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Urbanisation, Coastal Development and Vulnerability, and Catchments

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Opposite page: Coastal development at Catembe with Maputo in the background, Mozambique. © José Paula.

URBANISATION, COASTAL DEVELOPMENT AND VULNERABILITY

The growth of urban areas that form coastal cities, especially in the WIO, places an increasing demand on natural coastal extractive and non-extractive resources. The use and conversion of coastal land and catchments is considered a permanent effect of growth and development. Urbanisation has direct effects on biodiversity and the state of the coastal environment. The location of coastal urbanisation inherently translates to socio-economic vulnerability. Coastal cities of the WIO region are desirable places to live and work which results in ongoing and increasing urbanisation. The populations of the urban areas of the region are also vulnerable to natural disasters associated with this location in the coastal zone.

Urbanisation and globalisation are symbols of the 21st century (Barau and Ludin 2012). Urban areas are a confluence of people, economic activity, and the built environment. Urbanisation is simultaneously a demographic, economic, and land-use change phenomenon (Zhang and Seto, 2011). Urbanisation is a multifaceted, heterogeneous and complex phenomenon that is highly contextual. Urbanisation can refer simply to the growth of population in towns but a more complex definition would be to describe the social and political changes that may occur when people live in large, nucleated settlements. Urbanisation can also refer to two important structural changes, namely, the rate of change or growth of urbanisation levels (the share of the national population in towns) and the extent to which this change is accompanied by shifts in the economy and employment (UN-Habitat 2014).

Generally speaking, economic factors, especially spatial inequalities in economic development, employment opportunities and wages, are underlying drivers of urban migration (Seto 2011). The size and characteristics of rural and urban human settlements in Africa are also partially driven by climate change. The majority of migration flows observed in response to environmental change are within country boundaries (Tacoli 2009). The abundance of resources in the coastal zone and the general desirability of living near the ocean add complexity to the cause and effect of urbanisation.

Cities have become a focal point for production, exchange and consumption, and urbanisation is trademarked by mass consumption (Bogardi 2008, Beaverstock and others, 2011, Barau and Ludin 2012). African economies are demonstrating gradual improvement with an increasing number of nations progressing towards high rankings among the world's emerging economies. However, eastern Africa is the world's least urbanized but fastest urbanising sub-region on the continent and Africa as a whole still experiences massive urban poverty and other social problems (UN-Habitat 2014).

Three African cities - Dar es Salaam, Khartoum and Abidjan - are projected to reach megacity status within a generation from now (UN-Habitat 2014). The prevailing worldwide view is that cities are engines of growth and

human development, but this perspective is challenged by the unfolding realities in Africa. Most coastal cities in the WIO region are experiencing higher than average growth and development rates. The "high road" to urban economic and general developmental progress requires more broadly shared benefits to all socio-economic strata (UN-Habitat 2014). According to Seto (2011), the physical growth of cities (in mega-deltas) is limited by four interacting factors:

- Local biophysical constraints due to human activities;
- Large-scale environmental change;
- Uncertainties around future economic growth; and
- Effectiveness of urban planning institutions.

CATCHMENTS

The flow of coastal river catchments, which connect terrestrial and freshwater ecosystems to oceans, enables essential ecological processes in coastal and marine environments. As river networks drain watersheds, they transport freshwater, sediment, nutrients, biota and chemicals, which, along with oceanic forces, influence the availability of natural resources in estuaries and coastal environments (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a). However, this interaction between catchments and the coastal and marine environments has been identified as one of the processes subject to environmental pressures in coastal zones of the WIO region (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).

Three major issues linked to river-coast interaction in the WIO region are the modification of river flows (water quantity), water quality and sediment loads, primarily as a result of abstraction; damming; inappropriate land-use practices; and increased floods and seasonal flow patterns, as described below:

- **Water quality** has been most affected by nutrient loads and contaminants originating from domestic sewage and industrial and agricultural chemicals (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).
- **Water quantity** or the modification of river flows in the region has been attributed to: consumptive uses of water leading to reduced flow; impoundment or damming which increases the surface area of rivers; change in seasonal flow patterns; and increased floods as a result of wetland losses or the loss of water retention capacity. These are further exacerbated by the realities and uncertainties of climate change with some catchments predicted to receive more rainfall than normal while others receive less (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).
- The alteration of **sediment loads**, which has been attributed to climate change, land-use practices and the construction of dams, is widely evident in most of the rivers in the region. Increased sediment loads have impacted the region's coastal and marine environment through smothering of mangroves, coral reefs and seagrass beds. Decreased sediment loads have affected the coastal and marine environment in the region through the erosion of the delta mouth and through increased salt-water intrusion leading to the destruction of mangrove habitats (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).

An assessment of hydrological and land-use characteristics affecting river-coast interactions conducted for the WIO region, identified a number of socio-economic and environmental pressures linked to river-coast interaction throughout the region. These include:

- Economic growth, which continues to drive increasing demand on limited water resources in river catchments for industry, mining, urban development, agriculture and energy generation thereby affecting the flow and quality of rivers across the region;
- Poverty and inequality, which often lead to such unsustainable land-use practices as over-stocking of cattle resulting in over-grazing and ultimately increased runoff of nutrients and soil erosion;
- Climate and natural processes, which influence the flow of rivers, turbidity and sediment transport. Climatic changes have largely been linked to extreme events such as floods and droughts. Floods are linked to such impacts as soil erosion and sedimentation while droughts lead to increased pollution concentration and reduce water volumes to the coast which then affects the essential river-coast interaction;
- Population growth, which has been experienced throughout the region at medium to high rates and been linked to irreversible changes to river systems and to greater demand on limited supplies;
- Lack of financial resources and human capital for effective implementation of regulatory measures and water management strategies;
- Lack of effective governance, characterised by a lack of inter-sectorial coordination and the misuse of available resources. Some of the areas in the region lack adequate enforcement of legislation and there is a general lack of

legal and institutional frameworks for the management of trans-boundary catchments; and,

- Lack of knowledge and awareness of the nature, causes and impacts of certain environmental problems. Different stakeholders also still lack awareness of the impact of their activities on the ecosystems (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a).

COASTS AND CATCHMENTS OF THE WESTERN INDIAN OCEAN REGION

According to UN-Habitat (2014), more than a quarter of Africa's population lives within 100 km of the coast and more than half of Africa's total population living in low-elevation coastal zones is urban, accounting for 11.5 per cent of the total urban population of the continent (see Figure 29.1).

The decade 2000-2010 saw 20.8 million new urban dwellers in the Eastern African sub-region (Kenya, Tanzania and the Island States) and the forecast for the current decade (2010-2020) is that the total number of Eastern African urban dwellers will increase by more than 50 per cent (UN-Habitat 2014). The Southern African sub-region (South Africa and Mozambique) is, after Northern Africa, the continent's most urbanised and projected to reach a region-wide urban majority around the end of the current decade (2010-2020). South Africa reached an urban majority of 62 per cent in 2011 with Mozambique projected to reach an urban majority by 2050 (UN-Habitat 2014). The urban population of some WIO countries are given in Figure 29.2.

