The Economics of Climate Change in Zanzibar

4. Vulnerability, Impacts and Adaptation

Technical Report.
May 2012

Global Climate Adaptation Partnership

for UKaid from the Department for International Development

Summary

The study has undertaken a review and initial climate change assessment of vulnerability, impacts and adaptation on Zanzibar. These findings were discussed with stakeholders at workshops on Unguja and Pemba.

The findings are summarised below, presented by sector. A full report on impacts and adaptation work is included in a technical report, available on the project web-site at http://www.economics-of-cc-in-zanzibar.org/.

Coastal Zones

The coastal zones of Zanzibar contain high populations and significant economic activity. These areas are at risk from future sea-level rise and storm surge, as well as from coastal erosion.

- The coastal areas of Zanzibar are already vulnerable to coastal erosion and there are reports of enhanced flooding on the islands, as well as salt water intrusion in water supplies. While changing weather patterns on the islands may have a role, these effects need to be seen against a background of socio-economic development, population growth, land pressures, resource use, and natural processes, i.e. they are not due only (or indeed mostly) to climate change. Nonetheless, addressing these existing impacts is an early priority, to reduce existing impacts and help build resilience for the future.

- As an island, Zanzibar will be vulnerable to future sea level rise from climate change. The potential impacts of sea-level rise include flooding and loss of low-lying areas, shoreline (coastal) erosion, saltwater intrusion and increased salinity in aquifers and water supplies. The inundation and erosion (flooding and eventually loss of land) may affect human settlements, agricultural land, infrastructure, transport, and water resources within the coastal zone, as well as tourism and provisioning services (fishing, aquaculture and agriculture).

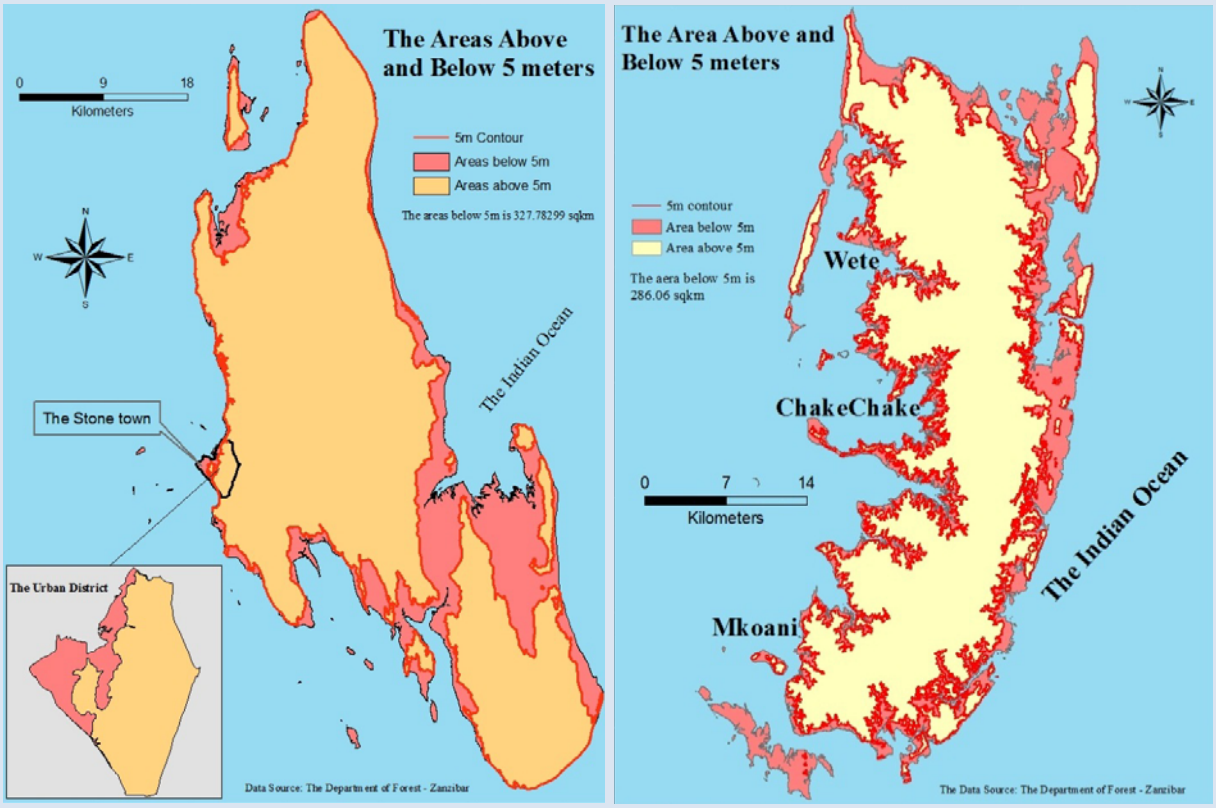
- The study has progressed a rapid analysis of the vulnerability of the islands to sea level rise. Contour mapping show the areas at potential risk on both islands (shown in the figures below). This reveals significant low lying areas, on both islands, though it is stressed that these are the areas at risk of flooding (not of disappearing under water). The results show a high proportion of the land – and an even higher proportion of the population – is located in these low lying coastal zones. Based on these results, further work on more dis-aggregated contour mapping and hazard analysis is recommended – as this would allow more accurate identification of the potential areas at risk.

- It is highlighted that this information also needs to feed through to spatial planning/land-use policy and infrastructure siting decisions, to avoid building and development in areas of current or future high risks. There is also a need for enhanced capacity building including awareness raising, institutional strengthening, and monitoring and assessments to provide the evidence base for future decisions, including coastal and marine data (e.g. sea surface temperatures, wind speeds, shoreline erosion)

- The study has also reviewed potential adaptation options and costs, drawing on the previous Zanzibar Adaptation Programme of Action (ZAPA) and other literature. While hard coastal protection may have a role for some key areas (Stone Town), the most promising and cost-beneficial options are likely to be ecosystem-based adaptation, because of multiple benefits that these options offer (so called 'no regret' options). These include shoreline vegetation and forest planting, mangrove restoration and replanting (i.e. coastal forest buffer zones) and seagrass replanting. There is also a need for strengthening of the on-going plans for integrated coastal zone management.

The Coastal Areas most at Risk

The figures below show the 5 m contour line for Zanzibar. These are the areas below 5 metres that are hydrologically connected to the sea.



5 metre contour line for Unguja and Pemba

These represent land area most at risk from major storm surges and high tides (which are likely to increase with sea level rise) – but it is stressed that the area that will be inundated will be much lower (as sea level rise is only likely to rise by 0.3 to 1 metre over the next century).

The mapping of the country shows large low-lying areas. For Unguja, around 328 km^2 is below the 5 metre contour line and for Pemba, around 286 km^2 is below the 5 metre contour line. This equates to 19.7% of Unguja and 28.9% of Pemba.

Similarly, the population in these zones has been estimated. For Unguja, around 224 000 people live below the 5 metre contour line (29%) and for Pemba, the number is higher at around 281 000 (54%). This highlights that a high proportion of people and assets (homes) are likely to be concentrated in many of these at-risk areas.

These maps can identify areas at risks, and help prioritise potential adaptation, though further work to improve the resolution of mapping is recommended. They can also provide important information on vulnerable areas, which are important for spatial planning and development, allowing the most at risk areas to be avoided, and thus reducing future risks.

Coastal and Marine Ecosystems and Ecosystem Services

Coastal and marine ecosystems are the backbone of the Zanzibar economy, and support a very large number of livelihoods on the islands. They provide large economic benefits, known as 'ecosystem services', by providing food, shoreline protection, and tourism revenues.

- The economic value provided by fisheries, seaweed farming, and tourism make up over 30% of Zanzibar's GDP. These coastal ecosystem services are critical to the economy of Zanzibar, but are at potentially at high risk from climate change.

- All of these coastal ecosystems are already under pressure from other drivers already, and these pressures are likely to increase on the islands with rising population and development. Again addressing these existing risks is a key priority for early action.

- Climate change has potentially negative effects on all of these ecosystems, and the services they provide. The degradation and potential loss of ecosystems will cascade through to many other sectors, affecting coastal infrastructure and increasing erosion, but also affecting key economic sectors such as tourism, and island livelihoods more generally.

- The study has reviewed potential adaptation options. As highlighted above, ecosystem based approaches would have multiple benefits in replenishing these ecosystems (and enhancing their economic value) as well as providing wider benefits. The ZAPA identified these options as a priority, recommending management practices that will ensure the successful attainment of conservation and management goals, promoting management practices that confer resilience to the ecosystem, and protecting and enhancing habitat protection

More detailed information is provided by category below.

Fisheries

Fish constitutes the most important source of protein in Zanzibar, and fisheries are an important economic sector on the island as well as sustaining many livelihoods.

- The impacts of climate change on fisheries potentially include shifts in species, food chain effects, diseases, and increased ocean acidity. There is some evidence that warming temperatures are negatively affecting some fisheries. However, this is an emerging area and a key priority is to get better monitoring and to enhance research.

- The study has reviewed potential adaptation options. An obvious early institutional adaptation is to bring climate change within existing sectoral policy. The current update to the Zanzibar fisheries policy provides an opportunity to take climate change into account. There is also a need for greater monitoring, linked to the physical changes in the sea around Zanzibar (see earlier section) and a greater focus on marine species monitoring, to be able to track changes (noting the complex issue of attributing changes). Finally, there are also a large number of cross sectoral linkages to other areas, notably enhancing the resilience of coral reefs and mangroves, because of their importance in fish stocks, because of their important role as breeding grounds and nurseries for young fish.

Coral reefs

Coral reefs line the coast of Zanzibar and provide important resources for the local economies and communities. These reefs have important roles in coastal protection, fisheries, as well as being important tourist sites, i.e. they provide important ecosystem services and have significant economic value.

- Corals are vulnerable to sea temperature, most obviously seen through coral bleaching. There was mass bleaching of many of Zanzibar's coral reefs during the 1998 El Nino event, which was reported to have led to a large economic loss to the tourism industry. However, the reefs are also being degraded from a combination of other factors, including fishing, tourism and eutrophication. The MKUSZA II recognises that if coastal erosion and coral reef damages remain unchecked, it will affect all of these sectors. We also stress that it will also affect Zanzibar's economy.

- Coral reefs are particularly vulnerable to future climate change, and the risk of coral bleaching due to increased sea surface temperatures (leading to reduced growth rates and eventually mortality). Even modest sea surface temperature increases of 1 or 2ºC above average over a sustained period of time can cause mass bleaching, and there are a range of other potential impacts from seawater chemistry (acidification) and from rising sea levels. Further pressures also arise from decreasing coral calcification rates from ocean acidification, and from sea level rise. Existing monitoring data shows significant increases in local sea temperature over recent decades – and these are likely to increase with climate change. The threat to the corals of the islands is therefore considered high, with potential impacts on fisheries, tourism value, and leading to enhanced shoreline erosion, and is considered a priority area.

- The Zanzibar Adaptation Programme of Action for Zanzibar recognised the importance of corals and proposed a number of options. There are also a wider set of tools and strategies for enhancing coral reef resilience including monitoring, transplantation, marine protected areas, integrated coastal management and fisheries management. There is an adaptation fund project on the mainland that is supporting reef rehabilitation through in situ techniques for coral breeding and transplantation, along with better management and enforcement systems, which provides a useful example for the islands.

Seaweed and seagrasses

Seaweed farming is an important activity for Zanzibar, supporting livelihoods. It is also a source of major foreign currency, and helps to reduce the degradation of the marine environment. There have been reports of sea-weed die-off along the coast of Tanzania, including Zanzibar, and sea surface temperature is the most likely cause. This has led to a need to move sea weed farming to deeper water.

The islands are also home to seagrass meadows, which provide various ecosystem services (fish, filtering sediment, stabilisation of sea floor, and reduction of erosion). Sea grasses appear to be declining around many coasts, including Zanzibar, though this is largely attributed to human impacts.

- Climate change is likely to have a number of effects on sea-grasses from a large number of factors including changes in salinity and temperature, ocean acidification, storm activity and ultraviolet irradiance. However, there could also be some beneficial effects as increases in the amount of dissolved CO_2 could lead to higher rates of photosynthesis.

- A mangrove and seagrass monitoring project has been set up for Tanzania (including Zanzibar), which is a key first step towards adaptation. Moving forward, there are effective management practices that could avoid some of the potential impacts, i.e. to enhance resilience to climate change, as well as restoration projects, and these measures also offer broader benefits in terms of resilience to a wide range of sectors (including fisheries).

Mangroves

Mangroves provide coastal protection against storms and coastal erosion and they are important breeding grounds for fish and crustaceans. They also provide wood sources, act as natural filters, and they may also help in preventing saltwater intrusion. They provide an extremely valuable ecosystem function and service, which has a very high value (estimated at hundreds of thousands of $/hectare)

- These ecosystems are already under pressure from other factors (land-use change and other) on the islands, and there have been significant losses of mangroves recorded (which has led to other impacts, such as enhanced erosion, increased inundation, etc.).

- Mangroves are potentially vulnerable to the impacts of climate change, from a combination of sea-level rise, salinity (and salt water intrusion) and storms, as well sea surface temperature. However, impacts are determined by other factors notably whether these systems have sufficient sediment supplies and whether they have the room to move inland with rising sea levels.

- There are general resilience options for mangrove conservation, such as risk strategies, identification of critical areas, managing human stress, establishing buffer zone (for migration), restoration, connectivity, monitoring, adaptive strategies, alternative livelihoods and partnerships. As highlighted above, there is real potential for Zanzibar to use mangrove restoration as an ecosystem based adaptation, and this is considered a priority area for early adaptation.

Agriculture

The agriculture sector is another mainstay of Zanzibar's economy, as well as having a key role in sustaining livelihoods on the islands. It is also a very climate-sensitive sector.

- Recent climate variability, notably the poor and erratic rains in 2006/7, significantly reduced agricultural production and also led to widespread malnutrition. There are reports that greater unreliability of the rains is affecting farmers.

- Future climate change has the potential to exacerbate current production risks in agriculture, either from changes in temperature and rainfall trends, from greater extremes of climate variability, or from other effects. However, there are potentially positive as well as negative effects, and the changes vary strongly with individual crops and locations.

- While negative impacts on highly temperature sensitive crops such as maize are projected in the longer-term, there is only relatively low production of this crop on the island. However, changes in temperature and rainfall do have the potential to affect other major crops, especially those that are rain-fed. Rice is affected by temperature and precipitation, and national studies indicate a potential reduction in yields is possible. Banana yields could also be potentially affected by climate change (and also by changes in disease) and some regional studies indicate small decreases in yield. Cassava is considered a more resilient crop – and is seen as a promising adaptation strategy to cope with potentially hotter and drier projections in itself.

- As well as direct production, there may also be changes to pests and diseases. In the longer-term, there is the potential for major agro-ecological shifts, which is potentially an issue due to the small geographical area of the islands – though future zones are likely to remain within tolerance levels for production. A potentially greater impact – even in the short-term – is from the intensification of rainfall in rainy seasons, and higher levels of variability. There are also are risks from salt water intrusion for some coastal (rice) fields. High value exports, notably cloves, are vulnerable to increased storm and high winds, and this could be a future issue given the observed data on strengthening wind regimes. Finally, there are potential risks to the livestock sector, particularly through the potential from heat extremes, and from changes in the burden of pests and diseases.

- Agriculture is clearly a key priority for adaptation, especially in relation to existing climate variability. The study has reviewed potential adaptation options and costs, drawing on the previous ZAPA and other literature. There are a very large number of potential options identified, and a key issue will be to prioritise which of these should be taken forward. There is also a need for enhanced capacity

building including awareness raising, institutional strengthening (particularly for extension services), and strengthening the capacity of agricultural research institutes on the islands.

- There are obvious early (no regret) benefits from better information, with short-term and seasonal forecasting, and early warning systems (e.g. for heavy rain and flood risks, and droughts), and these are seen as an early priority. This links to the earlier discussion of better information on agro-meteorological services (capacity, equipment and data/monitoring) and enhanced disaster risk management including the communication and dissemination to key stakeholder (farmers).

- Recent studies have identified promising options that are robust to the possible future changes (in climate extremes and from climate change), particularly those that have wider cross sectoral benefits (e.g. soil and water conservation), those that might provide greater resilience as well as potential opportunities or synergies with low carbon (e.g. conservation agriculture, agroforestry), and those that offer no regret opportunities (e.g. reducing post-harvest losses). Furthermore the use of rain water harvesting and storage as a low cost approach for water management, particularly for small holder farmers, is a potentially important option. Many of the most promising options fall within a general definition of sustainable agricultural land management (SALM) practices, and these are considered a priority to build resilience, increase production and generate wider benefits for the islands.

Tourism

Tourism is already a major economic sector on the island, and underpins future growth objectives. It is also a highly climate sensitive sector. Climate change is therefore potential important for sector.

- Tourism on Zanzibar is a combination of beach, activity (water based), historic and destination tourism. The current (tropical) climate of the islands and beaches are undoubtedly one of main attractions of the islands, as are the coral reefs (see above). There does not appear to have been detrimental effects from recent extreme on tourism arrivals on the islands, but the loss of the electricity connector in 2009/10 did significantly impact the sector, and this highlights the potential vulnerability to shocks/extremes. Tourism is also a driver (and a pressure) on many of the other sectors highlighted elsewhere, e.g. in relation to water and energy use, natural resources, etc.

- The impacts of climate change on tourism on the islands are complex, because of the diverse nature of tourism on the islands, and because effects will occur in both direct and indirect ways. The tourism attractiveness of Zanzibar will change in many ways, and these effects also have to be seen in an international context, because of the comparative changes relative to elsewhere (i.e. to competing destinations). Effects are also strongly linked to the mainland as part of combined destination trips.

- Tourism is closely associated with climate, particularly beach tourism, and climate change can affect the destination preferences of tourist by changing temperatures (and rainfall). There is already a strong seasonality to the current tourism numbers, with peaks in the dry seasons and significantly lower numbers in the rainy seasons, and climate change has the potential to affect the attractiveness of the islands. The changes in average climate expected for Zanzibar are unlikely to lead to major effects in the short-term, but changes in extremes and variability are considered to be of more concern.

- There is a significant threat from the degradation and loss of marine ecosystems (corals) for diving/snorkelling related tourism. There are also threats to tourism hotels and infrastructure from coastal erosion and sea level rise, and in the longer-term, to key tourist areas such as Stone Town. It is stressed that tackling the threats of climate change in other sectors will reduce many of the potential impacts on tourism (or to put it another way, failure to tackle the issues in other sectors will have detrimental effects on tourism).

- Climate change will also affect the energy and water use of the tourism sector, increasing demand for both. Rising temperatures will increase air conditioning use (and costs) and will increase overall electricity demand on the island, especially with tourism growth rates and projected increases in high class tourism. Similarly, rising temperatures will affect water demand, which is already extremely high in the tourist sector (measured as litres per tourist per day), particularly from high class hotels. These effects will be compounded as the monthly flow of tourists is directly opposite the monthly rainfall received, i.e. tourist arrivals are highest when rainfall is lowest. While this is not surprising, it highlights an issue with supply and demand (and recharge levels) that could be exacerbated by climate change and by tourism projections, particularly with the lower rainfall in dry months projected from climate change. It is also highlighted that water demand from the tourism industry is likely to increase due to higher temperatures from climate change, exacerbating these pressures.

- The study has reviewed potential adaptation options for tourism, drawing on the previous ZAPA and other literature. Many of the threats to the tourism sector come indirectly, and thus the adaptation responses in other sectors will have benefits for the tourist sector. Because of this, adaptation for tourism needs to be considered from a cross-sectoral perspective.

- Given the importance of the tourism sector to future growth objectives for Zanzibar, there is a need to make sure sectoral policy builds in climate considerations. A key early step is therefore to include climate change in sector development plans, to raise awareness of the issue, to build capacity, and to undertake research to look at the potential effects.

- While there is the potential for protection (defences to protect shoreline tourism infrastructure) and beach nourishment (for beach erosion), as highlighted above, a preferred approach would be to encourage ecosystem based adaptation for protecting tourist assets. There are also early (no regret) priorities to address the impacts of rising cooling demand and water use, with energy efficiency, passive alternatives, and the efficient use of water. All of these areas represent early priorities for the sector, reducing costs and enhancing resilience. Many of the future potential threats to the sector could be addressed through development controls and standards (e.g. requiring buildings to be set back and raised, requiring energy and water efficiency as conditions in planning consents) and this is highlighted as a priority for early investigation, especially given the proposed numbers of hotel planned for the islands.

Health

While Zanzibar has had made significant progress in reducing cases of malaria, other climate sensitive diseases are still prevalent. There are also periodic outbreaks of water borne disease, associated with floods (from contamination) or from droughts (when people turn to alternative water supplies).

- Climate change has the potential to affect human health on Zanzibar in the future. This may happen directly, as with the effects of flood injury, wind storms or heat extremes 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).

- Given current malaria rates and control programmes, the most important impact from climate change is likely on diarrhoea, i.e. food and water borne disease, associated with higher temperatures but also extremes (floods and droughts). An indicative analysis estimates that the additional costs of climate related health impacts on Zanzibar could run to several $million/year by the 2030s.

- The study has reviewed potential adaptation options and costs, drawing on the previous ZAPA and other literature. 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. The importance of community awareness on existing issues is highlighted, and a number of no regret options are identified (notably safe water and sanitation), which are essential in reducing the future impacts of climate change, and re-enforce the earlier discussion of the need to address the current adaptation deficit.

Energy

The energy use of Zanzibar is described in more detail in the low carbon section. The discussion here relates to how climate change might affect energy supply and demand. This is a particularly important issue for Zanzibar as an island state, because of the risks of supply disruption.

- On the energy supply side, the main issue is reliance on mainland connection, which itself has a high reliance on hydropower, and has been affected heavily by drought events in recent years. While adaptation responses on the national grid mix fall to the mainland, there are options for Zanzibar in reducing transmission losses and other forms of energy efficiency, and the potential for local generation and diversification, discussed in the low carbon section. Furthermore, a high proportion of electricity on Zanzibar is used for water pumping, and again there are low carbon options and efficiency options that could be explored.

- As well as energy supply, climate change also affects energy demand, as outside temperature is a key factor in cooling (from air conditioning). Climate change will increase energy demand associated with cooling and this is important because of the high cooling demand in the tourism sector on the islands. The level of increase depends on the temperature (and humidity) but also income levels and penetration rates. As well as the extra cost of electricity, increased energy for cooling might also increase emissions from non-renewable plants or local diesel generators, and heat extremes may also cause additional issues of peak electricity demand.

- The lack of data makes a quantitative analysis of these effects difficult at the current time, and investigating these areas is an early priority. However, it is clear that the effects of climate change (and even other drivers associated with development) are not taken into account in the electricity plans for the island and this is an important omission.

- The study has also reviewed potential adaptation options and costs. There are a range of options available to address these impacts, from energy efficiency (more efficient AC units) through to passive ventilation, building design, etc. However, many of these require a greater planned response (including e.g. building regulations or codes for new hotels) and are most cost-effective at the construction stage. They are particularly important given the long life-time of buildings. A greater focus on awareness-raising of energy efficiency and passive alternatives is key, but the potential for the introduction of proposed efficiency standards, and even consideration for building codes (for new tourism or other building infrastructure) are highlighted.

Water

Water is a critical sector for Zanzibar. In addition to the multi-sector links to agriculture and energy (above), it is important for tourism; it supports livelihoods, and affects ecosystem services (provision of fuel wood, water purification, climate regulation, etc.). Ancillary stresses of pollution, salinisation, sedimentation and over-extraction of groundwater exacerbate current vulnerability, and future drivers such as population and economic growth are likely to put additional pressures on resources.

In terms of public water supply, groundwater is the primary source of water in Zanzibar. Zanzibar receives relatively high rainwater (see earlier climate section, though this does vary across the islands) and has large groundwater resources (especially on Unguja). There are cases of salt-water intrusion into a

number of water supplies on the island, but these are thought to be due to a combination of factors, rather than just climate change.

- The impacts of future climate change will have effects on future water resources, though other drivers (population, abstraction rates) are likely to be more important. Nonetheless, future climate trends has the potential to exacerbate growing issues of water demand and supply and additional issues are likely to arise from the increasing extremes (heavy rainfall) and potentially decreases in rainfall during the dry season.

- Zanzibar already has one adaptation project, funded as part of the URT NAPA (Shallow Water Wells Affected by Inundation). The study has reviewed potential adaptation options and costs, drawing on the previous ZAPA and other literature. This identifies a large number of measures, though many studies have highlighted the potential for small-scale rain water harvesting on the islands. However, a key priority appears to be the need for better monitoring of existing water abstraction and groundwater levels, and the need to move towards integrated water resources management, especially as pressures on available water supplies increase. Finally, an early no regret option is to address the current connections and leaks to improve the efficiency of the current system.

- For the risks of flooding, a number of adaptation options are available, a number of which were identified in the ZAPA. Early steps are to identify areas at risk, and for dense urban areas, an obvious response is to improve flood management. There is already a large Zanzibar Urban Services project which is constructing storm water drainage channels outside of Stone Town and this provides a useful example for wider application.

Forests and terrestrial ecosystems

Zanzibar has extensive forest vegetation, and the forests of the two islands form an important part of the East Africa Coastal Forests Eco-region. These forests have been under pressure and have been significantly reduced in area, but there is now a Zanzibar National Forest Plan, and Zanzibar (as part of the URT) is a pilot REDD+ country (Reduced Emissions from Deforestation and Degradation).

- 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. They are therefore at risk of climate change from a combination of temperature, precipitation and extremes, as well as other factors such as changing pests and disease.

- These forests support wider biodiversity, and changes to these areas and other terrestrial vegetation will also affect wider biodiversity. Some species are capable of adapting to climatic shifts will survive, but for an island state such as Zanzibar, the potential for species movement is very limited, and this is highlighted as a critical issue.

- The study has reviewed potential adaptation options and costs, drawing on the previous ZAPA and other literature. A number of options are highlighted, many of which overlap with the REDD+ actions. However, it is important that climate change is factored into these plans, to ensure that appropriate buffer zones and planning takes account of the future shifts in climate on the islands.

Cross cutting issues

The study has also considered some of the issues with climate change in relation to gender and inequality. A number of the effects outlined above are likely to have a strong gender bias (e.g. the impacts of sea surface temperature on seaweed farming). It is also clear that there will be a strong distributional aspect to the impacts, and climate change will not be felt equally across Zanzibar, in different locations, and across groups in society. The poor are particularly vulnerable to climate change on the islands,

because of their limited livelihood base, poor access to markets and services, and low adaptive capacity. Further work is needed to explore these effects in detail, and design adaptation strategies accordingly, and this is highlighted as a priority. It is also stressed that the previous ZAPA identified a priority for community based adaptation as a way of addressing some of these issues.

Moving to Adaptation Pathways (Prioritisation)

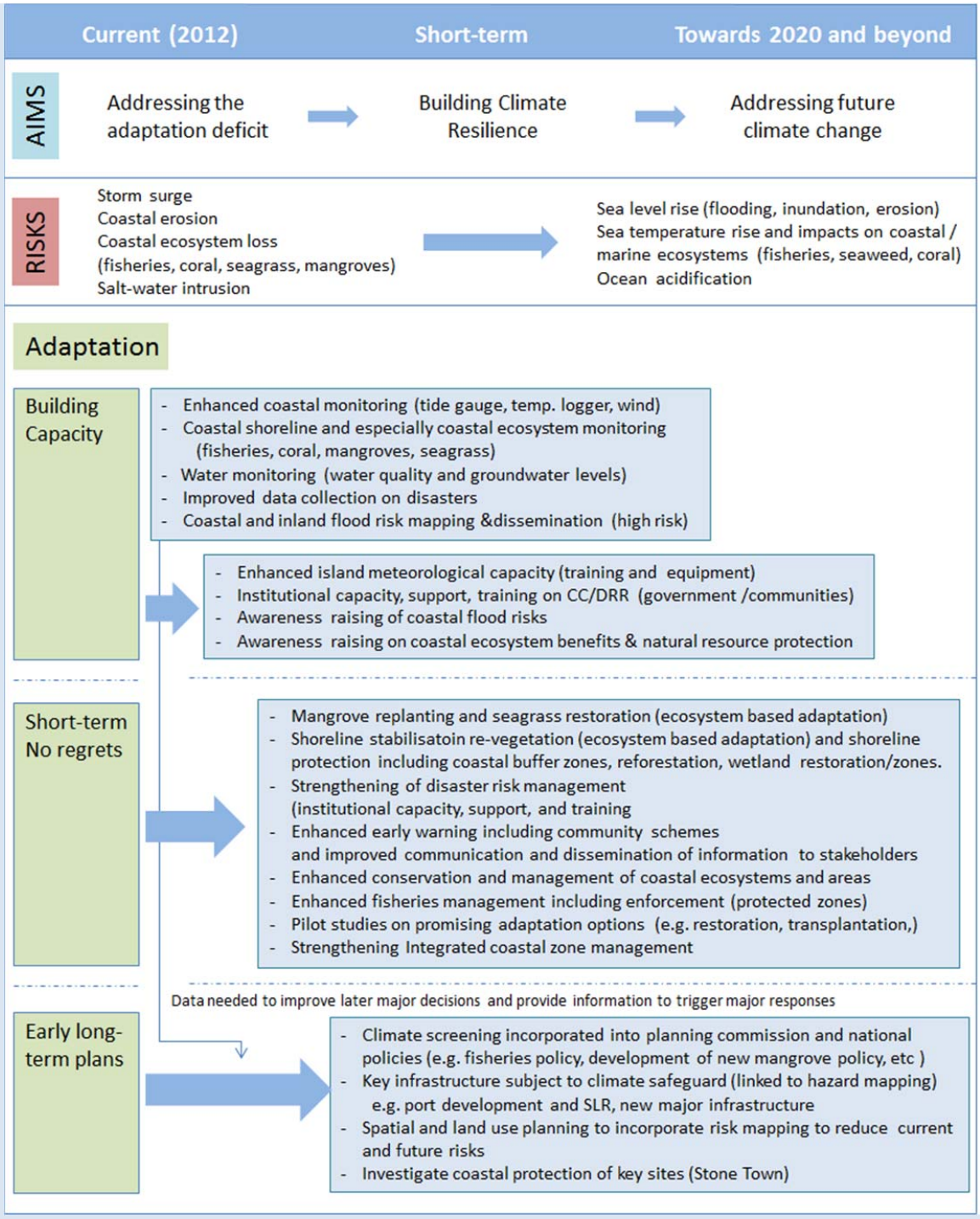
While the general climate trends are clear, there is uncertainty on the specific changes with climate change. More importantly, there are already existing risks from current climate variability, which need to be addressed first, and which offer the opportunity for immediate benefits as well as future resilience. Set against this background, and the very wide range of potential future impacts, it is often difficult to know what to do first. In response, the study has advanced a framework to prioritise early adaptation, which considers uncertainty, and helps to identify the most rationale and efficient early steps.

The proposed framework identifies early priorities for adaptation based on:

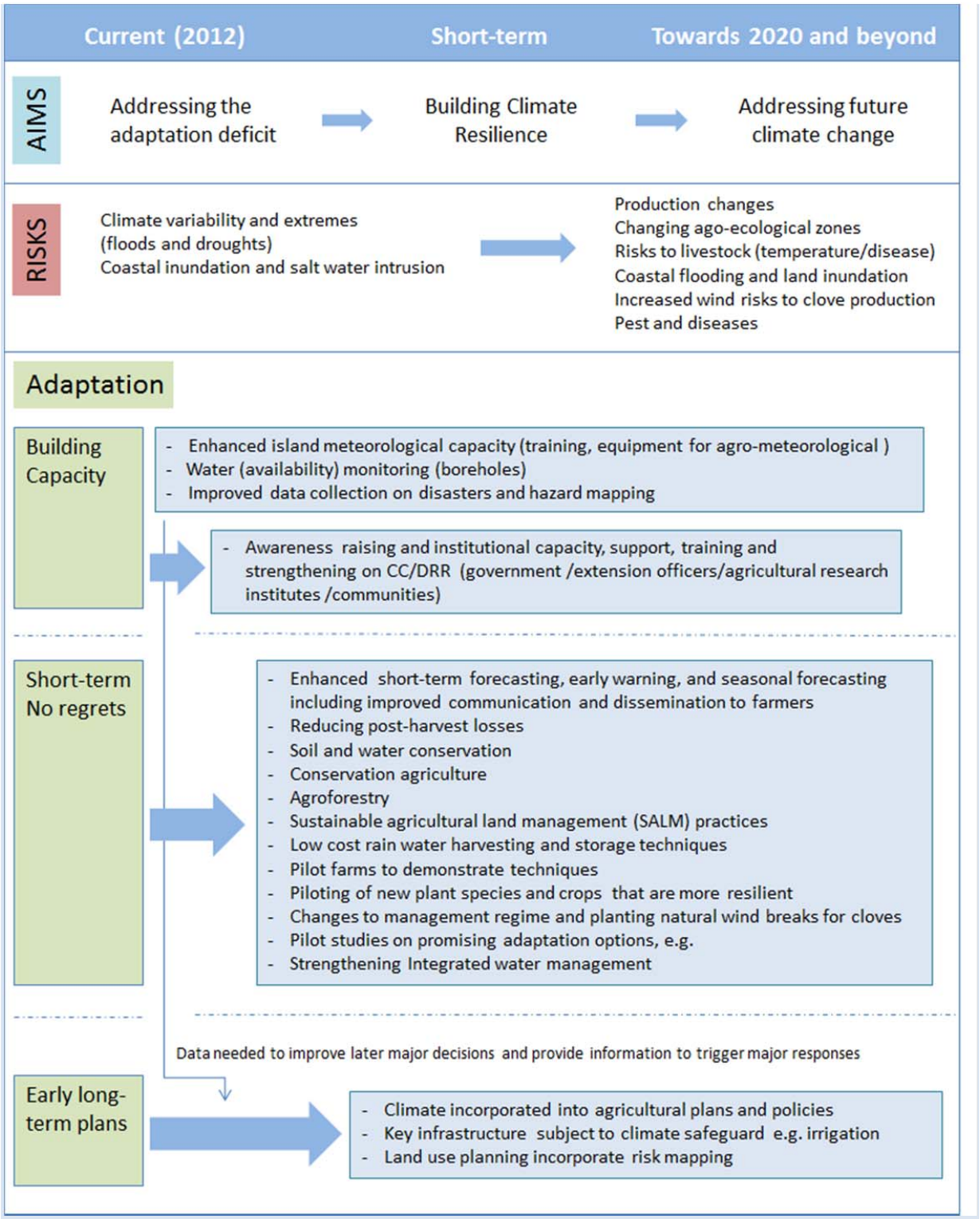
- Building adaptive capacity;
- Focusing on win-win, no regret or low cost measures (justified in the short-term by current climate conditions or wider benefits);
- Encouraging pilot actions to test promising responses;
- Identifying those long-term issues that require early pro-active investigation (though not necessarily firm action), particularly areas involving infrastructure (long life-times), decisions that take a long time, areas, decisions that are irreversible (such as land-use planning) or that areas that involve major risks in the future (such as major ecosystem loss).

