National Institute for Disaster Management

Study on the Impact of Climate Change on Disaster Risk in Mozambique: Synthesis Report

May 2009

Instituto Nacional de
Gestao de Calamidades

Republica de
Mozambique

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Cover photographs: © Skip O’Donnell, 2007, desert; Valeriy Kirsanov, 2007, wildfire; Brett Charlton, 2007, tropical cyclones and Mark Rigby, 2008, flooding

Photographs included in this report illustrate situations that are likely to occur with greater frequency and/or intensity as a result of climate change.

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INGC. 2009. Synthesis report. INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [van Logchem B and Brito R (ed.)]. INGC, Mozambique.

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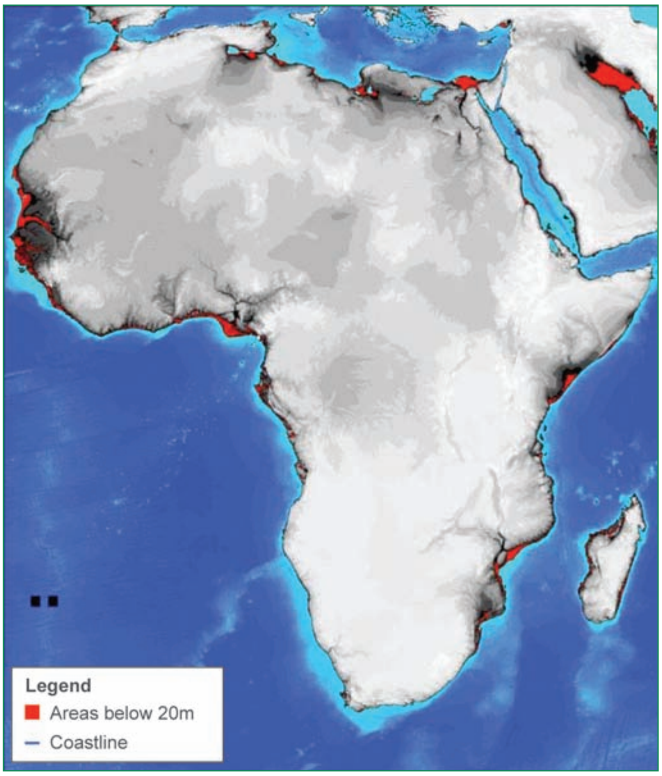
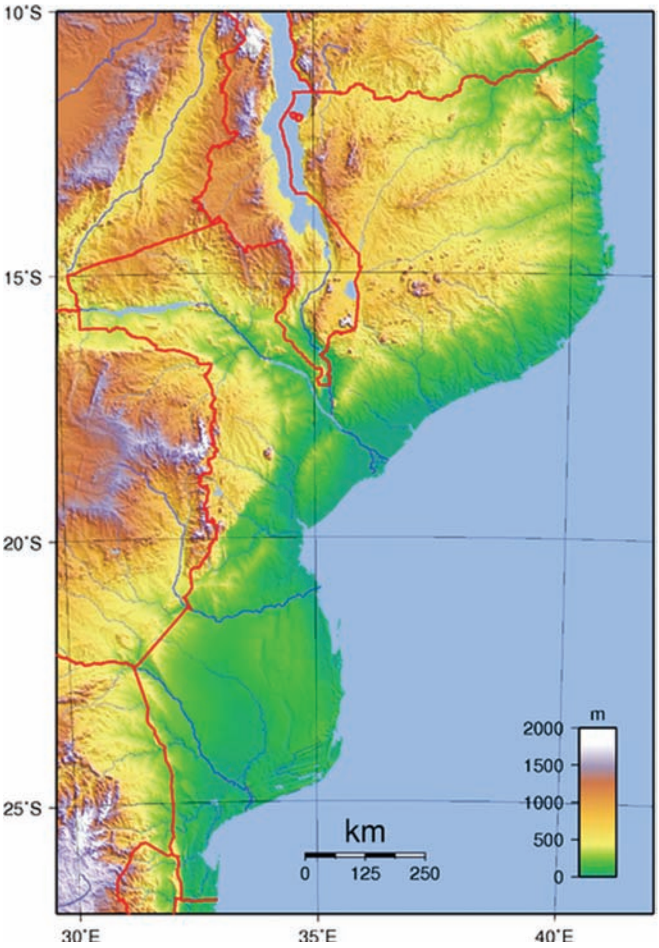
Acronyms

BASICS	British Association for Immediate Care
DJF	December, January, February months
ENSO	El Nino Southern Oscillation
GCM	General Circulation Model
GDP	Gross Domestic Product
HDI	Human Development Index
ICT	Information Communications Technology
IIAM	Institute of Agricultural Research of Mozambique
INAHINA	National Institute for Hydrography and Navigation, Mozambique
INAM	National Institute of Meteorology of Mozambique
INGC	National Institute for Disaster Management, Mozambique
IPCC	Intergovernmental Panel on Climate Change
IPCC 4AR	Intergovernmental Panel on Climate Change – Fourth Assessment Report
IPCC-SRES	Intergovernmental Panel on Climate Change - Special Report on Emissions Scenarios
ITCZ	Inter-tropical Convergence Zone
JFM	January, February, March months
JJA	June, July, August months
MAM	March, April, May months
MICOA	Ministry of Coordination of Environmental Affairs
MINAG	Ministry of Agriculture and Rural Development
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPA	National Adaption Plan for Action
OND	October, November, December months
PET	Potential evapotranspiration
PMI	Potential Moisture Index
SLR	Sea level rise
SON	September, October, November months
UNDP	United Nations Development Programme

Mozambique has a coastline of almost 2,700km. Approximately 20.5 million people, more than 60% of the total population, live in coastal areas. In many places this consists of lowlands with sandy beaches, estuaries and mangroves. Survival and everyday life in these areas depends to a large extent on local resources, such as rain-fed farming and fishing, whilst infrastructure is weak or even non-existent. These conditions mean a high vulnerability of both people and landscape to tropical cyclones and sea level rise (Mavume, 2009). Of particular concern is the tendency for people to migrate to the coastal zone, thus placing more people, infrastructure and services at risk.



