

# Climate change and coastal cities: the case of Mombasa, Kenya

CYNTHIA BRENDA AWUOR, VICTOR AYO ORINDI AND  
ANDREW OCHIENG ADWERA

Cynthia Brenda Awuor works as a Research Fellow on Climate Change in the Energy and Water Security Programme at the African Centre for Technology Studies (ACTS), Nairobi. Her work focuses on climate change impacts, vulnerability and community-based adaptation in Africa.

Address: African Centre for Technology Studies (ACTS), ICRAF Campus, PO Box 45917-00100, Nairobi, Kenya; e-mail: c.awuor@cgiar.org

Victor Ayo Orindi works as a Research Officer in the Climate Change Adaptation in Africa (CCAA) Programme at the International Development Research Centre, Nairobi. His work focuses on participatory action research on climate change adaptation.

Address: International Development Research Centre – Eastern and Southern Africa Regional Office, Liaison House, State House Avenue, PO Box 62084-00200, Nairobi, Kenya; e-mail: vorindi@idrc.or.ke

Andrew Ochieng Adwera formerly worked as a Researcher in the ACTS Science and Technology Institute. He is currently pursuing a Masters Degree in Science, Society and Development at the University of Sussex.

**ABSTRACT** This paper discusses the risks that the city of Mombasa faces from the direct and indirect impacts of climate change. Mombasa is Kenya's second largest city and has more than 700,000 inhabitants. It is the largest seaport in East Africa, serving not only Kenya but also many landlocked countries and the north of Tanzania. The city has a history of disasters related to climate extremes including floods, which cause serious damage nearly every year and, often, loss of life. The floods in October 2006 were particularly serious, affecting some 60,000 people in the city and the wider province. In addition, around 17 per cent of Mombasa's area could be submerged by a sea-level rise of 0.3 metres, with a larger area rendered uninhabitable or unusable for agriculture because of water logging and salt stress. Tourism is an important part of the city's economy. Thus, sandy beaches, historic and cultural monuments and several hotels, industries and port facilities would be negatively affected. This paper also discusses the measures needed to reduce the vulnerability of Mombasa's population and economic base to climate change.

**KEYWORDS** adaptation / agriculture / development / drought / floods / health / settlements / vulnerability

## I. INTRODUCTION

Climate change has been singled out as a major challenge currently facing the world. It is caused by emissions of greenhouse gases, largely from energy production and consumption, agriculture and other ecological processes. The activities causing most emissions are key drivers of global socioeconomic development. High-income countries are responsible for a large percentage of these emissions, with the USA and Europe emitting 51 per cent of total greenhouse gases into the atmosphere, compared to Africa's 2.5 per cent.<sup>(1)</sup>

Low- and middle-income countries are considered more vulnerable to the effects of climate change than high-income nations because of high dependence on natural resources and low capacity to adapt. For Africa, low adaptive capacity results largely from the limited financial, technological and institutional capacity, relatively low levels of economic development and high levels of poverty widely experienced in the continent. Increased climate change threatens to undo decades of development and poverty reduction efforts so far achieved in most countries.

It is therefore important to strengthen the link between climate change adaptation and development, increase public awareness and

understanding of the issues, and pragmatically tackle the challenges posed by the phenomenon.

Many world cities, including those in Africa, are centres of economic, political, cultural, social and commercial activities. Human populations in cities tend to be highly concentrated compared to those in rural areas because of the availability of more employment and business opportunities as well as the better quality of social services. Due to the high population densities, cities are also associated with high levels of energy, water and food consumption.

The impacts of climate change on cities threaten to cause very serious damage and loss of resources. The latest report from the Intergovernmental Panel on Climate Change (IPCC) identifies various climate change-related health impacts, including altered distribution of some infectious diseases and disease vectors. According to the report, projected trends in climate change-related exposures will increase malnutrition and consequent disorders; increase the number of people suffering from death, disease and injury from heat waves, floods, storms, fires and droughts; and will continue to change the range of some infectious disease vectors. The burden of diarrhoeal diseases will increase and the geographical range of malaria will expand in some nations and contract in others, and transmission seasons will alter.<sup>(2)</sup> This could negatively affect the productivity of large human populations concentrated in cities.