The study has considered these adaptation responses as a series of complementary activities, together forming an ‘adaptation pathway’. These identify a range of actions, split into capacity building, short-term measures and planning for the future, with a focus on the key recommended actions in early years.

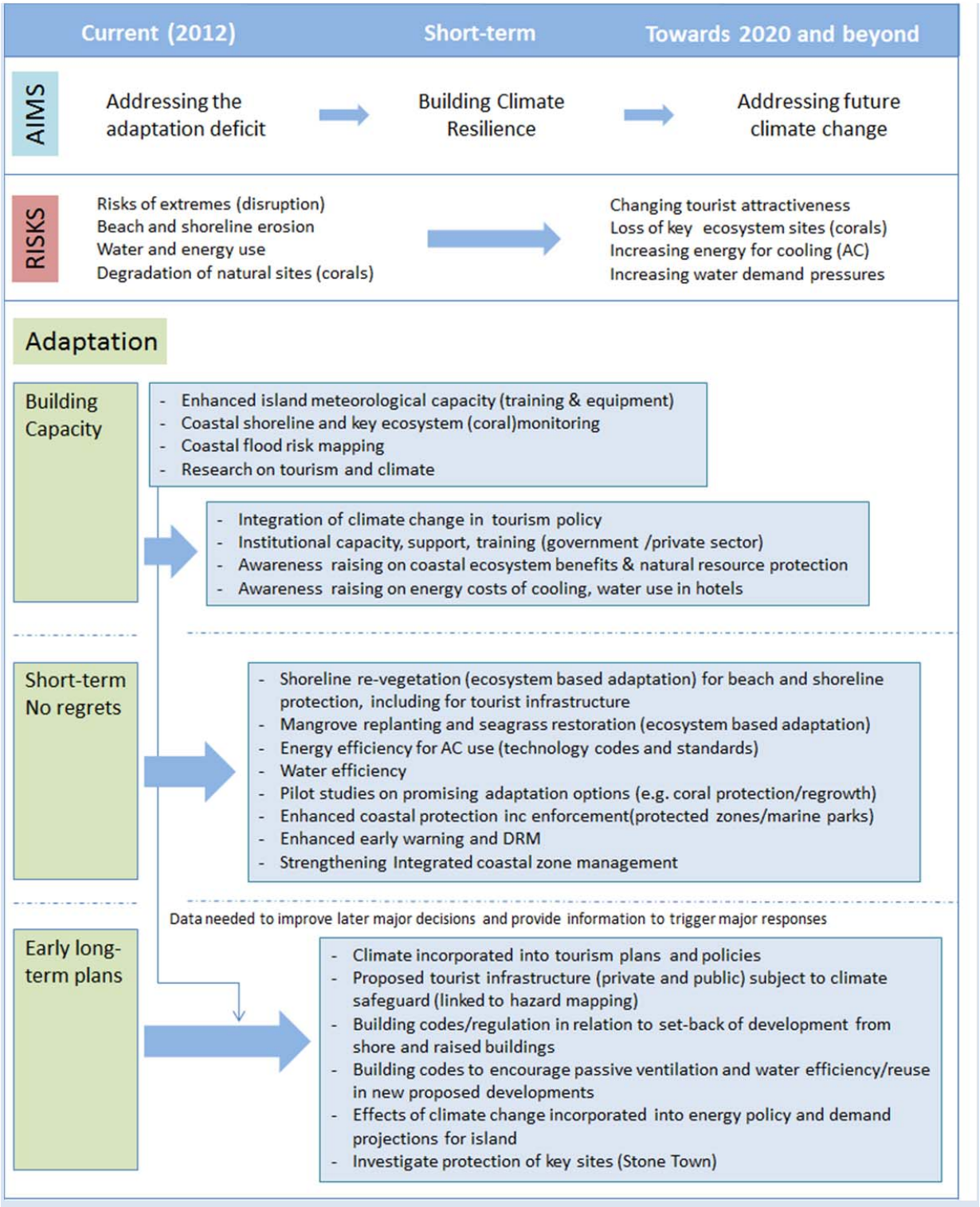
These are presented below.



Adaptation Pathway for Coastal Zones (Sea Level Rise, Coastal Ecosystems)



Adaptation Pathway for Tourism



Adaptation Pathway for Agriculture

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This report was prepared for the Study Advisory Committee in Zanzibar,

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Note: in this inception report, the use of the Zanzibar is a shorthand for the Zanzibar Archipelago and thus includes Unguja, Pemba and other islands.

Introduction and Method

As an island state, with a high dependency on agriculture, tourism and the coastal/marine environment, Zanzibar has potentially high vulnerability to current and future climate change. A key issue is therefore to assess the potential vulnerability and impacts of climate change in Zanzibar, and to look at the potential adaptation options. Consistent with the study objectives, a key theme has been to look at economic information in all of these areas (impacts and adaptation).

There are a number of previous studies that have undertaken similar approaches, notably in the region national level, such as for the United Republic of Tanzania (Watkiss et al, 2010). These tend to use a scenario based approach with detailed impact assessment analysis (see later discussion).

However, the detailed use of scenario based impact assessment – to assess the future impacts and economic costs of climate change (and the costs and benefits of adaptation) – is a very resource and time intensive activity. Within this study, there has not been the time or resources to do new detailed impact and economic analysis. Nevertheless, it has been possible to take existing information and extend this where possible, to provide a semi-quantitative analysis for Zanzibar. The following sectors therefore synthesis the information on impacts and adaptation, drawing in quantitative and economic estimates wherever possible.

Stakeholder Consultation on Impacts and Adaptation

Following the first draft version of this report, two workshops were held to discuss the information on climate variability, impacts of climate change and adaptation options, one in each of Unguja and Pemba, in April 2012. The information from these workshops provided some critical information on the relative importance of participants, and on the relative attractiveness of different options. The results of the workshop findings are drawn into the text below, and a separate workshop report is also available that provides a summary of the ranking and scoring exercise on the day.

Previous and On-going Studies

Because of the review based approach used here, the study has needed to build on existing studies and reports. A number of particularly relevant studies are highlighted below. Other sectoral projects are discussed in the text.

The Zanzibar Adaptation Programme of Action (ZAPA)

The United Republic of Tanzania (comprising Tanzania and Zanzibar) 1st National Communication and NAPA, summarised in Appendix 1, largely omitted the challenges for Zanzibar. As a result, Zanzibar stakeholders decided to develop a more specific Action Plan for Zanzibar (a so-called Zanzibar NAPA, referred to here as the ZAPA) to target specific climate change challenges in the small island state.

Under the SMOLE II project which supports the Department of Environment (DoE), among others, an international climate specialist was recruited and mobilised in September – October 2010 to train stakeholders and facilitate the process of creating a Zanzibar APA (first steps including preparing a 'road map'). The document was published in 2010 (Niras, 2010).

During the study, participants identified some of the core vulnerabilities in Zanzibar as water supply and salinisation of wells, food production, sea level rise, health, biodiversity and extreme weather. The document also suggests some early lists of possible adaptation options and set out a process for the Zanzibar APA going forward.

Impacts of Climate Change in Zanzibar (CARE/UNFCCC/Norway)

Primary data were collected from using structured and semi-structured questionnaires and focused group discussion. GIS data were collected to mark the sea level rise. Various published and unpublished documents were also used as secondary data. The study reported:

- Changes in weather patterns;
- Wetlands and ecosystem degradation, and deforestation (though from multiple causes);
- Trends of sea level rise and coastal erosion, and seawater intrusion into paddy fields (Pemba);
- Changes in water source rates (boreholes and spring), sea water intrusion;
- Increased flooding and health outbreaks;

Many of these are attributed to climate change, though as the previous data analysis section, and the sectoral assessment below has outlined, in practice there are many factors involved in these changes.

On adaptation, the report highlights that indigenous people have been practicing various adaptation measures to minimize the impacts of these trends. It reports that the dominant practices found are application of fertilizers, irrigation, exchanging agricultural practice, replantation and construction of wall front to the sea shore.

The document reports a number of recommendations.

- Institutional arrangements for climate change management in Zanzibar should be reinforced between Zanzibar, United Republic of Tanzania and international arena at large.
- Sea level rise and beach erosion are serious features around the Islands. The government and development partners should strategize to build sea walls at areas that are prone to erosion.
- Water resources management should be strengthened to sustain both quality and quantity perspective.
- Wetland management policy should be developed to serve sustainable usage.
- A species inventory should be conducted to keep scientific record on species diversity in Zanzibar.
- Adaptation knowledge needs to be communicated to communities.
- Early warning systems should be developed and installed to coastal areas.
- Coastal plantation and building seawalls should be emphasized to protect sea water intrusion in farmlands.
- Fish culture industry should be emphasized as an alternative livelihood to fishermen whose fishing grounds have been depleted.
- Climate change knowledge should be mainstreamed to the curriculum of schools for enhancing awareness from the grass root level.
- Wetland management policy should be prepared to control the improper use of wetlands.

Defining Vulnerability, Impacts and Adaptation

In collating information of relevance for this study, an issue has been the literature across the vulnerability, impacts and adaptation areas, and the definition of these key terms. While there are definitions available from the IPCC, it is stressed that there is an extremely wide definition of some terms, notably vulnerability. There are also existing studies that use different frameworks, either built around a more stakeholder led vulnerability assessment through to scenario-based impact assessments (see box).

Note that the focus on current vulnerability (and climate variability) has been captured in the earlier technical report 1 (current climate and extreme events), thus the focus of this chapter is on the effects of future climate change – though noting that many adaptation responses are directed at these short-term effects due to the potential for no-regret options.

Impacts, Vulnerability and Adaptation

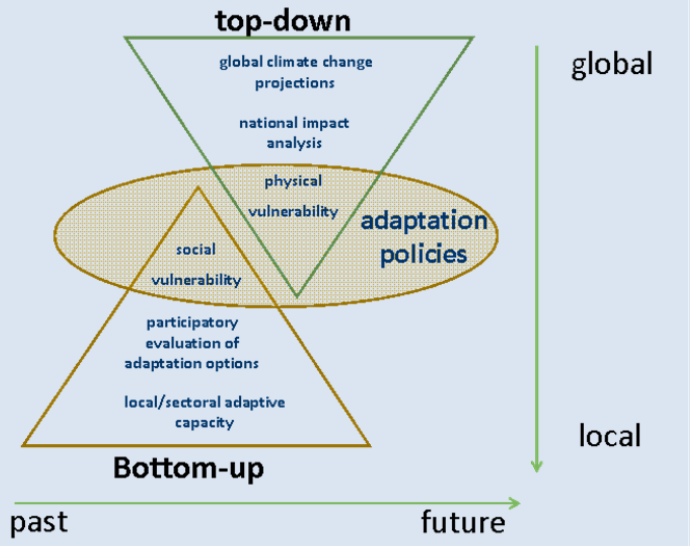
The IPPC Fourth Assessment Report, Working Group II, Chapter 2 (Carter, et al., 2007) advanced a widely used typology which split analytical methods into four categories: impact assessment, vulnerability assessment, adaptation assessment and integrated assessment, as shown below.

	Approach			
	Impact	**Vulnerability**	**Adaptation**	**Integrated**
Scientific objectives	Impacts and risks under future climate	Processes affecting vulnerability to climate change	Processes affecting adaptation and adaptive capacity	Interactions and feedbacks between multiple drivers and impacts
Practical aims	Actions to reduce risks	Actions to reduce vulnerability	Actions to improve adaptation	Global policy options and costs
Research methods	Standard approach to CCIAV Drivers-pressure-state-impact-response (DPSIR) methods Hazard-driven risk assessment	Vulnerability indicators and profiles Past and present climate risks Livelihood analysis Agent-based methods Narrative methods Risk perception including critical thresholds Development/sustainability policy performance Relationship of adaptive capacity to sustainable development		Integrated assessment modelling Cross-sectoral interactions Integration of climate with other drivers Stakeholder discussions Linking models across types and scales Combining assessment approaches/methods
Spatial domains	Top-down Global → Local	Bottom-up Local → Regional (macro-economic approaches are top-down)		Linking scales Commonly global/regional Often grid-based
Scenario types	Exploratory scenarios of climate and other factors (e.g., SRES) Normative scenarios (e.g., stabilisation)	Socio-economic conditions Scenarios or inverse methods	Baseline adaptation Adaptation analogues from history, other locations, other activities	Exploratory scenarios: exogenous and often endogenous (including feedbacks) Normative pathways
Motivation	Research-driven	Research-/stakeholder-driven	Stakeholder-/research-driven	Research-/stakeholder-driven

Source: Carter et al, 2007

Importantly, these approach the issue of climate change from a different perspective, often starting with current climate and socio-economic vulnerability (as with vulnerability assessment), or from projections of future climate change (impact assessment).

The former are often defined as bottom-up and the latter as top-down – as shown in the figure to the right (though note these should not be confused with economic definitions of bottom-up and top-down, which generally related to sectoral vs general equilibrium approaches).



Source Dessai and Hulme, 2004

The analysis is presented by sector, starting with the most important sectors for Zanzibar (coastal, agriculture and tourism) and then looking at additional sectors and cross-sectoral issues (including gender).

Coastal Zones

The risks of climate change to coastal areas are a key issue for Zanzibar, particularly from sea level rise, but also from other factors such as from sea surface temperature, salinity, wind speeds and direction, etc.

Sea-level rise from climate change, in combination with changes in the frequency / intensity of extreme weather events is expected to increase the flooding and inundation of coastal areas on Zanzibar.

The direct impacts of sea-level rise include (Nicholls et al., 2007).

- Inundation of low-lying areas,
- Shoreline (coastal) erosion,
- Coastal wetland loss,
- Saltwater intrusion and increased salinity in aquifers and water supplies,
- Higher water tables and higher extreme water levels leading to coastal flooding with increased damage

The inundation and erosion (flooding and eventually loss of land) affects human settlements, agricultural land, infrastructure, transport, and water resources within the coastal zone, as well as tourism and provisioning services (fishing, aquaculture and agriculture).

However, indirect impacts will also occur, which will include altered functions of coastal ecosystems and impacts on human activities. These broader impacts on the coastal and marine environment are particularly important, because they underpin the economy of the islands.

Ecosystems (and ecosystem services) provide many economic benefits as well as supporting livelihoods: coral reefs are an important resource (for tourism and fisheries) for the islands; mangroves provide physical protection against coastal erosion as well as providing resources for households and are important for the resupply of the coastal fisheries industry. The threats to coastal environments and ecosystems can occur for low-lying coastal areas, beaches, mangroves, coastal wetlands and estuaries.

However, it is stressed that the changes from climate change need to be seen alongside other drivers of change. Human-induced pressures on the coastal zone (e.g. rising population, water abstraction, etc.) are likely to exacerbate the effects of sea-level rise. Indeed, even without climate-induced sea-level rise, damages and costs are likely to increase due to the growing population, infrastructure at risk, etc. Many of the changes that are observed on the islands – and are attributed to climate change – are in fact the result of socio-economic drivers. Any observed changes have to be placed against a background of the decline in natural resources and biodiversity, evidenced by deteriorating conditions of coral reefs, and 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.

Looking forward, these same pressures will continue to be important, and have the potential to increases impacts and economic costs: in fact, future socio-economic drivers are likely to be at least as important, and probably more important, than from climate change, at least in the next few decades. An important aspect is therefore to consider the combined effects of climate and socio-economic change together, and to plan adaptation responses that address both.

The following sections consider some of the key vulnerabilities and impacts for coastal zones, and some of the possible adaptation options.

Coastal Flooding, Inundation and Erosion

Existing vulnerability

The existing islands of Zanzibar are vulnerable to the threat of sea level rise and inundation of low lying areas. **The Zanzibar Adaptation Programme of Action (ZAPA)** discussed some of the general threats of climate change on the islands coastal areas. Based on field trips, it highlighted that there was evidence of changes on the islands, but that there was not yet conclusive information about climate change induced adverse effects. The document reports that beach erosion is taking place at a high rate in some areas (affecting beaches and some houses), and highlights that climate (change) may have played role if sea levels have risen or if the winds had become stronger (changing sea currents along the beach). However, it highlights that the observed coastal erosion could also be due to damage on the fringing reefs which could allow more wave access. It also highlights that beaches naturally shift over time, and more recent events may be more an effect of people building too close to the shoreline.

The ZAPA and other studies also report that coastal plains with good soils for agriculture are now frequently flooded by sea water during spring tides (combined with strong wind), especially on Pemba. Further, that there is beach erosion on several localities in Unguja (e.g. Kiwengwa, Jambiani, Uroa, and Nungwi) with reports that the beach had receded more than 100 meters. Again, the study notes that care is needed in attributing such changes. They are likely to be due to a very complex combination of factors, notably removal of marine vegegation, reductions in protecting reefs, land-use changes, sand mining, the use of vertical seawalls, etc. as well as natural proceses. There has, however, been some observational changes in wind speeds which would have increased erosion from wave action (see earlier section on meterological observations).

Mustelin et al (2009) reports that the coastline of Zanzibar has been encroaching inland in some areas, and that coastal vegetation has reduced. This is strongest around hotel fronts. The study also reports that intertidal zones may have become shallower, affecting sea-grass and wave action (and highlight the strengthening of wave action and winds). The study also highlights the issue of sand removal (sand mining) for construction and beach nourishment elsewhere. The study tracked the historic changes along one stretch of coast, reporting an inward movement of beach and a loss of coastal vegetation. They also report that coastal erosion is seen as a threat by communities and the tourist industries: The study reports that coastal erosion is tackled by the communities by placing litter (household and plants) on the beach, as this is thought to stabilize beach slopes, whereas hotels have been investing in hard structures such as vertical seawalls, though this has accelerated erosion along other areas of the coastline.

There are also other reports of increasing erosion, particularly on the eastern coast of Zanzibar possibly from the strengthened north-eastern monsoon and increase of wave activity due to increasing wind regime. As a result, some hotels have implemented coastal protection. The study conducted by the Institute of Marine Sciences (IMS) under the RecoMap project revealed that the Jambiani coastal strip with its relatively wider lagoon and slightly deeper waters is generally more vulnerable to the observed wave erosion than the Paje coastal strip, located to the north of Jambiani, which is characterized by a narrower lagoon and relatively shallow waters. The study further revealed that, apart from the above natural factors, there is also a human dimension to the erosion problem (mainly due to the use of vertical seawalls) along the Jambiani-Paje coastal strip. IMS, through the TCMP-Pwani project are currently working with the local communities at Jambiani/Paje villages to formulate the climate change adaptation strategies. It is also noted that changes in erosion have to be seen against natural coastal processes.

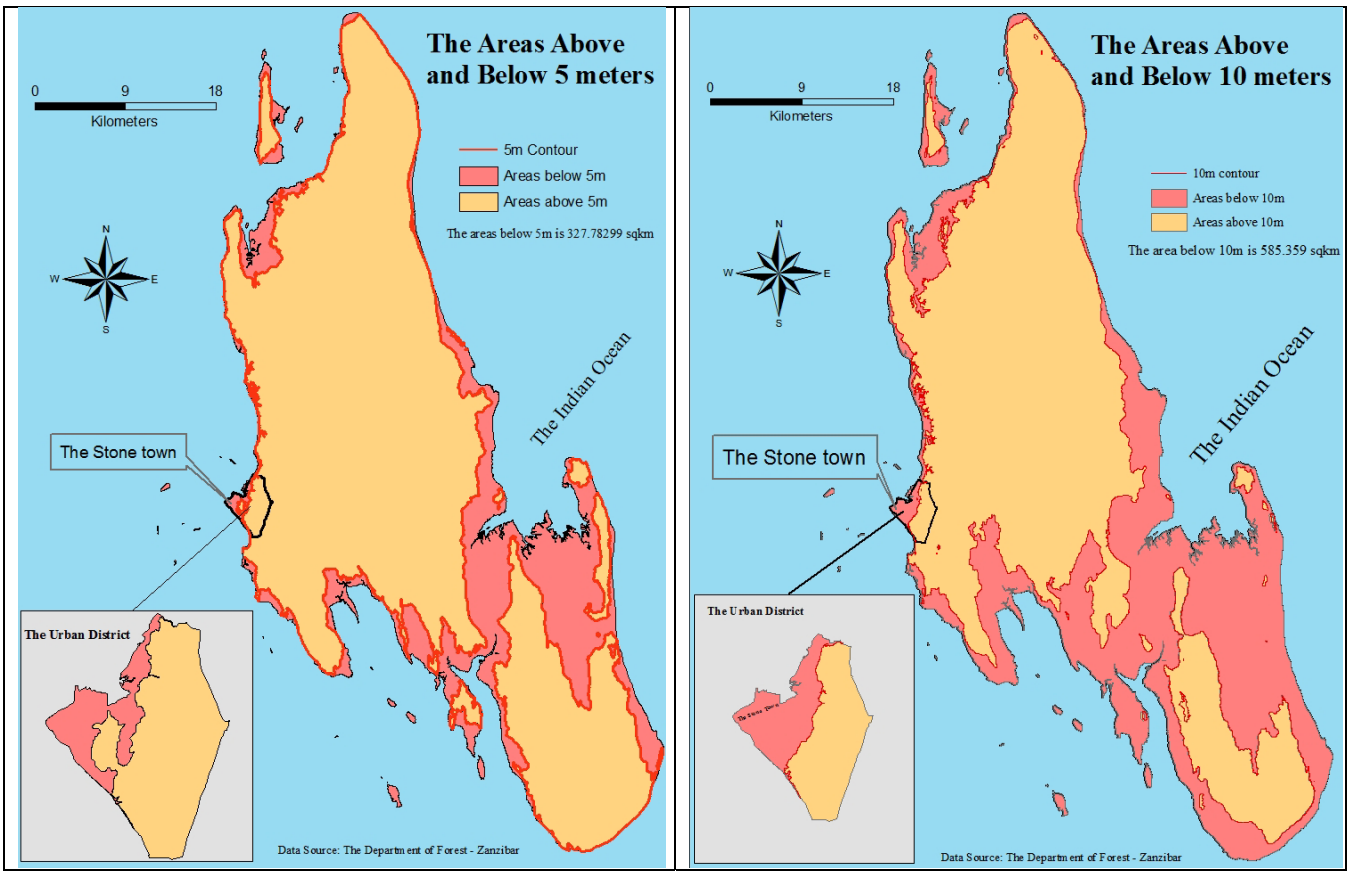
Hassan (2010) looked at local coping strategies for climate change around two marine protected areas in Zanzibar (Jozani forest/Chwaka bay complex and Ngezi forest including coastal zone) and reported enhanced beach erosion and flooding from higher high tides.

The future impacts of climate change

Climate change and sea-level rise are likely to exacerbate the issues above. It is likely that in the absence of protection, there will be a **loss of low-lying areas** of the islands, or an increase in **coastal flooding**, with potential impacts on urban areas, tourism industry, agricultural lands, important infrastructure (*e.g.*, ports) and other socio-economic activities located within the vulnerable coastal zone.

There have been studies at the Tanzanian level, which have assessed the impacts and economic costs of sea level rise (e.g. Watkiss et al, 2010) looking at these impacts. However, Mustelin et al (2009) report that to date, there has not been a systematic assessment of the threat of climate change for Zanzibar.

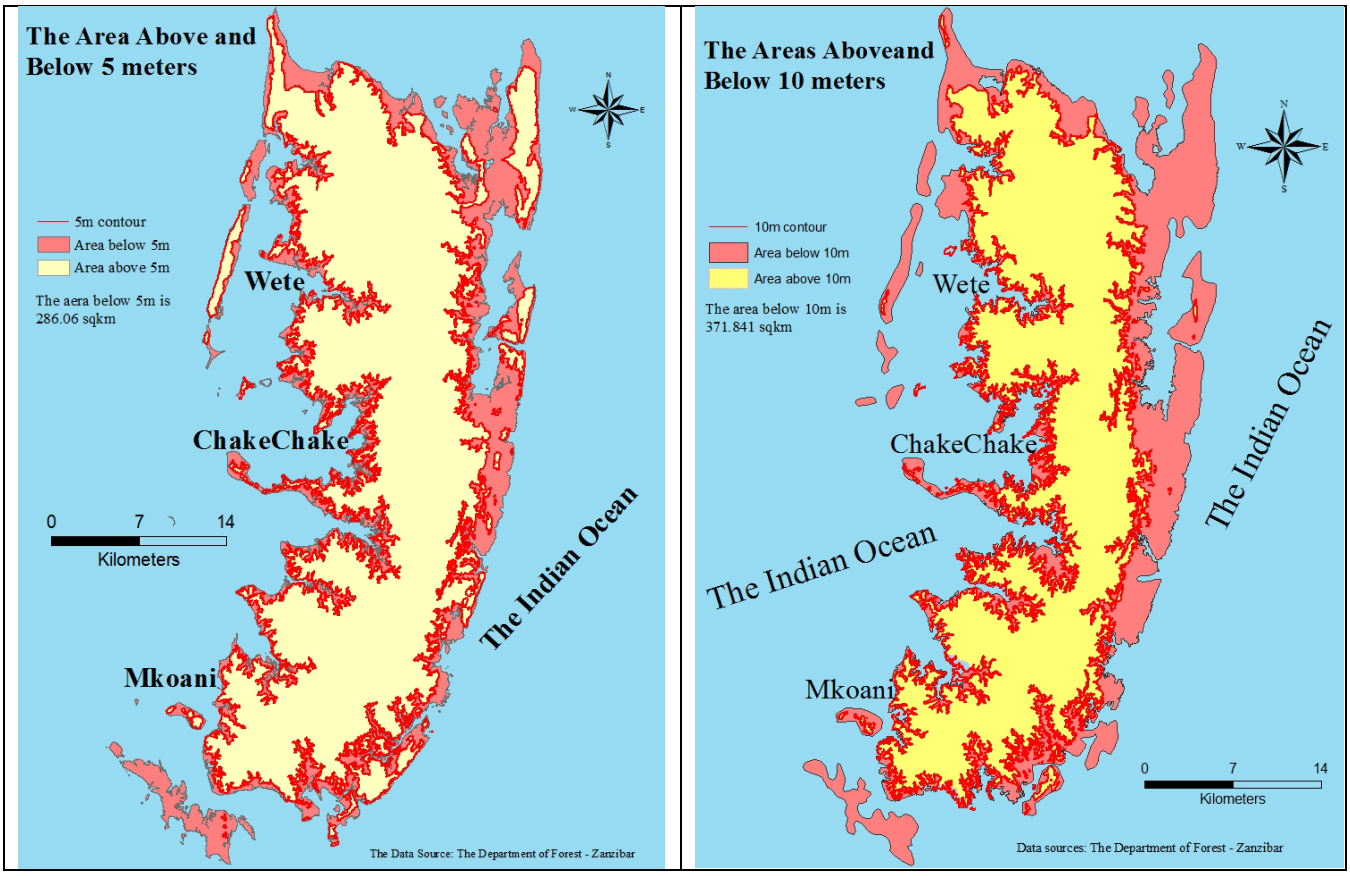
In simple terms, the areas at potential risk from sea level rise can be identified through contour maps, as shown below. The figure below shows the Low Elevation Coastal Zone (LECZ) of Zanzibar – areas below 5 metres and 10 metres that are hydrologically connected to the sea. These represent the land area most at risk from storm surges, and risks of flooding, associated with sea level rise.



Unguja 5 metre and 10 metre contours.

Source SUZA based on Department of Forests.

Note that the maps shows the low elevation zones. These reflect the areas at potentially higher risk of storm surge and flooding under climate change, but they are not the areas that will innundated, as sea level rise is not expected to exceed more than a metre over the next century.



Pemba 5 metre and 10 metre contours.

Source SUZA based on Department of Forests.

For Unguja, around 328 km^2 is below the 5 metre contour line (with 585 km^2 below the 10 metre line).

For Pemba, around 286 km^2 is below the 5 metre contour line (with 372 km^2 below the 10 metre line).

The Zanzibar Statistical Abstract (RGZ, 2010) reports that Unguja has an area of 1,666 km^2 and Pemba 988 km^2, thus the area under the 5 m contour line is 19.7% of Unguja and 28.9.% for Pemba.

The overall mapping shows large vulnerable areas, on both islands, though it is stressed that Zanzibar is not at the same level of risk of other pacific countries (such as the Maldives) and there is no risk that the islands will disappear due to sea level rise: the highest point on Unguja is around 120 metres above sea level. Nevertheless, some areas are vulnerable: on the island.

While there are reports that Ras Nungwi at the northern tip of Unguja is particularly threatened, the mapping shows a much wider set of areas that in the absence of adaptation (protection), could be at greater risk. This includes areas in the South-East of the island and a zone between the South and main part of Unguja Island (note that during the last interglacial period (Kent et al., 1971), Unguja was split into two Islets).

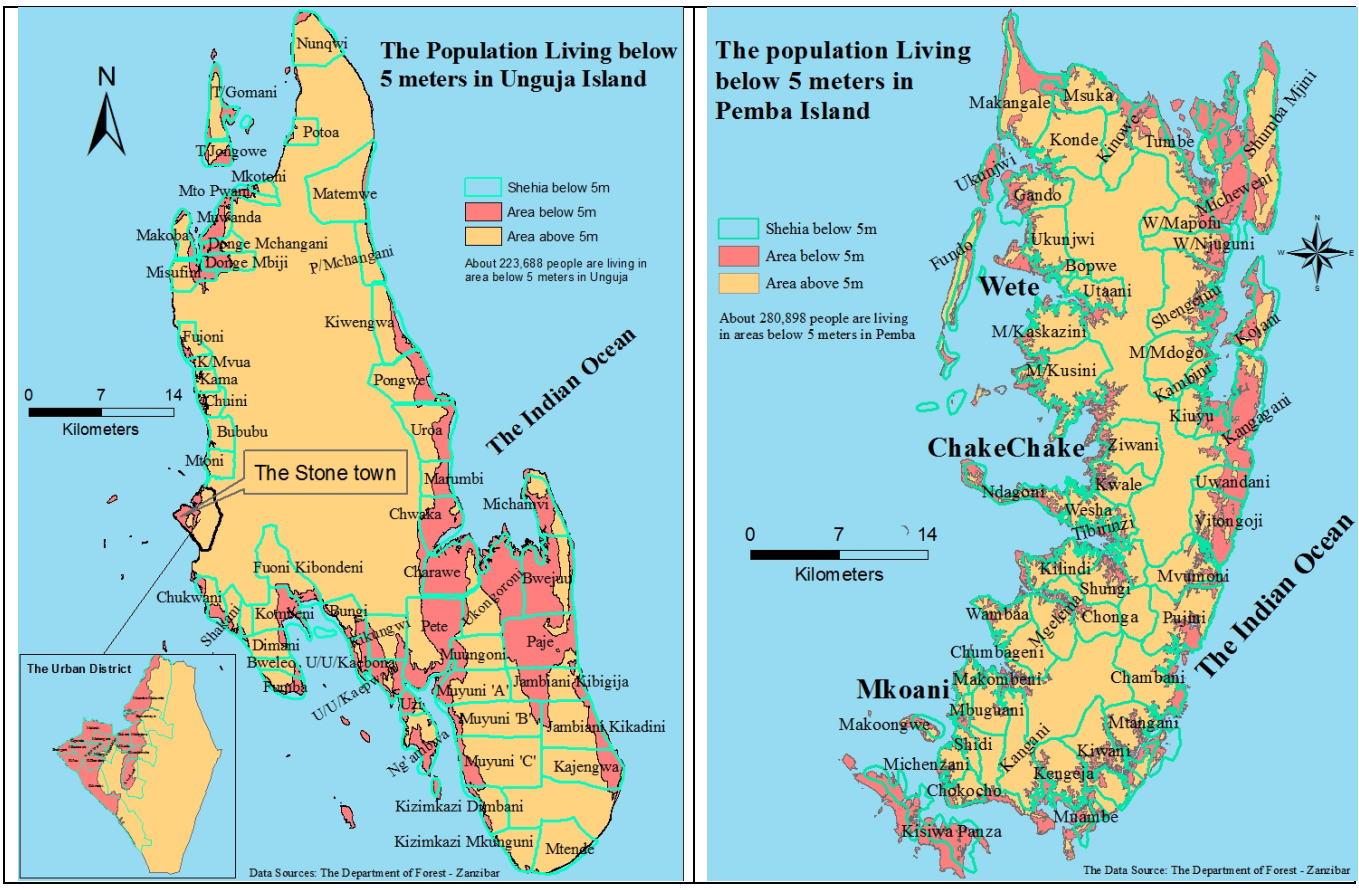
For Pemba, there is a wide band around the entire island, but particularly for many of the nearby islands, that are low lying and so at greater risk.