Map 1: Mozambique is recognized as one of the countries of Africa that are most vulnerable to climate change along its coasts. The red areas illustrate the extent of the 20m contour along the coast of Africa, where large estuaries and deltas form low lying land. ***Source: Bundrit and Mavume, 2009.***



Map 2: The topographic map of Mozambique clearly shows the low lying coastal plain covering much of the country in the South and Central zones (colored green/blue). The higher mountains/plateaus inland and to the North are also clearly visible. ***Source: http://en.wikipedia.org/wiki/File:Mozambique_Topography.png***

Introduction

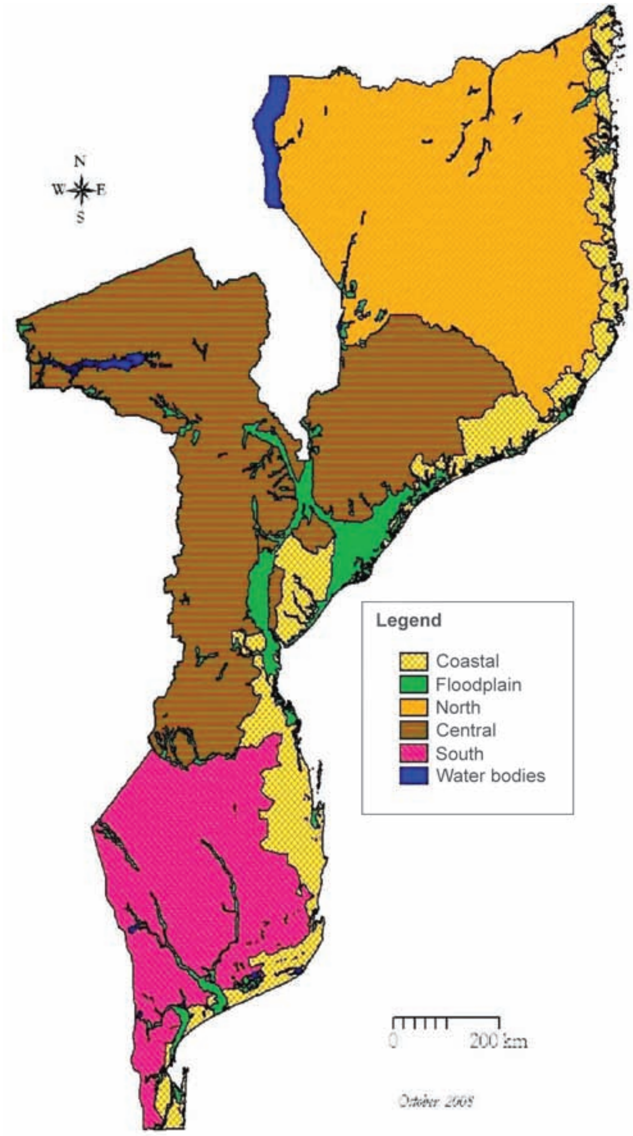
The study on 'Impacts of Climate Change on Disaster Risk in Mozambique,' conducted from May 2008-January 2009 by the National Institute for Disaster Management (INGC) and funded by Denmark, UNDP and GTZ, attempts to provide preliminary answers to the following questions:

This document summarises the main findings in answer to these questions. For more information on applied methodologies and more detailed results, the reader is referred to the main report. The team members who worked on this study are listed in Annex II.

'To what extent will vulnerability and exposure to natural disasters alter with projected climate change, given socio-economic developments, by 2030 and 2060? What are plausible extreme scenarios? What adaptation is needed to reduce vulnerability to these impacts of climate change?

Mozambique: land zoning

For the purpose of this study, Mozambique is divided into 5 zones. Three zones are based on the regional/provincial administrative division of the country i.e. South (Maputo, Gaza and Inhambane provinces), Central (Tete, Manica, Sofala and Zambezia), and North (Nampula, Cabo Delgado and Niassa). The fourth zone is the coastal zone, most vulnerable to cyclonic activity. It is where most socio-economic infrastructure currently exists, and is associated with dominant patterns of population settlement. The fifth zone represents the river flood plain systems, most vulnerable to both floods and water stress. A detailed baseline description for each zone is given in the main report (agricultural section).



The Northern Region is characterized by a relatively narrow coastal plain with few large rivers, a coastline of sandy beaches, sea grass meadows and fringing coral reefs, and a narrow continental shelf. The tides are moderate (2m in range), and the coast is subject to occasional tropical cyclones (4 in 16 years). Soils are low to moderately fertile. Inland there is moderate to strong erosion, and stony ground. Only some 627ha (19%) out of 3352ha equipped for irrigation, is operational (IIAM survey 2004). Main crops are groundnut, cassava, maize, rice, sorghum and cotton.