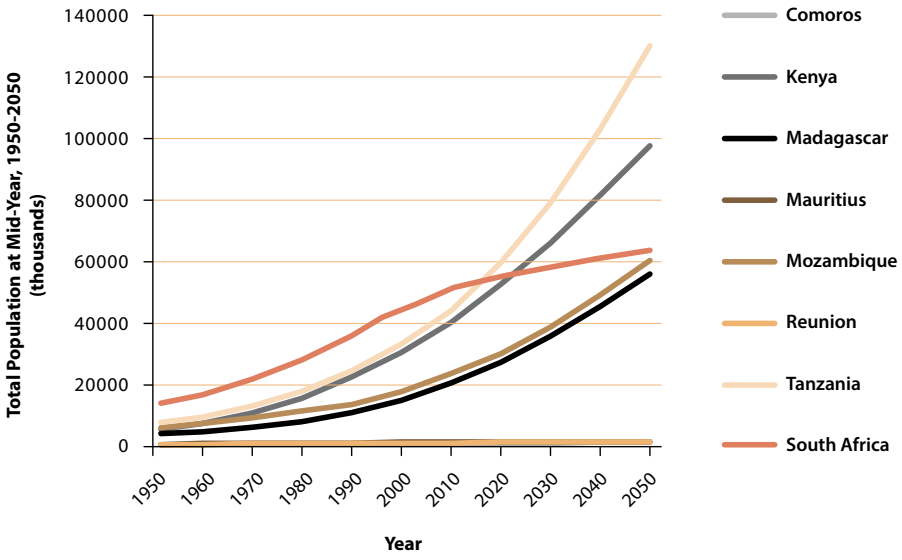

Figure 29.1. Total mid-year population of countries in the Western Indian Ocean. Source: DESA (2014).

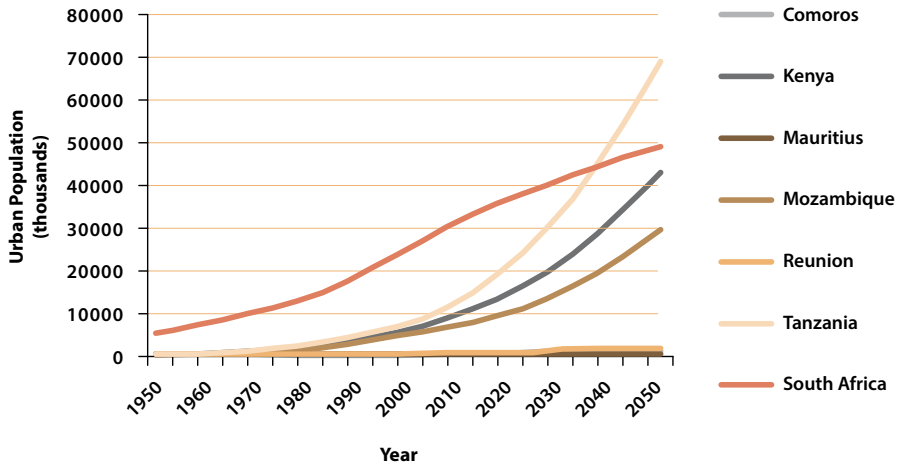

Figure 29.2. Urban Population at Mid-Year by Major Area, Region and Country, 1950-2050. Source: DESA (2014).

For the Eastern Africa sub-region, the 2030-2040 decade is projected to add numbers of urban dwellers equivalent to 110 per cent of the entire 2010 urban population. The total number of urban dwellers in 2040 is projected to reach a massive five times the 2010 figure.

These high projections are cause for concern given existing unemployment of the urban population and the extent and condition of slums in Eastern Africa. While there is a definite deceleration of urban growth (declining urbanisation rates), the absolute urban population is projected to increase and will remain a challenge. Small island states like Seychelles, Mauritius and, to some extent, French Reunion are exceptions to this generalisation since urban population growth is small, in absolute terms, or even declining (UN-Habitat 2014)

Tanzania has a particularly high absolute population growth with 41.9 million projected to increase to 61.5 million (2010-2050). Over that same period, Kenya will have to accommodate 38.1 million new urban dwellers, Madagascar 27.7 million, and Somalia 14.4 million. According to UN-Habitat (2014), four WIO countries are heading for urban majorities: Madagascar and Somalia (by 2050) and Mauritius and Tanzania (by 2040). Comoros and Kenya had a delayed entry in the global urban transition and are projected to remain rural despite their current strong to moderate absolute urban growth (UN-Habitat 2014).

Environmental impact of urbanisation

The expansion of the built environment is among the most irreversible human impacts on the global biosphere and urban land-use change remains one of the primary drivers of habitat loss and species extinction (Hahs and others, 2009). Figure 29.3 provides an indication of the development footprint of some of the major cities in the region. The data provided shows electric light emitted at night (2012) as a proxy for economic development and urbanisation (Doll and others 2006, Elvidge and others, 2009, Ghosh and others, 2010).