However, climate change is not the only driver of sea-level change. Geological movements (e.g. subsidence or tectonic movements) need to be combined to assess the relative sea-level rise (RSLR). As well as natural subsidence (or uplift), additional non-climatic factors may also be important, such as human-induced subsidence (due to groundwater extraction). As a result, 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 may therefore be uneven, even across the islands.

Unfortunately there does not appear to be good information on the underlying land movements of the islands. This is an area for futher investigation, because it may significantly increase (or decrease) the relative vulnerabilty of the islands to sea level rise.

Nonetheless, with a large and growing population and a low adaptive capacity due to low wealth and other development indicators, Zanzibar is highly vulnerable to sea-level rise from climate change.

The study has also combined the mapping above with various data sets, to build up potential hazard maps and quantitative estimates of potential risks.



Population within the 5 metre contour.

Source SUZA.

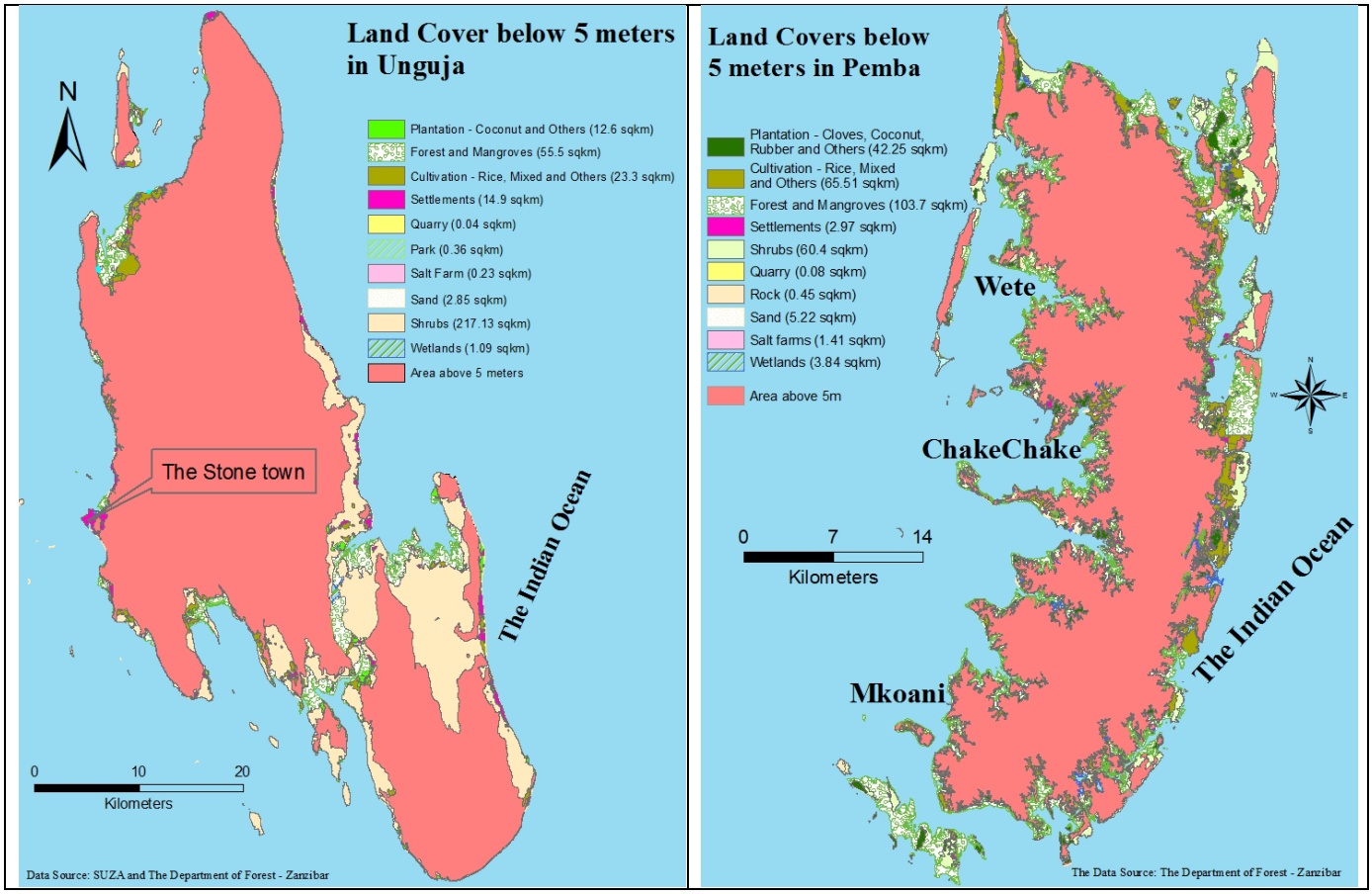
Note that due to the available level of the population data, some interpolation has been applied to these maps, see the the overlay of areas and districts.

For Unguja, around 224 000 people live below the 5 metre contour line (with 281 000 below the 10 metre line).

For Pemba, around 281 000 people live below the 5 metre contour line (with 309 000 below the 10 metre line).

In many island areas, the population is fairly concentrated around the coastline, and these leads to relativley high exposure. When compared to current population, 29% of Unguja and 54% of Pemba population are within the 5 metre contour zone.

It is also possible to look at the land cover in the coastal areas.



Land Cover within the 5 metre contour.

Source SUZA based on Department of Forests.

Further work on more dis-aggregated contour mapping and hazard mapping analysis is recommended. There has been discussion of the potential for 2 metre contour maps (SMOLE, personal communication) and this would seem an obvious priority for early work, as this would allow more accurate mapping the potential at risk areas and prioritisation of the most at risk areas.at risk.

A look at various land area at risk, and the value of land types, shows the potentially high costs involved with higher risks of coastal flooding and even innundation. A large part of the land at risk is agricultural/plantations, which has a high economic value on the islands given land constraints. However,

the potenital loss of forests and mangroves has potentially even high costs, due to the very high ecosystem services of these systems (e.g. for mangroves, the estimates in the global literature are $200,000 - $900,000 per hectare (Wells et al. 2006 and similarly wetlands are valued very highly (at $2 million per square kilometre on average in the OECD in 1990, Fankhauser 1994)). It is clear that the potential economic costs of sea level rise could be very significant for the islanads.

The second key vulnerability is from **coastal erosion** (and associated loss of land and damage). As highlighted above existing problems have been reported around the islands (Nyandwi, 2001; Makota *et al*., 2004)[1]. There have also been changes in wind speeds and mean wave height (see earlier). However, various issues may be associated with these observed trends, including coastal uplift, sea-level rise, changes in hydrodynamic conditions such as longshore drift, and other human activities such as extraction of sand, destruction of the fringing and barrier coral reefs by dynamite fishing, and removal of vegetation from mangrove swamps. Erosion is also a natural process, and it is not known if the rate of erosion is accelerating generally, though there do appear to be local erosion hot-spots, which may be caused due to the cutting down of mangroves.

Again, climate change would be expected to increase the rate of coastal erosion, from a combination of processes, notably that enhanced erosion is related to sea level rise. There are also potential increases in erosion from changing wind regimes, wave heights and tidal regime, which might also affect sediments. Many of these could potentially change – or increase - with climate change.

Adaptation

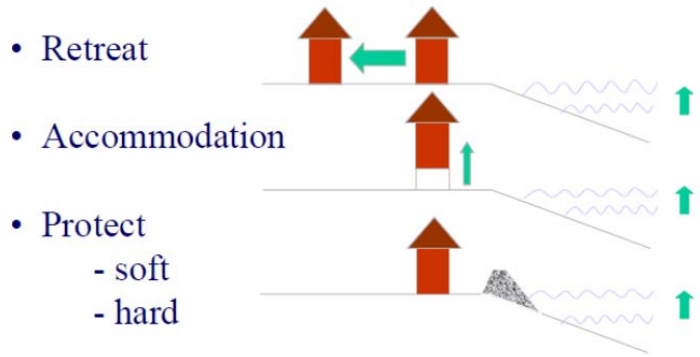
One of the most obvious gaps – and priorities for adaptation – is for accurate information on the changes taking place, i.e. for better monitoring and analysis, though a number of projects are advancing this (see later). As well as the information on marine monitoring discussed earlier (tide gauge and sea surface temperature) there is a need to get better information on erosion and flooding, and to assess key risks across the islands to identify priority areas. Once these areas are identified, a number of potential options can be considered.

Coastal protection to sea-level rise is often a costly, but a straightforward way to overcome the adverse impacts of climate change. Although developing countries have limited capacity to adapt, global and regional studies have highlighted that adaptation is vital and an urgent priority. However, limitations both in human capacity and financial resources make adaptation difficult for poorer areas.

The most obvious adaptation options to address the risks above, particularly for infrastructure, are coastal defences (*e.g.*, physical barriers to flooding and coastal erosion such as dikes and flood barriers), but other options are possible, notably realignment of coastal defences landwards, beach stabilisation (using plants such as *ipomea*) abandonment (managed or unmanaged), and retreat measures to reduce the energy of near-shore waves and currents, coastal morphological management and resilience-building strategies.

In simple terms, planned adaptation options to sea-level rise are usually presented as one of three generic adaptation strategies (IPCC CZMS, 1990; Bijlsma *et al*., 1996; Klein *et al*., 2001), as retreat, accommodation or protection.

[1] see also http://www.africanews.com/site/Zanzibar_hit_by_erosions/list_messages/34232



The table below shows a list of the physical impacts of sea-level rise and the potential adaptation responses, illustrating these three generic strategies.

Major physical impacts and some examples of potential adaptation responses to sea-level rise, illustrating the Protect, Accommodate, and Retreat strategies (taken from Nicholls and Tol, 2006; Nicholls, 2007).

Physical Impact of Sea-Level Rise		Some Examples of Potential Adaptation Responses
Direct inundation, flooding and storm damage	S 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		

The choice and use of these adaptation strategies depends on the nature of the coastal zone and the type and extent of impacts. These have a site specific context, and if appropriately applied, different adaptation strategies will have different consequences for coastal ecosystems (Nicholls, 2007).

For instance, unlike the first option (protection), the two adaptation strategies (accommodation and retreat) reduce or avoid the problem of 'coastal squeeze' (preventing onshore migration of coastal ecosystems) between fixed coastal defences and rising sea levels. However, soft protection measures (such as beach/shore nourishment, beach/shore stabilization, and sediment re-cycling) can minimise this problem. It is also important to recognise the benefits of applying portfolios of adaptation strategies for example dikes can be combined with building codes/flood-wise buildings and flood warning and evacuation systems, and quite different adaptation strategies might be applied in a city versus a rural area.

Sallema and Mtui (2008) – and Shaghude et al (submitted) - set out the potential soft and hard options (adaptation technologies and legal instruments) to address climate change impacts to coastal and marine resources in Tanzania and the problem of shoreline changes in Tanzania and Kenya, respectively. Sallema and Mtui highlight the options of protection, establishment and management of marine and coastal protected areas, protection of resistant and resilient populations and communities, restoration of degraded habitats. They also highlight the large number of existing legal instruments addressing coastal and marine resources in Tanzania. Shaghude et al (submitted) observed that the installation of hard protection measures had been detrimental to the natural capital of the Tanzanian and Kenyan shores. Consequently, it is therefore necessary that before these shore protective measures are used the benefits of such interventions are weighed against their true costs, not only the required labour and materials, but also longer-term costs to coastal stakeholders and the supporting ecosystems within the wider coastal management area.

The URT NAPA (URT, 2007) identified a large number of coastal and marine adaptation responses for Tanzania, shown in the Appendix. The scoring and ranking exercise concluded that for coastal and marine resources, the priorities were the construction of artificial structures, e.g., sea walls, artificially placing sand on the beaches and coastal drain beach management system, followed by restoration of degraded habitats. For human settlements, the priorities were to establish good land tenure system and facilitate sustainable human settlements, followed by relocation of vulnerable communities to other areas, and then establish disaster committee and plans at village level. For tourism, the priorities were to establish alternative source of income for the community in the tourist area.

The **Zanzibar APA** reported that several beaches are suffering from heavy erosion, and that many settlements and hotels are constructing sea walls and breakwaters, that farmers are already experiencing flooding of fields by seawater. It also highlighted sewage and wastewater are often emptied directly in the ocean due to low collection rates and a lack of a solid wastewater treatment plant, highlighting linkages with flooding and pollution. As a result, it identified the following actions.

The Zanzibar Adaptation Programme of Action (2010) identified the following:

- Developing county-scale maps depicting which areas will require shore protection (e.g. dikes, bulkheads, beach nourishment) and which areas will be allowed to adapt naturally.
- Analyzing the environmental consequences of shore protection.
- Engaging state and local governments in defining responses to sea level rise.
- Improving early warning systems and flood hazard mapping for storms.
- Promoting shore protection techniques that do not destroy all habitat.
- Protecting water supplies from contamination by saltwater.
- Enhance the capacity for waste management to prevent pollution of marine environment.
- Acquire appropriate sewage treatment technologies.
- Establish marine protected areas.
- Identifying land use measures to ensure that wetlands migrate as sea level rises in some areas.

Two important issues are relevant here. First, to highlight that adaptation has a cost, and this therefore influences the adaptation response. Second to stress that there are alternatives to hard engineered protection are possible, that have wider ecosystem and ecosystem services benefits.

There are studies that assess the potential costs and benefits of coastal adaptation, though these tend to be focused on hard protection. Watkiss et al (2100) for United Republic of Tanzania, found 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 could be significantly reduced.

There are already a number of coastal protection projects in place on Zanzibar, and these provide useful information on potential adaptation responses and costs.

The most prominent current World Bank funded Zanzibar Urban Services project[2], which is the rebuilding of part of the coastal protection wall in Stone Town, the construction of the Mizingani sea wall and associated promenade. This subcomponent – which is costing US$8.5 million[3] - enables the conservation of a public seafront and the historic buildings along Mizingani Road while preserving and enhancing the traditional seafront setting and its historic and architectural context within the Stone Town (UNESCO World Heritage City). The design is consistent with and based on the "Stone Town Conservation Plan", which respects the requirements of maintaining the World Heritage City status for the Stone Town (which means much higher costs than for a traditional sea protection). The project is a) constructing approximately 340 meters of a seawall, extending out of its existing boundaries, including appropriate backfill and foundation work and b) refurbishing underground infrastructure including water, sewer, storm sewer and electrical and telecommunication lines located below the roadbed of Mizingani Road; c) resurfacing road and introduction of traffic calming measures; and d) creating a pedestrian promenade, including landscaping, street lighting and street furniture along the sea side.

Note that while the project did not explicitly take climate change into account, there was a contingency built in (over design), to allow for sea level rise. The additional marginal cost of this were low – the built of the project costs are with the project itself, but it provides a good example of how climate change needs to be factored into major infrastructure projects with long life times.

There is also a current Adaptation Fund project in Dar es Salaam, which is implementing shoreline protection. Part of this is to rehabilitate and raise the sea wall, as part of a wider shoreline protection project. The cost of the hard coastal protection along 1.34 km (in areas showing particular damage in Dar es Salaam city center and in Kigamboni area) is $3.4 million, equivalent to $2.5 million per km.

For high value areas such as Stone Town, or where immediate and urgent action is necessary to protect other major assets (that would otherwise be lost), coastal protection is likely to be key. This may take the form of engineered defences. These engineered protection defences are expensive. Lower cost options are available, and a number of these have already been built in Pemba, to address concerns over sea water flooding, see box below.

For erosion, much of literature addresses the issue of with beach nourishment. Some costs (e.g. Nicholls et al, 2009) cite values of US$5/$m^3$ where sand is plentiful (e.g. it can be dredged from a local channel), a midrange figure of US$10/$m^3$, and a low supply area figure of US$15/$m^3$. In all cases there is an additional, fixed cost for example, for the mobilization of equipment and a variable cost of placement.

There is some anecdotal evidence on the costs of local protection measures[4], with the costs to protect a boundary of 20 metres using coconut poles, costing between $500 and $600, however, there is some evidence these are not very effective, and may even be a form of mal-adaptation.

Given the low levels of protection on much of the island, and the high costs, it is clearly not going to be possible to protect all the vulnerable areas with highly designed structures. Furthermore, it is often not appropriate to build hard protection. Lower cost defence options are available, and these include a variety of soft and ecosystem based adaptation approaches (see box) that are likely to be more beneficial for many parts of the coasts of Zanzibar.

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[2] http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187283&siteName=WDS&entityID=000333037_20110206231829

[3] Cost benefit analysis of the Mizingani Sea Wall yields a net present value (NPV) of US$ 15.03 million at a discount rate of 12 percent with an internal rate of return (IRR) of 47 percent.

[4] http://news.bbc.co.uk/1/hi/world/africa/7100107.stm

Dikes on Pemba

As highlighted by the coastal elevation maps earlier, a significant area of Pemba is at low elevation. In some areas, coastal flooding has increased on marginal land – mostly due to mangrove removal and siltation from inland forest clearance (allowing water to flow further inland) – but with some potential influence from higher tide heights.

In response to the potential risks of further inland flooding, and partly to reclaim marginal land for rice growing, a number of dikes have been built in Pemba. These have been basic dike structures (either mud or with some additional rock or rubble), with gates to allow flood water outflow and prevent salt water inflow. The schemes have also replanted mangroves (restoration) to provide natural flood protection on the coastal side.

New Dike

Mature Dike

Mangrove planting

Gate system

Agricultural fields behind the dike (left early, right mature)

Mustelin et al (2009: 2010) studied potential adaptation strategies in northeast Zanzibar. They highlighted that coastal erosion, deforestation and habitat fragmentation will become even more serious problems in coastal locations when coupled with the projected impacts of climate change, but that anticipatory adaptation does not need to wait for specific climate scenarios, instead focusing on current vulnerabilities and possible no-regret strategies. They stress, however, that these need to accommodate multiple stakeholder preferences. It explored such preferences with coastal communities' and their preferences for adaptive strategies. The study suggests that coastal forest buffer zones as an anticipatory adaptation measure, which is based on soft measures such as vegetation planting, awareness raising and stakeholder cooperation

This option - restoring the natural coastal vegetation to enhance coastal forest buffer zones in chosen locations along the coast -can be considered a no-regret ecosystem-based adaptation measure because it would produce multiple benefits even in the absence of climate change impacts.

- First, it would function as shoreline protective barrier, for instance, against storms and even tsunami.
- Second, it would help prevent erosion by stabilizing beach sand and absorbing wave energy.
- Third, 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.

There are therefore 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. Mustelin et al (2009) reports that rehabilitation of the current vulnerable areas (30 hectares) would require over 40,000 seedlings and cost 14 000 Euro.

Ecosystem Based Adaptation. 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, 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.

Tanzania has also recently secured a $5 million project[5] from the Adaptation Fund (see later discussion). The project proposes an integrated blend of hard and soft coastal protection measures, the latter increasing the resilience of ecosystems that provide a protective or buffering service against climate change impacts on the coast, as well as measures designed to provide local communities with incentives to maintain the rehabilitated ecosystems.

There is also some information from the Tanzania Adaptation Fund project, which is of relevance for Zanzibar.

First, the fund is progressing **mangrove rehabilitation,** as part of the wider coastal protection project. This involves planting of resilient seedlings, dredging and the creation of no-take buffer zones. The benefits of mangroves are outlined below, but they act as a natural form of coastal protection. This implies low costs (around $1000 per hectare), though this is high compared to some international projects, and depends on the methods used[6]. The study also estimated the benefits of mangroves (see also later ecosystem services section) based on international values.

Second, it is advancing **Shoreline stabilization through reforestation.** The project is creating a revegetated band of 1500m long (by 20m wide), located directly behind the rehabilitated sea wall along Ocean road in Dar es Salaam. The aim is to create a solid band of compacted soil between the road and the wall, which will be revegetated to achieve maximum density, soil retention functions and vegetation (bushes, grasses and trees) for protection, i.e. as a supportive measure to create an additional line of protection, as well as to create an additional recreational ecosystem service. It involves planting native trees. The cost of this shoreline revegetation is estimated at 67,500 US$ along a stretch of 1500m in Dar es Salaam city center (approximately $45 000 per kilometre). The costs of revegetation include procurement of materials and equipment (trees, seedlings, soil, fertilizer and compost), labour, training as well as the costs of procuring expertise for assessing species resilience and landscape design.

It is also important to stress that adaptation is not just about protection (see earlier table).

As identified by Watkiss (2010) at there is a significant need for:

- A current strengthening of coastal adaptation (to cope with the current risks),
- A 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.

Conventionally, many coastal management practices have been more sectoral focused. 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

[5] Implementation of Concrete Adaptation Measures to Reduce Vulnerability of Livelihoods and Economy of Coastal Communities Of Tanzania.

[6] The cost of the Tanzania adaptation fund project for mangrove rehabilitation is 35,000 US$, including the costs of consultancies, environmental engineering services and assessments, equipment, biomass, and labour. This is expected to achieve rehabilitation (through replanting and hydrological restoration) of 40 hectares of mangroves. The document notes that the costs of mangrove rehabilitation vary greatly from one area to the next, and depending on methods used. These have been reported to range from as low as 41$/ha (e.g. VietNam) to 225$/ha, and in some cases, even 3000$/ha. It outlines that costs depend on the state of degradation and tree mortality, whether planting alone is required or if hydrological restoration is required, as well as the type and availability of species, propagules and seedlings, labour and expertise costs, transportation. In the case of Tanzania adaptation fund application, costs of mangrove rehabilitation were derived from previous experience in similar projects as well as from local consultations. It cites benefits from international studies, citing two studies, the first that estimates mangroves provide 6696 US$/ha/year in waste treatment services, 466 US$/ha/year in food production and 1839 US$/ha/year in coastal disturbances protection, and the second a combined value of 9270 US$/ha/year . It thus estimated the benefits of the scheme at US$ 370,800.

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 (as identified earlier).

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. Steering development away from low-lying areas, to other parts of the main cities (or outside the cities) 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 areas 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.

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 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.

It is stressed that there are a number of important ongoing projects already on Zanzibar, which is progressing some of the areas above. Many of these are in integrated coastal management, which are early adaptation no regret measures.

The Nordic Development Fund (NDF) Board has approved a EUR 0.8 million grant to support a study on the impacts of climate change on the coasts of mainland Tanzania and Zanzibar. The NDF grant will together with support from the World Bank allow a team of international and local experts to undertake an in-depth study of the coastal region[7]. The proposed study will document the existing impacts of climate change in the coastal region and identify priority adaptation investments to enhance resilience of local communities and ecosystems. The World Bank Tanzania Marine and Coastal Environmental Management Project MACEMP[8] is to improve management and use of Tanzania's Exclusive Economic Zone (EEZ) — the 200 nautical mile ocean space which is Tanzanian territory under the Law of the Sea Convention — and its coastal resources. The MACEMP will (a) implement a common governance regime for the EEZ; (b) support a comprehensive system of managed marine areas in the territorial seas, building on integrated coastal management strategies; and (c) give coastal communities access to economic opportunities that improve livelihoods and help manage the marine ecosystem.

[7] http://www.ndf.fi/index.php?id=32&tx_ttnews%5Btt_news%5D=64&cHash=5abcd4cee86b627ffaa6ea5157f29fcc

[8] http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/TANZANIAEXTN/0,contentMDK:20992192~menuPK:287367~pagePK:1497618~piPK:217854~theSitePK:258799,00.html

Coastal Ecosystems and Ecosystem Services

Zanzibar has diverse ecosystems from coral reefs, sea grasses, and mangroves often referred to as a "seascape" reflecting their interdependence and terrestrial systems such as coral rag forests, all are interconnected, with the seascape being influenced by the terrestrial systems as well as the open ocean (Moberg and Ronnback 2003). These coastal ecosystems provide many benefits to society, which in turn have multiple economic benefits that are rarely captured by markets. These are known as 'ecosystem services'. These 'ecosystem services' can be divided into:

- Provisioning (e.g. agriculture, fisheries, timber, water),
- Supporting (soil formation, nutrient recycling),
- Regulating (climate regulation, flood protection, water quality regulation),
- Cultural services (recreational, educational and cultural benefits).

These ecosystem services are integral to the economy of Zanzibar and underpin a large proportion of GDP, as well as foreign revenue and export earnings. These areas also sustain a very large proportion of the population. While all services are important, it is clear that provisioning services are particularly important to Zanzibar. The main provisioning services include: fishing and fishing-related activities, seaweed farming, and mangrove harvesting for fuel, timber, (Naber et al. 2009, Lange & Jiddawi 2009). 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. Each ecosystem provides a variety of ecosystem services, shown below.

Distribution of valued ecosystem services by ecosystem type

Ecosystem Service	Marine system	Mangroves	Coral Reefs	Intertidal Habitats	Estuaries*	Seagrass	Coastal Zone
Provisioning services	52%	41%	26%	7%	28%	50%	26%
Regulating services	0%	24%	13%	15%	28%	25%	21%
Cultural services	48%	13%	52%	72%	22%	0%	37%
Supporting services	0%	21%	9%	7%	22%	25%	16%

Source: Naber et al (2009)

Economists distinguish the value of ecosystem-based activities, such as fishing are from the value of the ecosystem itself. Eco-system based services comprise of the combined value of several contributing factors— the ecosystem, labor, and capital; it is total value-added, the contribution to GDP. The value of the ecosystem alone in a given activity may be defined as the value of fish stock in fishing, or "resource rent" (Naber et al 2009).

In order to take a pro-poor approach to evaluate eco-systems, it is important to identify who in society benefits from different ecosystem services. Lange and Jiddawi (2009) define the main beneficiaries of ecosystem services in Zanzibar into five groups. The first two groups include beneficiaries in communities where activities based on marine ecosystem services occur, including Zanzibari villagers in coastal areas where most beach hotels are located and most fishing and seaweed farming occurs and urban Zanzibaris involved in businesses in Zanzibar Town and its suburbs. The second three are beneficiaries in Zanzibar, but are not in communities where activities occur such as urban Zanzibaris involved in businesses in rural coastal areas, usually tourism and the Zanzibari government, and beneficiaries outside of Zanzibar such

as people from mainland Tanzania and foreigners as (part-) owners of businesses, hired workers, or the mainland government.

As a whole provisioning ecosystem services provided by seaweed farming, fishing and tourism combined make up over 30% of Zanzibar's GDP, amounting to over 150 million USD in 2007, as shown below. Seaweed and fishing are particularly important for Zanzibaris living in rural coastal areas.

Contribution of marine ecosystem services to the macro-economy and distribution of income by beneficiary and activity in Zanzibar, 2007 (thousand US$)

	Seaweed farming and export	Fishing and marketing	Tourism	Total
Contribution to GDP	1663	29,179	119,636	150,478
Share of GDP	0.4%	6.2%	23.6%	30.2%
Foreign exchange earnings	2,397	-	184,929	187,326
Employment	16,422	37,203	9,351+	62,976 +
Share of investment projects 2003-2007		1%	76%	77%
Distribution of income among beneficiaries				
Zanzibaris total, of which	1,663	29,179	56,610	87,451
1. Zanzibari villagers in coastal areas	*1107*	*28106*	*15,633*	*44,846*
2. Urban Zanzibari in urban activities	*509*	*1073*	*8271*	*9853*
3. Urban Zanzibaris in rural coastal activities	*-*	*-*	*15211*	*15211*
4. Zanzibari government	*46*	*-*	*17,495*	*17541*
5. Non- Zanzibaris			*63,028*	*63028*
Total	*1663*	*29179*	*119,638*	*150,478*
Zanzibari share as % of total income (1-4)	100%	100%	47%	58%
Local Zanzibari share as % of total income (1-2)	97%	100%	20%	36%
Rent as % of value added (minimum)	3%	0%	3%	3%

Source: Naber et al. (2009)

Given the multiple services that ecosystems provide to society and the role they play as habitats of a diverse fauna and flora, their maintenance/enhancement is critical for building resilience to future risks, including climate-related ones.

The following sections discuss the main marine ecosystems and their services, their current vulnerability, and the risks from climate change. The sections also discuss early adaptation options.

It is highlighted that coastal environments were identified in the Zanzibar Adaptation Programme of Action as a key concern, and some actions were recommended, outlined below.

For adaptation, the Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Identifying management practices that will ensure the successful attainment of conservation and management goals
- Promoting management practices that confer resilience to the ecosystem
- Protecting and enhancing habitat protection
- Acquisition of appropriate sewage treatment and disposal technologies to protect water resources and to counteract reduced assimilation capacity

It is stressed that a number of initiatives are underway.

The World Bank MACEMP (mentioned above) is supporting a comprehensive system of managed marine areas in the territorial seas, building on integrated coastal management strategies; and giving coastal communities access to economic opportunities that improve livelihoods and help manage the marine ecosystem. There is a GEF funded Marine and Coastal Environmental Management Project to improve sustainable management and use of the URT's Exclusive Economic Zone, territorial seas, and coastal resources, which while national level, includes Zanzibar. There was also the USAID funded SUCCESS project (SUstainable Coastal Communities and EcoSystems Support Services) which ended in 2009. The Program's goal was to help people improve both their quality of life (health, income, education) and their physical environment through good governance. In East Africa, the Western Indian Ocean Marine Science Association (WIOMSA) in collaboration with the Institute of Marine Sciences (based in Zanzibar) implemented the program. This effort included a regional training initiative and supported livelihood development in mariculture in Zanzibar as well as in Mkuranga and Bagamoyo. The project initiated and enhanced the development of enterprise cooperatives and associations and introduced jewellery making in Zanzibar using shells and pearl (farming), allowing the members to move up the value chain, improving their products, marketing, and sales. Half-pearl farmers and jewelry-makers on Zanzibar received business development assistance and training. The project also supported a community-based cockle management initiative in the Menai Bay Conservation Area on Zanzibar (USAID 2009). From 2009 the REcoMAp project supported by EU and the Pwani project also supported by USAID with the same mandate as the success project continued to support the community of Fumba peninsula.aiming at empowering them economically while conserving the environment (Jiddawi, 2011 and Hamed, 2009).

Marine Fisheries

Fish constitutes the most important source of protein in Zanzibar. The potential fishing zone within Unguja and Pemba Islands lies within the 50-fathom contour around the two islands, and covers an estimated total area of 4,450 km^2 (RGZ, 2010). Baseline fish catch data and estimated value is presented below.

Estimates of Fish Catches, 2006 – 2010 Value '000 T Shs

	2006		2007		2008		2009		2010	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value
Zanzibar	23,286	26,561,739	23,582	34,639,223	24,805	36,895,539	25,397	47,714,076	25,693	61,784,310

Source: Zanzibar Statistical Outlook, RGZ, 2010. Department of Fisheries and Marine Products and JKU

Other sources report that fish catches contributed $26.2 million US to Zanzibar's economy in 2007.

Fish catch and use in Zanzibar, 2007

Reported Catch and Value of output	23,582 tons	US$27.78 million
Total Catch and Output Including own-consumption*	25,940 tons	US$30.56 million
Contribution to GDP – Value added (Output – costs of fishing)		US$26.22 million
Per capita consumption of fish	23 kgs	$27
*Zanzibar national accounts assume that an additional 10% of reported catch is retained for own consumption. Note: exchange rate for 2007 is Tanzania shillings 1247 to the US$, from (OCGS, 2008)		

Source: Fish catch from Department of Fisheries, 2007; contribution to GDP from (OCGS, 2008); number of fishers from (Jiddawi and Khatib, 2007), Naber et al. (2009).

The table below shows an estimate of how income from fishing is divided up among the beneficiaries. As the sector is informal, it is likely hard to record earning that people make selling the fish to hotels.

Total contribution of fishing to GDP, exports and distribution of income by beneficiaries and activity in Zanzibar, 2007, thousand US$.

	Fishing	Processing / marketing	**Total**
Beneficiaries	26,223	1,883	28,106
1. Zanzibari villagers		-	-
Wages & salaries			
Mixed income, Operating surplus	26,223	1,883	28,106
2. Urban Zanzibaris in urban activities	-	1,073	1,073
Wages & salaries	-	-	-
Mixed income, Operating surplus	-	1,073	1,073
3. Urban Zanzibaris in rural coastal activities	-	-	-
4. Zanzibari government	-	-	-
5. Non-Zanzibaris	-	-	-
Total	26,223	2,956	29,179
% of GDP	5.6%	0.6%	6.2%
Employment	34,269	2,934	37,203
Male	30091	na	
Female	4178	na	

Source: Lange and Jiddawi (2009)

Employment and earnings (value-added) from fishing and related activities in Zanzibar, 2007)

	Employment	**Average annual earnings US$**	**Total value added/ earnings, thousand US$**
Total fishers	34,239	765	26,223
			Fish related workers
Auctioneers	260	560	145
Retailers	946	1073	1014
Wholesalers/retailers*	752	1809	1360
Primary processors	206	259	53
Secondary processors	770	498	383
Subtotal fishing-related	2934		2956
*Some wholesalers also act as retailers. Earnings are revenues net of all costs including purchase of fish, equipment, transportation, etc.			

Source: Coles, Lange and Jiddawi (2009), cited in Lange and Jiddawi (2009)

As well as providing an important current resource, there is the potential (RGZ, 2010) for domestic fishers for off shore fishery expansion in Zanzibar. There has also been recent work into fish aggregating devices (FADs) for enhancing coastal artisanal fisheries, particularly for high value species, with trials in Zanzibar[9].