## II. VULNERABILITY OF MOMBASA TO CLIMATE CHANGE

In this paper, the city of Mombasa is considered to be Mombasa district and consists of four divisions, namely, Mombasa Island, Kisauni, Likoni and Changamwe. Situated within Kenya's coast province in the south-east of the country, Mombasa is Kenya's second largest city. It is situated about 4.1° south of the equator and 39.7° east of Greenwich meantime.

According to Kenya's National Bureau of Statistics, Mombasa district had a population of 665,081 persons in 1999, and is projected to increase to approximately 870,197 in 2008.<sup>(3)</sup> Mombasa residents derive their livelihoods from a variety of economic activities, ranging from small-scale agriculture, livestock production and fishing, especially in the peri-urban space, to formal employment in different sectors, including industry. Some of the major industries in Mombasa include cement manufacturing from the abundant limestone, salt processing from seawater, and businesses associated with import and export at the city's port. Food security and general economic performance is however very low; the latest available figures (from 1997) show that 38.2 per cent of the population face absolute poverty and 38.6 per cent face food poverty.<sup>(4)</sup>

Mombasa is the largest seaport in East Africa and has two harbours – Kilindini and Old Port. It plays an important role in both the country's and the region's economy because the commercial imports and exports of land-locked countries such as Uganda, Rwanda, Burundi, Congo, Southern Sudan and even parts of Tanzania transit through Mombasa. Anything affecting the port, and by extension the city's operations, is therefore likely to be felt beyond the coastal and national boundaries. The city is also a popular tourist destination due to the presence of various terrestrial and marine-based ecological attractions, including warm weather, sandy beaches,

**Address: Institute of Development Studies, University of Sussex, Brighton, BN1 9RE, UK; e-mail: A.Adwera@ids.ac.uk**

1. Dow, K and T Downing (2006), *The Atlas of Climate Change*, Earthscan, London.

2. Confalonieri, U, B Menne, R Akhtar, K L Ebi, M Hauengue, R S Kovats, B Revich and A Woodward (2007), *Human Health. Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pages 391–431.

3. Government of Kenya (2006), *Population and Housing Statistics: Population Projections*, Kenya National Bureau of Statistics, Ministry of Planning and National Development, accessible at [www.cbs.go.ke](http://www.cbs.go.ke).

4. IEA (2002), "Socioeconomic and political profiles of Kenya's districts", in M Danda (2006), *Vulnerability and Capacity Assessment in Mombasa District*, Survey Report for the Kenya Red Cross Society, Mombasa Branch, unpublished.

5. Government of Kenya (2006), *Statistical Analysis of Tourism Trends Globally and Locally*, Ministry of Tourism and Wildlife, November, accessible at [http://www.tourism.go.ke/ministry.nsf/doc/Tourism\\_Trends\\_OCT2006\\_Revised.pdf/\\$file/Tourism\\_Trends\\_OCT2006\\_Revised.pdf](http://www.tourism.go.ke/ministry.nsf/doc/Tourism_Trends_OCT2006_Revised.pdf/$file/Tourism_Trends_OCT2006_Revised.pdf).

6. Government of Kenya (2002b), *Kenya's First National Communication to the Conference of Parties to the United Nations Framework Convention on Climate Change*, Ministry of Environment and Natural Resources, Government Printers, Nairobi; also Government of Kenya (2002a), *Mombasa District Development Plan 2002-2008*, Ministry of Finance and Planning, Nairobi.

7. Bindoff, N L, J Willebrand, V Artale, A Cazenave, J Gregory, S Gulev, K Hanawa, C Le Quere, S Levitus, Y Nojiri, C K Shum, L D Talley and A Unnikrishnan (2007), "Observations: oceanic climate change and sea level", in S Solomon, D Quin, M Manning, Z Chen, M Marquis, K B Averyt, M M Tignor and H I Miller (editors), *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 and New York, pages 385-432.

8. Mahongo, S (2006), "Impacts of sea-level change", Paper presented at the ODINAFRICA/GLOSS Training Workshop on Sea-Level Measurement and Interpretation, 13-24 November, Oostende, Belgium.

