48 Mt to 110 Mt CO_2e, with per capita emissions rising from 1.15 to 1.5 tCO_2e. Including the LUCF sector, emissions are set to rise from 110 to 250 Mt CO_2e by 2030, while emissions per capita increase from 2.7 to 3.4 tCO_2e. These are shown in the figure below.

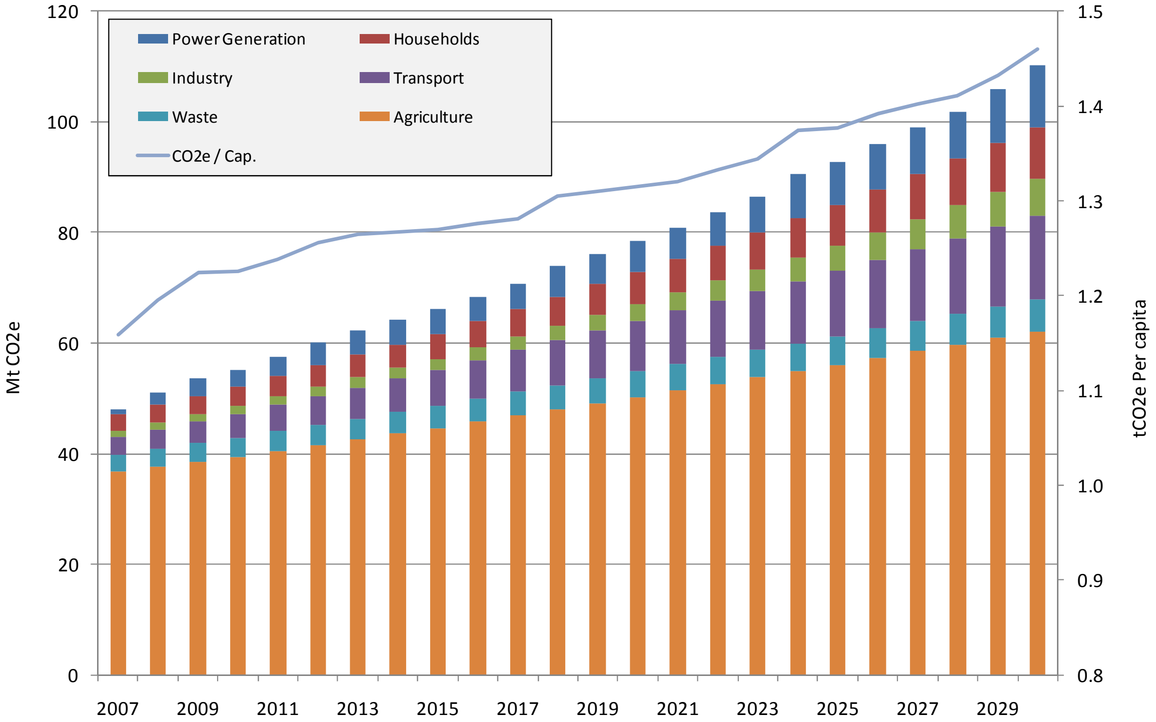


Figure 31. GHG emission projections for Tanzania (excl. LUCF), $MtCO_2e$, 2007-2030

- The underlying drivers of this emissions growth is the rapidly increasing population and forecast GDP growth. Population is forecast to grow significantly from just under 40 million in 2005, to 75 million by 2030, and 110 million by 2050 (UN 2010). Annual GDP growth rates remain at over 7% out to 2030.
- These drivers lead to large absolute and per capita increases in demand for energy, increasing fossil fuel consumption, electricity and biomass, increasing the pressure on the forest resources. Population growth in particular leads to significant increases in food production, whilst industrial growth and rising purchasing power increases the demand for transport services, in particular private cars.
- In turn, these trends result in significant emissions increases, particularly as fossil-fuel consumption increases, for example in the transport sector, and forest resources continue to be used. Emissions in other sectors will also rise, such as the electricity generation sector, where planned increases in the use of fossil generation (due to the need for diversification and use of indigenous resources) will increase the carbon intensity of generation.
- These increases will occur at a time when there are likely to be greater economic opportunities for international carbon credits, particularly if national level GHG mechanisms emerge.

- Furthermore, the current plans across the economy (or for some sectors, the lack of plans) could 'lock-in' Tanzania into a higher emission pathway. The increases 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.

Of course, increases in emissions will be necessary for Tanzania's growth, and given its development status, there is no suggestion that future emissions should be constrained.

However, the emissions growth above is related to a specific development pathway that has high fossil fuel use and unsustainable use of natural resources. Such a pathway will lead to an increase dependence on and inefficient use of fossil energy, with associated economic, social and environmental impacts, for example, increased congestion, higher fuel costs, greater fuel imports and higher air pollution.

There is, however, an alternative growth strategy, based around low carbon options, that would be more sustainable, and which would have the considerable benefit of providing potential carbon financing.

Tanzania currently has relatively low emissions of Greenhouse Gas (GHG) Emissions, but these are set to double over the next 10-20 years

8.3 Low Carbon Options

The future emissions pathway is based on many different assumptions and is uncertain, particularly in the longer term. However, its main purpose it to illustrate that greenhouse gas emissions are likely to increase significantly over the next twenty years. This growth in emissions is indicative of rapid population growth and strong economic growth, and reflects the increasing demand for energy, both biomass and fossil-based sources, transport services and agricultural production. From these projected increases in emissions, the analysis has then focused on exploring opportunities for low carbon investments that could both generate carbon finances and promote a more sustainable growth pathway that is in Tanzania's self-interest. We have identified four broad drivers that illustrate why investments in low carbon projects could be in the interest of Tanzania, shown below.

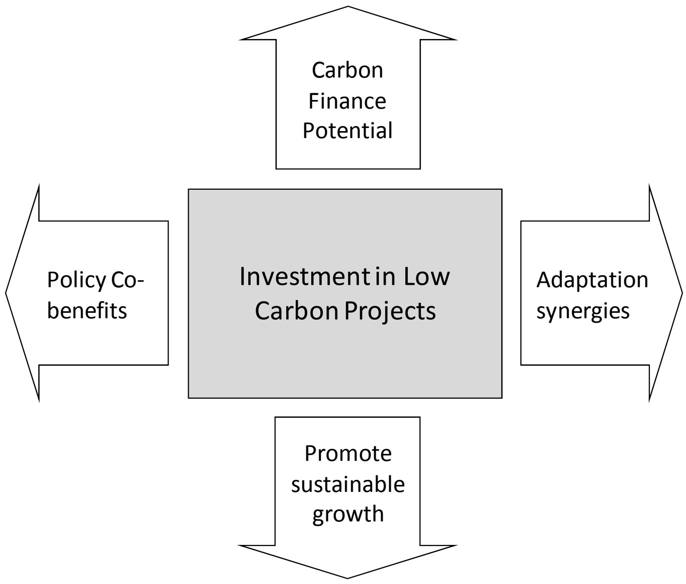


Figure 32. Policy drivers for investments in low carbon projects

- *Policy co-benefits* are where low carbon investments are aligned to current or planned policies.

- *Promotion of sustainable growth* is where low carbon investments could actually stimulate new economic sectors and reduces costs e.g. through energy efficiency measures, and promote greater sustainability.

- *Carbon financing potential* reflects opportunities for investment and financing from projects or programmes that reduce CO_2 emissions.

- Finally, *adaptation synergies* are where these investments align with actions needed to enhance climate resilient growth.

Opportunities have been assessed across all sectors, including an economic assessment of their cost-effectiveness for reducing GHGs. This has also considered existing options: it is evident that Tanzania is already carrying out a range of low carbon projects; however, there is scope to do more, and thus benefit from existing and future streams of carbon finance.