The Central Region is characterized by a wide and flat coastal plain, with many large rivers and deltas, a dynamic sediment-rich muddy and sandy coastline, and wide and very shallow offshore tidal flats. The tides are large (up to 7m in range), and the coast is the most subject to tropical cyclones (6 in 16 years). It has the highest maize yields in the country; other important crops are cassava, rice, sorghum, sugarcane. There is a moderate to high risk of drought in some of the areas in the interior. Approximately 15,685ha (41%) of 38,621ha equipped for irrigation, is operational. Soils are moderately to highly fertile, lower inland where land is rocky and there is moderate erosion. The coastal area deals with poor drainage, flooding, cyclones, saline intrusion and erosion.

The Southern Region is mainly semi-arid or arid and has a relatively narrow coastal plain, with some large rivers, a sandy coastline and a shallow bight in Maputo Bay. The tides are moderate (2m in range), and the coast is subject to occasional tropical cyclones (4 in 16 years). Inland and coastal soil fertility is mainly low, but higher in the floodplains. There is a moderate to high risk of drought, (wind) erosion and salinity; and flooding in coastal plains. Only approximately 23,145ha (30%) of 75,747ha equipped for irrigation is operational. Main crops are cassava, maize, groundnuts, rice and sugarcane.

Map 3: Mozambique: land zoning. ***Source: IIAM, 2008.***

1 Past trends and future changes in the climate of Mozambique

1.1 Observed trends in temperature (period 1960-2005)

The most important weather systems that determine rainfall amounts and patterns over Mozambique are the Inter-tropical Convergence Zone (ITCZ); tropical cyclones; thermal lows along the coast as a result of the deepening of the semi-permanent trough of the Mozambique Channel; and incoming Easterly waves (INAM, 2009).

- During the period 1960-2005, significant positive trends in temperature change are observed across most of the country and all four seasons. However, the warming tendency has not been uniform across the country. Between 1960 and 2005, during the winter season, increases of up to 1.6°C are apparent over the Centre, whereas maximum temperatures during the March-April-May (MAM) and the September-October-November (SON) months have increased by approximately 1.1°C in the North. Annual mean maximum temperatures in the North, pre-1990 were often below 30°C, and post-1990 consistently above 30°C. The Centre recorded average mean maximum temperatures around 31°C before 1990, and significant increases after (Queface, 2009).

- There was an increase of 9 days in the duration of the longest heat waves during the SON period. The number of cold nights and cold days has decreased in the same period, whereas the number of hot nights and hot days has increased over the whole of the country. This is most notable in the north where the number of hot nights has increased by 25% during the December-January-February (DJF) season and the number of hot days has increased by 17% during the SON season. Droughts are therefore increasingly marked by higher mean maximum temperatures, which in turn augment evaporation (Tadross 2009).

1.2 Observed trends in precipitation (period 1960-2005)

Significant past trends in rainfall are not readily apparent, largely due to the high inter-annual variability of rains over different seasons compared to the period of record. However, there are indications of a later start to the rainfall season, as well as an increase in dry day persistence and dry spell length in the northeast of the country during the MAM and SON months.

- In the North the mean dry spell length during June-July-August (JJA) was 7 days longer in 2005 than in1960, increasing by up to 20 days for specific locations during the SON months (likely reflecting a delay in the end of the dry season). During the same period the start of the rainfall season was delayed by up to 45 days at specific locations (Tadross, 2009).

Figure 1 shows that the largest changes in observational records between 1960 and 2005 have occurred in the North; both in terms of observed increases in temperature and observed delays in rain.

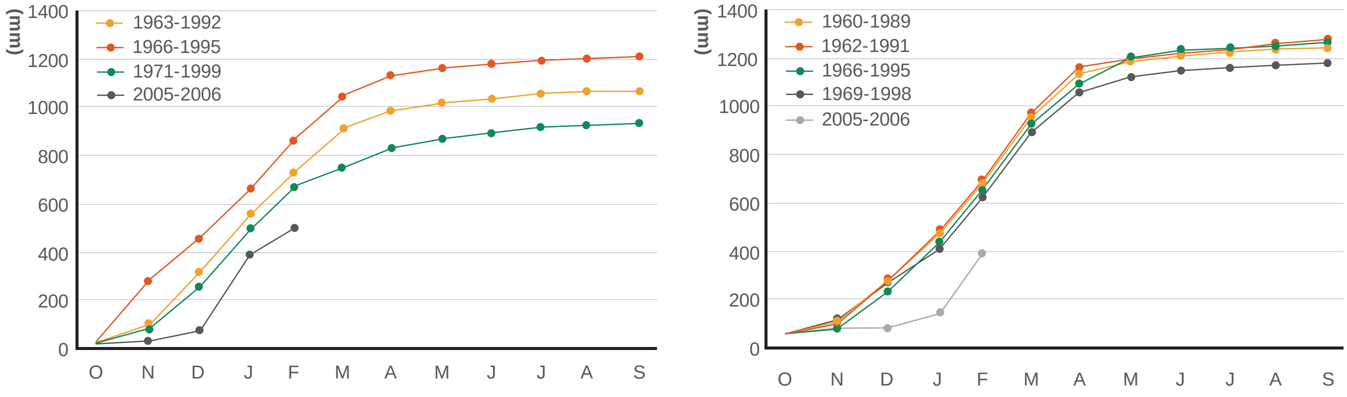


Figure 1: Observational records showing the start of the rainy season in the North (period 1960-2005). The blue line (North) and purple line (South) should be interpreted with caution as they only represent 1 year whereas the other lines represent periods. ***Source: INAM, 2009.***

1.3 Observations of natural disasters (period 1960-2005)

Figure 2 illustrates the increase in the number of natural disasters observed in Mozambique over the past three decades (Queface, 2009). Figure 3 shows the spread of disasters by zone.