9. See reference 6, Government of Kenya (2002a).

and historical and cultural monuments. Tourism remains an important foreign exchange earner for Kenya and contributed more than 12 per cent of the Gross Domestic Product in 2004 and continues to grow.<sup>(5)</sup>

Three factors contribute to Mombasa's high level of vulnerability to climate change: low altitude, and high temperatures and humidity levels. Regarding the first of these, Mombasa is on the coastal plain, which is 4-6 kilometres wide and lies between sea level and about 45 metres above sea level. Parts of the city and its surroundings are likely to be submerged with a rise in sea level, and this would consequently disrupt ecosystem functions and balance, disrupt agricultural and industrial activities, cause the destruction of human settlements and interfere with the water supply.<sup>(6)</sup> This will impact negatively on the city's economy and, by extension, on the national economy due to the many activities and investments found in the area.

According to the IPCC Fourth Assessment Report, it is estimated that during the twentieth century, sea level has been rising at a rate of about two millimetres per year, with the fastest recorded rates averaged along the global coastline (four millimetres per year) occurring in the 1990s.<sup>(7)</sup> It is estimated that about 17 per cent of Mombasa, or 4,600 hectares of land area, will be submerged with a sea-level rise of only 0.3 metres.<sup>(8)</sup> At the same time, there will be large areas that may be rendered uninhabitable as a result of flooding or water logging, or will be agriculturally unsuitable due to salt stress, especially in the peri-urban space where agriculture is practised. Sandy beaches and other features, including historical and cultural monuments such as Fort Jesus, several beach hotels, industries, the ship-docking ports and human settlements could be negatively affected by sea-level rise.

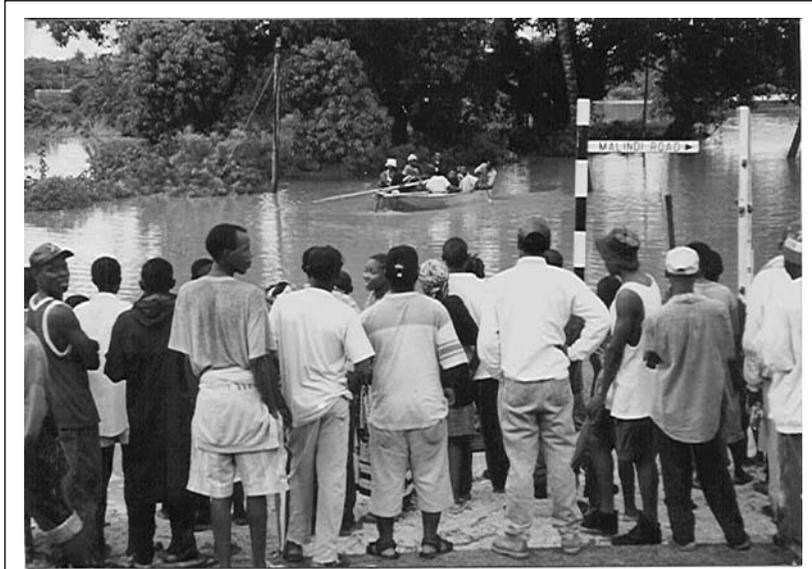
Other potential impacts of sea-level rise that could affect Mombasa include: increased coastal storm damage and flooding; sea-shore erosion; salt water intrusion into estuaries and freshwater aquifers and springs; changes in sedimentation patterns; decreased light penetration to benthic organisms leading to loss of food for various marine fauna; and loss of coral reefs, contributing to loss of biodiversity, fisheries and recreational opportunities, among other.

The high average temperatures (26.4°C) and humidity (65 per cent at noon) are already approaching intolerable limits and can be uncomfortable at times.<sup>(9)</sup> An increase in temperatures and humidity could create health-related problems such as heat stress, both on land and in the ocean, leading to ecosystem disruption, migration and the possible extinction of various species of fauna, flora and microorganisms. In addition, increased temperatures could result in the increased use of energy to power air-conditioners. This increased use of energy for cooling would essentially mean increased use of fossil fuels, as Kenya partly generates her electricity from imported fossil fuel resources.

In addition to the low altitude and high average temperatures and humidity, socioeconomic factors, particularly unplanned settlements and structures, are also contributing to the city population's increased level of vulnerability to climate change impacts. The high population densities, together with the large number of unplanned settlements that have encroached into areas demarcated for infrastructure such as roads, drainage and sewerage lines, not only increase the risk of flooding

whenever it rains but also make rescue operations difficult whenever disasters strike. The Mombasa district commissioner, while inspecting the extent of damage caused by floods in April/May 2006 attributed the poor drainage to the mushrooming of slums and land grabbing in Mombasa.<sup>(10)</sup> The district commissioner also noted that the building of perimeter walls and unplanned structures along waterways interferes with water drainage, leading to flooding in most parts of the city. (Photos 1 and 2.)