Electricity generation sector

Tanzania already has a low carbon electricity sector. The overall plans for the electricity sector indicate an even higher level of renewables in the generation mix in future years. However, these reductions are potentially offset by planned use of coal and gas fired generation. The emissions profile for the sector plan is shown below. Figure 33 shows the total absolute increase in emissions from the sector. Note that the orange line reflects the average carbon intensity of the electricity mix. It can be seen that the carbon intensity is increasing in the short-term due to the added fossil fuel on the system.

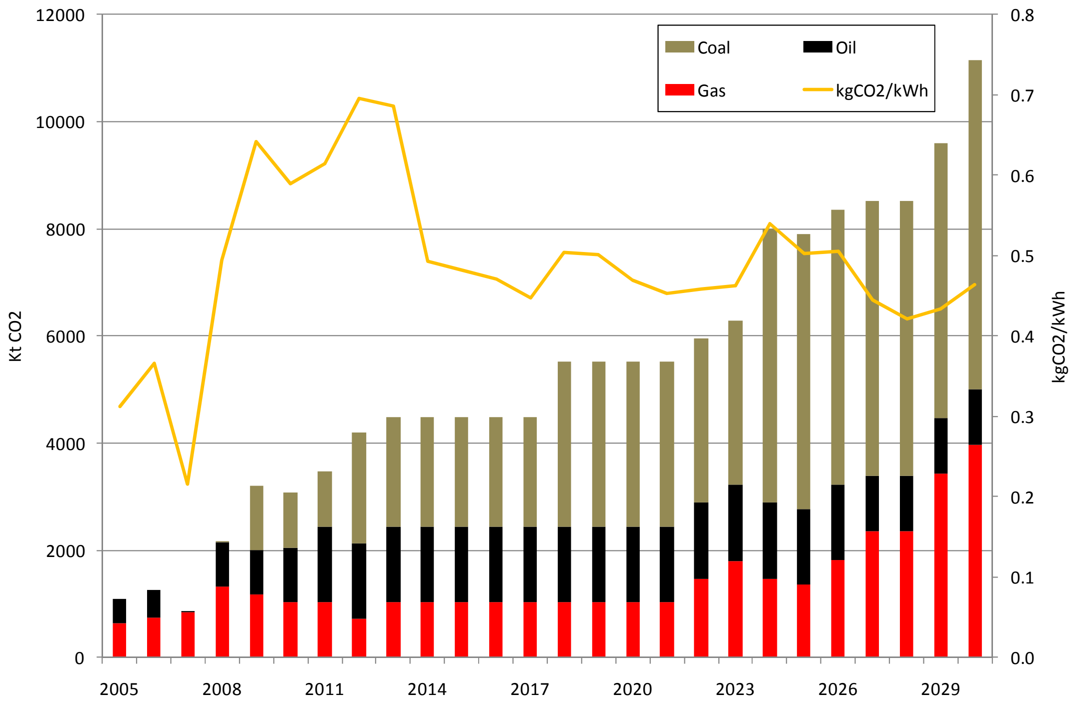


Figure 33. Projected CO_2 emissions from electricity generation sector, Kt CO_2 and carbon intensity of generation (kgCO_2 per kWh generated)

As highlighted above, these increases in emissions in the sector would occur at 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 Tanzania, i.e. they represent a lost opportunity for future credits, because of the 'lock-in' of high emission plant.

Key low carbon opportunities include the development of 'new' renewable sources including solar, wind and geothermal, improved transmission and distribution to reduce losses (and therefore CO_2 intensity of electricity), demand side management and efficiency, and improved interconnection with neighbouring countries.

Renewable micro and mini-grid generation options also have an important role to play in providing access to clean, affordable and modern energy in rural areas. Such opportunities are already being considered and realised by the REA, and under World Bank (2007) projects such as TEDAP.[32] This is particularly important in the context of large rural areas with low population density for which centralised distribution does not make economic sense.

Solar household systems represent an important technology for rural electrification; bringing lighting services and provision of electricity for electrical appliances. Such technologies can be cost-competitive relative to alternatives, including kerosene for lighting and small scale diesel generators for electricity. They also have important socio-economic benefits – promotion of local commerce, lighting to help facilitate learning and other social activities, and reducing indoor air pollution – an example is given in the box below.

Case study: Off grid solar electricity

Only 10% of Tanzanians have access to electricity from the national power company, and electrification rates are lower in the countryside, where 80% of the population lives. For electricity access in rural area, options include community-based mini-grids (micro-hydro or biomass) or solar electric systems.

Solar Home System on a house in Zanzibar

Solar home systems (SHS), or solar business systems, are an important option for rural electricity. Donor-funded projects to support private sector solar companies have been major drivers of the industry's growth, for example the Sida/MEM Solar PV Project targets sixteen regions and includes (1) business development services for solar companies, (2) marketing and awareness raising, (3) network building amongst solar industry stakeholders, and (4) policy and institutional support for the implementation of national quality control standards.

Due to such project, there has been a large increase in solar technology awareness and a 15-fold increase in the size of the solar market. There are currently nearly a dozen Tanzania solar importers/wholesalers and over 200 retailers in the regions and districts around the country. While there remain some issues, and barriers, further work is on-going to overcome these, such as through the Clusters Solar PV Project which is structured to provide standardized high-quality solar systems, bulk purchases to reduce cost, credit financing and subsidies. The Clusters PV Project is currently benefiting cashew, tea and coffee farmers in Southern Tanzania, and there are plans for separate other projects in other regions.

Access to affordable credit is key to ensuring this technology can be rapidly scaled. There are now REA/REF subsidies to support solar PV systems, but whereby all small rural PV systems need to be installed by a developer. Importantly for Tanzania, there is a buoyant private sector market that could realise such scaling. In addition, ensuring the quality of technology is critical for ensuring that SHS delivers the benefits and customer expectations are met.

The generation system is likely to expand rapidly over the next few years. It will remain relatively low carbon (compared to systems in other countries) due to the continuing use of hydro generation. However, renewable opportunities remain – although more work is needed to understand the resource and structure the tariff system to incentivise investors. Incentives may also come through the CDM mechanism although Tanzania needs to demonstrate that such a mechanism can be effectively used in this sector.

[32] Tanzania Energy Development and Access Project (TEDAP), funded by the World Bank, to improve the electricity generation system and off-grid generation. An important environmental objective is to abate greenhouse gas emissions through use of renewable energy in rural areas for provision of electricity. An important part of the project is the off-grid component which is looking for opportunities for technology scale-up to increase rural electrification in association with the REA.

With carbon finance incentives, these low carbon options can become even competitive. In addition, further use of indigenous generation sources reduces Tanzania's exposure to international fuel price increases and fluctuations. A more strategic risk in the context of fuel prices and evolution of carbon financing is that investments now in fossil-based generation could lead to technology *lock-in.* This is because generation plants typically have lifetimes of 30-40 years meaning that they will be used to pay-back any investment made. This could well be in spite of high energy prices and significant opportunity cost relating to carbon financing.

This raises an associated issue in the context of negotiation discussion on programmatic CDM and the Registry of Nationally Appropriate Mitigation Actions (NAMAs). A move towards fossil based generation could have implications for sector based programmes in the energy sector, or even national level financing in the context of NAMAs.

Increased reliance on renewable sources, however, must take account of climate resilience issues (discussed later), including water availability for hydro generation and the changing demand load for electricity, as cooling demand increases. Note that this also potentially applies to fossil stations, not least because of their relatively high water demands. Tanzania is going to need to ensure it balances its system so that it has generation options that can guarantee contribution to peak demand.