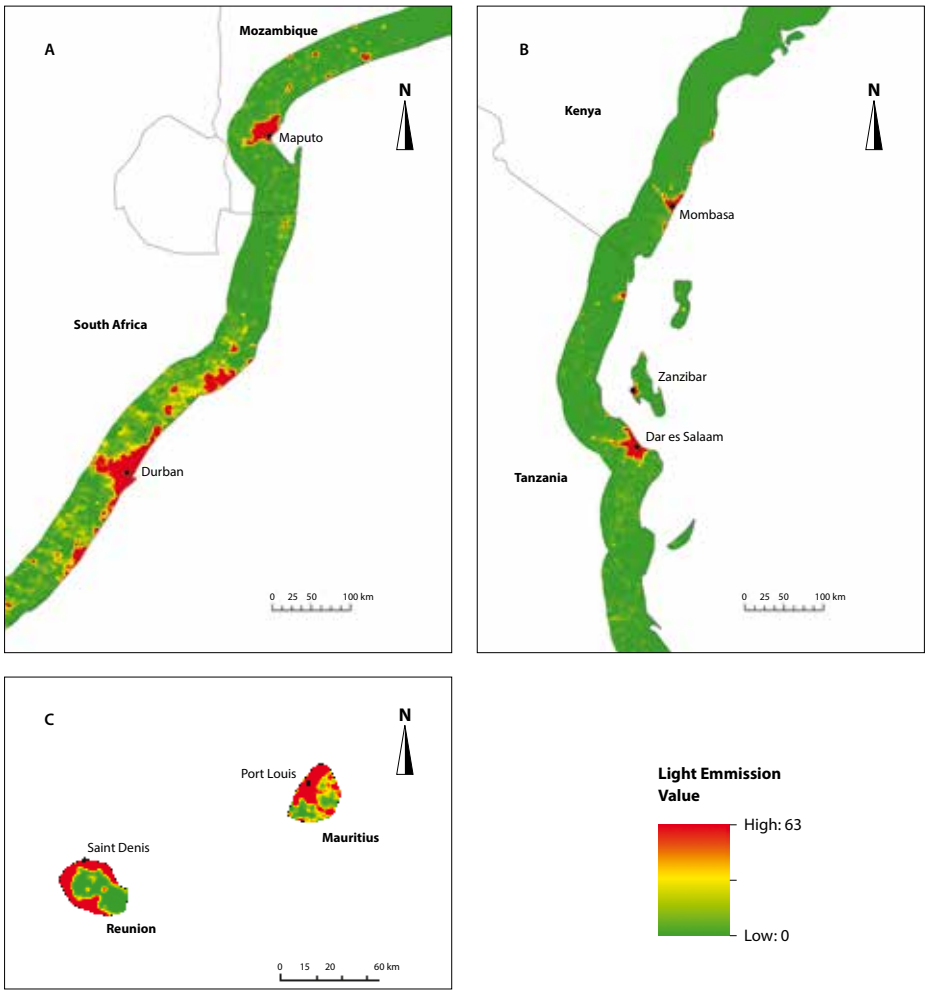

Figure 29.3. Night light emission from cities; **a)** Durban and Maputo; **b)** Dar es Salaam and Mombasa; and **c)** Port Louis and Saint Denis in the Western Indian Ocean region as a proxy for economic development and urbanisation. Source: ngdc.noaa.gov/eog/dmsp.html.

The use and conversion of coastal land, urbanisation, population growth, demographics shifts, poverty and a lack of alternative livelihoods, increased wealth, urbanisation and consumption rates (eg building materials, fish; ASCLME/SWIOFP 2012a, ASCLME/SWIOFP 2012b) intensifies the demand on coastal and marine resources at the national level. The transboundary diagnostic analysis (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b) identified several direct causal links between urbanisation and water quality degradation, habitat a community modification and a decline in living marine resources. Some of the specific links between urbanisation and coastal environmental quality included:

• Water quality degradation:

- Alteration of natural river flow and changes in freshwater input and sediment load;

- Degradation of ground and surface water quality;

- Microbiological contamination from land-based (domestic, industrial, agriculture and livestock) and marine (mariculture, shipping) sources; and

- Solid wastes / marine debris (plastics etc.) from shipping and land-based-sources.

• Habitat and community modification:

- Shoreline change due to modification, land reclamation and coastal erosion;

- Disturbance, damage and loss of upland / watershed habitats (>10 m elevation);

- Disturbance, damage and loss of coastal vegetation and floodplain habitats (to 10 m elevation);

- Disturbance, damage and loss of mangrove habitats, coral reef habitats and seagrass habitats; and the

- Introduction of exotic non-native, invasive and nuisance species.

• Declines in living marine resources;

- Decline in populations of reef and demersal fish; and

- Decline in populations of prawns and shrimp.

Coastal urbanisation, environmental impacts and vulnerability

Coastal urban areas on the mainland countries of the WIO are mostly located in the vicinity of estuaries, mangrove swamps and coral lagoons. The island states have quite different patterns of urbanisation due to their small land-areas. For all the islands, except Madagascar, the entire land area can be considered to be part of the coastal zone. The environmental impacts of urbanisation depend on the national environmental, social and political context (Table 29.1).

Table 29.1. Urban features of and associated issues in the Western Indian Ocean countries.

Country	Features	Major issues relating to urbanisation	Coastal alteration, infrastructure and populations
Kenya	The relatively short coastal region has about 2.5 million people (population density of 77/ km^2) which is 8 per cent of the total national population (ASCLME 2012). Major urban areas include Mombasa, Malindi and Kilifi and Mombasa County accounts for 27 per cent of the total coastal population. Features include: Important infrastructure in the coastal region: roads, airports, railways, ports and harbours, energy, water supply and sanitation. Urban centres include: Kilifi, Lamu and Malindi. Mombasa has one of the largest sea ports in Eastern Africa. Presently, there are plans to construct a second large port at Lamu. A number of smaller ports exist in Lamu, Malindi, Kilifi and Shimoni.	Over-exploitation of nearshore fisheries, degradation of mangrove areas, shoreline changes and conflicts in the use of natural resources. Increased generation of waste and disposal of domestic sewage and industrial waste. Increased incidents of contamination of ground and surface water resources and associated public health risks. Most of the pollution hotspots are located near urban centres (Republic of Kenya 2009).	Low levels of alteration of the coastline. Port assets exposed at Mombasa and potentially more so in future eg planned Lamu port. Coastal infrastructure at risk in limited number of coastal urban areas.
Tanzania	Five coastal regions cover 15 per cent of total land area hosting 25 per cent of the population. Dar es Salaam is the largest city and seaport followed by Tanga and Zanzibar. The port handles cargo destined for land locked countries such as Burundi, Rwanda, Uganda, Malawi and Zambia. Dar es Salaam is projected to reach mega-city scale within the current decade 2010-2020 (UN-Habitat 2014).	Pollution; accessibility (hospitals, markets); lack of infrastructure; population pressure, resource degradation; increased unplanned settlement; crime, lack of good quality data on the coastal infrastructure; and inadequate research on the coastal regions infrastructure status.	Low levels of alteration of the coastline. US$ 130 million ports assets exposed to climate change impacts (Nicholls and others, 2008).