10. *The Daily Nation Newspaper* (2007), "Kenya: climate change fuelling conflicts", Nairobi, May 8.



**PHOTO 1**  
**Flooding in Mombasa**  
 © Dr C Oludhe



**PHOTO 2**  
**Settlements close to the ocean shore in Mombasa Old Town**  
 © Kenya Meteorological Department

### III. CLIMATE CHANGE IMPACTS IN MOMBASA

The impacts of climate variability and change pose grave threats to the city dwellers' lives and livelihoods as well as to the country's socioeconomic development.

Mombasa is already affected by extreme climatic events, especially floods, droughts and strong winds (Photo 3). These climate-related disasters are projected to increase in frequency and intensity with long-term climate change, and Table 1 gives a summary of those that have occurred in Mombasa in the recent past.

Wind storms, cyclones and floods damage productive land, thus causing agricultural losses and increased food insecurity; they also damage transport and telecommunications infrastructure such as roads, bridges and pipelines, as well as electricity and telephone lines. When they occur, they negatively affect economic and commercial activities.

Sea-level rise and frequent flooding may not only cause damage to existing infrastructure in cities such as Mombasa but may also result in inundation, rendering many areas uninhabitable and unsuitable for food production. This, in turn, can lead to migration in extreme cases and

**TABLE 1**  
Climate-related disasters typology, trends and impacts

Disaster type	When is/was experienced	Established incidence rate or return period	Impact profile: who/what was affected most and quantity/ extent of damage	Remarks
El Niño	1947 1961 1997	Approximately five years	<ul style="list-style-type: none"> <li>Houses destroyed</li> <li>Property lost</li> <li>Livestock and crops lost</li> <li>Human lives lost</li> <li>Increased incidence of disease (cholera, typhoid)</li> </ul>	Most affected areas are estates located near the ocean that either lack or have poor drainage structures or systems
Floods	Frequently (almost annually)	Unpredictable	<ul style="list-style-type: none"> <li>Houses destroyed</li> <li>Property lost</li> <li>Livestock lost (all types)</li> <li>Human lives lost</li> <li>Increased incidence of disease (cholera, typhoid)</li> </ul>	Most affected areas are estates that either lack or have poor drainage structures or systems
Tsunami	2006	Unpredictable	<ul style="list-style-type: none"> <li>Several fishing boats reportedly destroyed</li> </ul>	One human life reportedly lost
Drought	2005/6	Every 4–5 years	<ul style="list-style-type: none"> <li>All agricultural activities are affected</li> <li>Women spend more time looking for water</li> </ul>	As time is spent looking for water, other activities suffer from time allocation; droughts also cause famine
Hunger/ famine	Every year	Every year	<ul style="list-style-type: none"> <li>Loss of human lives from starvation (not quantified)</li> <li>Gross malnutrition and underfeeding leading to poor economic productivity</li> </ul>	Effects are felt across all age groups and gender

SOURCE: Adapted from Danda, M (2006), "Vulnerability and capacity assessment in Mombasa district", Survey Report for the Kenya Red Cross Society, Mombasa Branch, unpublished.



**PHOTO 3**  
**Cargo containers at the Port of Mombasa partly submerged in water during flooding**

loss of cultural heritage, especially historical and archaeological sites and monuments. It could also cause the spread of climate-sensitive diseases such as cholera, which may affect large numbers of people due to high population densities in cities, and could lead to high loss of life as health institutions and residents are often caught unawares. These impacts also disrupt normal livelihood activities and school attendance.

The 2004 Indian Ocean tsunami and the 2006/07 flooding experienced on the Kenyan coast exemplify the risks that Mombasa faces. They led to very large economic losses as major infrastructure and fishing vessels were damaged, and one life was reportedly lost in the tsunami. During the flooding in Mombasa in 2006, the Ministry of Health issued a cholera alert, and the Chief Public Health Officer in the Ministry of Health reported 94 suspected cases of cholera on the coast between 20 October and 11 November 2006. Thirteen cases were found to be positive for cholera and at least two deaths were reported. In addition, water sources were contaminated, several drainage systems collapsed and water pipes were washed away. The Kenya Red Cross estimated that approximately 60,000 people were affected by the floods in the coastal part of Kenya, a high proportion of whom were in Mombasa (the coast's main population concentration).<sup>(11)</sup>