Using higher cost generation sources could also potentially lead to increases in the cost of electricity (depending on how the market and tariff structure evolves) and impact on affordability. Increasing access is an important objective that must not be compromised by higher prices; such adverse impacts would need to be mitigated.

Increasing decentralised and off-grid generation is also going to be important for provision of electricity to rural communities. This appears to be the most important household technology that could be scaled. There is also the benefit of a buoyant and rapidly expanding private sector that could help deliver this. However, access to credit is going to be critical to ensuring affordability obstacles can be overcome. In addition, product quality needs to be ensured to avoid undermining the technology in the eyes of the consumer. Opportunities for programmatic CDM in this area should be explored, to see what carbon financing opportunities exist.

Household energy sector

The household sector is the most significant user of energy in Tanzania, through consumption of fuel wood and charcoal. The baseline projection illustrates that these will remain important sources in the near and medium term. These are affordable, indigenous sources of energy, and whilst modern energy forms will become more prevalent as incomes increase, they will probably only replace a fraction of the households using wood fuel and charcoal.

However, the rate of biomass consumption is unsustainable, driven by population growth and a rapidly dwindling forest resource (as illustrated in the forest sector projections above). Therefore, opportunities for funding to promote more sustainable resource use through low carbon projects should be considered. In addition, account needs to be taken of affordability, with few alternatives for low income households.

Improved biomass / charcoal stoves could realise significant cost savings to households across Tanzania, and lead to significant benefits for reducing depletion of forest resources. In addition, the health benefits through reducing indoor air pollution could also be considerable. However, as with solar home systems, ensuring quality of these technologies is important. Many improved technologies in the existing stock are not delivering the savings or retaining their quality over the specified lifetime (Malimbwi et al 2007). The barrier of cost also needs to be addressed, particularly to enable low income households to access such technologies. Finally, better understanding of consumer behaviour is critical to increasing uptake rates through new stove programmes.

Improved charcoal production is another important opportunity to promote sustainability in the use of biomass resources. Significant savings could be achieved through reduced use of wood fuel, and greater emphasis on forest replenishment. This could also safeguard the longer term viability of the industry. However, rapidly growing demand due to population growth is going to make this challenging; therefore, switching to alternative fuels away from charcoal is also important. A case study of an ongoing initiative to develop a more sustainable charcoal market illustrates additional challenges (see box below)

Fuel switching (from charcoal to modern energy sources) will inevitably happen as incomes increase. However, the rate of switching required to significantly reduce charcoal demand needs to be much more rapid. Challenges include meeting supply requirements and ensuring affordable access. For electricity using appliances, there is a real challenge to promote more efficient appliances, including for lighting, particularly in the near term as the market size rapidly increases.

Forestry sector, including REDD

Addressing the current use of forest resources is key to the future of Tanzania, in economic, social and environmental terms. Importantly, there is significant potential for forest conservation, due to the high level of emissions associated with forest deforestation and degradation, to raise significant carbon financing that can fund forest protection but at the same time provide important income streams, particularly to rural communities. This could be achieved through the REDD+ scheme, where payments will be made by the international community for forest protection.

Tanzania has been an active member in developing 'Reducing Emissions from Deforestation and forest Degradation (REDD) and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks'. The process of REDD+ implementation has started in the country through national planning processes and the development of pilot projects, giving some sense of what REDD+ might look like in practice to the wider region.

Under REDD+, Tanzania will implement policies to address the drivers of deforestation and degradation. Examples of policies include enhancing community based forest management,[33] developing 'payment for environmental service' schemes and changes to agricultural and energy policies. Financial support is already being given to Tanzania to develop national REDD+ plans, and to start implementing projects. The innovation in REDD+ is that financial support from the international community to implement these policies is likely to be linked to performance in reducing deforestation and degradation rates.

Some key challenges for the large-scale implementation of REDD+ include:

- Strong linkages in socio-ecological systems may be disrupted by change in forestry management policy and regulation. Care will need to be taken in ensuring that REDD schemes are integrated properly into existing Participatory Forestry Management (PFM) structures.
- Despite many years of developing PFM, and the presence of valuable stocks of timber on many areas under PFM, there is very little revenue being captured at the village level from these resources.
- Poor governance and local law enforcement, e.g. in preventing illegal logging.
- Insecure tenure is a major issue, which makes it difficult to ensure emissions reductions are permanent, and may therefore make investment unattractive.
- Lack of regular, reliable, specific and accurate data for computing baseline emissions, and therefore expensive survey work.
- Leakage has also become very challenging in the implementation of REDD initiative, because local projects, albeit successful, might fail to deliver any net emission reductions from reduced deforestation in the aggregate.
- Very high deforestation rates make large scale implementation critical. However, the scale of the problem makes the challenge of addressing the issue through REDD significant.
- REDD+ could create incentives for government or investors to occupy poorly defined 'surplus' land. In addition, lack of clarity over rights to carbon and lack of access to legal systems even where rights are well defined may exclude poor people.
- Establishing and maintaining benefit sharing systems will require significant government capacity.
- High transaction costs of implementing REDD+ in areas where forests (or their ownership) are fragmented, may exclude communities from REDD+ schemes.

[33] The existence of community based forest management means that Tanzania is potentially well placed to implement REDD. Policy reforms in forestry management mainly through the National Forest Policy in 1998 and the subsequent Forest Act of 2002 facilitated community engagement over 15 years ago.

Case study: Sustainable Charcoal

Charcoal is the most important energy source for millions of urban dwellers in Tanzania with ~ annual consumption of 1.6 million tonnes, requiring approximately 15 million cubic meters of wood. Since the wood is harvested unsustainably (and often illegally), without tree planting, the charcoal results in significant degradation of forest land with and ~ 100,000 – 125,000 hectares of lost forest area has been attributed to charcoal production (WB, 2010), with impacts on biodiversity and ecosystem services as well as net GHG emissions from deforestation and other combustion emissions. However, addressing the problem is complicated, because of the role in rural incomes, the large market in Dar es Salaam, valued at approximately $350 million (though this is a highly informal sector) and because 90% of urban Tanzanians use charcoal as their primary or secondary source of domestic energy. Alternatives, such as electricity, LPG or biomass briquettes are either perceived as too expensive or hampered by undeveloped distribution and marketing.

A Half Orange Brick Kiln constructed in one of the villages under the Dar Charcoal Project

The Dar es Salaam Charcoal Project aims to address the environmental problems resulting from charcoal production and consumption by promoting sustainable charcoal production and gradual switching to alternative fuels. The three overall components of the project are sustainable charcoal production, fuel switching/alternative fuels and improved charcoal sector coordination. It works with rural communities, advances village land use plans, and gives training to charcoal producer groups in governance, establishing nurseries and woodfuel plantations, encouraging efficient kilns for wood to charcoal conversion, introducing local government enforced sustainable charcoal certification, and sustainable charcoal marketing and distribution.

However, the sustainable charcoal is more expensive, and to address this, the “green” product is exempted from taxes, and awarded sustainable charcoal producer groups with voluntary carbon credits. For example, the $144 per ton of sustainable charcoal (from one example scheme) more than compensates for the additional cost of producing charcoal sustainably.

The alternative fuels component of the Project targets urban Dar es Salaam is encouraging a gradual shift away from charcoal dependence towards green energy sources.

The Dar Charcoal Project finally began in late 2009,. WWF secured internal funding as well as support for the Project from Barclays Bank UK, and via Camco, funding from USAID. The Project’s sustainable charcoal project has been introduced in twelve villages. To date, land use plans have been developed in the villages, 50 charcoal producer groups have been formed and trained nurseries have been established, and efficient kilns constructed. The marketing of the first production of sustainable production is scheduled for the last quarter 2010. Simultaneously, USAID has supported a two-year campaign to market biomass briquettes as an urban domestic energy alternative to charcoal.