Country	Features	Major issues relating to urbanisation	Coastal alteration, infrastructure and populations
Mozambique	Forty five coastal districts and a total population of 20.5 million. Seventy per cent of the population lives in coastal districts. The districts with larger populations are Maputo City, Massinga, Nampula, Nacala-a-Velha, Alto Molocue, Milange Morrumbala, Mocuba, Maganja da Costa, Ile and Angonia. High degree of natural coastal and marine living resources use by coastal communities. Main sea ports are located in Maputo, Beira, Nacala and Pemba. An extensive coastline, along with ten ports, highlights the strength and promise of coastal transport in Mozambique. The scale of the coastline magnifies the importance of ports, particularly as a means of developing trade.	Extensive natural resource base, along with opportunities for mining development, could potentially facilitate national growth. Highly vulnerable to natural disasters, in particular events such as floods, drought, wave and tide hazards and cyclones (UN-Habitat, 2014, Theron and Barwell 2012).	Exposed soft sand coasts with high coastal and marine living resource dependency. Low levels of alteration except in port-urban areas. Rural and urban population susceptible to climate events such as cyclones. US$ 400 million ports assets exposed to climate change impacts (Nicholls and others, 2008)
South Africa	Total population estimated at 49.32 million of which 21.2 per cent is concentrated in KwaZulu-Natal and 13.5 per cent in the Eastern Cape of the WIO region. Forty per cent of total population lives within 100 km of the coast. Coastal population is concentrated in the cities (and ports) of Durban, Richards Bay, East London and Port Elizabeth. There is also a large rural population along the Wild Coast and ribbon development along the coast of KwaZulu-Natal, excluding the MPA in the north of the province	Intense development pressure on the coastline threatens natural biodiversity and ecosystem service delivery such as protection from storm damage. Many linefish species targeted by increasing numbers of recreational fishers. Coastal development ruining the aesthetic appeal of scenic areas. Lack of effective land use management and spatial development planning by local municipalities, particularly in the underdeveloped former homeland areas such as Kwa-Zulu, Transkei and Ciskei, has also facilitated strip development of coastal areas. Most local municipalities are understaffed and have problems securing and keeping suitably qualified staff.	Highly altered, significant investment in coastal infrastructure including ports. US$ 570 million ports assets exposed to climate change impacts (Nicholls and others, 2008)
Comoros	The Comoros, consisting of three islands, has Ngazidja (Grande Comore) as the most populated island with 296 177 inhabitants, followed by Ndzuwani (Anjouan) 243 732 and Mwali (Moheli) 35 751. The population is mainly concentrated along the coasts and spread over a small insular territory. The Comorian population is predominantly rural with 72.1 per cent in rural areas against 27.9 per cent in urban areas and remains amongst the world's most sparsely urbanised countries. Comorian urbanisation is strongly concentrated in three cities: the two insular capitals (Matsamudu and Fomboni) and the federal capital Moroni. Harbours play a vital role in the country's insular economy where the demand for manufactured goods, food and energy products such as hydrocarbons are met almost entirely from imports. Ports also provide transportation of goods and passengers between the islands. Mutsamudu harbour on Anjouan is the only deep water port.	Unbalanced spatial distribution of the population; irregular occupation and construction; problems of housing; sanitation; urban security; environmental degradation and urban unemployment.	Medium levels of alteration and high dependency on natural goods and services. Island populations both urban and rural highly susceptible to climate events. Ports play a critical role in national economy.
Seychelles	More than 80 per cent of the population reside on Mahé which is 60 per cent urbanised. The capital, Victoria and the main fishing port are located on its central east coast. Approximately 40 per cent of the population lives on the East Coast of Mahé, a coastal belt about 7 km long and 1 km wide (Shah 1998). Ninety to 100 per cent of the population is concentrated on the coastal zone (Shah 1998). The coastal population of Seychelles (found within 100 m of the coastline) is expected to increase from 161 to 203 persons/km^2 between 1995 and 2015 (Payet 2002). Port Victoria is a major hub for the Western Indian Ocean tuna fishery. In 2003, it handled 88 per cent of the total amount of tuna caught by purse seiners in the Western Indian Ocean (SFA 2003).	Coastal development, without consideration for sealevel rise and increase in the frequency and intensity of extreme natural events such as flooding and storm surges. Properties lack the necessary setback distance to the beach or are directly on the shoreline and on the sand dunes. Severe projected climate change issues including but not limited to: damage to properties and infrastructure located on the coastal plains and reclaimed land; eroding shorelines and beaches; threat to groundwater aquifers and coral island fresh water lens (Government of Seychelles 2011)	High levels of alteration and high dependency on natural goods and services. High proportion of island populations living near the shoreline where both urban and rural residents are susceptible to climate events.

Country	Features	Major issues relating to urbanisation	Coastal alteration, infrastructure and populations
Madagascar	The 2009 total population of Madagascar was estimated at 19 600 000 inhabitants (INSTAT 2011) of which 34 per cent live within 100 km of the coast. They are distributed in 13 coastal regions, subdivided into 43 coastal districts occupying an area of 404 519 km^2. Average density in coastal areas is 22.44 inhabitants/km^2. Madagascar is served by 6 international ports: Toamasina, Mahajanga, Antsiranana, Nosy-be, Toliara, and Ehoala, and 12 coastal navigation ports: Vohemar, Maroantsetra, Mananjary, Manakara, Taolagnaro, Morombe, Morondava, Maintirano, Port Louis, Antsohihy, Sambava and Antalaha.	Accessibility (hospitals, markets), lack of infrastructure, population pressure, poverty and lack of sanitation. Near coastal cities, unregulated coastal activities are increasing considerably especially overfishing, exploitation of mangroves, and tourism. Pollution is particularly noticeable in all coastal areas of Madagascar. This can be due to watershed soil erosion and deforestation, chemical pollution caused by industrial activities, and municipal and domestic wastes.	Low levels of alteration and high dependency on natural goods and services. Island populations both urban and rural highly susceptible to extreme climate events.
Mauritius	The 2010 population was 1 283 415. Mauritius is one of the most densely populated countries in the world with 629 inhabitants/km^2. Approximately 27 per cent of its total population and 50 per cent of its rural population live within the coastal zone. Infrastructure is well-developed and contributes to supporting the economic development of the country. Port Louis is the main navigational gateway for trade. However, there are no regular maritime connections with the other islands of the South West Indian Ocean.	Critical habitats such as coral reefs and seagrass beds impacted by climate change and over-exploitation with reduction of associated benefits. Major challenge is human capacity. Requirement to mainstream environmental protection in development planning processes. Need for an integrated approach for management of the coastal zone. I addition, an effective regulatory framework and mechanism is required to replace the presently scattered responsibilities among various agencies. Other issues: pollution control including wastewater; industrial effluents; soil erosion; agriculture and livestock runoff control; solid waste and marine litter.	High levels of alteration and high dependency on natural goods and services. Island populations both urban and rural highly susceptible to extreme climate events. High degree of reliance on contribution of port to GDP.

Coastal cities

Cities are often the most vulnerable to disasters, due to dense populations (Figure 29.4), extensive infrastructure and variety of activities within comparatively small geographical areas. Even though the extent and scale of disasters at city-level are often localised, the impacts often extend to the national scale, given the critical political, social and economic roles of cities (UN-Habitat 2014).

Coastal cities are more than a collection of people and buildings and form complex systems of habitation, infrastructure, public services – and their wastes. The inherent vulnerability of WIO cities to natural disasters is exacerbated by being located in low-lying coastal and estuarine delta areas. Contributing factors to specific vulnerability in the WIO coastal zone include being located in very low-lying coastal plains, in close proximity to the shoreline, a high incidence of poverty, a low capacity to build and maintain infrastructural defences, susceptibility to cyclone activity, and soft erodible coasts.

In most cases, coastal cities are associated with ports, which contribute to their regional importance. Nicholls and others (2008) contend that the concentration of future exposure to sea level rise and storm surge in rapidly growing cities in developing countries in Africa, amongst others, emphasises a need to integrate the consideration of climate change into both national coastal flood risk management and urban development strategies. The contribution of port cities to global trade also means that failure to develop effective adaptation strategies would inevitably have local, national and wider economic and security consequences; therefore local strategies will need to be incorporated within a wider spatial and time frame to address broader issues (Hanson and others, 2011).