#### **a. Indirect and anticipated impacts of climate change on Mombasa**

Frequent droughts and the attendant reduced water availability in the city's water catchments could lead to more severe water shortages. During droughts, food prices normally increase, exacerbating food insecurity and malnutrition, especially among poor city residents. Among the low-income groups in the city, who either depend on communal taps or water

11. United Nations Office for the Coordination of Humanitarian Affairs (OCHA) (2006), *Regional Overview of the Flooding in the Horn of Africa No 1*, accessible at <http://www.reliefweb.int/rw/RWB.NSF/db900SID/KKEE-6VMNPX?/OpenDocument>.

kiosks or, in some cases, on wells, drought often translates into increased amounts of time spent fetching water.

The exacerbated loss of biodiversity is also a threat, as several ecosystems, particularly the marine ecosystem, are changing rapidly, and some of the species (especially endemic species such as coral reefs) that inhabit them may be unable to adapt. Anything that has a negative impact on the marine ecosystem is bound to have a negative affect on the local people who depend on fishing.

Sea-level rise could also lead to the inundation of land and saltwater intrusion into inland waterways. The fact that some city residents get their water from such sources means that they are likely to experience problems obtaining fresh water. As noted above, migration may be necessary, leading to overcrowding upstream and potentially fuelling social conflict between migrants and other residents. This disrupts activities such as schooling and other livelihood and social activities. Inundation would push many peri-urban farmers into destitution, as the source of their livelihood is destroyed. It could also necessitate major infrastructural investments such as redesign and reconstruction of the city's ports to enable their optimal functioning. Industries such as the cement industry and the oil refinery may also require heavy financial and capital investments, to reduce the negative impacts of climate change on their operations.

The complexity and uncertain nature of various climate change impacts are a major challenge for development given that climate change mainly has negative implications for economic growth, human security and improved social welfare in the region.

In view of the country's relatively limited capacity to adapt, it is important that the issue of climate change is taken seriously and given the necessary attention. It is also important that context-specific measures are put in place to adapt to current impacts and to mitigate against anticipated future impacts. It is worth noting that lately there has been increased activity from various civil society organizations, development agencies and government ministries geared towards understanding and addressing the challenges posed by climate change. These include the development of various adaptation policies, strategies and programmes.

From the foregoing discussion, key issues that need to be addressed include:

- timely prediction of climate-related disasters and effective early warning;
- disaster preparedness;
- effective coordination of disaster relief and recovery, through better planning and enforcement of regulations;
- facilitation of climate change adaptation, and restoration of communities' livelihoods; and
- climate change mitigation where feasible.

#### IV. ADAPTATION TO CLIMATE CHANGE IN MOMBASA

The Kenya government, through various ministries, departments, the city council and various state corporations and other stakeholders such as NGOs, private companies, charity foundations and religious institutions, are making efforts to address some of the challenges faced as a result of current climate variability and long-term climate change. Most of these efforts are geared towards disaster management, with a focus on recovery and relief and with little, if anything, being done to prevent some of the effects.

Efforts to adapt to climate change impacts in Mombasa have been promoted since the occurrence of the tsunami, and are geared towards dealing with future tsunamis, floods and cyclones. The government, through the local administration and the Kenya Meteorological Department, has taken a leading role in gathering climate information and sending information to the residents and businesses in the expected impact areas, especially strategic holiday and business areas. The Kenya Meteorological Department is working towards establishing an operational weather observation network of the western Indian Ocean within Kenya's exclusive economic zone, and has procured and installed various equipment including three tidal gauges fitted with meteorological sensors, 35 drifting buoys and one marine automatic weather station. This will help in monitoring sea-level rise and in detecting extreme events such as tsunamis, storm surges, coastal flooding and tropical cyclones. Plans are underway to establish a national network of seismic gauges to monitor earthquakes, with an emphasis on the coastline.<sup>(12)</sup>