More understanding will be needed concerning the linkages between REDD+ and the wider policy changes required to reduce deforestation and degradation rates. For example, energy policies and agricultural policies will need to be integrated into the overall REDD+ framework and will demand much more effective cross-sector coordination at national and local levels. These policies may have implications for different stakeholders, which need to be better understood. As a key driver of deforestation and degradation, unless energy needs of the population are addressed, enforcing forest protection is going to be increasingly difficult. Where REDD affects fuel wood and charcoal availability, this could also have significant distributional impacts on low income households who cannot afford any alternatives.

Another set of issues that have not yet been fully analysed are the distributional effects and benefits of for communities. In Tanzania it is hoped that REDD+ will deliver pro-poor Community Based Forest Management approaches (as discussed above). However, while such policies to date have been relatively successful at delivering environmental benefits, they have not been of specific economic benefit to more marginal communities. However, it is still far from clear whether the scale of benefits from REDD+ can help to overcome such issues, or in fact whether REDD+ may actually result in new pressures that exacerbate existing inequalities.

Transport sector

An efficient and reliable transport system is vital for ensuring future economic development. With rapid urban population growth predicted, effective planning of transport infrastructure and systems is needed, particularly to ensure the objectives of efficiency and reliability, and maintain urban environmental quality. This is currently not happening, with severe congestion and environmental quality being experienced in major urban centres, notably in Dar es Salaam.

Low carbon investments in the transport sector have strong synergies with the development of efficient, reliable and clean transport system, particularly in urban areas. This is because lower carbon options include the promotion of public transport, more efficient vehicles, alternative modes of transport, and alternative fuels

Development of the biofuel market could offer significant benefits for Tanzania through generating rural employment, providing agriculture sector investment, reducing reliance on fuel imports and creating a new export commodity. Recent analysis (by FAO 2010) suggest that, depending on the crop grown, this need not compromise food production or water resources but could actually lead to increasing food productivity through additional sector investment. To realise economic benefits to rural communities, the sector model taken forward will be key to ensure small holders can supply energy crops. The international community also needs to buy in to the sustainability of such an industry to ensure that any export markets are sustainable in the longer term.

Development of carefully planned public transport provision will be critical for provision of transport services to a rapidly growing urban population. This planning will need to be integrated with other service provision to ensure that transport systems can meet the evolving urban area, and its associated demographic characteristics. Significant challenges include raising the capital investment required, co-ordinating with different planning agencies, implementing and enforcing spatial planning policies, promoting a shift away from private car use and ensuring that the type of scheme developed is affordable for lower income groups. The benefits in terms of lower pollution levels (and reduced GHGs) could be significant, particularly if schemes also introduce more advanced vehicle types (e.g. hybrid or electric buses).

Key issues of affordability remain with promoting advanced vehicle types and restricting lower efficiency vehicles. As incomes increase, purchasing of newer vehicles will become more the norm (as opposed to second-hand vehicles). A move to more advanced vehicles will be dependent on their wider global commercialisation (potentially allowing technology *leap frogging*) and the price differential versus a conventional vehicle. It is therefore partly a function of timing.

Introducing enforced maintenance or restricting the older vehicles on the market needs to be carefully thought through in terms of impacting on affordability of transportation, required for a growing economy. For larger commercial operators, such internal measures could have the potential to lead to significant cost savings.

Limited focus has been given to non-transport modes. Further consideration could be given to the use of the railways for freight and passengers as a means of reducing road transport-based emissions. However, it is likely that significant investment and incentives will be required to reduce recent decline in the use of rail infrastructure. Air emissions are likely to increase in future years as Tanzania increases its export markets, and higher levels of international investment flow into the country. Currently, international emissions, whilst subject to estimation, are not accounted for nationally under current international agreements. This could change in the future, and therefore it is in the interest of Tanzania to assess future risks under future international obligations associated with increasing emissions from this sector.

Agriculture sector

A key domestic policy objective is for Tanzania to modernise the agriculture sector and improve productivity, particularly to ensure food self-sufficiency. This will be particularly important in a situation where the agriculture sector becomes more vulnerable to climate change impacts. For Tanzania, projects that can generate carbon finance will have to complement (but not compromise) agriculture sector priorities like food security, land productivity and rural economic growth. Another important issue to highlight is that agriculture is a very climate sensitive sector and will be affected by climate change. The consideration of options to reduce emissions in this sector must be undertaken alongside consideration of the potential effects of climate and enhanced resilience.

Alongside the exploitation for wood fuel and charcoal energy, the sector is also an important driver of deforestation. Therefore, introduction of low carbon approaches need to take account of impacts on the forestry sector. For example, whilst a more intensive farming system has increased energy and fertiliser inputs, which in turn increase GHGs, it could also mean less land utilisation by the sector (or at least reduce current rates of increase) and the ability to increase productivity and develop export markets. Therefore, potential trade-offs exist.

Emission reduction projects could still have a role to play, where they can increase productivity, and take account of the need for climate resilience (due to current and future climate impacts). Given the structure of the agriculture sector, involving many small holders with very low incomes, carbon finance could be an important source of additional income. In addition, these options are usually relatively low cost. However, with large numbers of small holders, implementing such projects is challenging. Project opportunities may therefore be more efficiently targeted at larger agro-forestry companies where intensive systems and heavy fertiliser use are in place, resulting in poor soil carbon management techniques and intensive livestock practices.

Importantly, albeit limited, access to carbon finance in the agriculture sector is a reality today. For example, a project called *Emiti Nibwo Bulora* (translated as Trees Sustain Life) in Tanzania's Kagera region, developed by Vi Agroforesty, is promoting agro-forestry techniques (FAO 2010c). The project involves integrating tree planting into the agricultural area through boundary planting, dispersed interplanting, fruit orchards and woodlots. Whilst only in the implementation phase, this project is expected to benefit over 1000 households over the next few years through voluntary carbon financing.

Another interesting recent example is the Kenya Agricultural Carbon Project, located on 45,000 hectares in the Nyanza Province and Western Province of Kenya, which aims to reduce emissions through cropland management whilst also improving yields.[34] This is the first project of its kind, to generate finance from reducing soil carbon emissions through techniques such as covering crops, crop rotation, compost management, and agro-forestry, and is being supported by the World Bank BioCarbon Fund and implemented by Vi Agroforestry. The direct benefit to local communities is over $350,000 with an initial payment of $80,000 to be made in the first year, 2011.

The key objective for Tanzania is the development of a modern, more productive agriculture sector that ensures food self-sufficiency and can help develop the rural economy. Low carbon options have been shown to enhance productivity, increase resilience to climate change and provide opportunities for climate financing. They also tend to be low cost and have significant benefits for wider environmental sustainability, including reducing deforestation.

However, there are issues of scale with only a limited number of relatively small scale projects. These are important for local communities, and demonstrating the benefits of approaches such as agroforestry. A question will be whether such initiatives can be scaled and integrated into Tanzania's evolving agriculture sector, delivering significant emission reductions and significant levels of carbon finance.

8.4 Economic Benefits of Sustainable / Low Carbon Options

The sections above have described the range for low carbon projects that could help Tanzania move towards a more sustainable growth path, in addition to generating carbon finance to support such investment. Low carbon projects can help safeguard forests, reduce reliance on energy imports, provide more access to modern energy services, promote more sustainable biomass use, promote efficient and clean transport systems, and enhance

[34] The World Bank website, http://go.worldbank.org/WIWKCYP9T0

economic competitiveness. 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.