- The Centre is more prone to floods, tropical cyclones and epidemics, followed by the South and North. The South, with its tropical dry savanna climate, is more prone to droughts than the Centre and the North, which are dominated by a tropical rainy climate and a moderately humid climate modified by altitude, respectively.

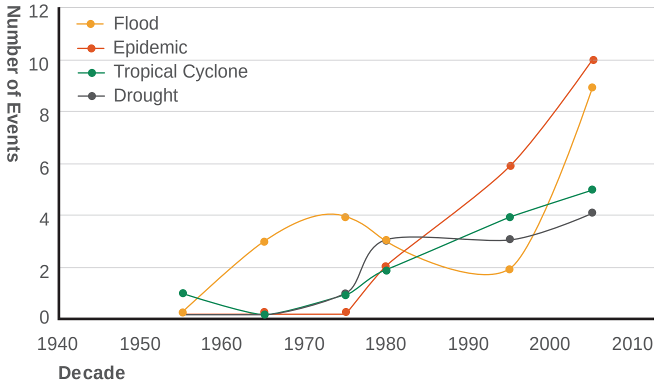


Figure 2: Number of natural disasters in Mozambique (period 1956-2008). ***Source: Queface, 2009.***

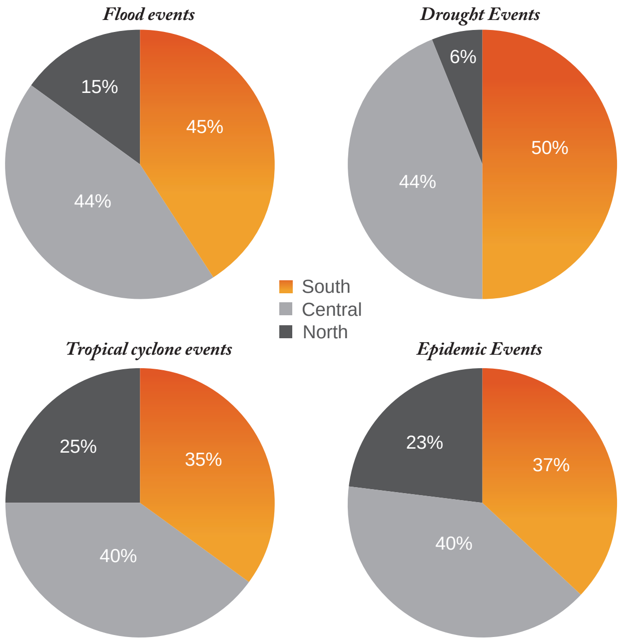


Figure 3: Disasters by region (period1956-2008). ***Source: Queface, 2009.***

Table 1 details an estimate of the impacts of natural disasters between 1956 and 2008. Droughts affected the highest number of people.

N°	Disaster type	# of Events	Total Killed	Total Affected
1	Drought	10	100,200	16,444,000
2	Flood	20	1,921	9,039,251
3	Tropical Cyclone	13	697	2,997,300
4	Epidemic	18	2,446	314,056
5	Windstorm	5	20	5,100
6	Earthquake	1	4	1,440

Table 1: Summary of the impacts of natural disasters (period 1956-2008). ***Source: Queface, 2009.***

Note 1

[1] Sources used for Figures 1-3 and Table 1 include INGC; FEWSNET; British Association for Immediate Care (BASICS) www.basedn.freeserve.co.uk/; UNDP/CRED (2006); EM-DAT www.em-dat.net; Université Catholique de Louvain – Brussels; Global Disaster Identifier Number (GLIDE) www.glidenumber.net; Münich Reinsurance Company www.mmathan.munichre.com.

1.4 Future changes in temperature (approximately 2046-2065)

Figure 4 shows the climate variability and future projections of climate change in November-April minimum and maximum temperature per zone.

- All seven General Circulation Models (GCMs)[2] project the highest increases in temperature inland and during the SON months. Maximum temperatures increase between 2.5°C and 3°C (median estimate of all GCMs). Similar increases in minimum temperature are projected over the Limpopo and Zambezi valleys during the SON months. Seasonal variability in maximum temperature decreases in the North during the SON months, but increases over most of the country during the MAM and JJA months. Variability in minimum temperatures increases in the North during the MAM and JJA months, and in the South during the SON months.
- By 2081-2100 increases in temperature are projected to increase by as much as +5-6°C over the Centre during the SON months.
- Increases in the likelihood of extreme maximum daily temperatures above 35°C are simulated for all regions, increasing by 25-33% by 2080-2100 (Tadross, 2009).