There is also some emerging mariculture (the marine form of aquaculture) on the islands. This includes culture of milk fish (Chanos chanos, mullet and Tilapia (Dubi et al, 2006). Another emerging mariculture is pearl farming using oyster species Pteria and Pinctada (Ishengoma et al, 2011, jiddawi, 2011Jiddawi and Hamed, 2009).

Of course, these fisheries are under many existing threats. Historically there are negative environmental impacts caused by habitat destruction of coral reefs and mangroves from illegal fishing techniques, such

[9] http://www.researchintouse.com/nrk/RIUinfo/PF/FMSP11.htm

as spear fishing, drag netting and dynamiting. While there is now some (anecdotal) evidence that action on stopping illegal nets and increased surveillance – working with the local fishing communities – has been effective in helping fish stocks risks, the main threat now and in the future (with rising population) is the threat of overfishing.

There have been some reports of fish mortality, linked to hotter temperatures (sea surface temperatures) – an issue that came up at the workshop, though there is no evidence to confirm this.

There is a new fishing regulation Act (2010) and the Ministry is currently producing an updated fisheries policy that will update the 2002 policy. This revised policy has the opportunity to take climate change into account.

The World Bank MACEMP also has an initiative to establish a common and sustainable governance structure for the migratory fishery in the Exclusive Economic Zone. The Recent agreements will allow for the establishment of a Deep Sea Fishing Authority has already been established since 2010 to manage both mainland Tanzania and Zanzibar deep sea fisheries, and the headquarters is based in Fumbawhich will be in place by early next year. This should mean more revenues (up to $200 million per year), and the sustainability of fish stocks through better monitoring. The aims are to gather new and important information about ocean currents and how they interact with and influence the climate, biodiversity and economies of the western Indian Ocean region;

It will document the environmental threats that are faced by the countries in a Trans-boundary Diagnostic Analysis (TDA); to develop a Strategic Action Programme (SAP) which sets out a strategy for the countries to collectively deal with trans-boundary threats; to strengthen scientific and management expertise, with a view to introducing an ecosystem approach to managing the living marine resources of the western Indian Ocean region.

The impacts of climate change

The future impacts of climate change are expected to result in a number of changes in the abiotic (i.e. sea level, sea temperature, acidity, salinity, stratification, light, and possibly thermohaline circulation) and biotic (i.e. primary production, food webs, etc.) conditions of the sea. It is generally accepted that the reproductive success of marine organisms depends almost on these environmental conditions, and so these will affect fisheries.

A critical issue is that fishing is a "harvesting" activity and human activities affect the reproductive success and abundance and distribution of marine organisms. Climate change is an additional pressure on fish stocks whose resilience may be low, because of the impact of existing fishing activities and, to a lesser extent, pollution or physical destruction of habitats.

The impacts of climate change on marine food webs and on fish is particularly complex, and in the case of Zanzibar it is also linked to the health of the coral reefs and mangroves. Some of the earlier signs of climate change (in other areas) have been observed changes in the distribution of fish and other species, as species adjust to changing temperature. This is because the marine environment offers lower barriers to dispersal of species, i.e. many (but not all) marine species generally have a high potential for migration. Changes in distribution due to future climate change do not necessarily reduce the overall fishery potential, but might lead to changes by region, or changes in the commercial value by region.

The other impacts of climate change on fisheries potentially include food chain effects, diseases, and increased ocean acidity.

There is some evidence that warming temperatures are negatively affecting some fisheries in WIO (Roessig et al., 2004). However, this is an emerging area and a key priority is to get better monitoring and research information.

One of the coastal resources that are vulnerable to impacts of climate change and variations is the shrimp fishery because coastal panaeid shrimp species abundances and catches have shown to be influenced by habitat conditions such as temperature, nutrient, salinity and oxygen concentration (Ulltang et al, 1985; Bwathondi et al, 2002; Mwakosya, 2004).

The IPCC (AR4, 2007: Nicholls et al, 2007) reports that climate change impacts will be greater on coastal than on pelagic species, and for temperate endemics than for tropical species. It also highlights that ocean acidification is a concern, but impacts are uncertain. Climate change also has implications for mariculture but again these are not well understood.

There are some international studies that are looking at this, such as QUEST Fish[10], though these have not yet produced final results.

Adaptation

An obvious early institutional adaptation is to bring climate change within existing sectoral policy. The current update to the Zanzibar fisheries policy provides an opportunity to take climate change into account. There is also a need for greater monitoring, linked to the physical changes in the sea around Zanzibar (see earlier section) and a greater focus on marine species monitoring, to be able to track changes (noting the complex issue of attributing any changes).

There are also a large number of cross sectoral linkages to other areas, notably enhancing the resilience of coral reef, because of their importance in fish stocks, and mangroves, because of their important role as breeding grounds and nurseries for young fish.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following:

- Establish aquaculture/mariculture as an alternative to natural breeding to reduce the economic and social impacts of changing fish abundance
- Promote poultry raising and other livestock as alternative sources of protein to reduce over-dependency on fish for protein
- Integrated reef fishery management
- Research on Impact of Climate change on Fisheries, Sea weed farming and coral reefs

Seaweed and sea grasses

Seaweed farming is an important activity for Zanzibar, supporting livelihoods and a source of major foreign currency earning crop. It also helps to reduce the degradation of the marine environment. Current production is over 11, 000 tons.

The seaweed farming industry which started in Zanzibar during the late 1980s and is viewed as a potential economic opportunity, an alternative livelihood option, an alternative supplement option and an alternative option for reducing pressure on marine resources such as coral reefs, fish and mangroves (Msuya, 1998).

[10] http://www.quest-fish.org.uk/

Seaweed farming has been an important source of income and improved living standards for women on the island (Tobey and Torell 2006), estimates of the contribution of seaweed farming to GDP as well as beneficiary are given below.

Total contribution of seaweed farming and export to GDP and distribution of income by beneficiary and activity in Zanzibar, 2007 (thousand US$)

Beneficiaries	Farming	Processing & export	Total
1. Zanzibari villagers	1,017	90	1107
Wages & salaries		90	90
Mixed income, Operating surplus	1017		1017
2. Urban Zanzibari in urban activities		509	509
Wages and shares		509	509
Mixed income, Operating surplus	-	-	-
3. Urban Zanzibaris in rural coastal activities	-	-	-
4. Zanzibari government		46	46
5. Non- Zanzibaris			
Total	1017	645	1663
Resource rent as share of value added	-	3%	3%
Seaweed % of GDP	0.2%	0.1%	0.4%
Foreign exchange earnings from exports	-	2397	2397
Employment	16,206	216	16,422
Most seaweed farmers are women, not less than 20,000 Most workers in exporting are men, and exact figures are known but there are far fewer workers in exporting than farming.			
Income from seaweed farmers includes the small amount paid to hired labourers; it is not possible to determine how much was paid during these studies. Operating surplus for seaweed exporting companies was assumed to be near zero in 2007			

Source: Lange and Jiddawi (2009)/ Naber et al. (2009)

De la Torre-Castro and Rönnbäck (2004) interviewed fishermen in Zanzibar and found that they valued the supporting ecosystem services that seagrasses had for fish communities and had an in depth local ecological knowledge. They note that there was no institution dealing with seagrass in the area, and that a seascape management approach is recommended to improve social-ecological resilience. They also found with interviews with people in Chwaka village that seagrasses have a variety of uses both as fertilizers and in traditional medicine.

Seaweed farming in Zanzibar has empowered the women from their long time dependent on their husbands in controlling the family's socio-economic needs (Msuya, et al., 1994; Msuya et al., 1996, Jiddawi and Ngazy, 2000). Anecdotal survey from the seaweed farmers show that seaweed farming had been going on very successful during the early 1990s, but serious seaweed die-offs started to be experienced during the late 1990s and 2000s.

Although the sea-weed die-offs along the entire coast of Tanzania was associated with a number of environmental parameters such as increasing sea surface temperature, changing rainfall climate regime, change of wave and climate regime, amongst others, the study of Mmochi et al (2005) conducted at four seaweed farming villages in Tanga revealed that elevation of sea surface temperatures above the tolerance limit of the seaweeds on the intertidal waters was the mostly likely environmental parameter which could be associated with the major die-offs of the seaweeds in many seaweed farming sites. Later studies by Msuya et al (2007) in Bagamoyo, Tanzania mainland where seaweed farms were established in relatively deeper waters using floating lines approach demonstrated that indeed elevated temperatures on the intertidal waters during low tides have been the major limiting environmental factor for the seaweed farming.

There is also some anedoctal evidence of higher sea temperatures leading to increased jellyfish blooms but there are no data records on the islands. Recently there have been episodes or outbreaks of cynabacteria blooms which cause rashes and itchiness among farmers. This has started to be noticed in the last two years specifically along the south East coast of Zanzibar (Bwejuu, Paje and Jambiani) (Jiddawi pers obsr, 2012)

Seagrass meadows provide ecosystem services of valued catches and provide protective shelter for many animals, including fish, and can also be a direct food source for the marine food chain. The roots and rhizomes of seagrasses also stabilise sediments and prevent erosion while the leaves filter suspended sediments and nutrients from the water column (Bjork et al, 2008). They have important linkages to corals and mangroves.

Several studies have been conducted on Seagrass in Tanzania related to biodiversity and environmental impact (Mtolera, 2003; Beer et al, 2006. Gullström et al, 2006, Oliveira, et al 2005).

Seagrass meadows do have high ecosystem service value, with recent estimates (ICUN) of around $19,000 per hectare.

These areas are declining, due to a combination of threats, notably nutrient run off and pollution. There are potential threats from climate change from (Bjork et al, 2008) rising sea levels, changing tidal regimes, UV radiation damage, sediment hypoxia and anoxia, increases in sea temperatures and increased storm and flooding events.

Impacts of Climate Change

The IPCC (Nicholls et al, 2007) notes that sea grasses appear to be declining around many coasts, though this is attributed to human impacts. This might accelerate as climate change alters coastal waters. This may arise from a large number of factors: changes in salinity and temperature, ocean acidification, storm activity and ultraviolet irradiance. However, there could also be some beneficial effects as increases in the amount of dissolved CO_2 could lead to higher rates of photosynthesis (similar to CO_2 fertilisation effects on land), though there may be other limiting factors.

Adaptation

A mangrove and seagrass monitoring project has been set up for Tanzania[11] the Mangrove Management Project (MMP), which is a key first step in the progress towards adaptation. Moving forward, there are effective management practices that could avoid some of these impacts, i.e. to enhance resilience to climate change (ICUN/Bjork et al, 2008) and these measures may also offer broadly benefits in terms of resilience (to the supporting services highlighted above).

This can even include restoration projects (short-term costs of planting projects range between $25,000 and $50,000 per hectare, while long-term costs over the lifetime of a project may be $80,000 per hectare). When compared to the annual benefits of seagrasses (see above), then such projects have a high benefit to cost ratio.

Coral Reefs

Coral reefs line the coast of Zanzibar and provide important resources for the local economies and communities, as well as attracting tourists. These reefs have important roles in coastal protection (against waves, storms and erosion), fisheries, as well as being important tourist sites, i.e. they provide important

[11] http://www.wiomsa.org/mpatoolkit/Themesheets/G4_Monitoring_mangroves_&_seagrasses.pdf

ecosystem services. They therefore have significant economic value. Global estimates of the total annual economic value of reefs has been estimated at between US$100 000 and US$1 million per km^2, where these are close to populated areas or near tourism areas.

There are studies that have quantified the structure of Zanzibar's coral reefs (Bergman and Öhman. These report that Zanzibar (Unguja) has near-shore fringing reefs on the eastern ocean-facing side of the island, though these are limited in extent. There are also small islands and sand bars fringed by coral reefs in the Zanzibar channel, the islands, islets and sand banks in the vicinity of Zanzibar Town, including Chumbe Island Coral Park, Pange, Bawe, Changuu Island) as well as island sites around the north and northwest of the island (Kichwani, North Mnemba and Kendawi Reef). Also several studies related to the status of coral reefs in Tanzania, temperature on shallow reefs off Zanzibar town, environmental effects on the distribution of corallimorpharians in Tanzania, effects of climate and seawater temperature variation on coral bleaching and Mortality has been done in Tanzania (Garpe et al, 2006; Muhando, 2002; Muhando et al, 2002; Muhando and Mohammed, 2002; Mohammed et al, 2005; Mohammed and Muhando, 2002; McClanahan et al, 2007). Regarding coral adaptation to climate change, it has been found that Zanzibar reef building coral species are developing adaptation to climate change at very low rate (Leonard Jones Chauka, unpublished PhD thesis, 2012).

However, there has been widespread degradation of the reefs from a combination of factors, including destructive fishing methods, tourism and eutrophication (Johnstone et al, 1998). These threats are recognised. The MKUZA II (RGZ, 2010) highlights that if coastal erosion and coral reef damages remain unchecked, it will eventually affect tourism, fisheries and Zanzibar's biodiversity.

Vulnerability

Corals are vulnerable to temperature, most obviously as coral bleaching (a whitening of corals, due to stress-induced expulsion or death of their symbiotic protozoa, zooxanthellae). There was mass bleaching of Tanzania and Zanzibar's coral reefs during the 1998 El Nino event (Obura, 2002) with 50% mortality in some regions.

Coral damage following 1997/98 El Nino event

Area of reef	Estimate of coral damage
Tanga	25% of corals bleached
Zanzibar Area	25-50% of corals bleached
Changuu and Chapwani, Zanzibar	Less than 40% surviving after bleaching
Bawe, Zanzibar	60-80% survival after bleaching
Chumbe	80-95% of Acropora Spp. bleached, 60-80% survival of corals after bleaching
Mafia Marine Park	80-100% of coral death
Tutia Marine Park, Mafia	More than 95% coral damage
Mnazi Bay, Mtwara	15-25% of corals bleached, with 50% survival of corals after bleaching
Kinasi Pass	80-90% Acropora spp. death

Source: Oburu (2002)

The IPCC's Fourth Assessment Report (A4R) mentions the coral bleaching event in 1998 citing this reduced the combined tourist revenue of Mombassa and Zanzibar by an estimated 12 to 18 mill USD.

There is anecdotal evidence that coral reefs around Pemba may be less affected by coral bleaching due to high sea surface temperatures than similar reefs around Unguja. Most of the coral mortality during the 1998 El Nino event was experienced in Zanzibar and Mafia[12].

Impacts of climate change

Coral reefs are particularly vulnerable to future climate change (Grimsditch et al (2006) due to coral bleaching (whitening) from increased sea surface temperatures, leading to reduced growth rates and potential mortality – and even modest temperature increases of 1 or 2ºC above average over a sustained period of time (i.e. a month) can cause mass bleaching. While some corals recover their natural colour, their growth rate and reproductive ability may be significantly reduced for a substantial period. If bleaching is prolonged, or if SST exceeds 2°C above average seasonal maxima, corals die, with branching species appearing to be more vulnerable.

As highlighted earlier, it is likely that sea surface temperature (SST) may be increasing faster in shallow areas (see earlier chapter). This would imply that Zanzibar (Unguja) may see a faster increase in SST than areas with deeper water such as Pemba. It might also suggest that the shallow corals will be affected first.

What seems certain is that bleaching events are likely to become more common, and is likely to further reduce both coral cover and diversity on reefs over the next few decades (Nicholls et al, 2007). These systems are very vulnerable to thermal stress and have low adaptive capacity. It is also very likely that projected future increases in SST of about 1 to 3°C (see earlier section) will result in more frequent bleaching events and widespread mortality, if there is not thermal adaptation or acclimatisation by corals and their symbionts.

Apart from coral bleaching, the other climatic issue of concern on coral reefs is sedimentation. The anticipated increase in rainfall, increase in wind speeds and increase in wave climate regime may lead to higher sedimentation on coastal areas with adverse impacts on the coral reefs. Excessive sedimentation smother the corals tissue and reduce light levels and food supplied to the coral by the symbiotic algae (Woolfe and Larcombe, 1999). Excessive sedimentation may also hamper, coral settlement, survival and growth in coral restoration programmes (Muzuka, 2010).

Additional impacts may arise from excessive UV-radiation, from changes in seawater chemistry (acidification) decreasing coral calcification rates, growth rates and structural strength and from rising sea levels. Again, these risks need to be seen in the context of other pressures, notably from human activities. There may also be pressures from additional increases in storm intensity.

The loss of corals will affect marine ecosystems and fisheries, but also can result in increased wave energy and shoreline erosion (due to the loss of wave protection that the corals provide).

Adaptation

The Zanzibar Adaptation Programme of Action for Zanzibar recognised the importance of corals and proposed a series of measures (see box).

Other studies report on possible approaches. Tools and strategies for enhancing coral reef resilience (Grimsditch et al (2006) include monitoring, transplantation, marine protected areas (mpas), integrated coastal management (icm) and fisheries management. The IPCC also highlights some adaptation potential, with natural adaptive shifts to symbionts with +2°C resistance which might delay reef mortality over the next century (though highlighting this requires additional research and will vary local).

[12] Personal communication Val Byfield, Phil Woodworth and Simon Holgate (University of Southampton/Liverpool).

Zanzibar has set up a number of marine parks and conservation areas, including the Jozani Chwaka Bay National Park (NEMC (2006) and Mnemba Island Marine Conservation area (MIMCA), Menai Bay conservation area, Unguja and Pemba Channel conservation area (PECCA) Pemba.

There is further coral reef research and capacity building on-going at the Institute of Marine Science, including the mapping and characterisation of coral reefs and associated threats.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Acquire appropriate sewage treatment technologies
- Analyzing the environmental consequences of shore protection
- Developing county-scale maps depicting which areas will require shore protection (e.g. dikes, bulkheads, beach nourishment) and which areas will be allowed to adapt naturally
- Engaging state and local governments in defining responses to sea level rise
- Enhance the capacity for waste management to prevent pollution of marine environment
- Establish marine protected areas
- Identifying land use measures to ensure that wetlands migrate as sea level rises in some areas
- Improving early warning systems and flood hazard mapping for storms
- Promoting shore protection techniques that do not destroy all habitat
- Protecting water supplies from contamination by saltwater

There is also some relevant adaptation options from the mainland, reported in the Tanzania adaptation fund application. This includes actions to support reef rehabilitation with a view of restoring live coverage, using in situ techniques for coral breeding and transplantation, and instituting, with the support of local NGOs and communities, better management and enforcement systems. The estimated costs are based on the World Bank Reef Rehabilitation Manual (as well information from) other countries and the proposal estimates the cost of rehabilitation, including equipment and labour, training, and breeding, at 110,000US$ to undertake spot seeding and transplantation for a total area of 2000m^2 (0.2 ha) of degraded reef, with each plot expected to increase at a 75% annual rate, when combined with protection and management. Note that there is some field evidence on transplantation of corals in Tanzania, which leads to the rates cited[13].

Mangroves

Zanzibar has extensive mangrove stands (see later forestry section). The MKUZA II (RGZ, 2010) highlights the maintenance of these stands is important, not only for protection against coastal erosion and storm protection, but also because it provides breeding grounds for fish, crustaceans and molluscs. They also provide wood sources, as well as acting as natural filters, and they may also help in preventing saltwater intrusion. Mangroves provide a valuable ecosystem function and services. The ecosystem services are significant, and have a high economic value (estimated in the global literature at $200,000 - $900,000 per hectare (Wells et al. 2006).

[13] The project report cites documented experience in Tanzania which showed that transplanted corals demonstrated 90 to 100% survival after 8 months, and growth and increased coverage rates of 54% to 125% for certain species after 23 months. Therefore, combined with appropriate training for local communities and reef users, the project reports it could help increase reef coverage by an average of 75% annually (for an estimated area of 18,757 m2 by the end of the project, continuing afterwards).

There is some potential for mangrove harvesting. Although locally significant, mangrove harvesting is presently a minor activity because of the massive loss of mangrove forests, particularly on the main island of Unguja. Rough estimates indicate that the value of mangrove harvesting in 2007 was in the range of $28,000 (Lange and Jiddawi 2009, Nbsser et al. 2009).

There are numerous studies of the mangroves on the islands (Ngoile and Shunula, 1992; Wily et al, 2001; Myers, 2002; Shunula, 2002; Wang et al, 2003; Masoud and Wild, 2004; Saunders et al, 2008; Bandeira, et al, 2010; Saunders, et al, 2010;Crona, et al, 2009). These reveal the significant pressures these mangrove systems are already and the loss that has already happened. These wider pressures on these important systems is critical to the implementation of future risks and adaptation.

However, these trends can be reversed. The management of mangroves in Jozani Chwaka Bay National Park (NEMC (2006) have encouraged more sustainable mangrove use. Similarly, the Menai bay conservation area, Zanzibar, which has applied restoration approaches include: raising awareness of local communities on environmental education, regeneration/ restoration of mangroves and management of tourism.

As highlighted above, a mangrove and seagrass monitoring project has been set up for Tanzania the Mangrove Management Project (MMP).

Impacts of Climate Change

Mangroves are potentially vulnerable to the impacts of climate change, from a combination of sea-level rise, salinity (and salt water intrusion) and storms, as well sea surface temperature. However, impacts are determined by other factors notably whether these systems have sufficient sediment supplies and/or room to move inland with rising sea levels (McLeod and Rodney, 2006). They may also be affected by changes in temperature and precipitation (and hydrology), as well as from atmospheric CO_2 concentrations (including potential positive effects from fertilisation). Mangrove ecosystems on low relief islands may, however, be particularly vulnerable. There may also be interactions between coral and mangroves (e.g. in terms of protection). All of these changes have to be seen in the context of other pressures, notably from human activities (land use change, unsustainable use of wood products, eutrophication and pollution, etc.).

Adaptation

There are general resilience options for mangrove conservation, such as (McLeod and Rodney, 2006) risk strategies, identification of critical areas, managing human stress, establishing buffer zone (for migration), restoration, connectivity, monitoring, adaptive strategies, alternative livelihoods and partnerships. The possible use of mangroves as an adaptation measures (ecosystem based adaptation) was described in detail in the earlier section. It is highlighted that these offer a low cost measure for enhancing coastal protection, as well as increasing all the ecosystem service benefits of mangroves. There is also some potential in relation to sequestration/carbon sinks discussed later.

Agriculture and Livestock

Agriculture is one of the key economic sectors for Zanzibar. It is also the main source of employment for the population, as well as an important economic sector for food production, employment generation, production of raw materials for industry and foreign exchange. Cash crops are grown entirely for export and manufacturing, with small amount are used as spices.

The main food crops grown in Zanzibar are cassava, rice, banana, sweet potatoes, yams, legumes (cowpeas, green gram and pigeon peas), fruits and vegetables. Cereals such as maize, millet and sorghum are also grown although not widely. Cassava is the primary staple, which is virtually grown by almost every rural household. The data on recent food production is summarised below.

Production of Food Crops, 2006 – 2010 (tons)

Crop	2006	2007	2008	2009	2010
Maize	3,927	1,931	1,933	2,063	3,112
Sorghum	409	794	615	457	572
Paddy	24,730	20,038	20,889	26,980	31,000
Cassava	190,266	187,213	153,103	195,674	229,284
Banana	88,438	93,641	103,145	100,873	102,258
Sweet potatoes	63,949	45,620	55,301	53,596	58,958
Yams	5,100	8,192	3,516	11,373	7,488
Tania	8,408	4,191	8,459	5,883	5,812
Groundnuts	1,800	76	465	320	432
Pigeon peas	-	-	1,682	2,292	510
Cowpeas	960	771	1,719	1,394	1,103

Value of Food Crops, 2006 – 2010 Million T Shs

Crop	2006	2007	2008	2009	2010
Maize	1,669	821	958	1022	1,862
Sorghum	182	353	116	276	390
Paddy	7,815	6,332	12,816	16553	17,341
Cassava	21,881	21,529	33,745	43,119	57,882
Banana	22,552	23,878	44,331	43,355	46,502
Sweet potatoes	4,987	3,558	10,966	10,627	10,946
Yams	514	3,629	1,498	4,845	4,157
Tania	1,850	922	5,745	3995	5,194
Groundnuts	1,629	69	502	345	452
Pigeon peas	-	-	979	1,210	497
Cowpeas	436	350	1,038	842	1,122

Source: Source: Zanzibar Statistical Outlook, RGZ, 2010.
Ministry of Agriculture and Natural Resources, JKU and Mafunzo

Quantity of Production of Main Cash Crops, 2006 – 2010 (tons)

Crops	2006	2007	2008	2009	2010
Cloves	3,157	1,086	4,007	3,536	2,129
Clove Stem	132	227	345	445	317
Seaweed	7,543	8,485	11,177	10,248	12,516
Rubber	887	974.2	1,479	428	564

Source: Source: Zanzibar Statistical Outlook, RGZ, 2010.
Zanzibar State Trading Corporation (ZSTC)

Value of Main Cash Crops, 2006– 2010 Million T Shs

Crops	2006	2007	2008	2009	2010
Cloves	8,160	2,894	13,006	10,224	7,447
Clove Stem	8	16	32	44	45
Seaweed	871	1,269	1,784	1,666	2,983
Rubber	800	1,294	2,169	695	916
Total	9,841	5,473	16,992	12,629	11,390

Farming is generally small scale. As highlighted in the MUKZA II, Zanzibar's Agriculture sector is dominated by small-scale subsistence farming, with low productivity of land, labour and other inputs. The low productivity levels arise from a combination of factors (poor crops, lack of fertiliser, lack of appropriate technologies, lack of infrastructure, limited finance to obtain productivity-enhancing inputs; inadequate provision of agricultural support, etc.). As a result, much of the agriculture is subsistence farming. There are also high post- harvest losses due to poor handling, poor storage facilities and inadequate processing technology, reported as 13, 26, 42% for rice, cassava, vegetable (tomatoes) respectively. There have also been poor agricultural and soil management techniques which have resulted in loss of topsoil, erosion, and soil deterioration.

The total cultivable land in Zanzibar is estimated at 370,645 acres, out of which nearly 20% percent is grown under food crop (MALE, 2006) and the available irrigation potential is approximately 21,053 acres. Irrigation development is constrained by high cost pumped schemes and low efficiency due to lack of canal construction and poor water management. Paddy rice is the major irrigated crop. However, few farmers irrigate vegetables and fruits.

However, Zanzibar is not self-sufficient. The shortfalls come from imports, the main ones of which are rice, wheat flour, beans and other pulses, maize flour, sugar, fruits and vegetables. While most of the rice, wheat flour and sugar are imported from East Asia and Europe, maize flour and pulses come mainly from Tanzania mainland, which also supplies limited volumes of high quality rice (MALE, 2006).

The statistics also report approximately 160 000 cattle on the islands, 50 000 goats and over a million chickens. The livestock sub-sector is expanding rapidly.

There is high variability in the level of food production, and previous studies have undertaken livelihood mapping for the island[14]. More recent (see earlier section), soil mapping is being undertaken to build up a more detailed picture.

[14] The Household Economy Analysis for Zanzibar conducted by the Government of Zanzibar (GoZ) in collaboration with the World Food Programme (WFP) and Save the Children (SC-UK) in 2003

A number of agricultural initiatives are now in place to address many of these issues. The Tanzania Agriculture and Food Security Investment Plan (TAFSIP) has a set of initiatives, which include irrigation development, disaster management (and climate change mitigation), food and nutrition security etc. The Blueprint on rice and the Agriculture Transformation Initiative outline the need for irrigation and there is an Irrigation Master Plan, with a number of projects that will total some 4000 hectares of rice and 1000 hectares of horticultural under irrigation. The Zanzibar Agricultural Transformation Initiatives (ATI) is looking to pursue sustainable agriculture objectives (including conservation agriculture) and there are Agricultural Services Support Programme (ASSP) and Agricultural Sector Development Programme-Livestock (ASDP-L).

Vulnerability

Agriculture is a highly climate sensitive sector, and the poor performance of the sector in recent years (see GOZ, 2010) is due to recurrent droughts, which have recently increased both in frequency and severity.

In 2006 – and especially 2007 – had low and erratic rainfall led to widespread crop failures. The agricultural statistics do show lower value in 2007, as shown below, and appear to have contributed to a relative reduction in GDP in that year. The following year, 2008 Zanzibar experienced a hunger crisis resulting from 2006/07 poor crop performance, affecting 300 000 people (see climate variability section).

As highlighted in the Vision, and the MKUZA I and II documents, the transformation of Zanzibar's agricultural sector is key to its socio-economic development, and ideally the islands must progress further towards food self-sufficiency.

As well as impacts on agriculture the 2007 season led to the deaths of many livestock (see MALE, 2006), partly from problems with storage of pasture over dry and hot seasons. There have also been some cases of livestock disease (though also some response programmes).

These changes also need to be seen against international food prices, and the rise over recent years, which is important given food imports on the islands.

Another widely reported effect, as in the **Zanzibar Adaptation Programme of Action,** is the periodic flooding from sea water of rice fields and other low lying areas near the coast (potential sea level change or perhaps a result of degraded mangroves etc.). However, the ZAPA highlights there is no scientific evidence that climate change is the cause. Further it reported unreliability of seasons. Ten years ago it is reported that it was possible to almost tell the exact date on which the rainy seasons would start, but this is now highly unpredictable changing by more than a month in both directions. This affects crop planting dates for farmers, and reports that often the rainy season is too short to ensure a fully grown crop.

The Key Risks from Climate Change

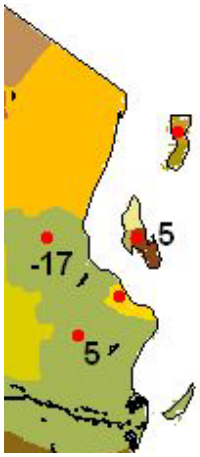
Agriculture is a climate sensitive sector and will be affected by climate change, potentially both positively and negatively. Temperature and other climatic changes will affect yield and growing season and there is also a potentially direct (positive) CO_2 fertilisation effect.

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).

There is the potential for agro-ecological zones on the islands to shift with climate change, which might significantly affect the current crop mix. For certain crops, there are likely to be negative impacts on productivity (yield).

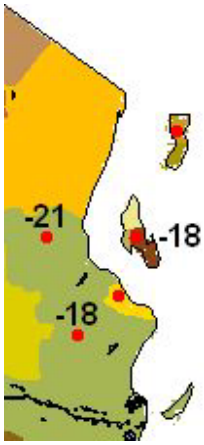
There are a large number of studies that have looked at the effects of climate change in Tanzania, which also cover Zanzibar. These focus on maize – a climate sensitive crop – and report overall maize reductions (in the absence of adaptation) overall, though individual areas of the country experience a mix of positive and negative effects.

As an example, Tumbo et al (2011) estimated the effects on maize, looking at the projected yield changes for two existing model emission scenarios, for 2030 and 2050, for URT. This has a high regional disaggregation and shows overall maize yield losses of between 10% and 20% by 2030 and between 20% and 40% by 2050 (with no adaptation), but noted that the scale of change depends on the climate projections, and highlight uncertainty on temperature and especially precipitation. The results for Zanzibar are shown below. These indicate potentially modest benefits in the short-term (possibly of a few % productivity), but then potentially large impacts (-18 - -46%) by 2050 – though there might be differences between the two islands in terms of the level of effects.

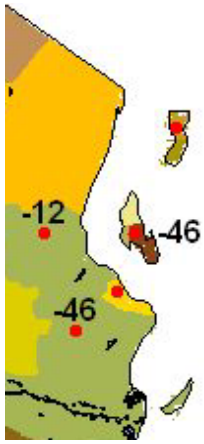


(a) 2030-A1B maize yield changes (%)

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



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



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

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
Source: Tumbo et al 2011.

In very simple terms, based on current (2010) maize production (see earlier statistics) this would translate through to losses of 500 to 1500 tons, and based on crop values reported in the statistics, losses of 300 to 900 million shillings, by the 2050s (around US$0.2 to 0.5 million/year), assuming no adaptation. Similarly, using the values cited by Munishi et al (2010), which cites the average price for Maize in East Africa (based on FAO, 2009) at US$332 per tonne, this would translate through to around $0.2 to 0.5 million/year by the 2050s. Note, however, that in the short-term (to 2030) very modest effects – or even slight benefits - are projected.

Of course, maize is not the most important agriculture crop on the island – as shown by the earlier statistics, although the effects of climate change would affect the islands by affecting production on the mainland and thus imports (and import prices).

Other crops therefore need to be assessed. Rice is a particularly important crop for the island. Rice is sensitive to temperature (as outlined by the IPCC, Easterling et al, 2007) though not to the same degree as maize. Rowhania et al (2011) investigated the effects of climate change on rice production in Tanzania, finding temperature increase (of around 2 degrees) would reduce yield by around 16% by 2050, that a small increases in rice yield might arise with precipitation increases, and that changes in seasonal precipitation (a 20% change in variation) could lead to a reduction of around 8%.

For bananas and plantains, climate change may alter both yields as well as vulnerability to disease. Some indicative studies estimate up to a 10% reduction in suitability for bananas in the region[15].

There are potential effects of climate change on cassava, mostly associated from the risk of increases in rainfall However, the crop is resilient to drier conditions, hence its widespread use in Africa, and its potential role as an adaptation strategy for areas projected to get drier and hotter.

As well as direct production, there may also be changes to pests and diseases. In the longer-term, there is the potential for major agro-ecological shifts, which is potentially an issue due to the small geographical area of the islands – though future zones are likely to remain within tolerance levels for production.

A potentially greater impact – even in the short-term – is from the intensification of rainfall in rainy seasons. There are also are risks from salt water intrusion for some coastal (rice) fields.