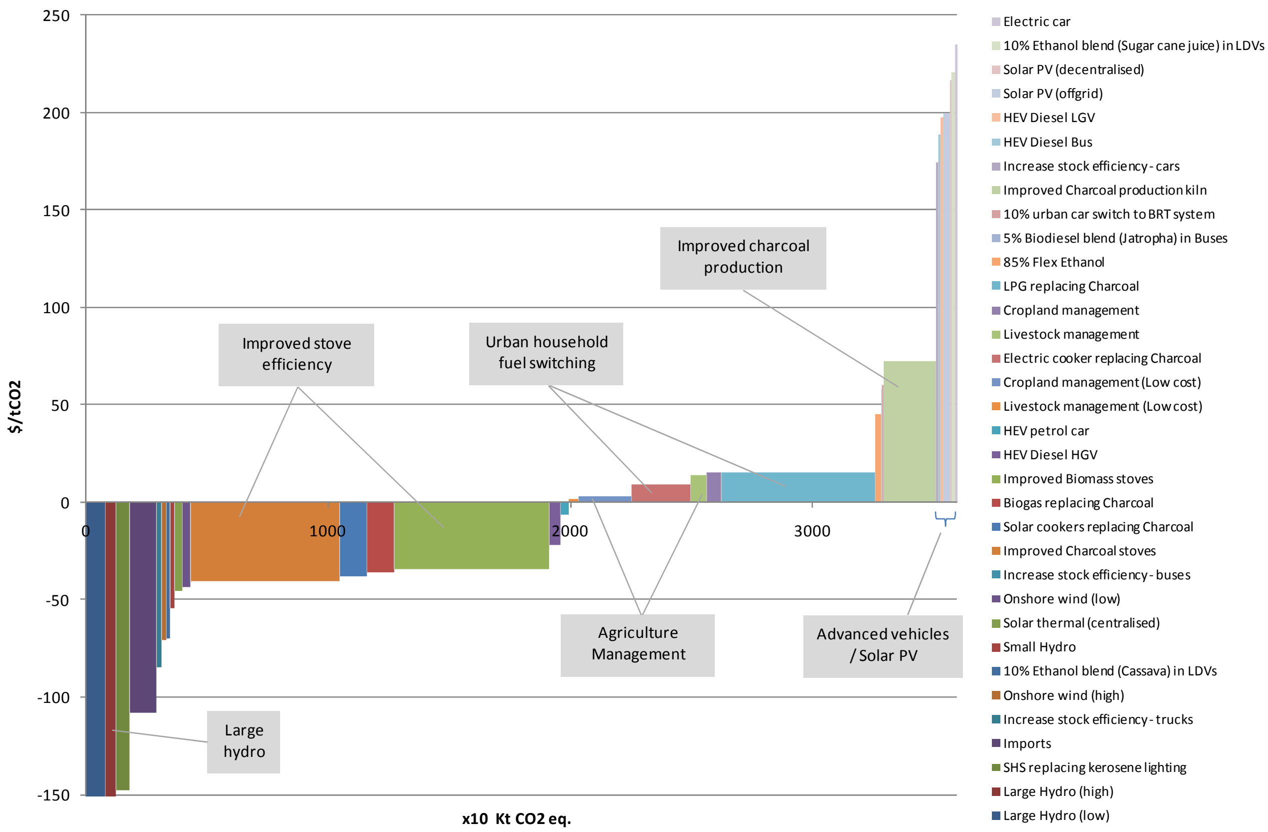


Figure 34. Indicative MAC curve ($/t$CO_2$ vs/ Gg) of selected abatement measures for Tanzania in 2030[35]

Each bar on the graph represents a specific measure, with the vertical axis indicating the costs that each of these measures can reduce a tonne of CO_2 at (the cost-effectiveness of abatement). Thus the costs of reducing emissions increase from the individual options (the bars) from left to right. The width of each bar on the horizontal axis indicates the total potential reduction associated with each measure (in tonnes of emissions), thus wider bars represent options that can reduce more emissions than narrow bars. The total cost of each measure if fully implemented is therefore the marginal cost (y-axis) multiplied by the abatement potential (x-axis).

[35] Future cost are discounted at 10%, using a net annualised cost metric.

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, particularly from improvements in transport vehicle efficiency, and performance of domestic stoves.

An important insight from the analysis is that many of the measures are 'no regret' measures (that are below the zero line on the horizontal axis) or very low cost.

These options actually save money and make the economy more competitive, as well as providing emission savings: 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. The negative cost or 'no regrets' options include improvements in transport efficiency, domestic stoves and agriculture.

Where cost are negative, this implies that such investments should be made irrespective of whether carbon finance is available, as over their lifetime such investments save money.

Note that 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. 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.

Due to the stove efficiency measures, the overall investment requirement shown in the MACC example is in fact net negative (i.e. introducing all the measures shown). The selected measures in the MACC could achieve up to 20% reduction of the baseline estimate in 2030, based on a relatively strong but not unrealistic take-up of different options. However, such cost estimates only take account of technical costs; introducing policy and transaction costs would reduce this savings figure significantly.

More work is needed to explore the uncertainties around such cost estimates, particularly because they are driven in large part by a limited number of large potential measures, particularly in the household and forestry sectors. In addition, this economic estimate of costs is very narrow as it only focuses on technical costs. Of particular interest is how these different options would affect the wider economy, and the implications for GDP growth.

The analysis demonstrates that many of the options are important and consistent with objectives of sustainable economic growth and other development objectives. 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

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.

Implementation

A significant challenge associated with many of the measures is their effective implementation through well designed policies and incentives. Many of the measures have key implementation challenges and considerable barriers (adding to costs). Effective and robust policies will be critical to realising these measures. A key concern, particularly for low income groups, is affordability. Even if technologies are cost-negative over their lifetime (i.e. payback their investment), it is often the upfront costs that will restrict access to lower income groups. It is not only affordability but the possibility to benefit from economic opportunities e.g. improved stove programmes, biofuel sector development etc. that need to be safeguarded. Policies should not be regressive but promote benefits to lower income groups.

To justify the introduction of these options and realise the many co-benefits, access to carbon financing will be key. If this cannot be accessed or the barriers are too significant, then stakeholders will disregard such investment due to lack of opportunity or incentive.

Implementation issues

Implementation of the identified options is predicated on overcoming significant regulatory, institutional and financing barriers, many of which have prevented large scale uptake of low carbon technologies to date. These barriers are present across all sectors reviewed, and include:

- Economic / market barriers (e.g. no finance, poor commercial case): Tanzania has been slow in accessing the international carbon finance markets to date, with only one project registered under CDM and only recent uptake of voluntary credit schemes in the forestry sector. Commercial banks seem currently unwilling to lend to low carbon projects due to the track record in implementation to date. There is also a mismatch between the short term domestic deposit base and the long term tenor required for capital intensive projects, creating a role for international financial institutions.
- Low levels of information / awareness: The relatively low levels of absolute and per capita emissions, lack of track record in low carbon development and competing priorities of poverty alleviation have resulted in low levels of awareness. Climate change continues to be seen through a development aid perspective, rather than from the perspective of domestic led economic restructuring or growth.
- Policy / regulatory framework: The development of a coordinated climate policy framework is at an early stage. The fiscal framework to support low carbon options remains under-developed. For example, utilities pricing supports traditional fossil fuel generation at the expense of other renewables, with limited use of technology specific tariffs;
- Technical problems of use in-country: Tanzania lacks the necessary operation and maintenance infrastructure to support complex technologies. Solar PV, however is building economies of scale and may be the first break through technology:
- Lack of skills / know-how: This is particularly pertinent to technical and financial project preparation, and acts as a barrier under CDM applications. Skills and training are of particular importance for those areas where behaviour is a significant element in emissions, such as forestry and agricultural soil management practices
- Limited institutional capacity: Multiple institutions play a role in low carbon policy development with a clear need for streamlining roles and responsibilities. This is particularly true of Forestry management and transport planning, which account for the bulk of forecast growth in Tanzania's GHG emissions

Despite the challenges, there are positive signs that Tanzania is beginning to embrace low carbon options both through its policies and regulatory structures, although these would benefit from further alignment. There are also clear signs of growing momentum within the private, voluntary and education sectors which are crucial to creating the implementation capacity required, and which may serve as a basis for scale-up of low carbon options over coming years.