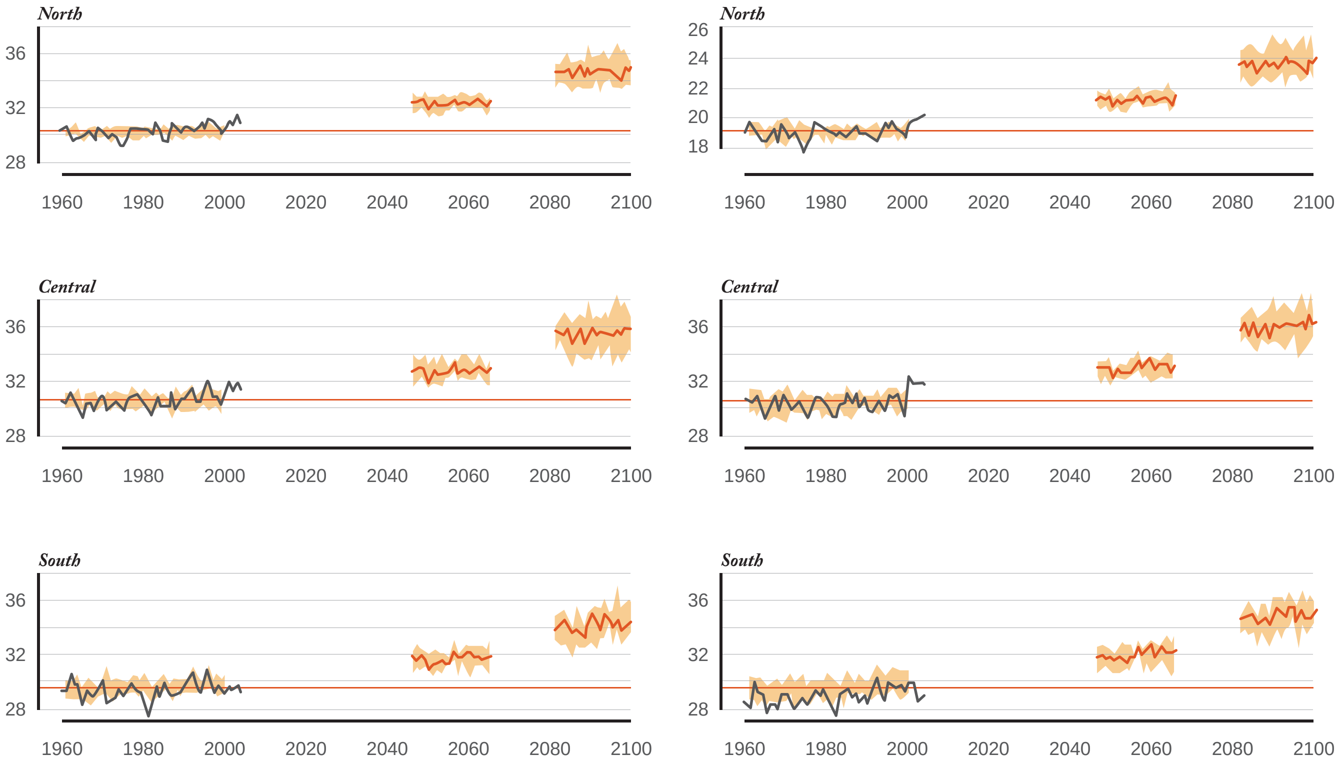


Figure 4: Climate variability and future projections of November-April temperature change per zone: minimum temperatures (left hand graphs) and maximum temperatures (right hand graphs). The black line shows observed trends (1960-2005), the red lines show future change (periods 1960-2000, 2046-2065 and 2081-2100). ***Source: Tadross, 2009.***

Note 2

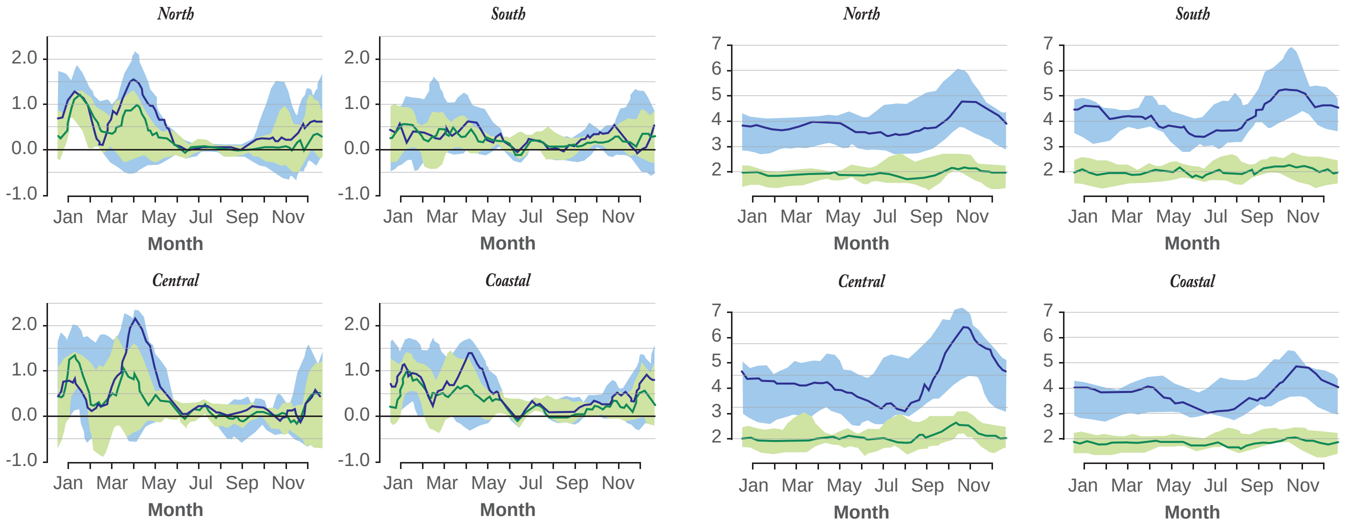
[2] All 7 GCMs of this study were used in the IPCC 4th Assessment Report (IPCC-AR4, 2007) and forced with the SRES A2 emissions scenario, which assumes that societies will continue to use fossil fuels at a moderate growth rate, there will be less economic integration and populations will continue to expand. CO_2 emissions will not be reduced in a significant manner in the coming 20 years or so leading to concentrations of approximately 550 ppm and a global average temperature rise of about 4˚C by 2050. The scenario corresponds to an average global sea level rise of approximately 20cm however this is based purely on thermal expansion of the oceans and does not include big rises which would occur if the Greenland or other big ice sheets were to collapse – this issue is dealt with elsewhere in this report.