Coastal vulnerability

Vulnerability is defined by UNEP as the extent to which a population or an ecosystem is liable to be affected by a hazard event, and mitigated by the capacity of a population or ecosystem to cope with these effects (UNEP 2005). Several regional assessments have identified East Africa as one of the most threatened coastal regions in Africa and globally (Dasgupta and others, 2011, Boko and others, 2007, Brown and others, 2009, Brown and others, 2011, Hinkel and others, 2012). Coastal and ocean systems are important

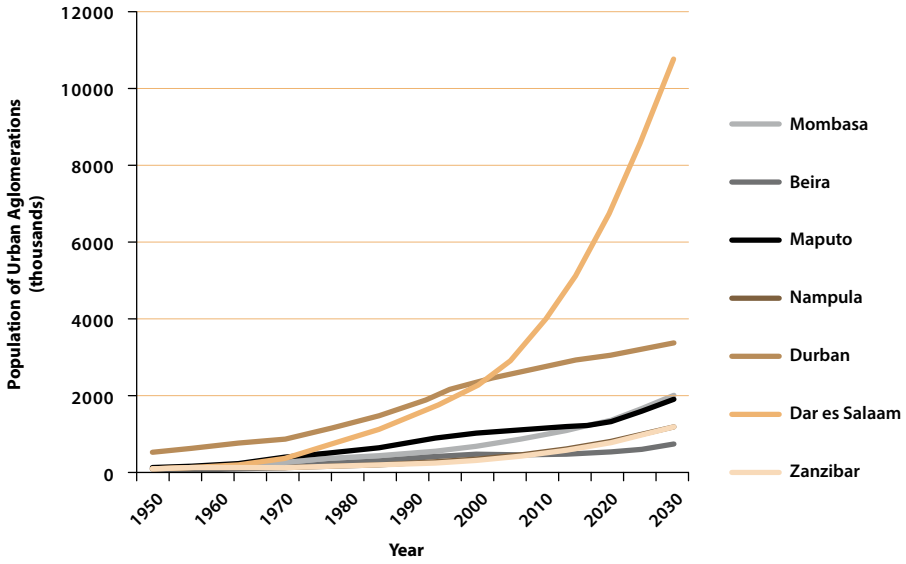

Figure 29.4. Population of coastal urban agglomerations with 300 000 inhabitants or more in 2014, 1950-2030 (DESA 2014)

BOX 29.1. CITIES AT RISK: DAR ES SALAAM, TANZANIA

View of Dar es Salaam from Kurasini Creek mouth. © José Paula.

Eight per cent of the city surface area lies within the low-elevation coastal zone defined as the land area below the 10 m contour lines; hosting approximately 5 per cent of the population (143 000) and an estimated US$ 168 million worth of economic assets, excluding the value of ports and harbours and tourism infrastructure. The population and economic assets at risk of 1-in-100-year return period extreme water levels by 2030 will range between 30 300 and 110 000 inhabitants and US$ 35.6 million to US$ 404.1 million (Kebede and Nicholls 2012). Some of the key findings proposed by Kebede and Nicholls (2012) included the development and implementation of appropriate land-use planning policy responses and investment priorities in order to steer land development away from low-lying areas. The authors conceded that enforcement of such policies could undoubtedly be an issue, especially where informal settlements dominate urbanisation (as in many developing countries).

for the economies and livelihoods of WIO countries, and are subject to existing stressors, such as overexploitation of resources, habitat degradation, loss of biodiversity, salinisation, pollution, urbanisation, overburdened infrastructure, coastal erosion, and rapid and unplanned growth (Alusa and Ogallo 1992, UNEP/Nairobi Convention Secretariat and WIOMSA 2009b, ASCLME/SWIOFP 2012a, ASCLME/SWIOFP 2012b, Kithiia 2011, Kebede and Nicholls 2012).

Coastal systems are expected to be exposed to hazards relating to sea level rise and to also experience impacts through high sea levels combined with storm swells

BOX 29.2. CITIES AT RISK: MOMBASA, KENYA.

View of Mombasa from KMFRI. © José Paula.

A popular tourism destination due to its favourable climate, Mombasa has many sandy beaches, and a considerable historical and cultural heritage. Tourism was shown to contribute more than 12 per cent of the Gross Domestic Product in 2004 and continues to grow. Mombasa is located at low altitude, and experiences high temperature and humidity levels, all of which contribute to its vulnerability to climate change. Parts of the city and its surroundings are likely to be submerged with a rise in sealevel resulting in a disruption of ecosystem functions and balance, agricultural and industrial activities, water supply, and the destruction of human settlements. As one of the biggest seaports in East Africa, this will impact negatively on the city's economy and, by extension, on the national economy. Awuor and others (2008) suggested that one of the key interventions to anticipate and manage the projected impacts would be to develop strategic options to guide future development of the city. They also suggested the development of a code of conduct to guide future development and that existing coastal management legislation must be reviewed. 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; see also Kithiia and Dowling (2010).

(Kithiia 2011, Hinkel and others, 2012). Key long-term impacts of climate change in the WIO region will be sea level rise, together with increasingly severe and possibly more frequent storms and storm surges. Most coastal cities in the region are situated at low elevation (below 10 metres above mean sea level), often next to lagoons and estuaries and more often than not associated with important harbours and industrial facilities (UN-Habitat 2014). Few, if any coastal cities are prepared for the predicted impacts of extreme climate events and cities such as Dar es Salaam (Box 29.1), Mombasa (Box 29.2), Maputo and Beira (Box 29.3), and Port Louis (Box 29.4), are particularly vulnerable to sea level rise.

Nicholls (2006) estimated that for the African Indian Ocean Coast in 1990, 7 million people were living in the hazard zone (potentially exposed population) and of those in the hazard zone 562 000 people were at risk to coastal flooding. The 2020 projection was that 14 million people would be living in the hazard zone and 1.2 million people would be at risk to flooding. In a similar continental scale (Africa) study by Hinkel and others (2012), 16–27 million people are expected to be flooded per year, and damage costs will reach between US$ 5 000 million and US$ 9 000 million per year in 2100, if no adaptation takes place. The same authors postulated that if adaptation measures (in terms of beach nourishment and dike construction) were employed, the number of people flooded can be reduced by two orders of magnitude and the economic damages cut by half in 2100.

Other climate change impacts, such as flooding of rivers, estuaries and deltas or an increased migration toward coastal towns due to increased drought inland, induced by climate change, will also affect coastal zones (IPCC 2014). Socio-economic vulnerability is expected to increase over the next two decades. The extent to which this vulnerability will increase with increased exposure to hazards depends on the adaptive capacity of countries in the WIO (Kebede and others, 2010, Theron and Barwell 2012).

Vulnerability to environmental change is increased where ecosystem goods and services are declining eg integrity of coral reef systems because of changing ocean pH, which in turn may reduce natural protection levels pro-

BOX 29.3. CITIES AT RISK: MAPUTO AND BEIRA, MOZAMBIQUE

View of Maputo from Catembe. © José Paula.