8.5 Challenges to Accessing Carbon Financing

Country context

Despite Tanzania's political stability, the investment climate has not led to high levels of foreign investment. The Government of the United Republic of Tanzania Tanzania has undertaken a number of steps to improve the business climate (many with DfID support). These have included redrawing tax codes, liberalising the financial sector, and cutting red tape. However, the World Bank 'Review of Doing Business' Report continues to identify Tanzania as a relatively complicated country in which to do business, and ranks it below most of the neighboring countries of the region. This has implications for private sector involvement in clean technology markets, and the challenges faced by potential entrepreneurs looking to drive growth. Of particular concern are issues relating to permitting and property rights, which are usually vital to low carbon infrastructure activities.

The increased uptake of low carbon investment in Tanzania – as in other countries - requires an effective institutional and regulatory framework. The success of delivering low carbon projects and programmes and achieving the associated economic benefits is therefore largely dependent on effective governance and the role of policy makers.

This study has identified some potential lessons that explain the relatively low level of climate finance - though many of which are common issues for Africa and explain the relatively low level of climate finance compared to other world regions:

- Fragmented low carbon plans, and low levels of integration between sectors (renewable energy, end use energy efficiency, transport, forestry and agriculture);
- Multiple ministries and agencies dealing with low carbon policy development and enforcement, and low levels of coordination among them;
- The slow pace of policy implementation in relation to carbon finance under the UNFCCC and Kyoto Protocol, resulting in limited investment/financial flows and no effective carbon price support for renewable energy or end use energy efficiency;
- The social complexities of introducing mitigation measures in agriculture and forestry, which remain the key emitting sectors in Tanzania (and most of Africa);
- A prevailing view of climate change mitigation and adaptation as donor-driven and government-owned, rather than as opportunities for private sector and NGO innovation.

Given the structures of international climate finance and the need to mobilise resources at scale, a core approach of institutional reform and political capacity building should form the basis of any low carbon investment agenda moving forward. Moreover, the structures for climate mitigation and adaptation finance in the region will continue to be structured for delivery primarily through national governments by international financial institutions, who remain best placed to address issues that relate to public goods and poverty related agendas.

Despite certain regulatory and market difficulties, the private sector is also relatively active in low carbon projects, as is the NGO sector. This growing momentum to address sustainability in development within the NGO, educational and private sectors provide a solid base from which to further extend the uptake of low carbon technologies at national level. However, they remain relatively fragmented and small scale. Achieving more significant GHG reduction potential identified will require concerted regulatory and policy support, and in particular a more streamlined access to finance private and public sector finance,

Accessing finance

The UNFCCC Report on Investment in Renewable Energy and Energy Efficiency states that the private sector is and is likely to remain the main source of financing for renewable energy and energy efficiency across the developing economies. Many low carbon technologies remain of higher cost than their carbon intensive alternatives. Even where payback periods are short, and the costs of abatement are negative due to increased efficiency and lower input costs, such technologies may require high upfront capital investment. These incremental costs and capital requirements are unlikely to be fully met from government funds in a resource constrained economy such as Tanzania, where there are competing high-priority social and economic programmes. The international carbon markets and targeted use of donor funds to leverage the private sector are likely to play a large role in bringing capital into the sector.

As a result, low carbon markets have tended to grow most rapidly in those countries with developed financial markets and active private investors. The relative lack of progress in Tanzania reflects the significant role played by the state and the difficulties in securing private capital to invest under current regulatory structures. The extent to which private funding might operate in low carbon technology sectors is not yet defined in regulation or in practice in Tanzania. This in part reflects the relatively limited extent of sector development and small numbers of projects with private sector capital.

In the absence of limited commercial private sector finance, national financing structures, such as national development banks, or targeted development funds such as the Renewable Energy Fund (REF) in Tanzania, can provide enabling finance to bridge potential shortfalls of mitigate risk. The REF has been the most active targeted form of support in Tanzania within the low carbon sector, funded by government budget, donor contributions and levies on conventional power generation. However, the relatively small size of such funds and the narrow sphere of their application (rural energy access) can limit their potential for leveraging private sector investment. There is a clear need to engage with private sector to build a broader clean-tech venture fund capacity that can partner with national development finance mechanisms.

From an international perspective, even with strong domestic policies and the prevailing capital flows to emerging markets, risk perception among many potential inward investors may still be too great. In this regard, there is a clear role for the International Finance Institutions (IFIs), and Credit Guarantee Agencies (CGAs) to play a role in supporting scale up and mitigating risk. This can be done through the provision of soft loans, or the use of targeted risk mitigation products (credit guarantees, political risk guarantees). The role of these institutions has grown recently, partly as a response to constraints in the international capital markets and partly in recognition of their increased role in scale up of low carbon economies. However, the scale of support offered does not currently reflect the scale of financing required under climate mitigation scenarios.

Tanzania has very good potential for development of CDM and related mechanisms, particularly in relation to renewable energy and rural electrification. However, despite an early start in developing the institutional capacity, progress has been relatively slow, with only one project - a relatively small landfill methane flaring project – having been registered with a value of 202,000 CERs. There have been no CDM projects in the power generation sector, and no CERs have actually been issued as yet. A number of issues have been identified:

- The CDM process is long and requires a high level of expertise, particularly in relation to the preparation of Project Design Documents (PDDs), where a thorough understanding of the different approved methodologies is required before applying them to a specific project.
- The transaction costs associated with CDM are relatively high in relation to the size and nature of potential projects in Tanzania.
- The length of time from project development to approval has been very long, creating high levels of risk perception among potential investors. The process of project approval by the DNA, and receiving a letter of no objection (LoNO) is regarded as slow compared to other countries.
- The price of CERs generated under the CDM has been volatile, reflecting both fluctuations in buyer demand (driven by projected shortfalls and surpluses in schemes such as the EU ETS) and the perceived approval and implementation risk of individual projects.
- Eligibility criteria for CDM financing sets limits on profitability not exceeding 15%. This may limit the development of new projects in Tanzania where market and regulatory risk, combined with high costs of finance, may mean that investors require a higher rate of return.
- The availability of DOEs (Operational Entities) in Tanzania for project validation is relatively limited.

Tanzania has been relatively slow to mobilise the use of voluntary carbon markets, as is the case in other countries in the region. However this is changing, with a number of voluntary market projects emerging in the Forestry and Land Use Sectors. This is due to increased investor expectations that credits will be accepted under the UNFCCC in future. Examples include:

- In September 2010, Tanzania was the country to see carbon credits from a land-use project verified and issued under the Voluntary Carbon Standard (VCS). The Uchindile-Mapanda project takes degraded grassland and converts it into sustainably harvested forests that sequester carbon emissions from the atmosphere and generate carbon credits.
- Carbon Tanzania is currently partnering with the Mpingo Conservation Development Initiative (MCDI), one of Tanzania's leading community-based forestry NGO's, on a pilot initiative in Kilwa District, where MCDI has been based since its establishment in 2004. The project will aim to extend MCDI's work, which facilitates villages to establish sustainable forest management plans based around harvesting high-value hardwoods.