Scientists from the Kenya Meteorological Department and the University of Nairobi, among others, have undertaken an analysis of Kenya's climate change vulnerability and adaptation and have submitted this to the UN Framework Convention on Climate Change in their first national communication. The report identified sectors that are most vulnerable to climate change, as well as gaps in the country's adaptation and mitigation strategies. In addition, the Kenya Meteorological Department undertook a project aimed at improving the factoring of weather and climate information into the various sectors of the economy between 2001 and 2002.<sup>(13)</sup> Currently, the country is in the process of preparing the second national communication. The government is also increasing its efforts towards creating public awareness of climate change – and associated communication and dissemination – by installing an automatic message switching system at Moi international airport in Mombasa. This equipment is capable of receiving early warnings of tsunami and other marine hazards on a real-time basis. In addition, a radio Frequency Modulation–Radio and Internet (FM–RANET) transmitter station for vulnerable communities is being installed on the coast, in Kwale. All these are expected to serve not only the coastal urban population but also the whole coastal region. A number of wind-up radios have also been procured.<sup>(14)</sup>

Concerted efforts by the government, marine scientists, non-governmental organizations and local communities are being undertaken to reforest the degraded coastal areas to ensure a healthy sea wall, among other important benefits. In addition, the government is in the process of formulating an effective and enforceable coastal zone management policy as required under the Environment Management and Coordination Act of 1999, to regulate developments along the coastline and provide for appropriate management of coastal resources. This policy will also provide for the type of structures to be constructed, depending on the vulnerability of different areas. It is in this respect that the government has drawn up a National Tsunami Action Plan under a multi-hazard framework, which will be implemented in cooperation with various development partners.

During the floods in 2006, the government sent a team of engineers to the coast to assess requirements for roads and bridges in light of the unusually long and heavy rains. This may be considered as an effort towards ensuring that any roads built can withstand increased rainfall associated with increasing climate variability and long-term change. The Ministry

12. The Kenya Meteorological Department (2007), *Polar Meteorology: Understanding Global Impacts*, Report for the World Meteorological Day 2007, Nairobi.

13. See reference 12.

14. See reference 12.

15. See reference 11.

of Health is also establishing emergency health management measures to deal with the sharp rise in cases of diarrhoea when floods occur.<sup>(15)</sup>

16. See reference 12.

The IGAD Climate Prediction and Applications Centre initiated regional climate outlooks, national user workshops and pilot applications projects. These projects aimed to address problems associated with information sharing and application among users and vulnerable communities. They have helped build capacity in many regions, have linked meteorologists and end-users of seasonal forecasts, have stimulated interest in, and recognition of, the impacts of inter-annual climate variability, and have helped demonstrate the economic value of applying climate information and prediction products in socioeconomic development.<sup>(16)</sup> There is a need for increased activity and a collective campaign for public awareness on climate change impacts and adaptation, particularly with regard to cities, which, apart from being centres of economic activities, also have the highest concentration of populations.

A team comprising the Kenya Red Cross Society, the Kenya Navy, the Kenya Ports Authority and the African Marine and Boat Operators carries out monitoring of the sea for any possible disaster, and determines whether there is a need for evacuation in the event of any consequential effects of disasters such as the tsunami.

The actual extent and efficacy of the activities and initiatives cited above on reducing the vulnerability of Mombasa to climate change have yet to be determined, as the initiatives are still in their early implementation stages. So far, most initiatives have focused on dealing with impacts of extreme events and not on the preparedness aspects that should form part of adaptation.

### **a. Reducing Mombasa's vulnerability to a changing climate**

A number of activities could be carried out to minimize the city's vulnerability to climate change, both in terms of adaptation and mitigation:

- to adapt to climate change, all natural system effects are allowed to occur and human impacts are minimized by adjusting human use of the coastal zone. In Kenya, as in many other low-income countries, adaptation is the immediate priority in response to climate change impacts; and
- to mitigate against climate change impacts, natural system effects are controlled by soft or hard engineering, reducing human impacts in the zone that would be impacted without protection.

This paper focuses on measures that could reduce Mombasa's vulnerability to the anticipated climate change impacts, as well as promoting adaptation. These range from immediate actions, such as enforcing the existing legislation, to long-term measures, such as coming up with development plans that take into account future climatic conditions.

Enforcing the Physical Planning Act and city by-laws to ensure that areas earmarked for basic services such as water and sanitation are not interfered with could help reduce flooding and the outbreak of water-borne diseases, as these have been blamed on blocked drainage and damaged water supply infrastructure. The district commissioner as the chair of the District Environmental Committee should undertake the steps necessary to repossess all public utility land and beach access roads that have been allocated to private developers, and have these registered under the Land

Perpetual Succession Act, CAP 286 of the Laws of Kenya. In addition, construction and maintenance of drainage facilities in estates with near-zero gradient and poor water seepage could significantly reduce prolonged flooding and its resultant side effects. Local residents must be made aware of, and sensitized to the need to improve the management of the areas they inhabit, even more so because of climate variability and its attendant impacts such as increased rainfall and flooding.