1.5 Future changes in precipitation (approximately 2046-2065)

The GCM models project an increase in rainfall over most of Mozambique during the DJF and the MAM months, whereas rainfall increases are less than increases in evapotranspiration during the JJA and the SON months. Higher increases in rainfall are suggested towards the coast and greater seasonal variability during all seasons across the coastal zones of the South; over the entire country most stations also suggest an increase in variability during the JJA months. The annual average over the entire country indicates a slight increase in rainfall (10-25%) compared to the average annual rainfall during the 1960-2000 period. The spread between models is large however, indicating that the changes in rainfall are not as consistently simulated as are changes in temperature.

Figure 5 shows the changes in future rainfall, maximum temperature, potential evapotranspiration (PET) and Potential Moisture Index (PMI) (approximating rainfall minus evaporation) simulated by the seven GCMs for the North, Centre, South and Coast for the 2045-2065 and 2080-2100 periods.

(a) Rainfall **(b) Maximum Temperature**



(c) PET **(d) PMI**

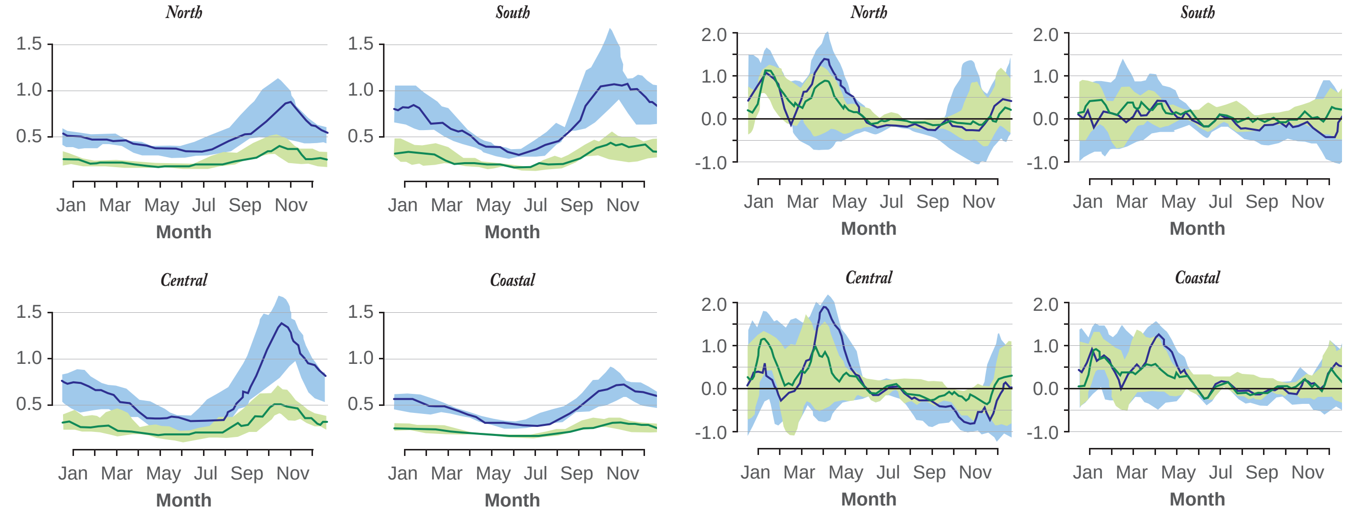


Figure 5: Changes in the annual cycle of a) Rainfall (mm day-1); b) Maximum temperature (°C); c) potential evapotranspiration (PET) (mm day-1) and d) Potential Moisture Index (PMI) (Rainfall – 0.5*PET) (mm day-1) simulated by seven GCMs for the North, Central, Southern and Coastal zones. Green shading indicated the range (olive line the median) for the 2046-2065 period, blue shading the range (blue line the median) change for the 2080-2100 period. *Source: Tadross, 2009.*

- Across all zones, increases in evaporation will likely be greater than increases in rainfall during the dry season (the JJA and the SON months), suggesting that the dry season will become drier everywhere by around 2055 and even more so by 2090. This is especially apparent over the Centre. Similar to increases in temperature, the interior areas will also suffer greater evaporation increases than those nearer to the coast. The largest increases occur during the SON months, particularly over the Limpopo and Zambezi river valleys. This suggests that evaporation will increase significantly in these areas before the onset of rains, which, depending on changes in rainfall, could result in decreases in soil moisture before the main cropping season starts.

1.6 General notes on data and climate models

- It should be noted that the station network over Mozambique provides coverage of only 1 station per 29,000km² (compared to 1 station/1,017km² in South Africa), and has major geographical gaps especially in Gaza and Tete provinces. Significant amounts of missing data limit its application for trend analysis, as well as the applicability of the data for downscaling future climate and using it to suggest changes in other areas.

- Most of the GCMs suggest a warmer Pacific, as well as warmer oceans in general. As the background climate changes, it is not clear if ENSO will project its impact on Southern Africa in the same manner it does now. Consistent shifts in the ITCZ, as defined by rainfall, are difficult to detect in the range of GCMs used in the IPCC 4th assessment report. The strengthening of the sub-tropical anticyclones during winter is a common feature in the GCMs, however, and this may lead to a delay in the southward migration of the ITCZ. It may also lead to a southward shift of mid-latitude cyclones. A combination of these dynamic changes and a reduction in moisture availability during winter, could lead to a delay in the start of the rains over some areas.