It is also important to consider cash crops, the most important of which are cloves. The Mkuza II document outlines the plans to increase clove productivity on the islands. There is generally a low level of knowledge on the direct effects of climate change on such aromatic plants (see Easterling et al, 2007). However, clove trees are susceptible to wind damage (with more extreme winds, trees lose their leaves which loses production for several years) – an issue that has become more evidence in Madagascar which has seen some recent intensification/frequency of cyclones (IDRC, 2010). While Zanzibar does not experience such strong wind extremes, this is a potential issue from changing climate variability.

Finally, it is important to consider the livestock sector. The 2005/6 dry spell caused shortage of pasture and water, increased livestock susceptibility to diseases, and reduced livestock productivity (MALE, 2006). These also present risks from future climate change, with the additional threat of heat stress of animals.

Adaptation

Agriculture is clearly a key priority for adaptation, especially in relation to existing climate variability. Earlier recommendations were made for enhancing food production that have high relevance for climate change, with the most important being to strengthen agricultural extension services, strengthen early warning systems and to improve agro-meteorological services.

MALE (2006) reports a number of short and medium-term that address food insecurity. These are reported below, as they have high relevance for the resilience to current vulnerability and future climate change. In the short-term, some issues still have relevance:

(The Government assists livestock keepers in hard hit areas to vaccinate calves against East Coast Fever (ECF) and black quota and de-worming them to protect them from diseases during the post drought period. It is also recommended that the Government reduce or waive taxes on livestock feeds, drugs and vaccines for a period of April-August 2006.

Farmers are advised to make full use of the masika rains by planting short-term, drought tolerant, and early maturing varieties that are also resistant to diseases to address the situation.

[15] available online at (www.amkn.org).

The Regional and District Authorities as well as the community at large solicit all possible coping strategies available in their respective locations based on sustained livelihoods before requesting for intervention from the national level.

In the medium-longer term, they highlighted

Rehabilitation of Irrigation Schemes: Currently only 494 acres are at present irrigated out of 1,235 acres developed. It is recommended to rehabilitate the 494 acres by reinstalling the infrastructure. It is also recommended to develop additional irrigation schemes to exploit further the available potential.

Strengthen agricultural extension services: It is necessary to increase farmers' access to quality agricultural extension services. It is recommended to provide extension workers with refresher courses to update their skills and to increase allocation of resources and equipment to extension services. It is also suggested to improve working environment to the staff. Extension services are also required in promoting, planting and managing pasture and use of crop debris in the dry season.

Strengthen Early Warning System and formulate FSIT: The Early Warning Unit (EWU) within MALE is still at juvenile stage as it lacks the capacity to monitor and assess the food situation. It is recommended to build the capacity of the EWU through provision of training and equipment and, at the same time allocate adequate budget. On the other hand it is suggested to formulate a Food Security Information Team (FSIT) that will involve various stakeholders for joint assessment and monitoring of food security and other disaster related issues.

Seed production: At present the Bambi and Ole Seed Farms in Unguja and Pemba respectively lack appropriate irrigation and seed processing infrastructure to meet production of seed demands. It is recommended to rehabilitate the farm through installation of irrigation infrastructure, machinery and equipment. It is also recommended to encourage community based seed production.

Agro-meteorological services: Most of Agricultural weather stations are either not working or in bad condition. It is recommended to rehabilitate the stations and installing new ones in selected strategic points. It is also suggested to increase collaboration and networking with TMA and other stakeholders.

The Zanzibar Adaptation Programme of Action for Zanzibar (ZAPA, 2010) identified the following

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Afforestation
- Agro forestry
- Altering the timing of planting seasons to adapt to changing growing conditions
- Alternative to wood energy, including efficient wood energy stove
- Breeding new plant species and crops that are more tolerant to changed climate conditions
- Community-based forest and rangeland management and rehabilitation
- Conservation and management of forest reserves/catchments/national parks
- Controlling insect outbreaks
- Developing the capacity of providers of business development services (BDS) and financial services (FS) to input suppliers.
- Drought early warning systems for disaster preparedness
- Environmental friendly enterprises
- Environmental/conservation awareness

- Establishment of demonstration farms with micro management of soils: spot irrigation, recycling of nutrients, mulching, pest management, etc.
- Establishment of forestry research plots where different tree species' production is moni-tored under different conditions
- Extension services in agricultural capacity strengthening for small scale farmers
- Extension workers trained in organic/biological pest and disease control methods.
- Increase local food production through new technologies and strengthening of marketing and sale of local food items
- Introduction of drought-resistant seed varieties.
- Poultry and fish production.
- Land use conversion from agricultural activities to livestock raising.
- Introduction of alternatives to fire wood of non-fossil energy sources.
- Low-interest credit made available to farmers to improve irrigation infrastructure (such as bore holes, pumps, pipes and drip irrigation technology), for example, in the form of cost-sharing revolving funds within producers' groups, along with investment in tech-nology affordable to farmers.
- Maintain nurseries that provide cultivars and other planting materials.
- Mangrove management.
- Promote partnerships with external institutions for expertise and knowledge sharing.
- Promotion of "Tree Planting Day".
- Promotion of private-public initiatives, such as investment by hotels in irrigation infra-structure.
- Promotion of, and training in, organically based agribusiness and support with certification (e.g. Tanzania Certification Organisation TANCERT) to help farmers command premium market prices.
- Protection and/or rehabilitation of rangelands, including construction of shelterbelts to reduce windstorm impacts.
- Quotas for logging to promote reforestation.
- Replacement of household goat herds with sheep herds to reduce pressure on fragile rangelands.
- Research and development of appropriate low-cost water harvesting and storage techniques.
- Seedlings production.
- Strengthening of agricultural and veterinary extension services, including demonstration of improved techniques suitable for small scale farmers e.g. conservation tillage and drip irrigation.
- Tax exemption for input suppliers to subsidise selling prices.

There is a need to consider these options against sectoral objectives and other plans.

The MKUZA II (RGZ, 2010) highlights that given the seasonality in crop production and climate, investment in water harvesting techniques and expansion of land under irrigated farming would be the best option for ensuring stable and higher agricultural productivity. There is potential to increase both smallholder and large-scale irrigation farming, as well as reducing post-harvest losses.

A new project on drought resistant maize (water efficient maize) has also recently started which includes Zanzibar[16]. There is also a Regional Initiative for Smallholder Agriculture Adaptation to Climate Change in the Indian Ocean Islands, which is advancing conservation agriculture.

[16] http://www.ippmedia.com/frontend/index.php?l=25900

A particular focus going forward (Tumbo et al 2010) is the need to pick adaptation options that provide resilience, and are robust against the range of potential future changes from climate change. The best of these also have wider ancillary benefits, in reducing impact to current climate variability, and helping with wider cross-sectoral issues of agriculture. This would include (Tumbo et al, 2011) measures such as

- Soil and water conservation, i.e. measures that can retain soil moisture and reduce soil loss. This can include a variety of approaches, grass strip, but also includes terracing which might have particular relevance for Pemba.
- Smallholder irrigation, to increase productive capacity, improve both household food security and income of farmers; and hence alleviate poverty.
- To strengthen the capacity of agricultural research institutes to conduct basic and applied research, improve the number of extension officers, and to encourage climate information data collection, analysis and dissemination (notably with weather forecasts). As highlighted above, 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, whereas village extension workers could act as important channel in the dissemination of climate and weather information.
- No regret options such as reducing post-harvest losses.

Some other potential options include insurance (or micro-insurance), non-farm employment and diversification.

There are also potential opportunities to the low carbon side – discussed in the low carbon report as well – which include climate smart agriculture, conservation agriculture, and agroforestry, some of which are already happening on the islands. 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.

Conservation agriculture incorporates a wide range of practices aimed at minimizing soil disturbance, such as reduced tillage, and minimizing bare, uncovered soils, as well as incorporation of residues or other mulches. Agroforestry generates adaptation benefits through its impact on reducing soil and water erosion, improving water management and in reducing crop output variability

Many of these are captured by sustainable agricultural land management (SALM) practices, which for example, adopts techniques to improve soil water infiltration and holding capacity, as well as nutrient supply and soil biodiversity, and include options such as agroforestry, soil and water conservation, reduced or zero tillage, use of cover crops, various soil and water conservation structures, and grazing land management.

While these SLM activities increase productivity in the medium to long run through improved soil characteristics and water retention, in the short run, cultivation intensities and yields can be modest, and there is a need to educate farmers on these benefits, to have pilot farms to demonstrate the benefits and enhance awareness raising and training, and broader support. There may also be a need for additional costs to offset short-term changes (see McCarthy et al, FAO, 2011).

These sustainable approaches are considered a priority for adaptation on the islands, because of their potential to build resilience, increase production and generate natural resource and ecosystem benefits.

For cloves, short-term responses involve pruning of clove trees to reduce the loadbearing capacity and reduce the risk of uprooting. In the medium term, there is the potential to try and diversify, though other options, such as re-vegetation to provide wind buffers could be important. Given the importance of this single crop, and the changes in extremes on the island, some early adaptation would seem sensible in this area.

Tourism

Tourism is an important and growing contribution to the economy of Zanzibar, especially when indirect economic activity linked to tourism are included, as well as being a significant source of employment on the islands (as an example, total employment in the tourism industry in 2008 was estimated at 10,500 people in direct activities and over 40,000 people indirectly, source ZATI, 2011). Tourism is also a highly climate sensitive sector, and thus a key area for analysis.

The number of annual international tourist arrivals has been increasing in recent years. Most of these are from Europe (with the highest numbers from Italy).

Annually Recorded Number of Tourist Arrivals in Zanzibar by Country

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010
Scandinavians	5,831	4,642	5,616	7,052	8,400	8,807	8,791	8,719	7,814
Germany	3,705	3,245	3,526	4,347	4,794	7,091	6,990	8,188	8,750
British	13,012	7,945	9,810	12,963	14,180	14,204	12,949	13,377	13,757
Italy	25,044	18,586	29,278	50,037	49,658	52,046	41,610	45,244	41,234
France	3,360	2,907	3,389	3,085	4,838	4,255	3,958	4,608	4,415
Other Europeans	14,509	13,816	16,087	17,777	18,329	18,744	14,740	16,778	17,647
U.S.A and Canada	6,178	4,137	4,949	6,915	8,624	10,328	10,100	9,540	9,436
Other Americans	270	197	911	310	491	577	590	931	1,309
Kenya	2,428	2,276	2,735	3,231	3,857	3,924	4,722	4,414	5,054
South Africans	3,356	3,170	4,595	8,993	11,769	9,246	8,746	9,575	9,410
Other Africans	2,103	1,420	1,723	1,874	2,618	2,863	3,744	3,406	3,015
Japan	707	540	566	571	678	915	727	799	718
Other Asia	2,734	1,807	2,913	4,406	4,169	5,572	6,326	5,477	5,708
Australians / New Zealand	4,274	3,677	3,597	3,961	4,706	4,693	4,452	3,898	4,569
Total	87,511	68,365	89,695	125,522	137,111	143,265	128,440	134,954	132,836

Source: Zanzibar Statistical Outlook, RGZ, 2010.

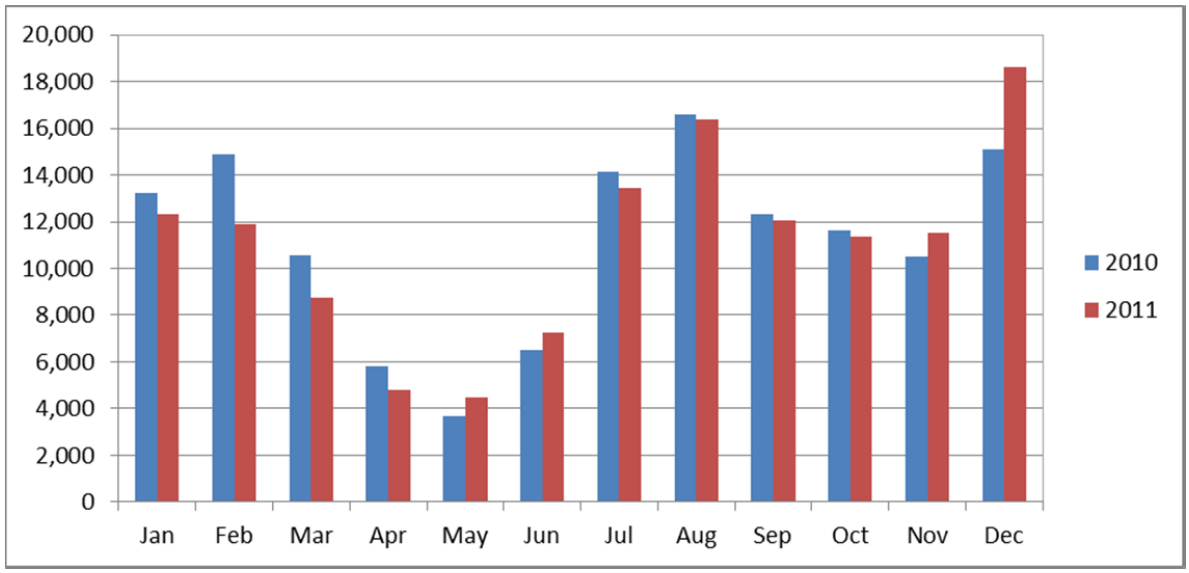
These figures do not include all arrivals, because of the number of people who come through Dar (e.g. on two centre trips) and separate information from ZATI estimates that the total number could be closer to 250,000 tourists a year, with recent annual growth rates that are very high (8-10% a year).

There is a strong monthly variation, which is important in relation to the climate, shown below for the past two years. This generally involve two peak seasons, first, the period December to February, and second the July – August European holiday season. Tourism numbers drop very significantly during the April to June wet season.

When indirect and multiplier effects are included, tourism is one of the biggest sector on the islands, and as highlighted in the earlier Vision document, the plan is for it to grow significantly in future years. Any potential impacts of climate change on this sector are therefore important.

Tourism on Zanzibar is a combination of beach, activity (water based), historic tourism (Stone town) and destination tourism – and there are a different tourism zones such as Stone Town, the Northern Peninsular and North-East Coast, the South East coast and Pemba – and a mix of high quality, middle

market and budget niches (and accommodation), though the plans are to focus on up market, high quality markets.



Zanzibar Monthly Recorded Tourist Arrivals, 2010 and 2011

Source: Zanzibar Statistical Outlook, RGZ, 2010.

The current (tropical) climate of the islands is undoubtedly one of the islands attractions. There does not appear to have been detrimental effects from recent extreme (climate events), but the loss of the electricity connector in 2009/10 did significantly impact on the tourism sector. This highlights the potential vulnerability to shocks/extremes.

The corals are an important part of Zanzibar's overall tourism attractiveness. The coral reefs provide excellent diving and snorkeling opportunities, which is also a major attraction for foreigners to the island. Tourists spent $184.9 million US in 2007. Beach vegetation is perceived important on social grounds as it shelters villages from beach users, the shelter provided has a cultural importance partly due the fact that Western tourists beach attire is in contrary to Islamic cultural norms (Mustellin et al. 2011)

Tourism is itself a major driver of socio-economic change, not least through development (Mustelin, 2009). It also leads to cross sectoral links (and pressures) in relation to water resource availability, energy demand, land-use (change), etc. However, there are some initiatives that are addressing this, such as responsible tourism.

Finally, tourism on Zanzibar is very closely linked to mainland Tanzania. Indeed, there has been a strong integration between the two. The average stay on the islands is only 3 - 4 days (ZATI, 2011) and thus many tourists visit as part of a longer country (URT) visit. This is important because the effects of climate change on mainland tourism will impact on Zanzibar (even though Zanzibar is looking to attract its own uniqueness as a destination).

Impacts of climate change

The impacts of climate change on tourism on the islands are complex, because of the combination of direct and indirect effects, but also because of the nature of the tourism on the islands which includes multiple segments (beach (mass, back-packer and exclusive/niche), historic, recreation (coastal and marine), adventure, and destination tourism.

Each of these will be affected in different ways by climate change, and these effects also have to be seen in an international context, because of the comparative changes elsewhere. It is also stressed that the impact of climate change on Zanzibar will be linked to changes on the mainland, because of the linkages of multiple destination trips (e.g. game parks in Tanzania followed by Zanzibar).

The most obvious effect on potential tourism is on the climate of the islands. Tourism is closely associated with climate, for both the source of tourists and their preferred destination. This is particularly true for European summer tourism, which makes up the majority of international flows (see table above) and is a major source of beach tourism from Italy, but in relation to the relative attractiveness of the islands as a destination in the dry versus the rainy seasons.

Changes in temperature and rainfall (i.e. climate) can affect the destination preferences of tourist, as shown clearly in the monthly statistics above. This can act in two ways. Future changes in climate may affect the attractiveness of Zanzibar as a European summer destination. This can be assessed by a measure known as the Tourism Comfort Index (TCI)[17]. However, these changes need to be seen in the context of other destinations, i.e. effects on Zanzibar will also be affected by the relative changes in other destinations, i.e. which will become more or less attractive (to Europeans) as a result of climate change (see box).

Changes in climate, primarily driven by increases in temperature, are expected to start affecting the TCI of some locations in Europe, whilst at the same time the TCI for many of the (currently cooler) regions is likely to improve.

A schematic of the sorts of changes likely to happen (for example in Southern Europe) in peak months (august) is highlighted right – such that tourists may switch to alternative cooler destinations. However, this may lead to some positive effects on these hotter climates, as their shoulder seasons become more attractive).

It is difficult to provide accurate assessments of the TCI for Zanzibar, because the meteorological data needed is not available (though it is possible this could be addressed with analysis). However, a simple comparison against current high season temperatures in Europe (e.g. see Ciscar et al, 2011) does not suggest that the TCI of Zanzibar would be too determinately affected, at least in the short-medium term.

However, there is a recent study that was conducted in Zanzibar, in order to understand tourist perceptions of climate change, the importance of climate for travel decisions, and the likely consequences of ongoing climate change for travel decisions (Gössling et al, 2006). The results show that climatic characteristics of destinations are important, though not the only factor shaping travel decisions. The authors also found that under a scenario of climate change, certain climate variables, such as more rain, storms, and higher humidity were likely to negatively influence travel decisions, rather than higher temperatures alone, which are not necessarily perceived as negative.

[17] The TCI is an index, ranging from 0 to 100, based upon a range of climate variables that reflects the suitability based upon an individual's bioclimatic comfort. The TCI can be constructed for different temporal and spatial scales (data permitting) and the variability between locations and regions can be examined. The TCI can be constructed on a daily monthly, seasonal and annual basis and can be driven by observational or modelled climate data.

In line with these findings, some of the greatest potential risks from changes in climate are likely to arise from any changes in the wet season and extreme events. The projections indicate much higher intensity of rainfall in the current wet seasons, which would be likely to further decrease the attractiveness of the islands during these periods.

The other direct effects on the industry are likely to be on the existing infrastructure and assets, i.e. the hotels, in the context of sea level rise and shoreline erosion. These have already been recognised by the tourism industry with the assets/infrastructure (Mustelin, 2009), from coastal erosion affecting beaches and coastal properties. These issues are discussed in the earlier coastal section.

A range of other effects on the tourist industry will also arise, from impacts on other sectors or tourism inputs, e.g. from changes to water resources (water availability and water supply), energy (especially for cooling/air conditioning), health and biodiversity and ecosystems.

In relation to energy, an additional impact on the tourism industry itself will be the higher costs of air conditioning with future warmer temperatures – discussed in the energy sector below. Survey work on the tourism industry reports that all four- and five-star hotels have air conditioners in their guest rooms (compared with 53 percent of one-star hotels). The growth in future hotels on the islands (many of which are targeted at higher end tourism) will increase the current cooling demand, and climate change will increase consumption rates even more.

Tourism is also a very water intensive industry, with high consumption rates per tourist (far in excess of baseline household consumption). There is some earlier data for Zanzibar (in Gössling et al (2012) reporting statistics from Gössling et al (2001)) which reports basic tourist consumption rates are around 136 litres per tourist per day in guesthouses (for showers, toilet, and the use of tap water) and 186 litres per tourist per day in hotels, with the higher demand in hotel a result of additional showers taken at pools, and more luxurious bathroom facilities. However, the same study also reports that total water use is much higher than this (at 248 and 931 litres per tourist per day in guest houses and hotels respectively). The particularly high rates in hotels are due to garden irrigation (around 50% of the total), swimming pools (around 15 %), restaurants, laundry and cleaning. As a result, for major tourist destinations such as Zanzibar, the tourism sector comprises a high proportion of total water consumption. Higher temperatures increase water demand, as irrigation demand increases, greater replenishment of swimming pools is needed, as more generally tourism use increases. Climate change therefore will act to increase water demand use by the tourist industry.

More recent data from Slade et al (2011) report that while villagers use 61 – 128 liters of water daily per household (an average of 93.2 liters/day/household), average consumption per room varied from 686 liters per day for guesthouses up to 3195 liters/room/day for 5-star hotels with an overall average of 1482 liters/room/day; a figure 16 times higher than average household daily usage. The report also notes that very few hotels implement water conservation strategies, or waste water recycling. Hannson (2010) cites lower values, with village consumption of 32.5 litres for domestic use, and based on national records, tourist consumption at up to 400 litres/person/day (though this is not based on observed data).

Gössling et al also make the important observation that for Zanzibar, the monthly flow of tourists is completely opposite to the levels of rainfall received, i.e. tourist arrivals are highest when rainfall is lowest (Dec-Jan and July-August). While this is not surprising (tourist do not much like high rainfall) it highlights an issue with supply and demand that could be exacerbated by climate change, as the projections indicate even lower rainfall in dry months. These are the periods when the recharge of the aquifers through rain is lowest.

It also has implications that enhanced pumping (and energy use) for water supply is likely to arise from the tourism industry.

Another key threat will be the effects on the marine ecosystems of the islands, and particularly the coral reefs and associated diving and snorkelling (see earlier discussion on coral reefs), as well as emerging conservation/green tourism. These are highlighted as a key vulnerability. As discussed above, the corals already provide considerable economic value through tourism,

There is also potential for impacts on cultural tourism from the general threat of sea level rise to areas such as Stone Town.

Simpson et al (2008) highlight that tourists themselves have high adaptive capacity to climate change, because they can just change their destinations. Similarly, tourism service suppliers (at least those that don't own infrastructure) also have high capacity to adapt, by changing destinations to meet demand. However, the destination sites and communities (such as the industry on Zanzibar) that have the lower adaptive capacity, because of their existing infrastructure and reliance on tourist preferences: this is exacerbated for small island states such as Zanzibar, because of the relatively lower level of potential for alternative sites or tourism diversification (e.g. compared to larger countries).

Related to this, climate change may also affect the attractiveness of long-haul destinations, through carbon pricing on aviation. This would have potential effects in decreasing the relative attractiveness of the islands, though this is discussed further in the low carbon section.

Adaptation

The Zanzibar Adaptation Programme of Action did consider the issue of tourism and identified some options, outlined below.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Awareness raising on the importance of creating a positive balance between conservation and the use of local resources.
- Coastal protection and coastal zone management to protect tourist infrastructure.
- Diversify the tourist product to reduce over-dependency on marine environment.
- Education of local farmers to change agricultural methods so they are better able to supply hotels.
- Risk management skills organized by institute of tourism.
- Stimulate employment of local people on hotels.

It is stressed that tackling many of the issues in other sectors will have direct benefits for tourism (or to put another way, failure to tackle the issues above will have detrimental effects).

Many of the threats to the tourism sector come indirectly. They will arise via the effects of sea level rise, the impacts on coral reefs, etc. and thus the adaptation responses in other sectors will have benefits for reducing impacts in the tourist sector. Because of this, adaptation for tourism needs to be considered from a cross-sectoral perspective.

Given the importance of the tourism sector to future growth objectives for Zanzibar, there is a need to make sure sectoral policy build in climate considerations. A key early step is therefore to include climate change in sector development plans, to raise awareness of the issue, and to undertake research to look at the potential effects.

There also some useful lessons from international studies, such as the OECD tourism study (Simpson et al, 2008). This highlights the benefits of building on current experience of coping with climate variability (discussed in detail in the first technical chapter on current climate and extremes). There is a potential for

large no regret benefits from acting to reduce current risks, because of the reduced impacts on the tourism industry (as well as other sectors). It also highlights the need for capacity building (knowledge and awareness, institutional strengthening) and the underlying protection of natural resources, as well as monitoring to assess key potential threats (e.g. shoreline or beach erosion).

In terms of tourism infrastructure, other studies have highlighted the potential for constructing new buildings set back from the shoreline and built at slightly higher elevation to avoid risks of storm surge (at least in terms of the main infrastructure and hotel complexes). There is also the potential for protection (defences to protect the shoreline) and beach nourishment (to address beach erosion), however, as highlighted above in the coastal section, a preferred approach would be to encourage ecosystem based adaptation, given the wider benefits that these will have. This also encourages community based adaptation – and integrated coastal zone management – to reflect different use groups.

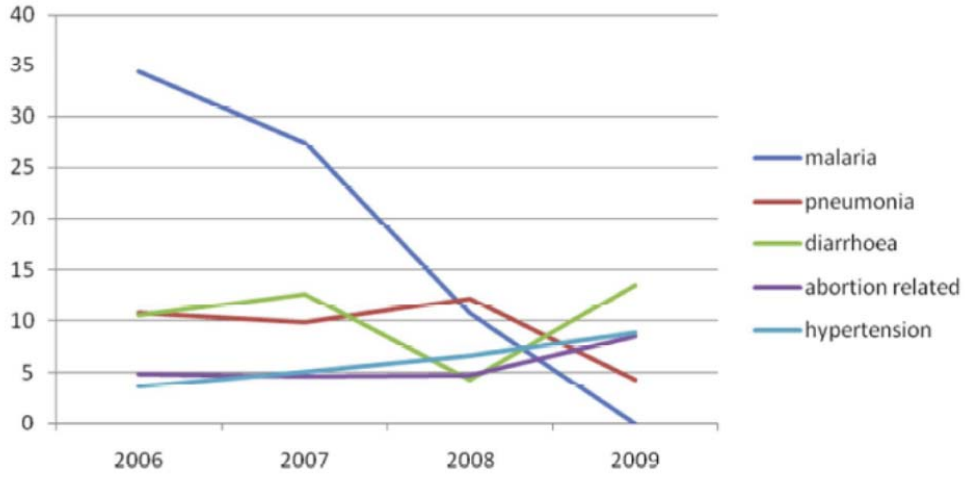
In terms of the indirect effects on the industry, there are clearly adaptation issues to address the impacts of rising cooling demand and water use, associated with climate change. These has linkages to the energy and water adaptation sections discussed elsewhere in this report, but there is a strong need to enhance energy efficiency and look for passive alternatives, and to use water more efficiently (e.g. rainwater harvesting, water efficient bathrooms, water conservation and water saving devices, water recycling (e.g. for irrigation). These areas represent no regret options, reducing costs as well as enhancing resilience and are key priorities for the tourism sector. There is also a need for greater involvement of the tourism industry in addressing the risks of coral reefs, recognising the services and income that these generate for the industry. Examples from Australia have advanced greater monitoring, awareness raising, early warning on bleaching events, and even some technical adaptations (e.g. using shading structures).

Health

Malaria is currently the largest health risk and cause of mortality and morbidity in Tanzania – the other major health hazards reported in relation to dysentery, cholera and meningitis. However, considerable progress has been made in disease reduction, notably through the earlier PRS initiatives and the Malaria Strategic Plan for Zanzibar (2007-2012) (ZMCP, 2007)[18] which had the aim to reduce the malaria parasite prevalence by 70% from the 2006 baseline by 2012, and baseline levels of the disease have been reduced dramatically in recent years (as document in RGZ, 2010), shown in the figure below[19].

[18] Zanzibar has reduced recent reductions in malaria cases as a result of intensive implementation of combined interventions i.e. case management through the use of Artemisin, Combination Therapy (ACT), intermittent presumptive therapy and the re-introduction of insecticides for malaria control through indoor residual spraying (IRS) and insecticide treated bed nets. This is supported by malaria diagnosis whereby around 76 percent of health facilities use microscopes and 24 percent use Rapid Diagnostic Test Kits. Further, malaria surveillance to monitor disease trends-morbidity and mortality is done in seven admission hospitals and Malaria Early Epidemic Detection System (MEEDS) was introduced in 2008 using an advanced technology of malaria reporting in a weekly basis via SMS.
The Zanzibar Malaria Control Programme (ZMCP, 2009) is also investigating further reductions, towards possible elimination of the disease (though noting this is tied to action on the mainland). This also looks at the possible costs (and financial feasibility) of elimination. The study indicates elimination is operationally feasible, but technically and financially challenging. The level of progress towards implementation strongly affects the future importance of future climate change and the disease, but at the same time, climate change might provide an additional stimulus for elimination.

[19] though some of this may be due to changes in diagnoses



Trends in Causes of Admissions to Hospitals in Zanzibar 2006-2009

Source: HMIS Bulletins 2006-2009 and RGZ, 2010.

While progress on malaria has been dramatic, there have been some increases in pneumonia, upper respiratory tract infections and diarrhoeal diseases. Diarrhoeal disease is one of the highest causes of morbidity in Zanzibar and accounts for 6% of all deaths in public hospitals.

In addition to these trends, there are high current vulnerabilities associated with the health effects of extreme events. This is a particular issue with droughts and floods. The 2007 erratic rains led to households using new unsafe sources of water, such as ponds and streams, with increases in water borne diseases such as diarrhea (MALE (2006) and bilharzia occurring in Shehias such as Kangagani in Pemba. Similarly, there have been frequent outbreaks of water borne diseases including cholera and dysentery, particularly during high rainfall seasons or extreme flood events, due to contamination of the drinking water (see earlier section on extreme events).

The impacts of climate change

Climate change is likely to affect 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 flood events. In many cases, climate change will act as an amplifier of current health problems, though it is likely to also give rise of new health stresses

The effects of climate change on malaria have been identified as one of the key concerns in the international context and for East Africa (McMichael, et al. 2004; Ebi, 2008). Most of the regional work has focused on how climate might affect malaria transmission by increasing relative humidity and modifying temperature, but this is primarily for the spread of the disease into previously unaffected areas at altitude. However, these concerns are not as relevant for Zanzibar, given the recent reductions in the disease will reduce the likelihood of future climate change impacts, though it remains possible that increasing malaria outbreaks could occur during years of excessive rains and flooding through prolonging the malaria transmission season. Other vector borne disease, such as schistosomiasis, dengue fever, yellow fever, encephalitis (tick) and Trypanosomiasis (Tsetse fly) might also be affected, by affecting the climate suitability for vectors (though note, changes can also be positive as well as negative).

A greater concern is associated with diarrhoea, i.e. food or borne disease, which is climate sensitive and affected by weather and climate variability. Previous studies have projected increases in morbidity with higher temperatures from future climate change (McMichael et al., 2004). There are also linkages with

climate variability and extremes, i.e. with high rainfall, flooding and loss of water and sanitation systems and /or contamination of drinking water, and water scarcity and 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 Zanzibar during recent decades.

With higher temperatures, and the potential for heat extremes, with heat related mortality and morbidity, though a potentially greater threat to Zanzibar is from increased incidence of deaths/injuries/disease linked to the coastal flooding, as well as secondary events from these and rainfall floods due to water borne diseases. There are also a wider set of indirect impacts from climate change on health, linked to other sectors (e.g. water quality, food security), discussed in other sections.

All of these health changes will 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.

There are also wider issues linked to food availability and security, and malnutrition. The MKUZA II reports that malnutrition is still an issue on the islands. While levels have improved (Vitamin A supplement and de-worming tablets are provided to the under-five children twice a year with over 90 percent coverage) malnutrition is estimated (RGZ, 2010) to be an underlying cause of 50% of under-five mortality and just under 4 out of every 10 children aged 0 to 59 months are chronically undernourished and about 1 out of every 5 children weighs too little. This links strongly to the agricultural sector discussion

It is stressed that the 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. For example, at higher per capita levels, the risk of malaria and diarrhoea are likely to reduce significantly.

Nonetheless, it is possible to scope out the potential effects, by looking at the climate risk factors used in previous studies, globally (McMichael et al, 2004) and in Tanzania (Watkiss et al, 2011), and combining these with current local incidence rates on the islands.

The study has estimated the impacts on climate change on health, focusing on climate sensitive disease (including malaria, diarrhoea and nutritional status, using the relative risk factors for climate change from McMichael et al (2004) (the WHO global burden of disease based approach), applied to development and climate scenarios in Zanzibar (assuming population growth in line with the earlier statistics).

Baseline health effects were taken from the Zanzibar Statistical Outlook (RGZ, 2010) for in and out patients for major disease (as diagnosed) for Diarrhoea Diseases (95000 cases recorded as out-patients in 2030, and a further 3600 as in-patients). The future incidence depends on the level of climate change, the underlying population exposed, and the changes in underlying health care and sanitation, noting the latter would be expected to reduce future incidence. The main driver for increased effects is the population growth on the islands, which based on current rates, would mean a total population in excess of 2 million people by 2030, though climate change would be expected to increase the relative risk by 1.05 to 1.11 by 2030. The effects of climate change would therefore lead to around 7000 (mid) to 11000 (high) additional cases per year (noting that under a high development growth baseline with advances in health protection, the increases would be effectively zero). These can be valued using the preventative costs, reported by Ebi (2008) at around $15 a case, i.e. $0.1 to $0.2 million per year by 2030 – though these could be much lower if baseline rate reduce due to improved health and sanitation. This value is relatively low, but it is influenced by the low reported cases, i.e. those that are severe enough to require hospital visits, or from people who have easy access to hospitals.