In the medium term, it is likely that much of the proposed voluntary activity associated with forestry will come within the regulated market either through increased use of the CDM (or successor) for Afforestation and Reforestation (A/R), or from approval of the REDD+ mechanisms within the UNFCCC process. While the voluntary markets have served a useful purpose in developing some of the standards associated with forestry credits, there remain concerns over monitoring and verification. To date, the price of voluntary credits has been relatively low and the volumes small in comparison with the regulated market.

It would be therefore in the interests of the United Republic of Tanzania to promote use of the regulated markets across a range of sectors, rather than to build policy around expansion of voluntary markets. This will allow it to access the major markets (such as the EU ETS), and avoid the exposure to economic growth than can affect the buyer demand in voluntary markets much more severely than that within regulated markets.

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Case Study - Reducing Emissions: Low carbon and forest management in Tanzania[36]

Technological and development patterns in Tanzania are measure in terms of their carbon emissions and consequently their contribution towards climate change. Recent studies have established that per capita and total emissions in Tanzania are still low, although some sectors are projected to have significant emissions in the near future. Presently the majority of the carbon emissions are from the agriculture and forestry sectors due to their high dependence on biomass for energy sources. Tanzania has a large agricultural sector with 90% of the country's population living in rural areas, where they rely on crop production and other natural resources for their livelihoods.

Emissions from deforestation add to the agricultural emissions trends. Charcoal production and firewood collection are the chief sources of energy in both rural and urban areas, as well as an important source of income generation for most rural areas. Deforestation patterns are also linked to ineffective policy strategies that fail to control illegal logging, infrastructure and settlement expansions, wildfires and overstocking among agro-pastoral communities of the lake, central and northern zones.

More recently, Tanzania has adopted participatory forest management strategies, which encompass community forest management and joint forest management to control deforestation, promoting instead forest conservation and improving livelihoods of rural communities. Evidence from the ground acknowledges that the strategies have been very successful, with few cases of failure. Key challenges in the participatory strategies were to enhance collective responsibility of forest management, creating awareness of environmental conservation and facilitating the sense of ownership among those reliant on the forest for their livelihoods.

These successes are potentially important for the more recent Reducing Emissions from Deforestation and Forest Degradation (REDD) strategy, which aims to reduce deforestation, enhance climate change mitigation, improve community livelihoods and address poverty. Despite this sound foundation, an effective strategy of financial payment for ecosystems services needs to be established, that doesn't rely on the Participatory Forest Management (PFM) financial flow. There is still the issue of how communities which control forests on 'village land' will be adequately compensated for their contribution to a national carbon sink. A key challenge will be how to make sure that communities are able to link conservation costs with financial flow through payment for ecosystem services (PES). This study assesses the low-carbon report for Tanzania, examining opportunities and barriers for REDD in Tanzania, its implications to future household energy consumption, and demonstrate the effects of REDD on the economy and environment.

[36] This summarises the findings of the report, Reducing Emissions: Low carbon and forest management in Tanzania, by Dr Pius Z. Yanda, IRA. The full technical report is available on the web-site (http://economics-of-cc-in-tanzania.org/).

Options for improving access to low carbon finance

- Implement Public Private Partnership (PPP) legislation to formalise private sector finance participation and reduce risk;
- Building public and private sector awareness of opportunities within the CDM market;
- Institutional review of the current DNA process to identify barriers to project approval;
- Encourage DOE verification and monitoring capacity in Tanzania/East Africa that can be shared between project developers in a timely manner;
- Explore options for accessing the voluntary market under current economic conditions;
- Map barriers to debt finance for EE and RE, and propose innovative risk sharing structures (first loss guarantees, partial risk guarantees) to encourage additional bank risk exposure;
- Review opportunities for equity finance and venture capital investment

8.6 Linking low carbon and climate resilient growth

In terms of the linkage between low carbon investments and climate resilient growth, the study finds a mix of potential synergies and conflicts. A number of areas are highlighted.

The impact of climate change will affect the energy system of Tanzania, and is important in considering the potential development of current and also low carbon growth pathways.

The climate model projections for Tanzania indicate future increases in average minimum temperature of 1 ºC to 3ºC above the baseline by the 2050s (years 2046 -2065) with greater warming in the north and northeast. Temperatures will rise further in future years without a global deal on emissions.

These increases in temperature will increase demand for cooling, which will in turn increase energy demand through air conditioning, unless alternatives are sought. These changes could be very significant in terms of the electricity sector, because it is likely to increase peak demand requirements on the system. These future changes need to be built into future electricity planning and demand forecasts. The available climate data indicates a 25 to 100% increase in likely cooling demand from climate change by the 2050s. This also needs to be considered in the context of rising future cooling demand from socio-economic change. There is also a need to look at low carbon development in the context of building design to provide alternatives to air conditioning.

The changes in precipitation are more uncertain: while all climate models show changes to rainfall, these vary with season and region. Many climate models project increases in rainfall in the north, while there is more disagreement on whether increases or a decreases will occur in the south of the country. The combined effects of changes in future temperature and precipitation will affect the electricity supply industry, particularly given the high proportion of hydro power, and should be considered in future scheme development. However, these changes in rainfall and in climate variability (particularly droughts) will also impact on fossil generation due to cooling water demands, thus a move to fossil generation may not necessarily reduce the impacts of current and future climate variability.

There are also potential changes in the frequency and duration of extreme events (floods and droughts). The future climate projections vary widely on the changes likely in future years, though these have implications for hydro and fossil supply, as well as risks to energy infrastructure. Some models indicate an intensification of heavy rainfall, particularly in some regions and thus greater flood risks. Droughts are likely to continue, and some (but not all) models project an intensification of these events, particularly in some regions.

Future climate change could have important impacts on agro-ecological zones, affecting forests. This is a key point in relation to REDD+. The limited studies that are available indicate potentially large threats to current zones, which could affect the viability of current afforested areas and thus the viability and revenues from such schemes. This issue is highlighted as a priority for consideration in the context of REDD development. The most immediate response needed is research into the potential for ecosystem zone shifts, and to increase monitoring programs to study response of forest and tree species to climate change. The additional stress of climate change is also likely to mean a greater focus on reducing and managing existing stresses, such as stopping fragmentation, pollution, population encroachment, habitat conversion, etc. Finally, additional measures are likely to be needed, which include forest buffer zones and increasing ecological zone connectivity. Given the irreversibility of land-use change, these are an early priority.

Regional Policy and Tanzania

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

This study has not assessed the potential effects of international climate change policy on Tanzania, 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 2025. This includes the international tourist sector. It also includes potential higher value added agricultural and horticulture products. However, 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 Tanzania, for example, in relation to the additional costs of carbon. This could affect demand or comparative advantage. Given their importance to the economy, export earnings, balance of trade, etc. it is considered a priority for Tanzania to consider the implications of international climate policy on it's domestic growth plans.

A future Vision for a Low Carbon-Climate Resilient Tanzania?

A final issue is the consideration of a more radical policy shift for Tanzania. Because of the level of current development and the importance of near-term decisions in determining the long-term economic and social structure of the country, it might be possible to truly promote a more visionary approach to low carbon development and climate resilient growth within the context of environmental sustainability and economic growth in Tanzania. This would position the country internationally along a very progressive vision.

8.7 Conclusions and Recommendations

Tanzania is a growing economy, aiming for strong development and growth over the next 10-20 years, as it seeks to raise standards of living and address levels of poverty. However, there are significant risks associated with the current growth pathway due to the unsustainable use of natural resources and the increasing reliance and inefficient use of fossil fuels. A more sustainable pathway could be adopted, to ensure that Tanzania can become a middle income country whilst protecting its natural assets and environment.