The city is vulnerable to the effects of climate change by virtue of its proximity to the shoreline. It is the most densely populated urban area in the country. Maputo's low-elevation zones with flat topography are host to large slum concentrations. During severe flooding in 2000, 2 million Mozambicans were affected, with 650 000 forced from their homes – a possible portent of future environmental change impacts (UN-Habitat 2014). Existing impacts of a rising sealevel include salinization, causing damage to agriculture ventures and contributing to urban poverty. In Beira, saline intrusion could extend tens of kilometres inland; and sealevel rise might exacerbate this pre-existing vulnerability (UN-Habitat 2014). Flooding of the most populated low elevation coastal zone may result in serious consequences for the urban poor whose capacity to adapt to climate change is limited. Shrinkage of sand strips on the beaches results in serious coastal erosion with negative consequences for economic activity. Some of the key actions towards better adaptation to the vulnerabilities include the development of adequate policy, strategic and planning tools based on the outcomes of stakeholder engagement/awareness and detailed assessments (eg Theron and Barwell 2012), in order to provide policy- and decision-makers with a range of adaptive options for cities.

vided by coral reefs from storm surges and tsunamis. Some countries such as Seychelles have embarked on a land reclamation adaptation project to boost climate resilience, but adaptation programmes are few and poorly carried out in the rural areas of the African sub-region, with adaptation essentially being "forced" upon the rural poor. They are not active participants in adaptation but are subject to it, forced to migrate to wherever the possibility of better survival exists. Many of the displaced walk hundreds of kilometres to reach places of safety, only to be further disenfranchised and exploited in their new countries or cities of residence" (UN-Habitat 2014)

Catchments of the WIO Region

The WIO region has twelve major river catchments (Table 29.2). Three of these catchments, namely the, Juba-Shabelle, Limpopo River and Zambezi River Catchments, are among Africa's major trans-boundary river catchments (UNEP 2010). The region's major rivers, namely, the Maputo, Incomati, Limpopo, Save, Tana, Athi-Sabaki, Rufiji, Zambezi and Ruvuma arise from central highlands and transport and discharge large volumes of siliciclastic sediment into the coastal zone (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a).

The status of some of the major WIO region catchments are summarised below.

Tana River Catchment

Water use in the Tana Catchment is dominated by hydropower electricity generation, which supplies an average of 40 to 64 per cent of Kenya's electricity demand (Knoop and others, 2012). The construction of hydropower dams in the upper Tana catchment has been largely linked to significant changes in the flow of the river in the lower Tana catchment (IUCN 2003, UNEP/Nairobi Convention Secretariat and WIOMSA 2009b, Knoop and others, 2012). While these dams have altered the river's downstream flow and its physical characteristics, it is noteworthy that they have played a significant role in decreasing the frequency

BOX 29.4. CITIES AT RISK: PORT LOUIS, MAURITIUS

View of Port Louis and harbour looking west from the Citadel. © Thierry.

A large proportion of the Mauritius urban population is concentrated in Port Louis, a major coastal city with most of the urban population of the island found within two neighbouring districts: Port Louis and Plaines Wilhems. The city is only located five metres above mean sea level and also hosts the only port on the island for import and export trade. Port Louis is exposed to risks and impacts associated with storms, storm-surges, flooding, coastal erosion and direct damage to infrastructure, services and property (Tadross and Johnston 2012). Climate change threats such as sea-level rise, storm surge and flooding include impacts to water and sanitation, transport, health, energy, and agriculture sectors. Some of the emerging priority vulnerabilities that need to addressed include the successful mainstreaming of climate change issues, which is presently scanty and fragmented into national development plans and strategies; development of a national adaptation and a mitigation strategy; and the setting up of the necessary regulatory and administrative framework to ensure that both mitigation and adaptation measures are being adopted and implemented in all sectors (Government of Mauritius 2010).

and magnitude of floods. Furthermore, dam construction on the Tana River has caused an estimated 56 per cent decline in sediment load, which has led to beach erosion and the loss of mangroves and wetlands along the Tana Delta (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b). Municipal water use and medium-sized irrigation schemes constitute other major forms of water use in the Tana catchment (Knoop and others, 2012). Overall, Tana catchment has been described as 'water scarce' given the decline in *per capita* water availability over the years, a trend mainly attributed to rapid population growth within the catchment area (Knoop and others, 2012).

The high population density and intense agriculture, especially in the Upper Tana catchment, have led to over-abstraction of surface water. Furthermore, water quality in this region is largely affected by pollution from tea factories and poor sanitation facilities used by tea zone dwellers.

The Middle Tana catchment is largely used for livestock, agriculture and tree harvesting, and is characterised by a lack of adequate natural resources management. This region faces water quality issues resulting from a lack of functional sewage systems, quarrying, sand harvesting and chemical wastes from farms (Knoop and others, 2012). The Lower Tana is characterized by water scarcity with high levels of evapotranspiration due to high temperature. Even so, this region is earmarked for agricultural growth, particularly for sugar cane farming, bio-fuel plantations, horticulture and rice (Knoop and others, 2012).

Athi-Sabaki River Catchment

Land and water use within this catchment area mainly includes intensive agriculture with both small-scale and large-scale farming, particularly livestock and wildlife overgrazing, resulting in soil erosion. The catchment largely features industrial and domestic uses as well. Overall, the major environmental threats in the Athi-Sabaki catchment include sedimentation, agricultural pollution and deforestation (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a).

Unlike the Tana River, which is also located in Kenya, the Athi-Sabaki River is not heavily dammed and has high levels of sediment loads ranging from 5 to 13 million tonnes

Table 29.2. Main characteristics of the twelve major catchments of the Western Indian Ocean Region.