The number of unreported cases is likely to be much higher, and even for countries with relatively good reporting rates, a factor of ten fold difference is common – though with some countries being much higher than this (Watkiss and Hunt, 2012). This is reflected in the Zanzibar household budget survey (OCGS, 2011) which reported that diarrhoeal diseases were recorded as the second most common complaint (around 10% of recently reported illness) after malaria/fever, affecting more individuals in rural areas than urban. Using the under-reported incidence factors to scale the likely total incidence, the estimated costs of climate change are likely to be at least $1 to $2 million a year by 2030, though plausibly much higher, though again these would be reduced with underlying health and sanitation improvements, highlighting the role for underlying health improvements as no-regret option.

For malnutrition, the current statistics report that just under 4 out of every 10 children aged 0 to 59 months are chronically undernourished. Again, using the growth in population rates, and the factors from McMichael et al this translates through to an extra 3000 to 10000 cases per year, and with preventative costs estimated of $25, a cost of up to $0.3 million (though again, under high development growth scenarios, the additional effects would be zero).

The analysis of malaria is more difficult. OCGS (2011) reports that in recent years, Zanzibar has recorded a significance improvement in reducing malaria, with prevalence reduced to less than one percent for children under-five years of age (2007/08 THMIS). The household budget survey reports that of those respondents reporting recent illness over last four weeks (around 10% of the total sample size), around 22% list malaria and a further 33% list fever. These figures indicate higher incidence than some of the national recorded statistics. The relative risk factors for malaria in McMichael et al are high (1.07 to 1.28 for mid to high estimates by 2030), thus if there are higher underlying incidence rates, or rates increase in the future, climate change could significantly increase the burden of the disease.

Adaptation

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

The Zanzibar Adaptation Programme of Action identified the following.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Building of community awareness regarding preventative measures for malaria, schistosomiasis, hook worms, and other water and soil borne diseases in connection to rain water harvesting (standing water, wet soil)
- Environmental health projects

- Immunization programs (resilience)
- Improve community sanitation and medical services, including capacities for diagnosis and treatment
- Improvement of irrigation system management so as to reduce breeding sites; and provision of alternative water supply systems for domestic use that do not involve open standing water areas.
- Promotion of good hygiene and safe sanitation
- Promotion of good nutrition
- Urban tree planting to moderate temperature increases
- Weather advisories to alert the farmers and fishermen about favourable or dangerous weather conditions.

Based on likely relative risks, a greater focus might be on Diarrhoea and on the issues with disaster risk reduction to extreme events, including direct effects, but also linkages to extremes (floods and droughts) and water supply.

The MKUZA I and II have had the objective of increasing the supply of safe drinking water (linking with health) and providing enough water for industries, institutions and irrigation farming. As highlighted in the MKUZA II, implementation in the MKUZA I led to the expansion of access to clean and safe water to 80% of the population in urban and 60 percent in rural areas (by 2008/09). This is likely to mitigate against water borne diseases – though these may still be susceptible due to extreme events (floods and droughts), either in terms of contamination (floods) or by leading to the use of different supplies (drought).

The government has also initiated programs to minimize the outbreaks of water-borne diseases by supporting water supply in schools and surrounding communities through a variety of technologies including hand-dug and machine-drilled wells fitted with hand pumps, construction of water storage facilities (tanks) which are connected to pipe water supplies and construction of hand wash basins in schools (RGZ, 2010). The government is also implementing Participatory Hygiene and Sanitation Transformation (PHAST) project to promote sound hygiene and sanitation practices through the design and implementation of community sensitization programmes.

There has also been the implementation of the sanitation and drainage programme Phase II. Nonetheless, there is no centralized sewerage system in Zanzibar, and the system that discharges from stone town does so along the coast. There also remains the risk of overflow from flooding. In Pemba there is limited drainage and sanitary network systems (RGZ, 2010). Addressing these is likely to be critical in reducing the future impacts of climate change, and while part of development, they re-enforce the earlier discussion of the need to address the current adaptation deficit.

Energy

The energy sector of Zanzibar is described in detail in the low carbon section. This section focuses on the impacts of climate change on energy supply and demand.

Climate change is expected to have a direct effect on both energy supply and demand, as well as on energy related infrastructure.

Energy Supply

Energy is primarily met through wood fuel, because it is low cost and accessible. This is discussed in more detail in the low carbon report (see separate document).

In terms of mainland Tanzania and the inter connector to the islands, there is a large proportion of hydro-electricity in the electricity mix, which while falling, still dominates the mix. This is potentially vulnerable to potential changes in precipitation from climate change. These changes arise from any trends in water resource availability, but also from any potential changes in variability from extreme events, notably droughts and floods.

A number of studies have documented the electricity issues on the mainland, and the effects of recent dry years on hydrogenation, noting there are a range of complex issues here including plant management. The future impacts of climate change have also been assessed, and concluded that climate change could affect some plants in Southern Tanzania, but that other areas might be relatively unaffected (other than from climate variability and extremes). However, the changes depend critically on the climate change scenarios and models, because of the wide range of potential changes (increases or decreases in precipitation, but also in relation to drought or flood events).

While adaptation responses on the national grid mix fall to the mainland, there are options for Zanzibar in providing own generation and for diversification, which are discussed in the low carbon section. It is also highlighted that transmission losses are high on the island and there may be potential for efficiency (as a form of adaptation). Similarly, a high proportion of electricity on Zanzibar is used for water pumping, and again there are low carbon options and efficiency options which are discussed below.

The Zanzibar Adaptation Programme of Action did provide some suggestions on this issue, though they mostly relate to the low carbon section that follows later.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Diversifying power supply in the event of power plant failures due to excess demand created by extreme heat, or by events.
- Increasing energy efficiency to offset increases in energy consumption due to warming.
- Protecting facilities against extreme weather events.
- Improved stoves and renewable energy for electricity production.

Energy Demand

As well as energy supply, climate change affects energy demand, as outside temperature is a key factor in cooling requirements. Previous studies have shown that the effects on energy demand are amongst the largest in net economic terms.

Energy demand increases with higher temperatures (for increased cooling) in tropical climates, though these are conditional on income levels and AC penetration rates. The average temperature increases associated with climate change will increase the demand for cooling across the year but especially in hotter (and more humid) months, though the scale of these effects is strongly determined by the climatic zone and socio-economic conditions. This is important because as well as the extra cost of electricity, it also increases the energy needed on the generation mix and can increase emissions from non-renewable plants (or local diesel generators). On top of the pattern of average warmer temperatures, climate models also project increases in the number of heat extremes (heat-waves), which can increase peak demand.

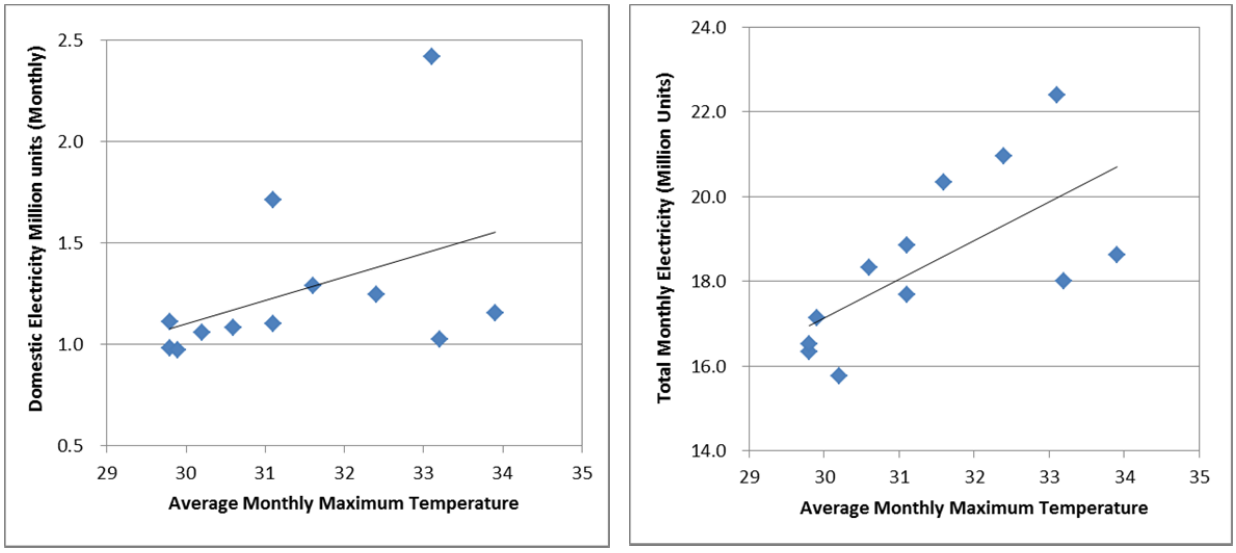
It is also a particular issue for Zanzibar because of the tourism industry, particularly for higher income international tourists. As an example, survey work on the tourism industry reports that all four- and five-star hotels have air conditioners in their guest rooms – and there are even ACs in over 50% of one star accommodation.

There is previous analysis of the potential effects on cooling demand in neighbouring East African countries (Watkiss et al, 2009). Under model-simulated baseline conditions, the rise in cooling degree days was projected to rise to between a 240 to 340% (average 300%) rise in the cooling burden for Mombasa. Zanzibar has a cooler island climate, and would not experience this level of increase, but the increase could still be significant, especially for the tourism 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. While increased energy use might in itself reduce demand, for some sectors (tourism in particular, when prices are not directly passed through) higher temperatures are likely to translate directly into higher energy use.

The current peak for electricity demand is the evenings on Unguja, due to demand for lighting, however, there are high levels of unmet demand, and high use of diesel back-up for generation (see later low carbon section). These factors make it difficult to establish relationships between temperature and cooling demand.

A consideration of the available data in 2011 (earlier data is affected by the major outages) shows a strong monthly trend between temperature and electricity use on Unguja – shown below for the domestic sector (right) and the total demand (right). Some care must be taken in interpreting this data. The large correlation between demand and temperature overall (on the right) is likely to just reflect the strong seasonality in tourist demand, which will drive much of the demand on the island. Note also there does not appear to be a strong link in the some of the hottest months of the year, though this could be due to demand outstripping supply. However, even the domestic sector (left) seems to pick up some trends between monthly temperature and demand, indicating that this is an area worth investigating more. Ideally this would need to compare daily (or even hourly) temperature and electricity demand, to try and see how much influence cooling has on the island.



Monthly Energy Consumption against Monthly Average Maximum Temperature (2011) for Unguja Left Domestic Sector: Right Total. Data from ZECO, TMA.

The Zanzibar Energy Policy 2009 sets out that the electricity sector in Zanzibar has during a long period been characterised by high technical and non-technical losses, tariffs that do not fully reflect costs, non-payment by clients, low collection rates and low capacity of the utility organisation. Importantly, it also reported that existing equipment such as fridges and air conditioners are older models which are usually

inefficient and thus less uneconomical (the tourism industry perhaps being an exception here), and highlighted issues with awareness (of the energy costs of older inefficient appliances), and maintenance. The Energy Policy does recognise the issue of climate change, and the need for renewables, but it does not address the link between rising temperatures and energy demand. This is a major gap and should be included in future revisions.

What is also clear is that demand for electricity will increase, with rising per capita growth (which is linked to electricity use), projected growth in the tourism industry, which is a high user especially for high end tourism for cooling, and rising use of electricity for water pumping (including for irrigation), which already is a major user of electricity (perhaps as much as 30% of overall demand). Climate change will also affect these growth trends, increasing electricity use for cooling and use of water (from increased temperature and possibly also from changes in rainfall patterns). It may also increase energy demand by increasing pumping distances for water, e.g. if salt water intrusion increases, there will be a need to pump supplies from further distances.

Adaptation

The rising cooling demand from future climate change has not been recognised in energy planning to date in Zanzibar, and this is identified as a key initial area for investigation. Future demand forecasts need to include the additional effects of climate change, because this could significantly increase average and peak demand.

For energy demand, the autonomous response to higher cooling demand will be for air conditioning, at least for higher income households or the service (tourism) sector.

The Zanzibar Energy Policy 2009 set out the need for norms, codes of practice, guidelines and standards to facilitate the creation of an enabling environment for safe use of energy efficient appliances and in particular appliances based on environmentally friendly technologies. It included a policy statement that Zanzibar shall introduce limits on standards for import of electrical appliances. Energy efficient equipment shall be promoted by lowering import duties for such goods. It also highlighted that a major obstacle for the development and market up-take of energy efficient technology was the higher (relative) capital costs) and the need to addressing financing. At the small scale it highlighted the potential role of micro-finance institutions in facilitating investments in energy efficient equipment and for large scale investments, energy efficiency funds.

Even simple measures can make a difference, with for example greater use of fans rather than air conditioning. Not all four and five star rooms have fans, and yet this could reduce electricity demand significantly.

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

There are possible ways around these issues, through simple building measures, orientation, building design (natural ventilation), and from spatial planning, as well as from energy efficiency measures. There is already some work being undertaken on such issues in the East Africa level (Watkiss et al, 2009Failure to build adaptation into building design will increase air conditioning demand in existing warmer regions and increase GHG emissions.

However, implementation is likely to be made more challenging by the necessary legislation and policies to support design, the lack of awareness on the need to design these options into buildings, even among

the architects. It is also an issue for some parts of Zanzibar (stone town) because of the historic building stock.

This should extend to consider the effects of climate on wider demand, such as for water pumping and irrigation from higher temperatures, but also for longer distances (e.g. due to coastal salt water intrusion).

Water, Infrastructure and Extremes

Water is a critical sector. It is essential in health, energy supply, agriculture, tourism, industry, and ecosystems. Zanzibar receives high rainwater (see earlier climate section) and has water resources which include groundwater, surface water, rain water, sea water, etc. However, there are high run off and evapo-transpiration.

However, ancillary stresses of pollution, salinisation, sedimentation and over-extraction of groundwater exacerbate current vulnerability, and future drivers such as population and economic growth are likely to put additional pressures on resource. There have been reports of salt water intrusion (see earlier section).

Water Supply and Demand

Groundwater is the primary source of water in Zanzibar, particularly on Unguja (though there is more surface water on Pemba, from rivers and from seasonal ponds). Statistics on current water sources are provided in the Statistical outlook, reported below. There is now a National water policy, which defines the roles of different stakeholders in the development, management and use of water resources countrywide.

Water Source and Tank Capacities 2006

	Water Source(Number)					
	Borehole	**Springs**	**Caves**	**Production ('000 Litre/Day)**	**Reservoir Tank (Number)**	**Average Capacity of Tanks (M3)**
Total	117	3	5	91,271	55	16,608

Source: Source: Zanzibar Statistical Outlook, RGZ, 2010.
Zanzibar Water Authority

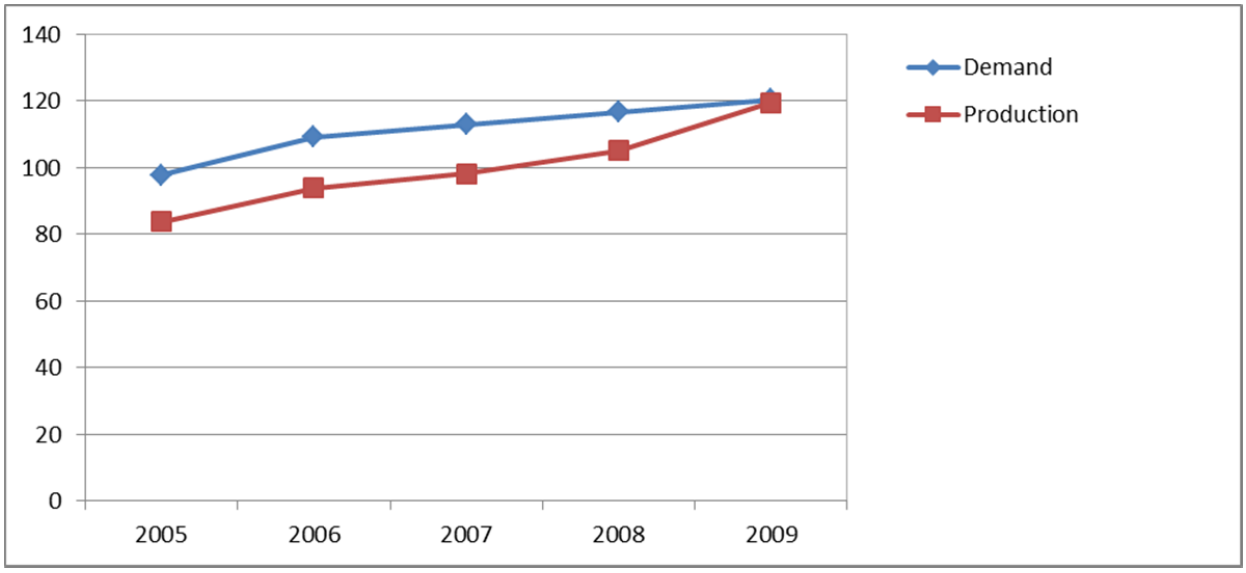
The current aquifers (on the eastern region of Unguja) are recharged by rainfall, and the overflow discharges to the sea preventing salt water intrusion (Mustelin et al, 2009). This is important as changes in future rainfall regimes could affect recharge rates.

The MKUZA II document (RGZ, 2010) reports that that in both islands, current ground water reserves are favourable but every care needs to be taken to ensure that the existing favourable situation does not deteriorate. However, it also reports that from an analysis of average daily water supply and for each region, water supply in Zanzibar has been short of the existing demand, particularly so in North Pemba and South Pemba where water deficit persisted throughout the period 2005 – 2009[20].

[20] Given the consumption of Domestic Urban as 100 l/cd (Urban Master Plan), Domestic rural = 50 l/cd (Rural Master Plan), Hotels = 200 l/bd (based on the country's recommendation of 70 litres/bed/day for a low class hotel to 400 litres/bed/day for a high class hotel), Commercial = 1,500 l/Inst/d (ZAWA estimates), Public use which include schools, hospitals, industries, mosques, cinemas, etc. = 25% of domestic (Rural Master Plan) and Agricultural = 25% of domestic (Rural Master Plan) as well as the water production figures be based on capacities of installed pumps and unaccounted for water of about averages of 35% (ZAWA estimates).

Moreover, the growing population rates, the pressures on water supplies from agriculture, tourism (see earlier discussion), etc. are likely to affect the future water supply-demand balance. There are also issues on the levels of formal and informal abstraction, notably in relation to tourism use (see Slade et al, 2011).

The New National Water Policy and reforms are aimed at addressing this balance. the MKUZA I and II set out objectives for increasing access to clean, safe and sustainable water, with the latter reporting approximately 80 percent (urban) and 60 percent (rural) had been achieved by 2008/9 (against targets of 95 and 65%).



Water demand and production for the years 2005 – 2009 (million litres per day)
Source: RGZ, 2010.

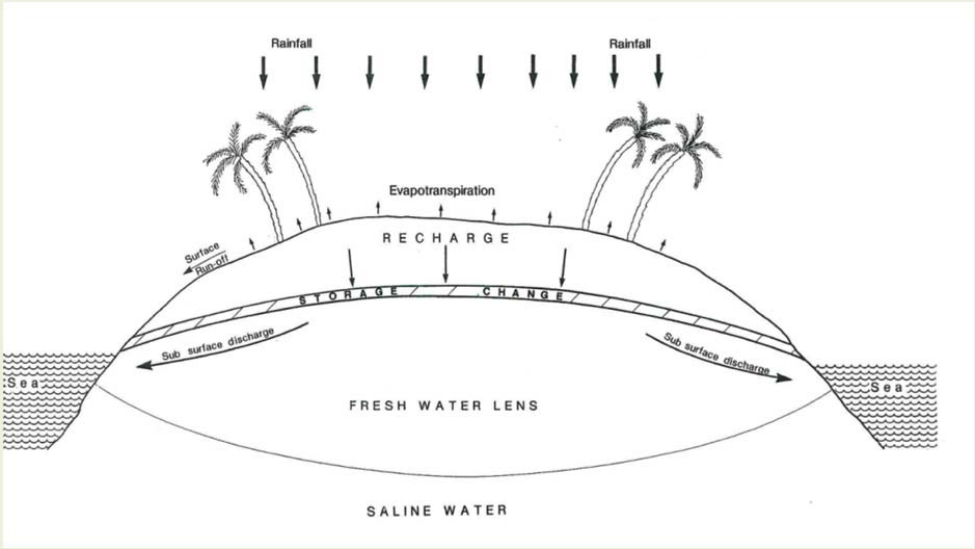
The most detailed analysis of water resources on the island is still the Halcrow (1994) report. This provides

Most recent documents, such as the the National Water Policy Document (2004) highlight that groundwater is the primary source of water in Unguja and Pemba, and as in the figure below, highlight that a fresh groundwater lens floats above the deeper saline water – which therefore requires the replenishment of groundwater resources to maintain the balance and prevent saline water rising or intruding into the freshwater lens or flowing inland from the sea. Importantly it states that there are not any large and adequate reserves which can be mined at unlimited discharges indefinitely, and that supplies have to depend on recharge from annual rains.

More recent work, Hansson (2010), has highlighted the current issues of salt water intrusion in drinking supplies. It also found supplies were contaminated with sewage (a factor in illness).

The Water Resources of Zanzibar

The Halcrow (1994) report outlines the water resources of the islands, and progressed a water balance based on a geographical basis. As well as rainwater, the analysis considered evapotranspiration, and the loss via surface rivers (from coastal rivers), and rivers that flow into the coral rag limestone (and don't reach the sea, but do recharge groundwater, as well as maintaining ground water outflows to sea). The report notes the very different characteristics of Pemba, which due to the hilly terrain, has more perennial river systems, which transport much of the rainy season as flows.



Source Halcrow, 1994.

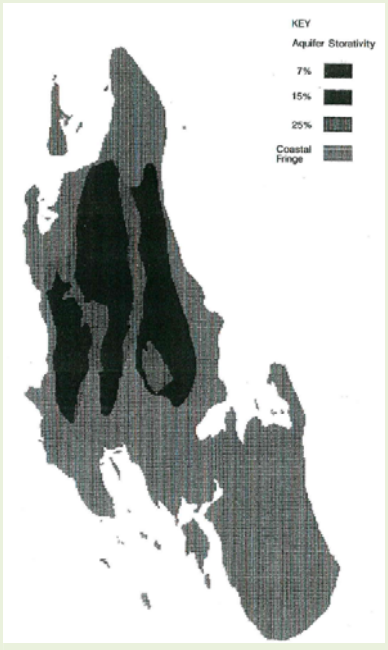
In Unguja, the study reported on three large hydrological zones (the eastern limestone/sandstone corridor, the western sedimentary corridor, and the coastal limestone deposits (coral rag)).

The systems on Pemba were concluded to be very different, lacking transmissive structures and thus only suitable for small local supply schemes, i.e. there were not considered any major aquifers.

The study undertook extensive borehole monitoring.The study found little indication that abstraction levels were affecting groundwater (expect for one site near Zanzibar city), and set out acceptable abstraction levels.

However, over the past fifteen years there levels of water abstraction have increased enormously, not least driven by the rapid extension of the tourism industry.

Enhanced monitoring is therefore needed to take stock of the current baseline conditions and future supply-demand balance.



Extent of Major aquifers on Unguja

The Risks of Climate Change

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 surface and groundwater systems, that would affect water availability and the function and operation of existing water infrastructure (including, irrigation systems, drinking water supply and waste water treatment). This could have impacts on agriculture, tourism, industry, etc. and biodiversity and ecosystem services.

The analysis of the impacts of climate change is made difficult by the high variability from the climate models on the average, seasonal and daily trends of future precipitation (see earlier section). While temperature change predictions are fairly consistent, rainfall patterns and water flows projection vary widely, including both spatially and temporally within seasons, although there does appear to be a trend of increasing rainfall intensity during wet seasons, and drying during dry 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.

One of the key issues has been the salinization of shallow water wells, the only source of domestic water supply in many areas. As outlined earlier, the URT NAPA (URT, 2007) attributes this to rising sea levels, and outlines that the process has caused both social and economic problems associated with lack of reliable safe drinking water to rural communities.

However, the **Zanzibar Adaptation Programme of Action** reported that the decline in the ground water level could be due to a decrease in precipitation (though the meterological data does not support this), increased rain intensity and more surface run-off leading to less recharge of ground water, but also that more intense extraction of water for a growing population, more intense irrigation of fields and the establishment of new hotels and associated water pumping/use could be the cause. It reported that as the decline is widespread (i.e. also in forested areas such as Jozani far from human settlement), this might indicate sinking ground water levels, possibly due to less ground water recharge. It also reported that both in the northern and the southern parts of Unguja the interviews reported sinking ground water level. In Jozani forest, there are anecdotal reports a lowering of ground water and reductions in forest floor flooding. In some caves there were hotel pumping stations. The ZAPA attributes ground water sinking to excessive and unchecked abstraction of ground water. Nonetheless, more intense rainfall over a shorter period of time could reduce ground infiltration and recharge.

While the interviews for the ZAPA report note that freshwater is an increasingly scarce resource, the document notes the large waste of freshwater from supply lines (such as the main water pipe providing water to Zanzibar Town) and in houses, which had dripping water taps and pumping tanks overflowing.

The SMOLE programme also investigated this issue. While the potential for more extreme high (spring) tidal events may be a factor, it considered a larger factor may be the cutting of mangrove forests (which also speeds up erosion).

Adaptation

During the URT NAPA process, the development of alternative water storage programmes and water harvesting were scored highest during the subsequent analysis. This led to the identification of one priority project that included Zanzibar**,** outlined in the box below.

Shifting of Shallow Water Wells Affected by Inundation on the Coastal Regions of Tanzania Mainland and Zanzibar. Summarised from the NAPA (URT, 2007)

The overall objective of this project is to construct new water wells to enable people have reliable access to safe and clean drinking water and for other development processes. The planned activities are:

• Awareness to the communities on the cause and impacts and explore their adjustments to the problems faced due to climate change impacts;

• Training on the sustainable use of water and methods of water harvesting;

• Conducting a survey to identify wells that have been inundated with sea water along the coast. The task of well survey will be conducted by the SSN adaptation team in Tanzania;

• Chemical testing of salts in wells that have been inundated with sea water to verify the extent of the problem. This task will be conducted by SSN Tanzania team in collaboration with other higher learning Institutions, particularly the University of Dar es Salaam;

• Survey for water sources alternatives for communities that need new water sources; e.g. other places for bore holes or possibility of gravity water supply. To achieve this task, water supply experts will be consulted and contracted;

• Rehabilitation of the traditional wells not yet inundated with sea water intrusion;

• Implementation of new water sources and supply. Bore holes drilling agents, and water supply companies will be consulted and contracted to complete the final stage of achieving adaptation goals;

• To reduce pressure on Coastal resources, promotion of alternative income generating opportunities; and

• Promotion of good practice in land management.

The short-term outputs are the communities at Bagamoyo District are able to express a basic understanding of current climate change impacts and adaptations options available; that shallow wells are relocated and new wells are being used; and shallow wells which have not been polluted are being used sustainably.

The long-term outputs are that the intervention will contribute to poverty reduction through reliable access to safe and clean drinking water, to provide more time for school children to attend schools, to free up money for investing in Small and Medium Enterprises (SMEs); and for people to be able to grow and irrigate some small vegetable garden for extra income.

The project budget is outlined below. The project will be implemented under the leadership of the Ministry of Water in collaboration with Ministries of Natural Resources and Tourism, Ministry of Agriculture and Food Security, Local Government Authority, Local Communties, NGOs/CBOs

Activity	Year 1	Year 2	Year 3	Total
	US$	US$	US$	US$
Project planning and appraisal	300,000			300,000
Facilitation of farmers	600,000	300,000	300,000	1,200,000
Establishment of tree nurseries	300,000	300,000	300,000	900,000
Establishing alternative income generating activities	300,000	300,000	300,000	900,000
Total	1,500,000	900,000	900,000	3,300,000

The Zanzibar Adaptation Programme of Action also identified a large number of water options.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Alternative water supply and storage programs
- Conserving soil moisture through mulching and other means
- Construction of dams and water storage facilities in some perennial rivers
- Drilling bores further inland
- Emergency management plans
- Encourage communities to protect and conserve natural springs
- Enhancement of capabilities of the Meteorological Authority to monitor hydro-climatic variables
- Extension services to build capacity in water capture and storage techniques for small-scale farmers
- Immediate repairs of damaged structures
- Improvement of access to groundwater supplies by humans and animals though installa-tion of water pumps
- Improving water use efficiency
- Increase safe rainwater harvesting and introduction of new water harvesting/spreading techniques making use of intermediate technologies
- Introduction of a revolving micro-credit fund to support implementation of small water harvesting projects
- Introduction of water-conserving agricultural land management practices
- Protect and preserve natural water catchment areas
- Protecting coastal freshwater resources from saltwater intrusion
- Rehabilitation of existing dams as well as improvements in water basin infrastructure for increased water storage capacity
- Support reforestation programmes in communities
- Undertake rainwater recharging of aquifers to reduce salinisation from saltwater intru-sion and storm surge flooding
- Water purification programs
- Water tank programs
- Watershed management plans

A key and immediate priority is for enhanced monitoring – both in terms of groundwater levels – but also in terms of demand and abstractions (recorded and unofficial). The lack of data on both of these makes it extremely difficult to know what the baseline and future scenario will be, and it is a priority for early action. The last detailed assessment seems to be the Halcrow study, undertaken almost twnety years ago, and this study has found it difficult to obtain more recent information.

There is also a need to move towards integrated water resources management, especially as pressures on available water supplies increase.

Furthermore, an early no regret option is to address the current connections and leaks to improve the efficiency of the current system.

Moving beyond this there are other key supply side water adaptation options which include:

- Demand-side management: e.g. improved end-use efficiency across demand nodes (a clear no regret option, though made more difficult by the lack of water charging and private abstractions).
- Supply-side management: e.g. water harvesting interventions, or perhaps "harder" options such as reservoir construction.
- Ecosystem protection: e.g. sustainable land management (SLM) interventions in agriculture to reduce soil erosion.

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.

However, at the smaller scale, the focus has been on rain water harvesting. Rainwater harvesting (RWH) is a simple and low cost water technique that captures and stores rainwater from roof and ground catchments for domestic, agricultural, industrial and environmental purposes (RGZ, 2007). Surface run-off can be collected in reservoirs, for management of floods and droughts, and used for recharging groundwater (aquifers, springs and shallow wells). It also has other social and economic benefits, and contributes to poverty alleviation and sustainable development. The Irrigation Master plan (MANREC, November 2006) attaches great importance to harvesting and storing rainwater for irrigation purposes.

The RGZ collaborative study (2007) assessed the potential for rain water harvesting on Zanzibar, as part of an Integrated Water Resources Management plan. This analysis revealed that Zanzibar receives a large volume of rainwater amounting to 4 km3 (Unguja and Pemba receive 2.4 km3 and 1.5 km3 respectively, with current usage rates of only around 1% of this). Run-off was estimated at 24% and evapotranspiration at 40%. 24% in Unguja and 7% in Pemba ends up in groundwater.

There have also been good examples of rain water harvesting schemes on Pemba.

The report highlighted that potential technologies are mainly focussed on enhancing groundwater, capturing runoff and collecting rainfall in-situ, noting that Pemba had a large number of rivers.

The analysis concluded that for RWH, Zanzibar needs to invest US$ 6,420,000 over a period of eight years, and that this would create annual water storage per capita of 1624 m3 (above the 1500 m3 minimum international bench mark). This investment was recommended for improving policies on IWRM, training all key stakeholders, setting up demonstrations and scaling up sites and monitoring and documentation of the entire process.

Extreme Events, Infrastructure (including Transport and Planning)

As highlighted above, Zanzibar 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.

Many of the climate model projections indicate an increase intensity of extreme rainfall events in much of East Africa, including in Zanzibar 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. The need to build resilience to floods is therefore a key priority.

There is a potential risk to the Zanzibar road network, or at least certain areas and critical infrastructure, from flooding. The road network is 1,150 km. Estimates report 427 km are paved roads and the remaining is either gravel or earth roads (TGZ, 2010), though current efforts as part of the Transport Master plan are upgrading and construction the remaining road network (723 km) to bitumen standards, and maintenance of the network. The MKUZA II reports that seventy percent of major roads in Zanzibar are now tarmac or work is in progress to tarmac them. Most of the network is generally well drained, but there are at risk areas. There are also plans for upgrading of public transport. However, there is an issue of the drainage capability of many secondary roads which are planned for road storm drainage improvements (RGZ, 2010). The Zanzibar transport masterplan highlights that the road network of Zanzibar includes almost 400 km of 'key economic roads', a further 180km of 'secondary economic roads' plus around 150km roads required for access to larger settlement areas. An important issue is the upgrading or construction of bridges, as these are particularly at risk from extremes, and critical for ensuring the network (i.e. there is probably some value in designing these to already cope with future risk levels). Given the low numbers of bridges, such a plan should be manageable. There would also be a benefit in screening major road development, to look for particularly at risk locations.

The risk of flooding from heavy rainfall can also affect urban areas (e.g. where drainage capacity is exceeded) or rural areas (with soil degradation and even landslides). For Zanzibar, a particular risk is from the growth of Informal (unplanned) settlements. As identified in the MKUZA II (RGZ, 2010) the physical and social infrastructure (basic services) such as storm water drains, safe water supply, roads, waste disposal, schools, health centres etc. in these settlements are either missing or is in very poor condition. There is also the potential for damage to cultural and historic buildings, notably in Stone Town.