The issue of squatters or landlessness is more acute in the coast province, including Mombasa, than in other parts of the country. Much of the land and other property is in the hands of absentee landlords and this contributes to the problem of unplanned settlement, especially in the supra-urban space. There is need to solve the problem of land ownership, to encourage the construction of planned settlements that makes it easy to provide basic services and reduce the risk of flooding, and outbreaks of waterborne diseases common in unplanned settlements, among others. Without addressing the issue of landlessness, it may be difficult to plan settlements, especially in the low-income areas.

It is recommended that the Coast Development Authority develops a strategic plan to guide future development of the coastal city. In addition, a code of conduct to guide developers and users of coastal resources should be developed, and existing coastal management legislation reviewed.

Planning and construction of new settlements outside Mombasa Island is necessary to avoid further concentration of population and activities in the most vulnerable areas. The city authority and government should encourage settlement in peri-urban space away from the ocean shores. It is now agreed that some impacts of climate change are unavoidable irrespective of what is done now, owing to past emissions. Encouraging settlement away from the most vulnerable areas remains one of the least expensive and pro-active ways through which future vulnerabilities may be reduced.

Building standards that can accommodate future climatic conditions such as high temperatures, humidity and flooding should be promoted. For example, it would be useful to construct buildings with strong, unoccupied open spaces on the ground floor; these could avert damage and loss of property and life during floods. Also, buildings could be designed and constructed in ways that promote natural air circulation and cooling to reduce temperatures and high humidity indoors. It would be important to engage qualified architects to provide guidance in designing such buildings.

The main water pipeline serving Mombasa is old and leaks frequently. This further reduces the daily amount of water reaching the city. There is a need to improve the management and renovation of the city's water and sanitation infrastructure to serve the increasing water demand. The Ministry of Land Reclamation and Regional Development and the Ministry of Water and Irrigation should work together with the city council to promote water re-use and recycling and implement other effective measures to increase water supply and access in Mombasa and its environs. This would stem the overexploitation of underground water that is exacerbating saltwater intrusion.

The impacts of sea-level rise could be reduced through properly planned irrigation away from sea shores, and other land management practices that could be used to manage floods and reduce water run-off into the oceans. The government, NGOs and local communities should

collaborate to construct water reservoirs and apply appropriate land management practices. In this regard, the measures taken should ensure the proper conservation and management of the coastal environment, including beaches and related ecosystems, taking into account available scientific information and indigenous environmental conservation practices.

The use of renewable energy at both household and industrial level should be promoted. Wind and solar energy are widely available in Mombasa and can be used in a number of areas. Solar energy can be used for water heating at the household level and in salt processing at the industrial level, while wind energy may be used in water pumping from boreholes. It is worth noting that the salt processing plants in Mombasa are already using solar energy for drying. More industries should be encouraged to adopt such environmentally friendly methods. At the household level, one of the factors that has limited the adoption and wider use of solar technology is the high initial cost. Even though the government zero-rated solar panels with regard to taxation, other components were not, hence it remains an expensive technology for the average household. The government can change this by removing all taxes and supporting local industries to produce the panels and components locally.

It is important that the existing district-level disaster surveillance and management committee becomes proactive and focuses more on disaster preparedness than on "after the event" relief and impacts management. The formation of similar committees at the sub-location, location and divisional levels, in collaboration with the municipal council, is also highly recommended. These will bear the responsibility of educating communities and enforcing regulations such as those barring the construction of buildings in flood-prone areas and ensuring proper drainage. Stakeholders need to make concerted efforts to track and/or explore predictive mechanisms for various climate-related disasters through networking, further research and information sharing. Interest- and economic activity-based groups such as boat operators, fishermen, food vendors, farming and other community-based groups need to be brought into the disaster management committees so that they can better understand and make use of early warning information signs, responses and recovery strategies. In addition, training in appropriate disaster preparedness and response should be undertaken.