Name of Catchment	Country/Countries Sharing Catchment Area	Catchment Area (km^2)	Characteristics
Juba-Shabelle	Somalia, Ethiopia and Kenya	783 000	The Juba and Shabelle Rivers stretch over a distance of 1 808 km and 2 526 km respectively. The two rivers originate in Ethiopia and merge in Somalia before reaching the Indian Ocean. These two rivers constitute the only perennial surface flow in southern Somalia. However, two thirds of the river catchments are situated outside of Somalia mainly in Ethiopia with part of the Juba catchment in Kenya.
Tana	Kenya	126 898	The Tana River Catchment covers about 23 per cent of the total area of the Republic of Kenya. The Tana River, the longest river in Kenya (850 km), originates from mountain ranges in central Kenya, meanders through the arid and semi-arid eastern landscape of Kenya and reaches the Indian Ocean through a Delta covering approximately 1 300 km^2. This river has an estimated discharge of 9 000 million m^3 (representing 32 per cent of the country's total annual river discharge) with an estimated 6.8 million tonnes of sediment load which varies seasonally. The Tana River Delta, which is colonised by mangroves (4 100 ha) features four main estuaries. These are Kipini, Mto Kilifi, Mto Tana, and Mto Moni. These estuaries extend up to 10 km inland and provide habitat and nursery ground for juvenile fish and shrimps.
Athi-Sabaki	Kenya	69 930	The Athi-Sabaki Catchment is the fourth largest in Kenya. It has two main tributaries, namely, Tsavo and Athi rivers, which converge at the lover region of the basin to form Sabaki River. The Athi-Sabaki River, the second longest in Kenya, flows into the Indian Ocean via the Sabaki estuary in Malindi Bay. The Sabaki estuary is 2.5 km long with a surface area of 0.58 km^2 and characterized by the high deposition of sediment load. The estuary is ecologically significant as a habitat and nursery ground for shrimps and feeding ground for birds.
Pangani	Tanzania, Kenya	43 650	The Pangani River basin in Tanzania has a total area of 43 650 km^2, located in northeastern Tanzania and drains into the Indian Ocean south of Tanga City. The main rivers in this basin are the Pangani River (which accounts for 27 300 km^2 and the coastal rivers of Umba, Sigi and Msangazi, located in the south of the basin. The headwaters of Pangani River are in the mountains of Kilimanjaro and Meru. The major tributaries of Pangani River are Ruvu, Weruweru, Kikuletwa, Rau and Kikafu rivers.
Rufiji	Tanzania	177 000	Rufuji catchment is the largest in Tanzania incorporating four major rivers, namely, Great Ruaha River, Kolombero River, Luwegu River and Rufiji. The Rufiji River contributes 50 per cent of the national total freshwater discharges to the sea. This catchment features a number of wetlands with major ones being the Utengule in the Great Rauha and the Kibasila in the Kilombero. The lower Rufuji floodplain features a permanent lake system made up of 13 lakes. About 50 km^2 of the Rufiji Delta is covered in mangrove forests, which greatly support the productivity of fisheries.
Ruvuma/Rovuma	Malawi, Mozambique, Tanzania	155 400	The biggest share of the total area of the Ruvuma catchment lies within Mozambique, which accounts for 65.5 per cent of the area, with Tanzania accounting for 34 per cent and Malawi for less than 1 per cent. The Ruvuma catchment features the Nyassa Nature Reserve and the Quirimbas National Park both of which are ecologically important landscapes. The Ruvuma estuary, which is shared by Tanzania and Mozambique, is rich in tropical coastal marine resources and is fringed by beaches and mangroves.
Zambezi	Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe	1 300 000	The Zambezi River Catchment is the fourth largest in Africa and carries an estimated runoff of about 103 000 million m^3 per year. The Zambezi River plays a critical role in sustaining and maintaining the productivity of aquatic flora and fauna in the Indian Ocean. The Zambezi Delta is about 100 km long 120 km wide at the coast covering a total area of 15 000 km^2. The Delta sustains the rich offshore Sofala Bank with its fisheries and is a key nursery ground for fish and offshore shrimp resources.
Pungwe	Mozambique, Zimbabwe	31 000	The Pungwe River is about 400 km long with 340 km of this river located in Mozambique. Zimbabwe shares only 5 per cent of the catchment. The estuary, through which the river enters the Indian Ocean, is utilised for aquaculture, mainly for prawn.
Limpopo	Botswana, South Africa, Mozambique, Zimbabwe	408 000	The Limpopo River is about 1 777 km long. It flows from the Limpopo Province in South Africa to form part of the South Africa-Botswana boarder in the north and then towards the east to form the South Africa Zimbabwe boarder and lastly southeast via Mozambique into the Western Indian Ocean. The Limpopo River estuary is relatively small and functions as a nursery for fish and shrimp. From its limited mangroves, the estuary is also a source of building material for local communities.

Name of Catchment	Country/Countries Sharing Catchment Area	Catchment Area (km^2)	Characteristics
Incomati	Mozambique, South Africa, Swaziland	46 800	South Africa shares 63 per cent of the total Incomati Tiver catchment area while Mozambique and Swaziland share 32 per cent and 5 per cent respectively. The river flows from South Africa through Swaziland and then back to South Africa before it reaches the Indian Ocean through Mozambique. The Incomati estuary is relatively small spatially and features a number of inter-linked habitats including a long narrow peninsula and a series of islands within the river. This estuarine ecosystem supports aquatic birds and provides food provisioning services.
Maputo	South Africa, Swaziland, Mozambique	28 500	South Africa and Swaziland share 93.9 per cent (28 230 km^2) of the total Maputo River catchment area, with the remaining 6.1 per cent (1 570 km^2) shared by Mozambique. Maputo Bay covers an area of 70 000 ha which comprise estuarine, mangrove and marine components. The large mangrove forest supports fisheries.
Thukela	South Africa	30 000	The Thukela River flows from the Drakensberg Mountains in KwaZulu-Natal province (KZN) in South Africa through central KZN and into the Indian Ocean. The river has an estimated runoff of 3 799 million m^3 per annum.
Betsiboka	Madagascar	49 000	The Betsiboka River has one of the largest catchments in Madagascar. The river's estuary is large but shallow and experiences significant tidal incursions during spring tides as well as accretion linked to high levels of sediment deposition. Mangroves (which cover 420 km^2) serve as feeding grounds for shrimp, crab and finfish. They also serve as a source of building material for local communities.

per year. The increase in sediment loads, particularly in the 1990s, has been attributed to extensive deforestation and expansion of agriculture within the catchment (Arthurton and others, 2008). This has resulted in a range of coastal issues such as choking of the estuary at Malindi and ultimately affecting tourism development. Heavy siltation is also causing accretion and pro-gradation of beaches between Ngomeni and Malindi. Siltation has also reduced the depth of water in Malindi Bay affecting its use as a port. Deposition of silt has also degraded sensitive coral reefs and seagrass habitats. A positive impact of the sediment accretion has been the increase in mangrove area in the Sabaki estuary (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a). This catchment is also affected by increased rainfall and extreme climate events.

Pangani River Catchment

Land and water use in the Pangani River catchment area include tourism, mining, industry, small scale fishing, agriculture, hydropower generation and domestic use. The catchment features a number of National Parks, Game Reserves and Controlled Areas. The catchment is exploited for its mineral and gemstone deposits, and particularly for tanzanite, a distinctive blue diamond unique to Tanzania. There are numerous environmental pressures in the catchment. These include deforestation, demands for land, destructive farming practices, uncontrolled development, uncontrolled mining activities, over-fishing, deteriorating water quality, introduction of alien species and a lack of environmental awareness. The changing flow regime has also altered the river channel and bed (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).

Rufiji River Catchment

Land and water use in the Rufiji catchment include agriculture, mining, forestry, livestock farming, fishing, wildlife, navigation and human settlements (RBWO 2007). Most of these exert negative environmental pressure on the river and estuary (UNEP/Nairobi Convention Secretariat and WIOMSA 2009a).

Maputo River Catchment

Water from the Maputo River is primarily used for irrigation and the generation of hydro-energy. In the catchment, agriculture is an important contributor to employment, poverty alleviation and input into the manufacturing sector. Farming accounts for 86 per cent of water use in the catchment. More than half of the 40 960 ha sugarcane crops in the catchment are irrigated. Forestry, another major water user, accounts for 367 700 ha of the catchment (SADC 2010). Agricultural, industrial and urban discharges into the river have been linked to deterioration of water quality in Maputo Bay (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).