The World Bank funded Zanzibar Urban Services project has mapped the potential areas currently at risk of flooding (see figure below) and is constructing storm water drainage channels, at a cost of US$10.8 million. This will enable the construction of 19.631 kilometers of surface water drains and related works within and in the immediate periphery of the ZMC in areas outside of the Stone Town. Six separate surface water drainage systems will be constructed with a total catchment area of around 1,698 hectares eliminating persistent stagnant water ponds of over 170 hectares which affect more than 20,000 persons living in and around 3,645 houses. It is highlighted that this project informally took future climate change into account: i.e. allowing some contingency for future changes in extremes (consistent with higher rainfall, as might be expected from climate change) and making sure outfalls were raised (over designing the gradient).

Potential Areas Currently at Risk of Flooding (Stone Town/Zanzibar City)

Source: World Bank funded Zanzibar Urban Services project

Similar activites would be useful in other key areas at risk, though it is stressed that this is primarily addressing the existing adaptation deficit.

While many of the models predict increases in rainfall on average, droughts are also 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.

While the exact changes are unclear – especially with the largely unknown effects of climate change on the ENSO - there are obvious early priorities to increase the resilience to cope with these extreme events, and to further plans for disaster risk reduction, as well as adaptation options to use spatial planning to

reduce future vulnerability. Given the islands are investing in future infrastructure, there is a need to ensure these investments are properly screened for future climate risks.

The Zanzibar Adaptation Programme of Action reported increasing frequency of flooding on the soccer field in Stone Town.

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Develop flood control measures.
- Improve building designs to increase resilience.
- Integrate climate change adaptation into national disaster management framework.
- Protect coral reef to maintain natural defence of islands.
- Strengthen land-use planning as a tool for protection of human settlements.

Forests and Terrestrial Ecosystems

Zanzibar has various types of forest vegetation, which includes a mosaic of forest patches, savanna woodlands, bushlands, thickets and farmland, dense forest and open natural forest on the coral rag area (CEPF 2005). The forests of Unguja and Pemba form an important part of the East Africa Coastal Forests Eco-region.

Land Classes in Zanzibar		
Land use class	**Total area (ha)**	**Percentage**
Coral rag forests	98,329	37.1
Mangrove forest	19,748	7.4
Forest Plantation and main high forest	9,505	3.6
Mixed wood vegetation	19,733	7.4
Agroforestry systems	85,084	32.1
Agriculture land	25,034	9.4
Settlement areas	7,858	3.0
Total	265, 292	100
Source: Leskinen et al. 1997, cited in DoE Zanzibar (2009)		

Both islands contain forest reserves, which are important both for the local economy as well as for species habitat, which include Jozani Forest (Jozani Chwaka National Park), Muyuni Forest, Kiwengwa Forest and Tumbatu Forest on Unguja. On Pemba Island there is one main coastal forest area, which is Ngezi Forest. In addition, there are 2 forests; Msitu Mkuu and Ras Kiuyu, and the Ngezi Forest Reserve.

People in Zanzibar have a heavy direct dependence on natural resources and this has led to a reduction in forest area, arising from cutting for wood fuel, cutting for building materials, shifting cultivation, and wider land-use pressures that have affected forests.

The Department of Commercial Crops, Fruits and Forestry developed the National Forests Management Plan with the support of FAO and WWF. This aims to enhance the national forest resource base and its contribution to local economic development without compromising the natural environment. It has been written in order to guide district land use plans to support forest conservation and development objectives. The plan has been separated into three major programmes; Capacity development, Biodiversity and Integrated Conservation and Sustainable Production and Utilization. A large number of objectives and “operational targets” have been set.

Zanzibar forest cover is estimated to be about 26% of the total land area, the rate of deforestation is approximately 1000 ha per annum. As a result, the 2008- 2020 Zanzibar National Forest Plan states that should annually grow or establish 2,450 hectares of new Forest Protected Areas (FPAs).

Zanzibar (as part of the URT) is a pilot REDD+ (Reduced Emissions from Deforestation and Degradation) country, see box below.

Nonetheless, by 2020 the domestic wood demand is expected to grow up to 3.6 million m^3 if appropriate substitutes to wood are not put in place. This issue is discussed in more detail in the low carbon section.

The potential impacts of climate change on forestry in Zanzibar

Climate change is projected to have a serious impact on forests across Africa, and in Tanzania.

Tanzania's National Adaptation Plan of Action (NAPA) predicts this climate change may result in sub-tropical dry forests and sub-tropical moist forests declining by more than 60%. This will also affect wider biodiversity, and species capable of adapting to climatic shifts may survive while others that cannot respond will be negatively affected. For an island state such as Zanzibar, the potential for species movement is very limited, and this is highlighted as a critical issue.

Due to the physical barrier of the sea it is difficult for terrestrial island species to migrate to other areas that may become more suitable as climatic conditions change. Changes induced by climate change may not only result in species range shifts, but also in changes in tree productivity, adding further stress to forest ecosystems (UNEP, 2004). Zanzibar's Adaptation Programme of Action (2010) reports the sinking of ground water levels, with ground water in Jozani forest reported to be more than one meter below the level 10 years ago. Ground that used to be flooded during the rainy season was no longer flooded, which has the potential to alter the species composition, although the causal link for this does not seem to be clear.

Impacts on forests are likely to have a large effect on people in Zanzibar due to high levels of direct forest-dependency and a low degree of adaptive capacity due to widespread poverty, emphasizing the importance of good forest management. Loss of forests will have significant negative consequences for rural populations: forests and woodlands are an important source of fuel in Tanzania; forest products may contribute to half of the total income of many Tanzanian households; and forests are a source of timber for construction, fodder for livestock, as well as providing fruits, medicinal plants, resins and meat.

A number of interventions were suggested in the Zanzibar Adaptation Programme of Action

The Zanzibar Adaptation Programme of Action (ZAPA, 2010) identified the following

- Afforestation
- Agro forestry
- Alternative to wood energy, including efficient wood energy stove
- Community-based forest and rangeland management and rehabilitation
- Conservation and management of forest reserves/catchments/national parks
- Environmental/conservation awareness
- Establishment of forestry research plots where different tree species' production is monitored under different conditions
- Introduction of alternatives to fire wood of non fossil energy sources
- Mangrove management
- Promotion of "Tree Planting Day"
- Quotas for logging to promote reforestation

The Hifadhi ya Misitu ya Asili (HIMA) REDD+ Project in Zanzibar

The Hifadhi ya Misitu ya Asili (HIMA) project, in English, Piloting REDD in Zanzibar through Community Forest Management aims to promote a pro-poor gender-equitable approach to community forest management. This includes the piloting of carbon financing for Reduced Emissions from Deforestation and Degradation (REDD), which provides forest-dependent communities with secure property rights, equitable rewards for providing ecosystem services and other livelihood benefits, and which informs the priorities of Zanzibar in the national REDD strategy. This was launched in 2010, and is the sixth NGO pilot project to be funded under the Tanzanian/ Norwegian partnership, and the first on Zanzibar.

The project aims to focus on gender equality, and ensure that productive forest ecosystems and REDD revenue schemes benefit women and men equally. Any potential costs to community members are identified and avoided or effectively minimised. The project targets the protection of 27,650 ha of forest (22,650 ha community upland forest and 5,000 ha mangrove forest) on Unguja and Pemba, with the objective of scaling-up to at least 60,000 ha of forest in Zanzibar beyond the pilot phase. The project is being implemented in 29 community forest sites in seven districts of Unguja (South Unguja, North B Unguja and Central Unguja districts) and Pemba (Wete, Micheweni, Chake Chake and Mkoani districts).

Target beneficiaries

The target beneficiaries include 16,000 rural households (an estimated 99,000 men, women and children), living adjacent to forests. This includes 49 Village Conservation Committees (VCCs) and their members; 750 members of Village Savings and Loan (VSL) groups; 3 umbrella organizations of VCCs namely: JECA, SEDCA, and NGENARECO; the Department of Commercial Crops, Fruits and Forestry (DCCFF) staff; the Department of Environment (DoE) staff; 59 Shehia authorities; and approximately 7,000 households in Zanzibar town and township.

Many forest areas in Zanzibar could be managed as COFM, and give greater benefits to local communities. Zanzibar's Forest Policy and the Poverty Reduction Strategy (MKUZA in Kiswahili) reflect the need for Community Forest Management (COFM) to combat deforestation and reduce poverty. However, despite a favourable policy environment for the implementation of pro-poor COFM, deforestation and forest degradation in the community forests is on the increase and COFM practice in Zanzibar remain a challenge. HIMA project is designed to address these challenges while alleviating the impact of poverty, generating carbon income, which will provide direct and equitable incentives to communities to conserve forests sustainably.

Key outputs of the HIMA project

- *Output 1: 12 new Community Forest Management Agreements (COFMAs) developed* (covering 10,650 ha of forest area) and 17 existing COFMAs (covering 17,000 ha forest area) reviewed and improved through the development and application of effective and equitable COFM strategies.
- Output 2: *Strengthen DCCFF, DOE and other relevant government institutions* and CSO/local NGO's REDD and climate change capacities.
- *Output 3: VCS and CCBA validation secured and marketing arrangements developed* based on national aggregation that maximizes benefits to men and women in the communities whilst ensuring environmental integrity.
- *Output 4: Replicable, equitable and cost effective measures to reduce degradation and deforestation and to control leakage designed and implemented.*
- *Output 5: Monitoring, evaluation, documentation and advocacy processes supported*, with particular emphasis on social equity, and experience/lessons disseminated to a wider audience.

Since the project started its activities in April 2010 the following activities have been accomplished:

- The project surveyed 31 Village Conservation Committees (VCCs) to determine the current status and perceptions of effectiveness by the local community. in addition, a new set of Community Forest Management Agreement (COFMA) Guidelines was developed.
- A training needs assessment has been carried out for the local NGOs working with the project and those operating within the project area as well as a capacity assessment of government institutions,

which was made on conjunction with the Sustainable Management of Land and Environment II (SMOLE II) project.
- The project gathered the necessary information to enable the REDD collaborating organization, Terra Global Capital to complete the carbon feasibility report by the end 2010 in order to determine the scale of carbon to aim for and the necessary mix of project activities between forest conservation and reforestation, and pave the way for the carbon baseline data collection to proceed.
- A programme of public education and promotional free gas distribution via Salama Gas has been launched, aiming to reduce the demand for charcoal by promoting the use of Liquid Petroleum Gas (LPG) for cooking instead of charcoal and firewood. A survey of users is being processed and the project is looking at using community managed wood lots to meet demand.

Climate change presents a major threat to terrestrial ecosystems more generally. 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. 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.

The combination of the principles of adaptation and the consideration of ecosystem services are being brought together under the concept of **Ecosystem-based Adaptation (EbA).**

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 changing climate conditions.

Cross cutting and community level

The Zanzibar Adaptation Programme of Action highlighted that communities should be at the heart of the (adaptation) projects, being genuinely involved in the formulation of the projects, to encourage ownership and responsibility to implement the projects. It also highlighted the need for strong gender awareness.

While highlighting the overlap with the areas above, it recommended.

- Assistance for relocation of communities to inland.
- A ban on sand mining in some communities.
- Capacity building for village social groups, and assistance to improve existing coping capacity.
- Coastal infrastructure protection (e.g. break waters).
- Education and awareness programs on climate change.
- Conduct village community reforestation programs.
- Disaster planning framework.
- Enforce government laws for sustainable management.
- Enforcing community by-laws, e.g. regulations where fine is imposed if a person uses banned forestry or fishing methods.
- Establish conservation areas and reserves.
- Establish marine protected areas and establish village laws for conservation of marine areas.
- Improved building codes resilient to more violent weather.
- Construct water tanks, dams and pans to store rain water for future use.
- Health programs in communities.
- Manage sand mining in village.
- Management program for mangroves and marine resources.
- Mandatory village inspections.
- Improve drainage systems.
- Practicing reactive responses.
- Reclamation of land.
- Reforestation program & establishment of nursery for forest and coastal trees.
- Relocate families if necessary.
- Restoration of coastal springs in communities.
- Re-forestation along water springs.
- Re-forestation on the coast and ensure cover of herbs.
- Trainings and workshops on agro forestry.
- Rain water harvesting support program.
- Women and youth groups responsible for maintaining water source area by cleaning and keeping it on a safe hygiene level.

Gender and Inequality

The study has also considered some of the issues with climate change in relation to gender and inequality.

Considering the effects outlined in the sections above, a number are likely to have a strong gender bias. Examples of impacts that would predominantly affect females include the impacts of sea surface temperature on seaweed farming, or on water availability and collection of water.

There will also be a strong distributional aspect to the impacts. It is stressed that the impacts of climate change will not be felt equally across Zanzibar, both in terms of specific locations, 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 work is needed to explore these effects in detail, and this is highlighted as a priority.

There is a need to ensure that adaptation strategies address these inequalities, otherwise there is a danger that adaptation will be focused towards higher cost interventions to benefit existing assets and more affluent groups.

Moving to Adaptation Pathways (Prioritisation)

The methods for assessing adaptation are still evolving. A number of key issues are highlighted for the current study:

- Climate change projections – and impact assessments - are 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 in the 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.
- 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 Zanzibar. Second, a focus on a short-term policy window, consistent with the 2020-2030 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.

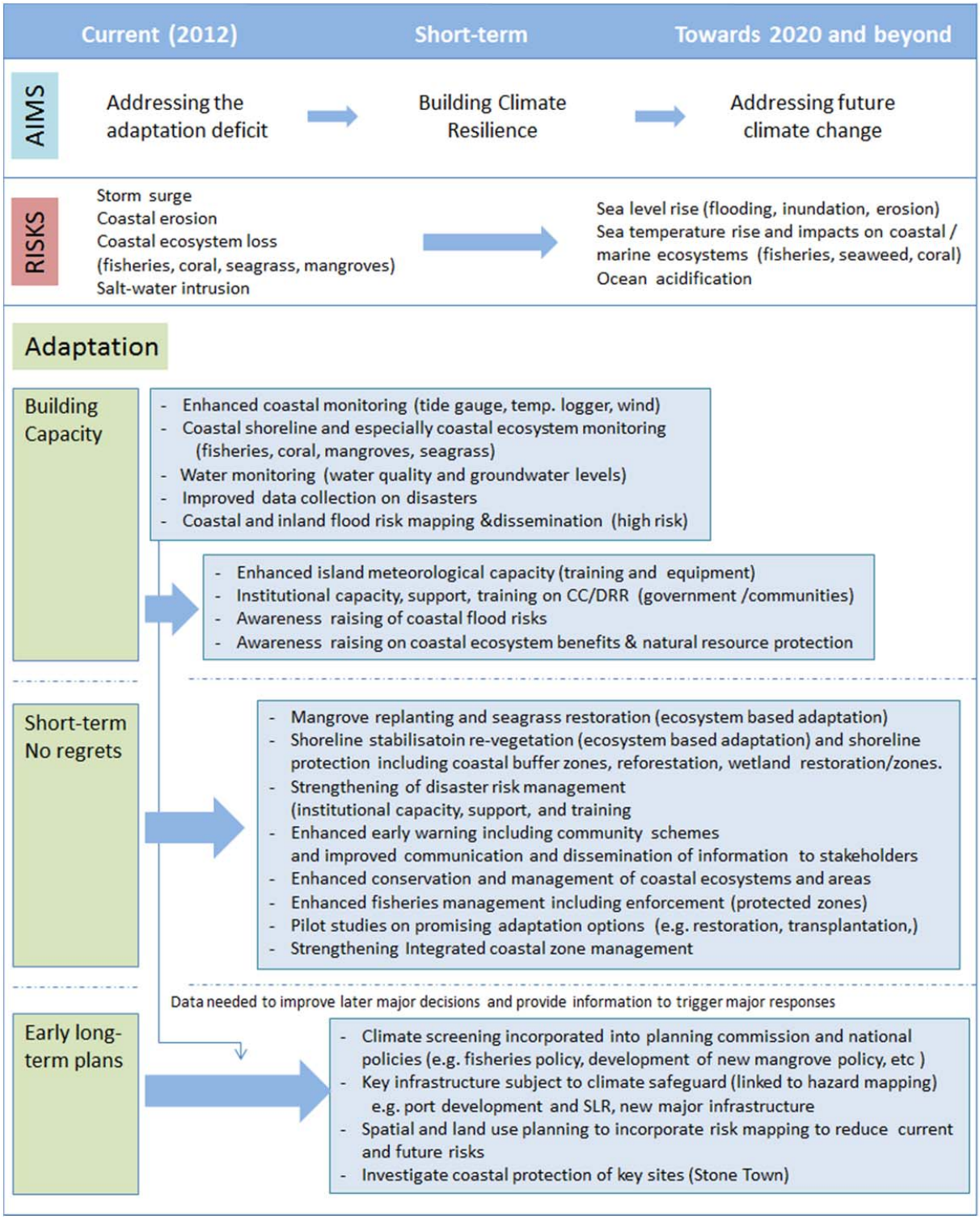
To address this, the study has considered four generic sets of adaptation responses.

1. Building adaptive capacity. This is important as a precursor to successful adaptation, providing the necessary architecture to enable future decision making, baseline information to assess future benefits, critical early actions to allow later options, etc. In economic terms, it is justified through the value of information and future option values.
2. 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. These include options which address current climate resilience and disaster risk reduction. They also include options that provide positive wider ancillary effects (e.g. other economic, social or environmental benefits) as well as reducing climate risks, and options that include minimal cost, or positive opportunities, providing they maintain flexibility for the future.
3. Encouraging pilot actions to test promising responses, allowing actors to act and then learn, and providing ex post information that will allow more effective and efficient sectoral implementation.
4. Identifying long-term issues that require early pro-active investigation or action. This includes a number of elements. It can include areas where current action involves long-life times, for example infrastructure that will be affected by future climate change. It can also include major effects that require early investigation or planning due to the time-scale involved, or the levels of risks and irreversibility involved. As an example, it might include assets or infrastructure which has very long life-times, where it is necessary to consider the potential implications of future risks. It might also include risks which involve thresholds, or irreversibility, which require a more precautionary based approach. Consideration of these longer-term issues may allow decision makers or planners to avoid future lock-in and prevent loss of future options. They may require early pro-active investigation (rather than early technical options) or initial short-term options that allow flexibility for future.

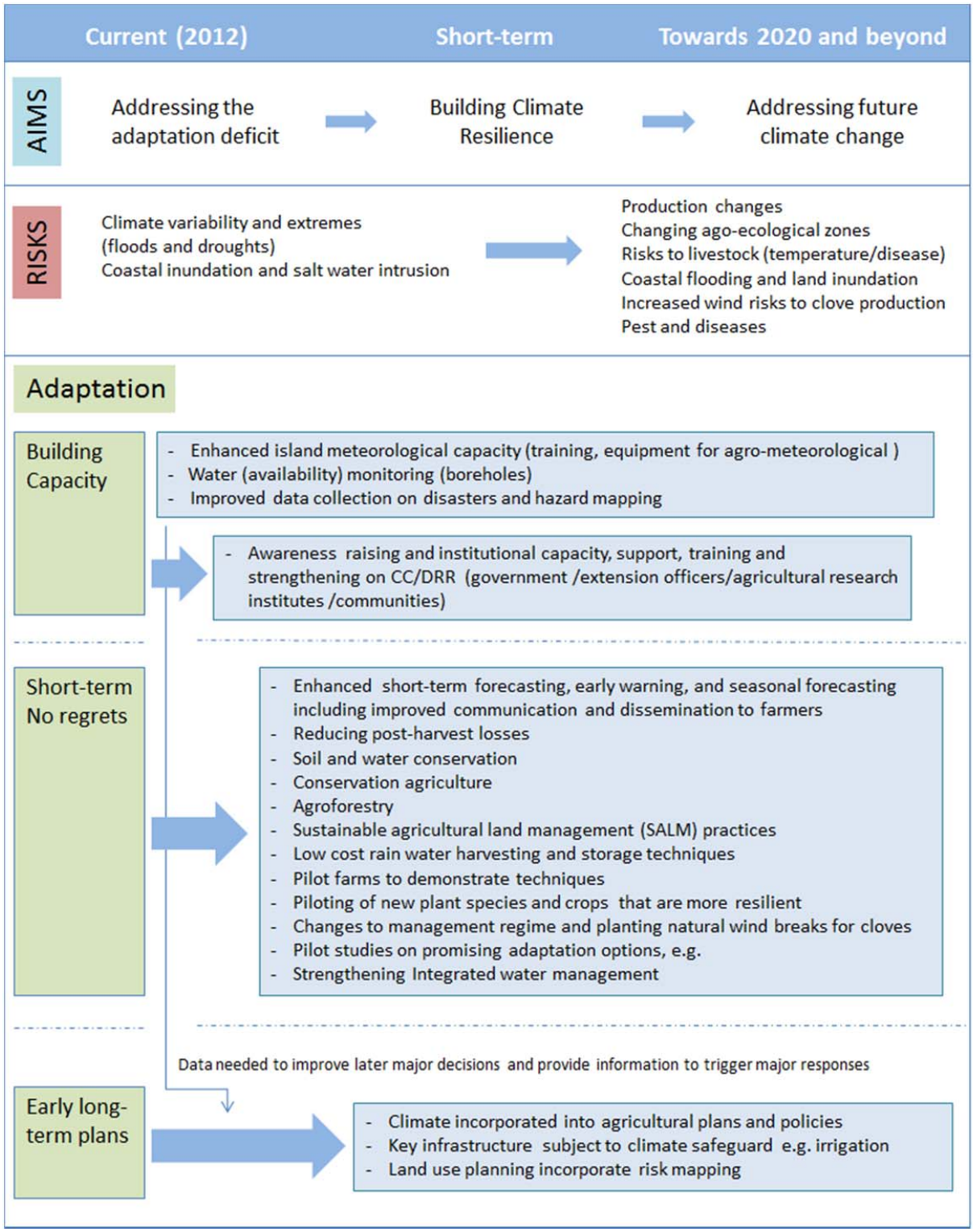
The study has considered this set of adaptation responses as a series of complementary steps, together forming an ‘adaptation pathway’. These identify actions in each of the areas above by sector.

The study has produced three adaptation pathways, for each of the major areas (coastal zones, tourism and agriculture). These split the most promising options into capacity building, no regret options (short-term) and planning for the future, and look at the most attractive options that would help Zanzibar adapt. A key criteria has been the focus on low cost options.

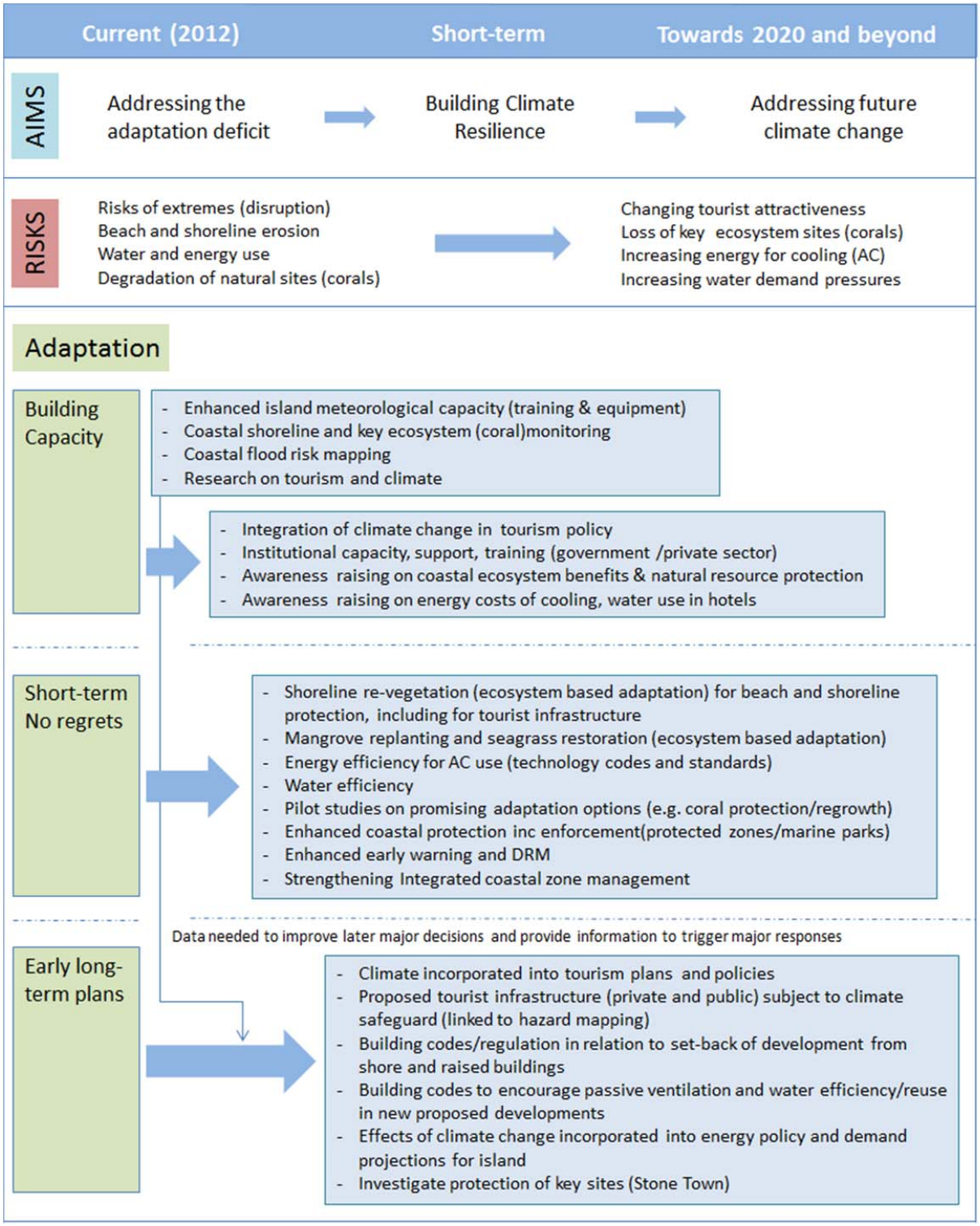
The pathways are shown below.



Adaptation Pathway for Coastal Zones (Sea Level Rise, Coastal Ecosystems)



Adaptation Pathway for Tourism



Adaptation Pathway for Agriculture

Next Steps: Towards a Zanzibar Climate Change Strategy

In terms of translating these findings into practical next steps, a number of recommendations are made:

1. The next step is for Zanzibar to produce and implement a Climate Change Strategy, explicitly considering and linking adaptation (climate resilience) and low carbon growth opportunities. This should involve stakeholder consultation and further analysis, and also look at some of the emerging opportunities for finance (see below).
2. This climate strategy would benefit from a focus on prioritizing options, i.e. identifying priority projects for funding. On the low carbon side, this can be addressed through a process similar to the NAMA (Nationally Appropriate Mitigation Action) and a similar approach for adaptation. This can be advanced in a number of ways, but analytical, technical and economic assessments provide key evidence streams for these decisions.
3. 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 strategy, but will require co-ordination and integration.
4. Zanzibar would also benefit from integrating climate change risks – and opportunities – into the Vision and Mkuza II. This would mainstream climate change resilience and low carbon thinking into development and long-term strategy. Climate could be included in any revision of the Vision and more strongly incorporated within the Mkuza II implementation plans, cascading through subsequently to sector objectives and policies. It would also be useful to introduce climate screening within the Planning Commission (within the President's Office Finance, Economy and Development Planning – POFEDP) to safeguard future decisions and particularly major future investment.
5. To achieve the steps above, there is a need for capacity building, with mechanisms, institutions and governance systems. There are plans for such capacity building already, but a key issue is to ensure that this happens right across government, not only in VPO-Environment. Thinking forward to the major climate funds potentially emerging, climate funding needs to be identified and prioritised into planning and budgetary systems – and there is a need to enhance the capacity and information needed to access funds, which is likely to require greater capacity within the Ministry of Finance and Economic Affairs (MOFEA).
6. Finally, Zanzibar needs to develop a strategy (or road map) for access to finance. There are a large number of different mechanisms for accessing climate finance (see box below), which will offer different benefits to the islands. There is a need to assess differing options for climate finance, including those of established and future potential funds. It is stressed that the relationship between sources and channels of finance is complex, because decisions are strongly linked to the mainland. A key part of the development of a Zanzibar climate change strategy will therefore be the review of alternative routes and options, including the institutional arrangements, to ensure Zanzibar benefits appropriately from the emerging opportunities.

Climate Finance

In summary, there are a number of available sources for climate finance. The first of these comes through the formal processes and mechanisms, the second comes through the wide range of emerging funds, the third comes through bi-lateral support and projects/programmes, the fourth comes from various private and foundation funds, and finally, there is the potential via the Budget and from own revenues streams.

The Kyoto protocol set in place the creation of carbon markets, linked to formal processes and mechanisms. This led to the formal process of the Clean Development Mechanism (CDM), and more recently the Adaptation Fund (AF), both of which are funded through the carbon markets. Additionally the GEF set up the GEF Trust Fund, the Special Climate Change Fund (SCCF), and the Least Developed Countries Trust Fund (LDCF).

Much of the current flows are channelled through UNFCCC mechanisms, and UNFCCC designated contact points for URT (on the mainland), such as with the Clean Development Mechanism (and the Designated National Authority (DNA) which currently sits in mainland VPO-E) and the Adaptation Fund (and the National Implementing Entity (NIE) – though this does not currently sit within the GoT, with UNEP playing this role).

However, over the past 5 years there has been a proliferation of funding initiatives, both bilateral and multilateral. Most of the finance is support from government ODA budgets. The initiatives include several multi-donor Trust Funds notably the Climate Investment Funds (CIFs) including Strategic Climate Fund and the Least Developed Countries Trust Fund (LDCF) and Pilot Program for Climate Resilience (PPCR) and Forest Investment Program (FIP) and Scaling Up Renewable Energy Program for Low Income Countries (SREP).

There are also voluntary markets, which are a source of climate finance, and other major funding sources (e.g. foundation funding).

In general the URT has had modest success in attracting climate finance, and this is reflected in the flows that have reached Zanzibar.

However, consistent with the pledges under the 2009 Copenhagen Accord, developed countries pledged to the goal of providing new, additional 'Fast Start' resources of $10 billion a year between 2010 and 2012 and $100 billion a year by 2020 to support climate action in poorer countries, and thus it is anticipated there will be increase in climate finance that will emerge over future years.

This has led a number of countries to move towards National Trust Funds, which can help channel finance, often using existing structures with high fiduciary standards. An ultimate aim (Bird, 2011) might be for the national budget to incorporate all external (ODA and climate finance) and domestic revenues, and allocate public financing under strong policy direction. To enable this there is a need for quality assurance and oversight mechanisms for all climate change programming and an institutional architecture that supports climate change programming and integrates this into appropriate sectors. It is also likely to need an active private sector to invest in climate resilient low carbon growth.

A clear focus of a Zanzibar climate change strategy will be to provide a route to finance. This will be strongly influenced by the decisions on the mainland, and the approach adopted, not least because of the DNA/NIE and broader national funding arrangements. As an example, if the mainland goes towards a national fund, then Zanzibar might have the opportunity to be part of these arrangements, for example through a specific thematic window. However, a large number of options do exist, and a Zanzibar needs to investigate these as a priority, including the legal and institutional arrangements.

References

Agrawala, S., A. Moehder, A. Hemp, M. Van Aalst, S. Hitz, J. Smith, H. Meena, S. Mwakifwamba, T. Hyera and O. Mwaipopo (2003). Development and climate change in Tanzania: Focus on Mount Kilimanjaro. OECD, Paris.

Beaumont N.J., Austen M.C., Atkins J., Burdon D., Degraer S., Dentinho T.P., Derous S., Holm P., Horton T., van Ierland E., Marboe A.H., Starkey D.J., Townsend M. and Zarzycki T. 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: Implications for the ecosystem approach. Marine Pollution Bulletin. 54: 253–265.

Beer S, Mtolera M, Lyimo T and Björk M. 2006. In situ Photophysiology of the Tropical Seagrass Halophila ovalis in Zanzibar, East Africa. Aquatic Botany 84: 367-371

Bergman K.C. and M.C. Öhman. Coral reef structure at Zanzibar Island, Tanzania. Department of Zoology, Stockholm University, 106 91 Stockholm, Sweden. Available at: http://gridnairobi.unep.org/chm/EAFDocuments/Tanzania/bergman_p263-276.pdf

Bandeira, S., C. Macamo, J. Kairo, F. Amade, N. Jiddawi & J. Paula, 2010. Evaluation of mangrove structure and condition in two trans-boundary areas in the Western Indian Ocean Aquatic Conservation: marine and freshwater systems . Vol 19. 45-55

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

Brown S, Nicholls RJ, Vafeidis A, Hinkel J, and Watkiss P (2011). The Impacts and Economic Costs of Sea-Level Rise in Europe and the Costs and Benefits of Adaptation. Summary of Results from the EC RTD ClimateCost Project. In Watkiss, P (Editor), 2011. The ClimateCost Project. Final Report. Volume 1: Europe. Published by the Stockholm Environment Institute, Sweden, 2011. ISBN 978-91-86125-35-6.

Burgess & Burgess (2002) Important Bird Areas in Tanzania, http://avibase.bsc-eoc.org/checklist.jsp?region=TZzn&list=howardmoore

Bwathondi, P.O.J., Chande, A.I., Mhitu, H.A., Kulekana, J.J., Mwakosya, C.A., Shayo, S.D. and Bayona, J.D.R (2002), Investigation on the Abundance andDistribution of Prawn at Bagamoyo and Rufiji delta, Tanzania Fisheries Research Institute

Juan-Carlos Ciscar, Ana Iglesias, Luc Feyen, László Szabó, Denise van Regemorter, Bas Amelung, Robert Nicholls, Paul Watkiss, Ole B. Christensen, Rutger Dankers, Luis Garrote, Clare M. Goodess, Alistair Hunt, Alvaro Moreno, Julie Richards, and Antonio Soria (2011). Physical and Economic Consequences of Climate Change in EUROPE. PNAS.
Proceedings of the National Academy of Sciences. Physical Sciences - Environmental Sciences. PNAS January 31, 2011. www.pnas.org/cgi/doi/10.1073/pnas.1011612108

Coles, C., Lange, Jiddawi (2009). A pilot study of patterns of income distribution and employment in the Zanzibar fishing chain. REPOA Report.