Much of this sustainable pathway aligns with low carbon development. This provides the opportunity for Tanzania to access carbon financing to help invest in sustainable technologies, and address current economic, social and environmental problems. It offers a way to raise much needed finance while at the same time supporting domestic priorities and moving towards a more sustainable and low carbon pathway.

Reducing the reliance on wood fuel energy and protecting forests will promote sustainable resource use, protecting biodiversity, as well as economic sectors relying on these resources. It also reduces household exposure to pollution and promotes a move towards more modern energy forms. Developing a sustainable transport system can help reduce reliance on oil imports, protect urban environmental quality, enhance urban infrastructure and potential help develop a sustainable biofuel sector. Promoting renewable electricity generation, both grid and household-based further strengthen energy independence.

Tanzania is and has already implemented many lower carbon opportunities. However, a more strategic approach by Government could ensure that all public policy is considered in the context of low carbon, climate resilient growth. This is particularly important given the linkages between potential low carbon measures, as illustrated below.

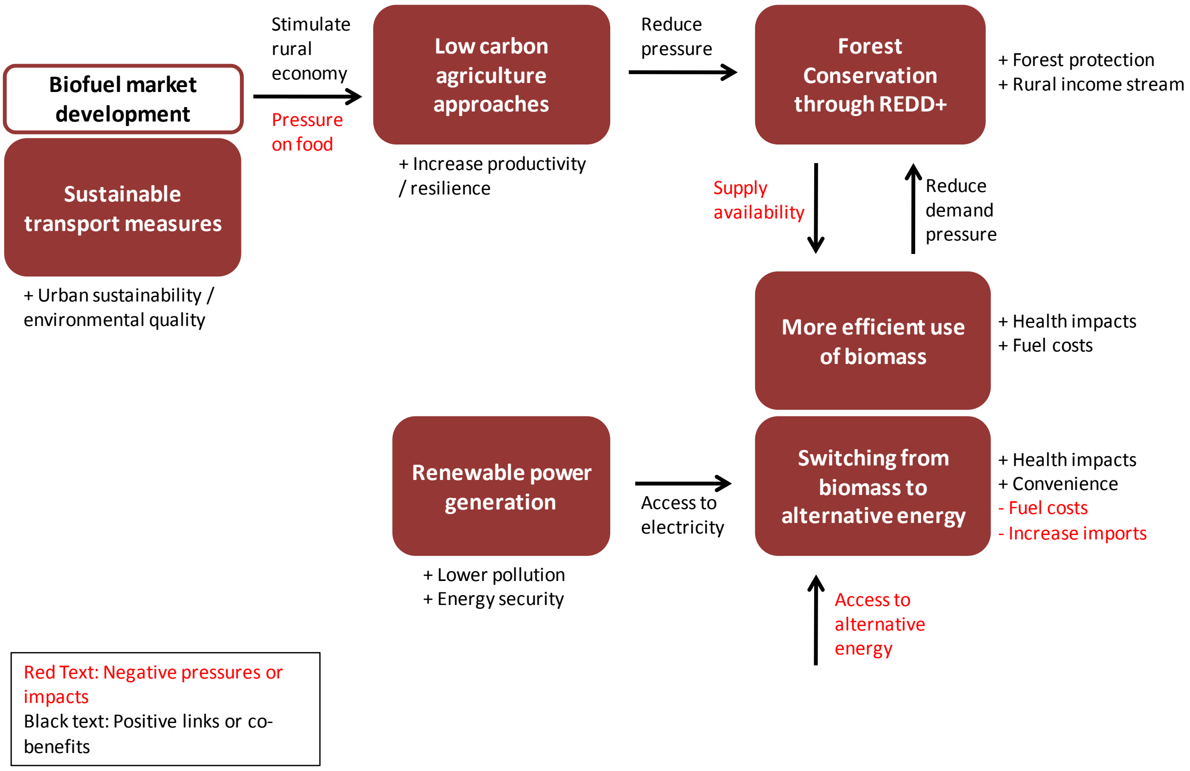

Figure 35. Linkages between different low carbon options

The extent to which Tanzania can develop these low carbon opportunities is dependent on a number of things.

- First, the confidence that carbon finance mechanisms will be there in the long term and can be accessed.
- Second, as discussed above, the policy co-benefits needed to strengthen the domestic policy agenda.
- Third, that low carbon opportunities are progressive, bringing benefits to lower income groups
- Finally, with regard for synergies with the adaptation agenda, to ensure not only low carbon but climate resilient growth.

A priority area for further assessment should also be the potential for regional cooperation in this area, as well as international aspects.

Overall, the study concludes that because of its location, availability of resources and socio-economic conditions, there are significant benefits for Tanzania in promoting low carbon projects to ensure a more sustainable growth pathway. Such a pathway appears strongly in the country's self interest, providing potential extra investment from carbon financing and numerous policy co-benefits. However, further assessment of the relative economic, social and environmental benefits and costs would be needed to further quantify the extent to which Tanzania should or could move in this direction. Focus needs to be given to assessing the macro-economic impacts of such investments, including the distributional impacts, to better identify the opportunities. Further assessment of the social and environmental benefits could also be developed e.g. quantifying health and environmental benefits.

A number of recommendations and future priorities can be proposed.

- **A key recommendation is the need for Tanzania to get ready and act now.** Key elements are to improve estimates, advance institutional and policy development, undertake investment analysis, revisit Vision 2025, to advance a more sustainable (and low carbon) path (in parallel to climate resilient growth) and to enhance regional co-operation.

- Specific recommendations include:

    - Improving the estimates. Further work is needed to improve these initial estimates and to give a degree of confidence in the analysis. 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, as well as on the links with climate change impacts. Further work should also be undertaken on the potential macroeconomic impacts, and more detailed assessment of the costs to different sectors / 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 Tanzania 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 more sustainable and lower carbon pathway. There are many benefits if Tanzania switches to a more sustainable and 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, i) low carbon plans should cut across all sectors and mainstreamed into sector plans, ii) areas of development increasing future threats to climate obligations in future years should be identified, iii) linkages between adaptation and low carbon development (especially in finance) should be further 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 Tanzania that addresses these areas, for example, with further development of the Vision 2025 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.
    - Early examples will help build confidence (domestically to demonstrate benefits - and externally for investment). There would be a benefit in an early implementation study, to fast track and demonstrate the benefits and financing possible from such a strategy. One way to progress this might be through a sub-national level: an example of a suitable pilot area might be to undertake a low carbon – climate resilience study for Zanzibar.

The steps above would provide national action on a low-carbon, climate resilience investment plan and would help Tanzania in negotiations and in securing finance.

A summary of key next steps is presented in the table below.

Low Carbon	Recommended Actions
Low-Carbon Growth (LCG)	• Full analysis of baseline projections, low carbon options, resilience to climate change, costs and prioritisation and development of strategy for mechanisms. • Develop national strategies to mainstream low carbon investment in planning. Build into long-term vision (e.g. Vision 2025), including potential effects from international action. • Facilitate carbon finance opportunities in voluntary and compliance carbon markets (VCM, CDM) and in REDD • Prioritize forestry, 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. • Conduct an early study, to fast track and demonstrate the benefits and financing possible from such a strategy at a sub-national level: an example of a suitable pilot area might be to undertake a study for Zanzibar.
Climate resilience and co-benefits	• Climate risk screening of low carbon growth pathways • Consideration of energy demand (cooling) and supply (hydro, fossil stations) effects from climate change, with associated adaptation (diversity, demand management). • Analysis of potential impacts of climate change on forestry (REDD), research into ecosystem shift, and introduction of monitoring and move towards early adaptation. • 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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Project Description and Project Team

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