Thukela River Catchment

The Thukela River catchment is located in a predominantly rural region of the province of KwaZulu-Natal in

South Africa. The impoverished communities are mainly dependent on subsistence farming in degraded agricultural areas (Chikozozho 2005). The catchment is characterised by commercial agriculture, manufacturing industry, trade, transport and a growing tourism industry around the Drakensburg Mountains. The upper Thukela catchment features three major dams and inter-basin transfer infrastructure used for water supply and stream flow regulation. These have impacted flow and sediment conditions of the Thukela River and estuary which has become one of the key environmental concerns in the catchment. The catchment is also affected by deteriorating water quality due to acid mine drainage and industrial and municipal discharges into the system. Stream flow reduction during dry winter seasons affects water quality at the estuary (UNEP/Nairobi Convention Secretariat and WIOMSA 2009b).

Betsiboka River Catchment

This catchment area incorporates some major cities in Madagascar including the capital city-Antananarivo, Maevatanana and Marovoay. Two large dams located in the Ikopa tributary, constitute the main source of drinking water for an estimated population of the 1.9 million inhabitants of Antananarivo. The environmental issues in the catchment result from poor land-use practices and the effects of climate change. The southwestern region of the catchment has been affected by increasing periods of droughts interspersed by highly variable rainfall patterns downstream. Land-use practices such as "slash and burn" farming is associated with land degradation which results in increased sediment loads entering Mahajanga Bay. The Betsiboka River is important for shipping and local transport. The estuary noticeably features red-coloured water as a result of sediments from the eroded catchment. Turbidity resulting from high sediment loads has also impacted local coral reefs in the Antrena coastal area.

EMERGING ISSUES AND POLICY RESPONSES

Urbanisation, Development and Vulnerability

The existing and emerging issues identified and described above require a number of policy responses in order to mitigate negative environmental, social and economic consequences. These are:

• Disaster risk reduction and climate change adaptation must be prioritised in order to better manage extreme events as well as distinctive slow-onset, semi-permanent changes such as sea level rise or rising temperatures. Vulnerability and resilience assessments, as well as explicitly human security considerations, are core concerns of disaster risk reduction and climate change adaptation, facing similar challenges. Some specific challenges that must be dealt with by policy includes; inadequate political will; lack of financial support for mainstreaming; and lack of investment in preventative and proactive measures to reduce vulnerability to probable future threats and vulnerability drivers;

• Promote and undertake research devoted to exploring innovative and cost effective ways of addressing the climate problem (Kithiia and Dowling 2010);

• Encourage and promote robust urban planning processes that seek to reduce the dichotomy between formal governing institutions and networks of actors that provide local capacities. National urbanisation policy frameworks must complement local strategies for changes to be quicker and deeper, and this includes identifying various levers by which action can be triggered and sustained. These actions are likely to be enhanced if good science (including the use of new data, methodologies and models), is used to inform policy (Kithiia and Dowling 2010)

• Reduce the high levels of vulnerability and low adaptive capacity in local governments with poor capacities and resources (Kithiia 2011). Weak local government creates and exacerbates problems including the lack of appropriate regulatory structures and mandates; poor or no planning; lack of or poor data; lack of disaster risk reduction strategies; poor servicing and infrastructure (particularly waste management and drainage); uncontrolled settlement of high-risk areas such as floodplains, wetlands, and coastlines; ecosystem degradation; competing development priorities and timelines; and a lack of coordination among government agencies (Kithiia and Dowling 2010, Kithiia 2011, IPCC 2014).

• Existing land-use plans in most WIO countries are inadequate or lacking, and in order to update such plans authorities need to identify and establish the environmental baselines to inform appropriate zoning and take into account the onset of climate change. Mechanisms such as coastal development setbacks and development limits must be incorporated into urban planning and building controls. Some specific measures, as described by Theron and Barwell (2012), include:

- Introducing policy and planning processes to ensure

that coastal construction is a safe distance away from the high-water mark, and reinstate natural defence mechanisms with the necessary environmental authorisations;

- Undertaking holistic planning and implementation through the development and implementation of coastal management programmes that incorporate shoreline management plans;

- Establishing a coastal development setback line which is designed to protect both the natural environment from encroachment of buildings as well as protecting beachfront developments from the effects of storms and accelerated coastal erosion;

- Working with nature by protecting the integrity of buffer dune systems, which should be vegetated with appropriate dune species, as per the original natural zones, and maintained;

- Maintaining, or even better, increasing the sand reservoir (volume) stored in the dune system; and,

- Protecting, restorating and maintaining natural systems like mangroves and coral reefs.

• Mainstream adaptation options into integrated coastal management and sustainable development plans. There is growing recognition that scientists, policymakers, residents, managers and other key stakeholders must work together to establish a framework for adaptation that is mainstreamed into the current coastal management processes and practices;

• Planning regimes of WIO coastal cities should consider the requirement for socio-political reforms and changes. Current planning remains largely piecemeal, responding only to a minority of, often wealthier, recipients. The negotiation of existing patterns of segregation, as well as how formal and informal systems combine are overdue and remain critical elements to unlocking the "dualistic" nature of urban development.

• Improve the capacity of municipal and central governments to govern urban land markets by collecting revenue from land and property transfers, sales, rates and taxes, upon which municipalities generally depend. The dual system of land management in Eastern African cities is unsuitable for the long-term development of these cities, since municipal revenues and the capacity to act are inadequate.

• Initiate a debate on coastal urban equity, since current coastal development is primarily intended for the wealthy, which threatens eviction of poor and low-income residents in some cases. Seek to address the general interest, rights and needs of all stakeholders. The needs of the poor should be incorporated through equality and human rights-based urban interventions. All WIO coastal cities need services provided by cleaners, waste collectors, gardeners, "askaris" (security guards) and other low-income service providers.

• Develop effective adaptation strategies for port cities of the WIO region. Integrate the consideration of climate change into long-term coastal flood risk management and disaster planning (Hanson and others, 2011).

Catchments

The catchment and estuarine degradation resulting from modified river flows, water quality and sediment loads are linked to a lack of appropriate governance and management interventions at regional, national and sub-national scales. Some suggestions for regional policy interventions include:

• Development of coordinated, non-conflicting and relevant legal frameworks for the management of transboundary catchments. This is a necessity since the majority of the catchments are shared between states;

• Effective implementation of inter-governmental management instruments for river catchment management;

• Development of protocols for inter-sectorial water governance and the involvement of the stakeholders from the sectors (agriculture, industry, water authorities, local government etc.) involved in water resource management;

• Improvement in the collection of data and information relevant for water resource management. Monitoring and assessment of rivers, catchments and estuaries are needed to understand and predict the changes in catchments and the effect on the coastal and marine environment;

• Improved financial investment in the development of human capital in order to facilitate and promote the effective implementation of agreements and water management programmes; and,

• The development of integrated regional policies for water resource management in order to address the growing demand on water resources.

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