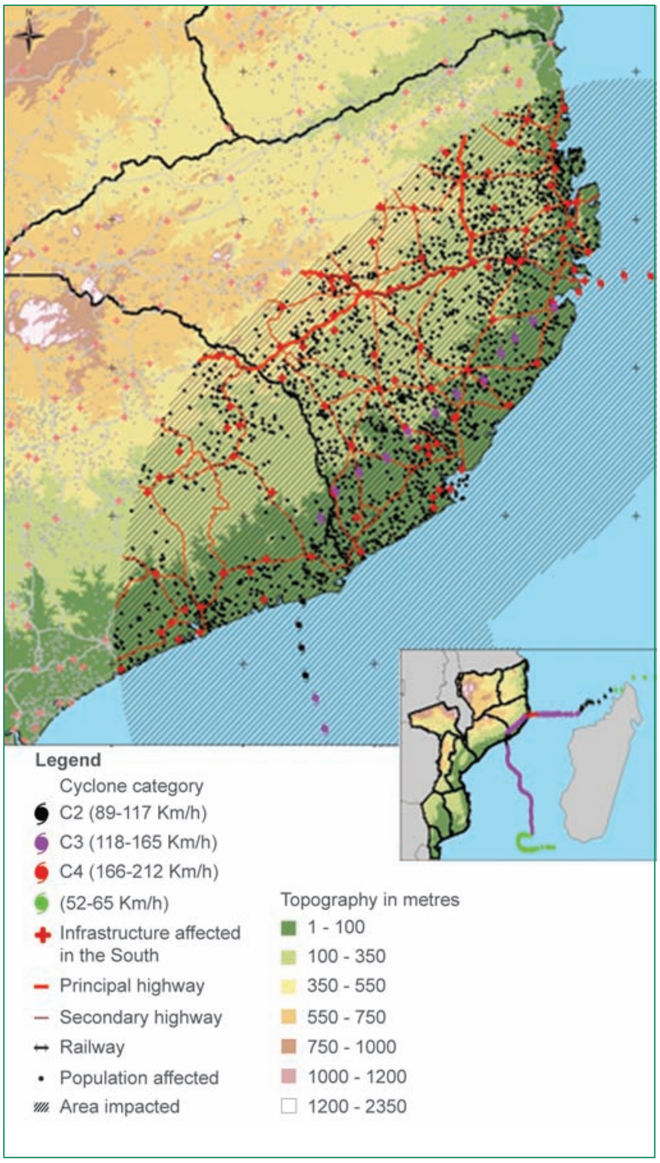
- Generally, the climate may be more extreme, with drought spells being hotter and more extreme floods. The Central zone is likely to be the hardest hit in terms of climate change, particularly those regions at lower altitude, which are already hot. For example, the Zambezi valley.

2 Past trends and future changes in cyclone activity and sea level rise

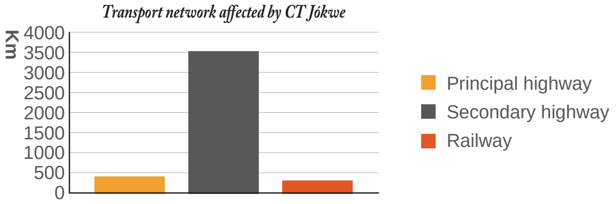
2.1 Observed trends in tropical cyclones (period 1980-2008)

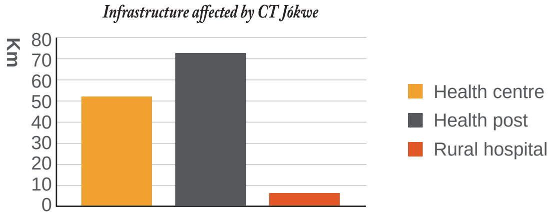
Of the 56 tropical cyclones and tropical storms that entered the Mozambique Channel in the period 1980-2007, a total of 15 (25%) made landfall on the coast of Mozambique. Four cyclones hit the North, eight hit the Centre and three hit the South. Only four occurred in the period 1980-1993, whilst the other eleven occurred in the later period from 1994-2007. Two cyclones in the period 1980-1993 were classified as category 3-5 compared to seven in the period 1994-2007. Observations also suggest a recent southward shift in their trajectories and landfall locations.

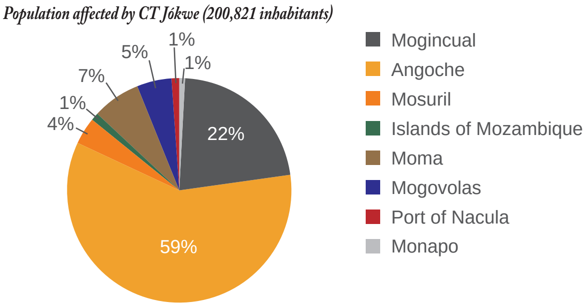
Map 4 shows the area, infrastructure and population impacted by a severe cyclone in the North, Map 5 in the Centre, and Map 6 in the northern part of the South. With cyclones becoming more intense, damage tends to increase exponentially (see also section 2.4).