Crona, B., Rönnbäck, P., Jiddawi, N., Ochiewo, J., Maghimbi, S., Banderia, S. (2009) Murky water: Analyzing risk perception and stakeholder vulnerability related to sewage impacts in mangroves of East Africa. Global Environmental Change 19(2): 227-239.

De la Torre-Castro, M. and P. Rönnbäck. 2004. Links between humans and seagrasses – an example from tropical East Africa. Ocean and Coastal Management 47:361-387.

DREF Bulletin (2007). TANZANIA : FLOODING IN ZANZIBAR. FINAL REPORT. No. 05ME025. 16 March 2007http://reliefweb.int/sites/reliefweb.int/files/resources/51A320ACE7D3E6B9C12572A000356A74-Full_Report.pd

Dubi, A.M., Mmochi, A.J., Jiddawi, N.S., Kyewalyanga, M.S., Msuya, F.E., Ngazy, Z. and Mwandya, A.W. (2006). Development of integrated pond culture of fish, shellfish and seaweed in Tanzania. Final report to MASMA after completion of 3 years MASMA grantee programme. 74 p

Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber and F.N. Tubiello, 2007: Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 273-313.

Ebi, K.L. (2008) 'Adaptation costs for climate change-related cases of diarrhoeal disease, malnutrition, and malaria in 2030', Globalization and Health, vol. 4, no. 9.

ECA (2009). Shaping Climate-resilient Development a framework for decision-making. A report of the economics of climate Adaptation working group. Economics of Climate Adaptation. Available at: http://www.swissre.com/resources/387fd3804f928069929e92b3151d9332-ECA_Shaping_Climate_Resilent_Development.pdf (Accessed January 2010).
Cited in ECA (2009) from James Machari, interview with Juma Ngasongwa, Tanzanian Minister for Planning, Economy, and Empowerment, June 1st of 2006 at the 2006 World Economic Forum; Reuters News

FAO (2010), Global survey of agricultural mitigation projects, Mitigation of Climate Change in Agriculture (MICCA) Project, Food and Agriculture Organization of the United Nations (FAO), August 2010

Fankhauser S, 1995, "Protection versus retreat: the economic costs of sea-level rise" Environment and Planning A 27(2) 299 – 319

Garpe, K.; Yahya, S.A.S.; Lindahl, U.; and Ohman, M.C. (2006) Long-term effects of the 1998 coral bleaching event on reef fish assemblages. Mar. Ecol. Prog. Ser.

Stefan Gössling, Paul Peeters, C. Michael Hall, Jean-Paul Ceron, Ghislain Dubois, La Vergne Lehmann, Daniel Scott (2012). Tourism and water use: Supply, demand, and security. An international review. Progress in Tourism Management, Volume 33, Issue 1, February 2012, Pages 1–15

Gullström M, Lundén M, Bodin M, Kangwe J, Öhman M C, Mtolera M, Björk M. (2006) Assessment of vegetation changes in the seagrass-dominated tropical Chwaka Bay (Zanzibar) using satellite remote sensing. Estuarine, Coastal and Shelf Science, 67:399-408

Stefan Gössling, Magnus Bredberg, Anna Randow, Elin Sandström & Patrik Svensson (2006) Tourist Perceptions of Climate Change: A Study of International Tourists in Zanzibar. Current Issues in Tourism Volume 9, Issue 4-5, 2006

Grimsditch, Gabriel D. and Salm, Rodney V. (2006). Coral Reef Resilience and Resistance to Bleaching. IUCN, Gland, Switzerland. 52pp.

Halcrow (1994). The Development of Water Resource in Zanzibar. Report to the Government of Zanzibar. October 1994.

Iddi H. Hassan (2010). A Study On Local Coping Strategies For Climate Change Around Two Marine Protected Areas In Zanzibar, Report from the State University of Zanzibar to UNESCO.

Erik Hansson (2010). Groundwater on Zanzibar: uses and pollutants. Institutionen för växt- och miljövetenskaper, Göteborgs universitet. November 2010

IUCN (2008). Mats Bjork, Fred Short, Elizabeth Mcleod, and Sven Beer. Managing Seagrasses For Resilience To Climate Change. IUCN Resilience Science Group Working Paper Series - No 3, ISBN: 978-2-8317-1089-1
http://data.iucn.org/dbtw-wpd/edocs/2008-024.pdf

IDRC (2010). Adapting to Cyclones in Madagascar's Analanjirofo Region
http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Climate_Change_and_Adaptation_in_Africa/Documents/Adaptation-Insight-Madagascar-Adapting-to-cyclones.pdf

IED (2009). Cultivating success: the need to climate-proof Tanzanian agriculture. Muyeye Chambwera, James MacGregor Available at : http://www.iied.org/pubs/pdfs/17073IIED.pdf

Ilskog, E (2011), The Zanzibar Blackout - a case study on consequences from an electricity power crisis, KTH, School of Technology and Health, Sweden
http://kth.diva-portal.org/smash/record.jsf?pid=diva2:450394

Isaac, M. and van Vuuren, D.P. (2009). Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy 37 (2009) 507–521

Ishengoma. E.B; Jiddawi, N.S; Tamatamah, R.A; and Mmochi, A.J. 2011. Wild Black-lip Pearl Oyster (Pinctada margaritifera Spat Collection in Tanzania Western Indian Ocean J. Mar. Sci. Vol. 10, No. 1, pp. 49-57

Jiddawi, N.S (2011). Pearl faming in Tanzania. In. Troell, M., T. Hecht, M. Beveridge, S. Stead, I. Bryceson, N. Kautsky, F. Ollevier, and A. Mmochi. (eds). Mariculture in the WIO region - Challenges and Prospects. WIOMSA Book Series No 11. Printed by Jamana Printers Ltd.. pp53-54

Jiddawi N.S. and Ngazy Z. 2000 A gift from the ocean: The importance of Eucheuma farming to the livelihood security of the people of Zanzibar. In Mshigeni, E. Asman, J and Bisanda E (Eds). Opportunities from Africa's Bioresources. Proceedings of the second International training workshop on the Zero emissions Research Initiatives, UNDP. University of Namibia.pp 132-146

Ron W. Johnstone, Christopher A. Muhando and Julius Francis. The Status of the Coral Reefs of Zanzibar: One Example of a Regional Predicament. Ambio. Vol. 27, No. 8, Building Capacity for Coastal Management (Dec., 1998), pp. 700-707

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

Kent, P.E., J.A.Hunt and D.W. Johnstone. (1971). The geology and geophysics of coastal Tanzania. Geophysical Paper No. 6, London.

Kombo, Y (2010), Zanzibar biodiversity, climate change and energy crisis: Toward Zanzibar Environmental Policy Formulation, March 2010, http://zanzibar-biodiversity-climate-energy.blogspot.com/2010/04/zanzibar-biodiversity-climate-change.html

Lange & Jiddawi (2009) Economic value of marine ecosystem services in Zanzibar: Implications for marine conservation and sustainable development. Ocean and Coastal Mangement 52 521-532.

Lange, G.-M., S. Dasgupta, T. Thomas, S. Murray, B. Blankespoor, K. Sander, and T. Essam (2010). Economics of Adaptation to Climate Change — Ecosystem Services. The World Bank.

Leonard Jones Chauka. (2012). Molecular Ecology and Photo-Physiology of Symbiodinium Harbored by Tanzanian Reef Building Corals. PhD thesis submitted to University of Dar es Salaam 175pgs.

Lovett, J.C., G.F. Midgely, P.B. Barnard. 2005. Climate change and ecology in Africa. African Journal of Ecology 43: 279-281.

Mahongo, S.B., 1999. Sea level measurement and analysis in the Western Indian Ocean. National Report, Tanzania Fisheries Research Institute, Tanzania. *Intergovernmental Oceanographic Commission (of UNESCO)*, 25 pp.

Mahongo, S.B., 2001. The Tanzania Sea Level Network: A National Report (Draft). Tanzania Fisheries Research Institute. Available on-line at: http://www.gloss-sealevel.org/publications/documents/tanzania_2001.pdf (last accessed on 11 October 2010).

Mahongo, S.B. and Khamis, O.I., 2006. The Tanzania National Sea Level Report. Tanzania Fisheries Research Institute and Department of Survey and Urban Planning. Available on-line at: http://www.gloss-sealevel.org/publications/documents/tanzania2006.pdf (last accessed on 11 October 2010).

Makota, V., Sallema, R. and Makika, C., 2004. Monitoring Shoreline Change using Remote Sensing and GIS: A Case Study of Kunduchi Area, Tanzania. Western Indian Ocean Journal of Marine Science, 3(1), 1-10.

Makame Omar Makame, (2007) "Adoption of improved stoves and deforestation in Zanzibar", Management of Environmental Quality: An International Journal, Vol. 18 Iss: 3, pp.353 - 365

MALE (2006).Rapid Vulnerability Assessment (RVA) of the Effect of Prolonged Dry Spell on Agriculture, Livestock Production and Environment in Zanzibar during the Agricultural Season 2005/06 By the Dry Spell Assessment Task Force Team. Coordinated by the Ministry of Agriculture, Livestock and Environment (MALE). Zanzibar, March 2006

Masoud , T. & R. Wild (2004). Sustainable use and conservation management of mangroves in Zanzibar, Tanzania IN: Mangrove management and conservation: present and future Vannucci (Ed). United Nations University Press.

Mathematica Policy Research (2011), Tanzania Energy Sector Impact Evaluation: Findings from the Zanzibar Baseline Study, On behalf of Millennium Challenge Corporation, March 2011, http://www.mathematica-mpr.com/publications/PDFs/international/zanzibar_baseline.pdf

Nancy McCarthy, Leslie Lipper and Giacomo Branca (2011). Climate-Smart Agriculture: Smallholder Adoption and Implications for Climate Change Adaptation and Mitigation. Food and Agriculture Organization of the United Nations (FAO). December 2011

McLeod, Elizabeth and Salm, Rodney V. (2006). Managing Mangroves for Resilience to Climate Change. IUCN, Gland, Switzerland. 64pp.

McMichael, A.J., et al. (2004). Climate change. In: Ezzzati, M., Lopez, A.D., Rodgers, A., and Murray, C.J., (eds) Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors, Vol 2. World Health Organisation, Geneva, 1543–1649.

Meehl GA, Stocker TF, Collins WD, Friedlingstein P, Gaye AT, Gregory JM, Kitoh A, Knutti R, Murphy JM, Noda A, Raper SCB, Watterson IG, Weaver AJ, Zhao Z-C (2007) Global climate projections. In: Solomon S, Qin D, Manning M et al., (eds) Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp 433-497.

Moberg, F. & R. Ronnback (2003) Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean Coastal Management 46 pp. 27-46.

Mtolera, M.S.P. (2003). Effect of seagrass cover and mineral content on Kappaphycus and Eucheuma productivity in Zanzibar. Western Indian Ocean Journal of Marine Science 2(2):163-170

McClanahan, T.R., Ateweberhan M., Muhando, C.A and Mohammed S.M. 2007. Effects of Climate and Seawater Temperature Variation on Coral Bleaching and Mortality. Ecological Monographs 7: 503–525.

Mohammed, S.M., Muhando C.A. and Machano, H. 2002. Coral Reef Degradation in Tanzania: Results of Monitoring 1999-2002. In: O. Linden, D. Souter, D. Wilhelmsson, & D. Obura (Eds.), Coral Reef Degradation in the Indian Ocean. Status Report 2002 (pp. 108). Kalmar: CORDIO. pp 21-30.

Mohammed, S.M., Muhando, C.A., Machano, H., Jiddawi. N and Yahya, S. 2005. Status of Coral Reefs in Tanzania. In: Souter, D and Linden, O. (eds.) Coral Reef Degradation in the Indian Ocean: Status Report 2005: pages 36-47.

Muhando, C.A. 2002. Seawater Temperature on Shallow Reefs off Zanzibar Town, Tanzania. In: O. Linden,D. Souter,D. Wilhelmsson, & D. Obura (Eds.), Coral Reef Degradation in the Indian Ocean. Status Report 2002 (pp. 108). Kalmar: CORDIO. pp 40-46.

Muhando, C.A., Kuguru, B.L., Wagner, G.M., Mbije, N.E. and Ohman, M.C. 2002. Environmental effects on the distribution of corallimorpharians in Tanzania. Ambio 31:558-561

Muhando C.A. and Mohammed S.M. 2002. Coral reef benthos and fisheries in Tanzania before and after the 1998 coral bleaching and mortality event. Western Indian Ocean J. Mar. Sci., 1:43-52

Mwakosya,C.A (2004), Assessment of Tanzanian Prawns Fishery resources, M.phil Thesis Report, University of Bergen, Norway.

Mustellin, M. Khamis, R. G. Klein, A. J. Mzee, T. A. Haji, B. Asseid and T. Sitari (2011). IN: Coastal Forest Buffer Zones and Shoreline Change in Zanzibar, Tanzania: Practical Measures for Climate Adaptation? Pp. 133- 151. Springer-Verlag Berlin

Mustelin, J., Assaid, B., Haji, T., Khamis, M., Klein, R., Mzee, A., and Sitari, T. (2009). Practical measures to tackle climate change: coastal forest buffer zones and shoreline change in Zanzibar, Tanzania. Turku University Department of Geography Publications.

Johanna Mustelin (2009). Adaptation of coastal communities in the cross-pressure of tourism and environmental change in Zanzibar, Tanzania. IOP Conf. Series: Earth and Environmental Science 6 (2009) 572030 doi:10.1088/1755-1307/6/7/572030

J. Mustelin, R. G. Klein, B. Assaid, T. Sitari, M. Khamis, A. Mzee and T. Haji (2010). Understanding current and future vulnerability in coastal settings: community perceptions and preferences for adaptation in Zanzibar, Tanzania. Population and Environment.
Volume 31, Number 5, 371-398, DOI: 10.1007/s11111-010-0107-z

Muzuka, A.N.N., Dubi., A.M., Muhando, C.A. and Shaghude, Y.W. (2010). Impacts of hydrodrographic parameters and seasonal variation in the sediment fluxes on coral status at Chumbe and Bawe reefs, Zanzibar, Tanzania. Estuarine Coastal and Shelf Science, 89(2): 137-144.

Myers, G.A. (2002). Local communities and the new environmental planning: a case study from Zanzibar. Area Volume 34, Issue 2, pages 149–159.

Naber, G.-M. Lange, and M. Hatziolos (2009). Valuation of ecosystem services a gap analysis. UNEP/ WCMC.

National Environment Management Council (2006). Integrated Ecosystems Assessment in Tanzania: Experiences in Ecosystems Management.

Ngoile M. A. K and J. P. Shunula, (1992). Status and exploitation of the mangrove and associated fishery resources in Zanzibar. Hydrobiologia Volume 247, Numbers 1-3, 229-234,.

Niras (2010). Preparation of an Adaptation Programme of Action for Zanzibar (ZAPA). Ministry of Foreign Affairs, MFA, Finland, Ministry of Water, Construction, Energy and Land, Zanzibar, Ministry of Agriculture, Livestock and Environment, Zanzibar, Sustainable Management of Land and Environment II, (SMOLE II) 2010 -2013. October 2010

Nhnyete, I.K. and Mahongo, S.B., 2007. National Report of The United Republic of Tanzania on Sea Level Measurements. *Tanzania Ports Authority and Tanzania Fisheries Research Institute*. Available on-line at: *http://www.gloss-sealevel.org/publications/documents/tanzania_gex2007.pdf* (last accessed on 11 October 2010).

Nyandwi, N., 2001. Reassessment of the nature of beach erosion north of Dar es Salaam, Tanzania. *In*: Richmond, M.D., Francis J., (eds), *Marine Science Development in Tanzania and Eastern Africa*. Proceedings of the 20th Anniversary Conference on Advances in Marine Science in Tanzania, 28 June – 1 July 1999, Zanzibar, Tanzania. IMS/WIOMSA, p. 107-120.

Obura D (2002). Status of coral reefs in Eastern Africa: Kenya, Tanzania, Mozambique and South Africa. Australian Institute of Marine Science URI: http://hdl.handle.net/1834/338 ISBN: 0-642-32216-3.

Obura, D Celliers L, Machano H, Mangubhai S, Mohammed SM, Motta H, Muhando C, Muthiga N, Pereira M, Schleyer M (2002). Status of coral reefs in Eastern Africa: Kenya, Tanzania, Mozambique and South Africa. In: C.R. Wilkinson (ed.), Status of coral reefs of the world: 2002. GCRMN Report, Australian Institute of Marine Science, Townsville. Chapter 4, pp. 63-78.

OCGS (2011). 2009/10 Household Budget Survey. Office of Chief Government Statistician Zanzibar.

Oliveira, E. C., Österlund, K. & Mtolera, M. S. P. (2005) Marine Plants of Tanzania: a field guide to the seaweeds and seagrasses. Eurolitho S.p.A, Rozzano (Mi), 267 pp. ISBN 91-631-6510-4.

Paavola, J. (2006). Justice in adaptation to climate change in Tanzania. In W. N. Adger, J. Paavola, S. Huq, & M. J. Mace (Eds.), Fairness in adaptation to climate change. Massachusetts Institute of Technology.

Pye et al (2010), Opportunities for Low Carbon Investment in Tanzania, Funded by UK Government (DFID), December 2010.
http://economics-of-cc-in-tanzania.org/images/Tanzania_low_carbon_growth_assessment_v7.pdf

Ragoonaden S (2006) Sea level activities and changes on the islands of the Western Indian ocean. West Indian Ocean J Mar Sci 5(2):179–194

Rahmstorf S (2007). A Semi-Empirical Approach to Projecting Future Sea-Level Rise. *Science*, 315, 368-370.

RGZ (2007). An Assessment of Rainwater harvesting Potential in Zanzibar. The Revolutionary Government of Zanzibar In Collaboration with Millennium Development Goals - MDG Centre, Nairobi Kenya United Nations Development Programme (UNDP), Tanzania and World Agroforestry Centre – ICRAF, Nairobi, Kenya. May 2007.

RGZ (2007) Zanzibar Strategy For Growth And Reduction Of Poverty (ZSGRP) January, 2007. Revolutionary Government Of Zanzibar.

RGZ (2010) The Zanzibar Strategy for Growth and Reduction of Poverty: 2010-2015 (Zsgrp ii) MKUZA ii. A successor to the Zanzibar Strategy for Growth and Reduction of Poverty 2007-2010 . (ZSGRP). Revolutionary Government Of Zanzibar.

Revolutionary Government of Zanzibar In Collaboration with SMZ (2007). An Assessment of Rainwater harvesting Potential in Zanzibar.

RGZ (Revolutionary Government of Zanzibar) (2009). The Status of Zanzibar Coastal Resources. Towards the Development of Integrated Coastal Management Strategies and Action Plan.

RGZ (2010), Zanzibar Statistical Abstract 2010, Office of Chief Government Statistician, Revolutionary Government of Zanzibar.

RGZ (2010c) Zanzibar Agricultural Transformation for Sustainable Development, 2010-2020 http://www.kilimoznz.or.tz/images/Agrictransform/Agrictransform.pdf

RGZ (2009), Zanzibar Human Development Report 2009, Prepared by Zanzibar Institute of Financial Administration (ZIFA), Revolutionary Government of Zanzibar, http://www.zifa.ac.tz/data/ZPHDR.pdf

RGZ (2008), Zanzibar National Forest Resources Management Plan 2008 – 2020, Department of Commercial Crops, Fruits and Forestry, Revolutionary Government of Zanzibar

RGZ (2005), State of the environment report for Zanzibar 2004/05

RGZ (2000), The Zanzibar Development Vision

Pedram Rowhania, David B. Lobell, Marc Linderman, Navin Ramankutty (2011) Climate variability and crop production in Tanzania. Agricultural and Forest Meteorology 151 (2011) 449–460

Saunders, F., S. M. Mohammed, N.Jiddawi and S. Sjöling (2008). An Examination of Governance Arrangements at Kisakasaka Mangrove Reserve in Zanzibar. Environmental Management Volume 41, Number 5, 663-675.

R. E. Sallema and G. Y. S. Mtui (2008).Adaptation technologies and legal instruments to address climate change impacts to coastal and marine resources in Tanzania. African Journal of Environmental Science and Technology Vol. 2 (9). pp. 239-248, September, 2008.
Available online at http://www.academicjournals.org/AJest

Saunders, F, Salim M. Mohammed, Narriman Jiddawi, Karolina Nordina, Bengt Lundèn and Sara Sjöling 2010. The Changing Social Relations of A Community-Based Mangrove Forest Project In Zanzibar. Ocean and Coastal Management. Vol 53.

Shaghude, Y.W. J.W. Mburu, R.S. Arthurton A. Dubi, S. Gachuiri, J. Kangwe, C. Magori, F. Msuya, R. Mwaipopo, N. Nyandwi, J. Ochiewo, H. Ong'anda, R. Sallema, I. Sanga, M. Shalli and J. Uku. Shoreline Change in Tanzania and Kenya: Assessment Procedures and Mitigation Strategies for Management. A Book on shoreline changes mitigation guidelines (submitted to WIO Journal of Marine Sciences).

Simpson, M.C., Gössling, S., Scott, D., Hall, C.M. and Gladin, E. (2008) Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices. UNEP, University of Oxford, UNWTO, WMO: Paris, France.

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

Shunula, J.P. (2002). Public awareness, key to mangrove management and conservation: the case of Zanzibar. Trees (2002) 16:209–212.

Lorna Slade, Ali Thani, Hajj M. Hajj with the assistance of Salum N. Mbarouk.(2011) Water Equity in Tourism: Zanzibar Case Study. For Tourism Concern October 2011

Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) (2007) Climate change 2007: The physical science basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Thompson, I., Mackey, B., McNulty, S., Mosseler, A. (2009). Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67 pages.

Tumbo et al (2011). Agriculture. Reported in Watkiss et al (2011) below.

Tobey J, Torell E (2006) Coastal poverty and MPA management in mainland Tanzania and Zanzibar. Ocean Coast Management 49:834–854

Torell, E.C., Amoral, M., Bayrer, T.G., Daffa, J., Luhikula, G. and Hale, L.Z., 2004. Building enabling conditions for integrated coastal management at the national scale in Tanzania. Ocean and Coastal Management, 47:339-359.

Ulltang, O., Brinca, L and Sousa, L (1985), State of Stocks of Shallow Water Prawns at Sofara Bank. In Revista de investigacao Pesqueira No. 13

United Nations (2010) Consultation and Outreach Plan towards Development of the National REDD Strategy. Dar es Salaam

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

UN (2008). UN world population prospects 2008, http://esa.un.org/unpp/p2k0data.asp

UN (2007) UN world urbanization prospects 2007 http://esa.un.org/unup/p2k0data.asp

United Republic of Tanzania (2007). National Adaptation Programme of Action (NAPA). Vice President's Office, Division of Environment, January 2007

United Republic of Tanzania (2003). Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC), 2003, The United Republic of Tanzania, Vice President's Office, Dar es Salaam, Tanzania available on-line: http://unfcc.int/resource/docs/natc/tanncl.pdf.

United Republic of Tanzania (2007). National Adaptation Programme of Action (NAPA). Vice President's Office, Division of Environment, January 2007

URT (2005), Baseline Study on Biomass Energy Conservation in Tanzania, SADC Programme for Biomass Energy Conservation (ProBEC)

UNESA, 2010. World Population Prospects: the 2008 Revision Population Database. http://esa.un.org/unpp/

United Republic of Tanzania (2010), The National Strategy for Growth and Reduction of Poverty (NSGRP II or MKUKUTA II), Ministry of Finance and Economic Affairs, Government of Tanzania, March 2010

URT (2009). ECONOMIC SURVEY 2009. Available at http://www.tanzania.go.tz/economicsurveyf.html

United Republic of Tanzania (2009), A study on integrated transportation system for increased efficiency and growth of the economy of Tanzania, National Institute of Transport, On behalf of President's Office, Planning Commission, September 2009

United Republic of Tanzania (2009b), National Framework for Reduced Emissions from Deforestation and Forest Degradation (REDD), August 2009, http://www.reddtz.org/images/pdf/redd%20framework%2009_new.pdf

United Republic of Tanzania (2008), The Economic Survey 2007, Ministry of Finance and Economic Affairs, Government of Tanzania, June 2008, http://www.tanzania.go.tz/economicsurveyf.html

United Republic of Tanzania (2008b), Power System Master Plan Study, Government of the United Republic of Tanzania, Final Draft Report, March 2008

United Republic of Tanzania (2008c), State of the Environment Report (2008), Published by the Vice President's Office, Division of Environment, United Republic of Tanzania, Dar es Salaam, 2008

United Republic of Tanzania (2003), Initial National Communication under the United Nations Framework Convention on Climate Change (UNFCCC), Vice President's Office, United Republic of Tanzania, March 2003, http://unfccc.int/resource/docs/natc/tannc1.pdf

United Republic of Tanzania (2003b), The National Energy Policy, Ministry of Energy and Minerals, Government of Tanzania, February 2003

United Republic of Tanzania (2001), Agricultural Sector Development Strategy, Government of Tanzania, October 2001

United Republic of Tanzania (1999), The Tanzania Development Vision 2025, Government of Tanzania, http://www.tanzania.go.tz/vision.htm

URT (2009) Tanzania's National REDD-Readiness Programme. Dar es Salaam. DoE-VPO

URT (2010) Tanzania-REDD Newsletter No. 1, May-2010

URT, 2010a. Water. United Republic of Tanzania. http://www.tanzania.go.tz/waterf.html

URT, 2010b. Water Utilities Performance Report for 2008/09. Energy and Water Utilities Regulatory Authority, United Republic of Tanzania.

URT, 2007. National Adaptation Programme of Action (NAPA). Vice President's Office, Division of Environment, United Republic of Tanzania.

URT (United Republic of Tanzania) (1998), National Forest Policy, Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania

URT (United Republic of Tanzania) (2002), The Forest Act 2002, No. 7 of 7th June 2002, Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania

Wang, Y., G. Bonynge, J. Nugranad, M. Traber, A. Ngusaru, J. Tobey, L. Hale, R. Bowen & V.Makota (2003). Remote Sensing of Mangrove Change Along the Tanzania Coast. Marine Geodesy Volume 26, Issue 1-2, pages 35-48

Watkiss, P. Downing, T., Dyszynski, J., Pye, S. et al (2011). The Economics of Climate Change in the United Republic of Tanzania. Report to Development Partners Group and the UK Department for International Development. Published January 2011. Available at: http://economics-of-cc-in-tanzania.org/

Watkiss, P, Downing, T., Dyszynski, J., Butterfield, R., Devisscher, T., Droogers, P., Pye, S., Ali, B., Harding, B., Tas, A., de Blois, M., Tadege, A., Hunt, A., Taylor, T., Bouma, M. Kovats, S., Maitima, J., Mugatha, S., Kariuki, P., Mariene, L., Worden, J., Western, D., Waruingi, L., Brown, S., Kebede, A., Nicholls, R., Lager, B., Otiende, B., Chambwera, M., Birch, T., Mutimba, S., Sang, S. (2009). The Economics of Climate Change in Kenya. Final Report to DFID and DANIDA. Led by the Stockholm Environment Institute, Oxford. Available at http://kenya.cceconomics.org/kedo/FINAL-kenya-report-April.pdf

Watkiss, P. and Hunt, A. (2012). Projection of economic impacts of climate change in sectors of Europe based on bottom up analysis: human health. Climatic Change, 2012, Volume 112, Number 1, Pages 101-126. DOI: 10.1007/s10584-011-0342-z

Woolfe, K.J. and Larcombe, P. (1999). Terrigenous sedimentation and coral reef growth. A conceptual framework. Marine Geology, 155:331-345.

Wily and Mbaya (2001). Land people and forests in eastern and southern Africa at the beginning of the 21st Century. The impact of land relations on the role of communities in forest future. Nairobi, IUCN-EARO.

World Bank (2008) Ecosystem Services in Zanzibar IN: Environment Matters Annual Review July 2007-June 2008.

ZATI (2011). Briefing Document on the Zanzibar Tourism Industry. Zanzibar Association of Tourism Investors, 2011

ZMCP (2009) Malaria Elimination in Zanzibar. A Feasibility Assessment. Available at: http://www.malariaeliminationgroup.org/sites/default/files/MalariaEliminationZanzibar.pdf

Appendix I United Republic of Tanzania and the NAPA

There has been considerable analysis undertaken at the national level in Tanzania on vulnerability, impacts and adaptation.

The earlier US Country Studies Programme assessment set out the vulnerability and adaptation response options for Tanzania (1997), using Global Climate Change Scenarios.

The 1st National Communication (URT, 2003) set out the impacts of climate change and vulnerability assessment, as well as reporting on greenhouse gas emissions and potential measures to reduce these emissions.

At the national level, immediate priorities for adaptation in Tanzania were set out in the NAPA (URT, 2006). A summary is included in the box below. One of the final six priority projects highlighted the application in Zanzibar (see main text).

The Tanzania NAPA (URT, 2007)

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

Initially, the process proposed 72 project activities with a breakdown of 11 in 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 finally, tourism had 5. Using a list of agreed criteria that best suits 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

The final choice was reduced to six projects :

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 (reported to the UNFCCC)

Coastal Areas

The URT NAPA (URT, 2007) identified a large number of coastal and marine adaptation responses for Tanzania, shown in the Appendix. The NAPA scoring and ranking exercise concluded that for coastal and marine resources, the priorities were the construction of artificial structures, e.g., sea walls, artificially placing sand on the beaches and coastal drain beach management system, followed by restoration of degraded habitats. For human settlements, the priorities were to establish good land tenure system and facilitate sustainable human settlements, followed by relocation of vulnerable communities to other areas, and then establish disaster committee and plans at village level. For tourism, the priorities were to establish alternative source of income for the community in the tourist area.

Existing measures	Potential Adaptation Options
Coastal and marine resources	
Marine and coastal 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 Conservation of marine and coastal resources measures:- • Mafia Island Marine Park • Mnazi bay Marine Park • Menai Bay Conservation Area • Misali Island Conservation Area • Chumbe Island Coral Park	Raise awareness on climate change Desalination of saltwater where possible Relocation of services, properties and existing infrastructures due to sea level rise Establishment of protected areas Restoration of degraded habitats *e.g.,* beach nourishment*, vertiva* grass planting, mangrove replanting, stimulation of coral reefs growth Construction of artificial structures, e.g., sea walls, artificially placing sand on the beaches and coastal drain beach management system Reduction or elimination of non-climate stress and monitoring; *e.g.,* Elimination of destructive fishing practices and over-fishing, Reduction of pollution and damaging extraction, proper management of salt production and seaweed farming, Coastal ecosystem monitoring

Human Settlements	
Coastal and beach erosion: there are plans for development of tourist hotels or buildings situated along the seashore (mainly in Dar-es- Salaam) Poor urban transport and drainage systems: preparation of town plans (Central Business District Schemes) Unplanned settlements: Regularization and upgrading of unplanned settlements. This also includes low lying flood prone areas, wetlands, hilly areas, and coastal areas along the oceans and lakes. Housing Development Schemes in different regions of the country	• Relocation of vulnerable communities to other areas • Establish good land tenure system and facilitate sustainable human settlements • establish rural areas improvement plan • sensitize the communities on the climate change related hazards • formulate a database for hazard prone areas and plan for appropriate measures - • Zoning planning • Establish disaster committee and plans at village level. • Establish a Disaster planning framework • Improve building codes
Tourism	
The establishment of national parks, forest, game and **marine reserves to ensure the sustainability of tourism industry**. Protecting the seashore by building barrier walls, e.g. along the Ocean Road. Implementation of the National Tourism Policy and Action Plan.	• Establish alternative source of income for the community in the tourist area • Implement sustainable tourism activities

Agriculture

The issue of agriculture was identified in the NAPA (URT, 2007). It outlined the following responses.

Existing measures	Potential Adaptation Measures
• Small scale irrigation • R&D on drought tolerant seed varieties • Agriculture extension activities • Diversification of agriculture: growing different types of crops on different land units • Water harvesting	• Alternative farming systems • Promote indigenous knowledge • Change planting dates in some agro ecological zones • Increase irrigation to boost maize production in selected areas • Drip irrigation for specific regions • Reduce reliance on maize as staple food by growing short-season and drought tolerant crops such as sorghum and millet • Shift crop farming to more appropriate agro ecological zones • Change crop rotation practices • Integrated crop and pest management • Make better use of climate and weather data, weather forecasts, and other management tools • Create awareness on the negative effects of climate change • Sustainable water management to boost food crop production • Strengthen early warning system

Water

The issue of water availability was identified as a priority in the NAPA (URT, 2007). It outlined the following sectoral responses.

Existing measures	Potential Adaptation Measures
Integrated water resource management • New Infrastructure • Conjunctive water Use • Inter-basin transfers • Protection of water Catchments • Rainwater Harvesting • New dam sites	• Develop alternative water storage programs and water harvesting technologies for communities • Strengthen integrated water resources management • Development of both surface and subsurface water reservoirs • Promotion of Community based catchments conservation and management programs • Promote new water serving technologies in irrigation • Development of recycle and reuse facility in industrial sector and potentially in households Develop early warning systems • Desalinization and defluoridation of water in areas with fluoride and saline content