Existing community-based groups can be used as immediate entry points towards improving livelihoods through the formation of simple/low-capital and focused economic enterprises, such as high-value agriculture (vegetable growing and horticulture), and livestock enterprises, such as poultry and dairy goat production in the city's peri-urban areas. Strengthening existing enterprises through technical/professional support from relevant ministries and NGOs would also contribute to increased incomes and possibly improve capacities to adapt to climate-related disasters. Diversification of economic activities, e.g. through the promotion of community-based seafood farming could be encouraged as an adaptation measure in suitable areas.

## V. CONCLUSION

Implementing many of these changes/recommendations requires support from the various government departments, city hall, civil society organizations (including NGOs) and the public in general. This will only

be achieved if people are made aware of, and understand the need for, such action now rather than continue with business as usual.

Effective and timely early warning systems are needed to deal with climate-related disasters. There is a need for the city council to work with meteorological/maritime departments, relevant government ministries and other stakeholders to facilitate coordinated efforts, and effective strategies.

Enforcement of city by-laws to ensure that people only construct buildings in safer and approved areas far from the beaches and avoid sewage lines and drainage etc. should be ensured. This will also reduce the risk of flooding and piped water contamination.

The government should resolve problems of landlessness and absentee landlords at the coast by repossessing grabbed public land, purchasing legally acquired land from absentee landlords, and plan developments in such areas appropriately. This would enable security of land tenure and encourage people to follow guidelines and build houses according to set standards.

To implement the recommendations above, appropriate capacity, both at the individual and institutional levels, and enforceable regulations and economic incentives are required. These depend on political will, funding and human capital.

## REFERENCES

- Bindoff, N L, J Willebrand, V Artale, A Cazenave, J Gregory, S Gulev, K Hanawa, C Le Quere, S Levitus, Y Nojiri, C K Shum, L D Talley and A Unnikrishnan (2007), "Observations: oceanic climate change and sea level", in S Solomon, D Quin, M Manning, Z Chen, M Marquis, K B Averyt, M M Tignor and H I Miller (editors), *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 and New York, pages 385–432.
- Confalonieri, U, B Menne, R Akhtar, K L Ebi, M Hauengue, R S Kovats, B Revich and A Woodward (2007), *Human Health. Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pages 391–431.
- Dow, K and T Downing (2006), *The Atlas of Climate Change*, Earthscan, London.
- Government of Kenya (2002a), *Mombasa District Development Plan 2002–2008*, Ministry of Finance and Planning, Nairobi.
- Government of Kenya (2002b), *Kenya's First National Communication to the Conference of Parties to the United Nations Framework Convention on Climate Change*, Ministry of Environment and Natural Resources, Government Printers, Nairobi.
- Government of Kenya (2006), *Population and Housing Statistics: Population Projections*, Kenya National Bureau of Statistics, Ministry of Planning and National Development, accessible at [www.cbs.go.ke](http://www.cbs.go.ke).
- Government of Kenya (2006), *Statistical Analysis of Tourism Trends Globally and Locally*, Ministry of Tourism and Wildlife, November, accessible at [http://www.tourism.go.ke/ministry.nsf/doc/Tourism\\_Trends\\_OCT2006\\_Revised.pdf/\\$file/Tourism\\_Trends\\_OCT2006\\_Revised.pdf](http://www.tourism.go.ke/ministry.nsf/doc/Tourism_Trends_OCT2006_Revised.pdf/$file/Tourism_Trends_OCT2006_Revised.pdf).
- IEA (2002), "Socioeconomic and political profiles of Kenya's districts", in M Danda (2006), *Vulnerability and Capacity Assessment in Mombasa District*, Survey Report for the Kenya Red Cross Society, Mombasa Branch, unpublished.
- Kenya Meteorological Department (2007), *Polar Meteorology: Understanding Global Impacts*, Report for the World Meteorological Day 2007, Nairobi.
- Mahongo, S (2006), "Impacts of sea-level change", Paper presented at the ODINAFRICA/GLOSS Training Workshop on Sea-Level Measurement and Interpretation, 13–24 November, Oostende, Belgium.
- The Daily Nation Newspaper* (2007), "Kenya: climate change fuelling conflicts", Nairobi, May 8.
- United Nations Office for the Coordination of Humanitarian Affairs (OCHA) (2006), *Regional Overview of the Flooding in the Horn of Africa No 1*, accessible at <http://www.reliefweb.int/rw/RWB.NSF/db900SID/KKEE-6VMNPX?/OpenDocument>.