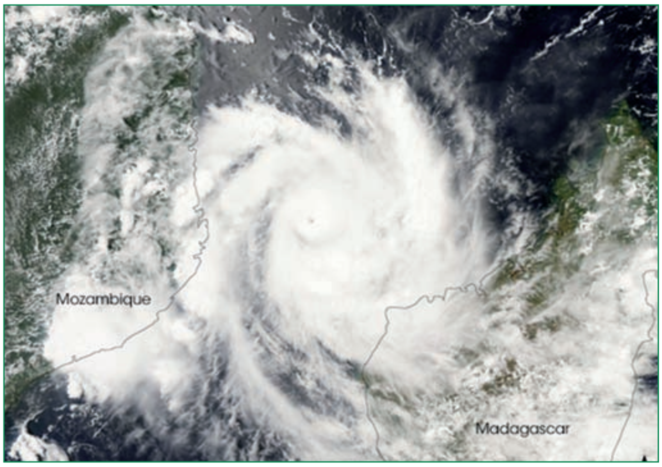


Map 4: The impact of a Category 4 cyclone in the North. Area of impact is shaded, road network is shown in red lines, population in black dots. ***Source: Bundrit and Mavume, 2009.***

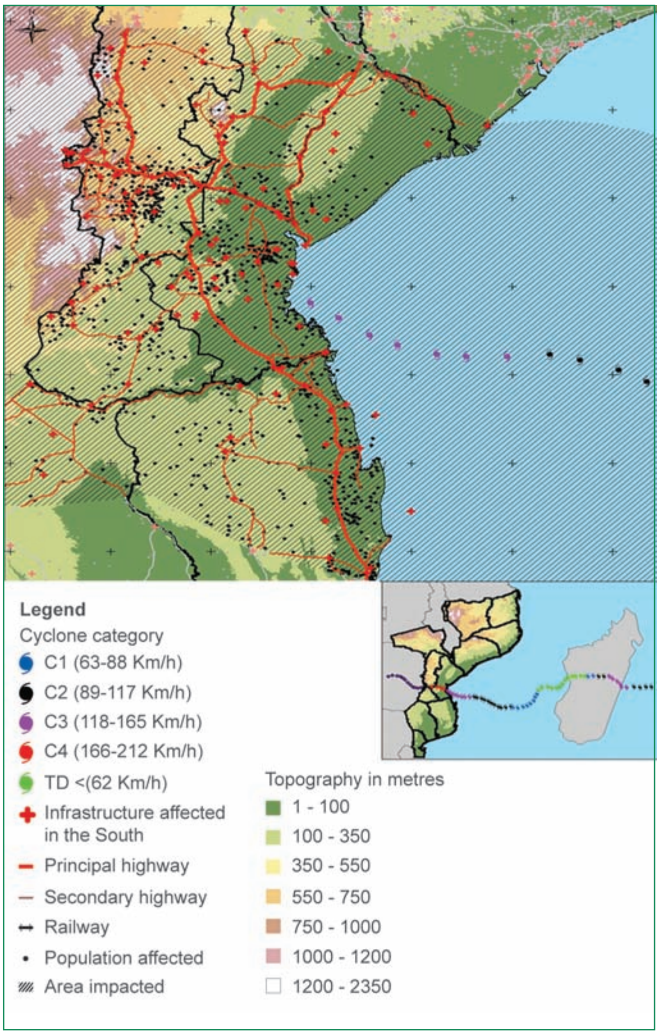

Transport network affected by CT Jókwe


Infrastructure affected by CT Jókwe

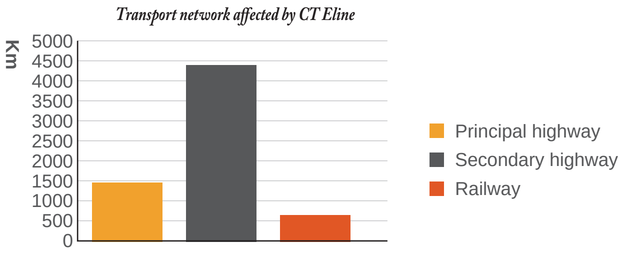

Population affected by CT Jókwe (200,821 inhabitants)

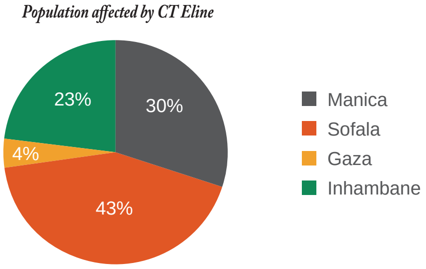


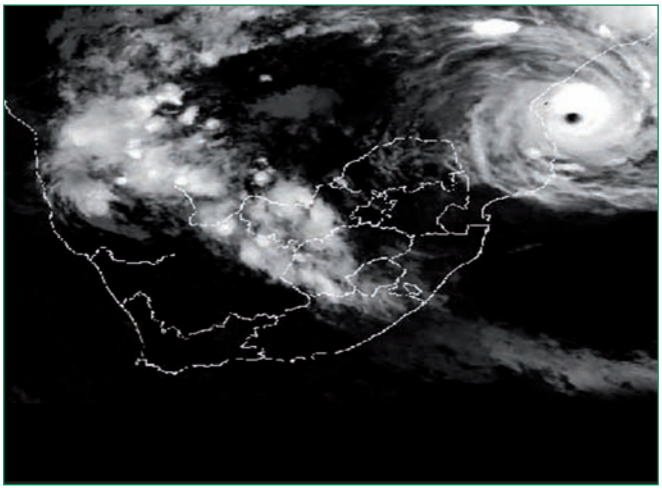
2.1 Observed trends in tropical cyclones (period 1980-2008) ***Continued***



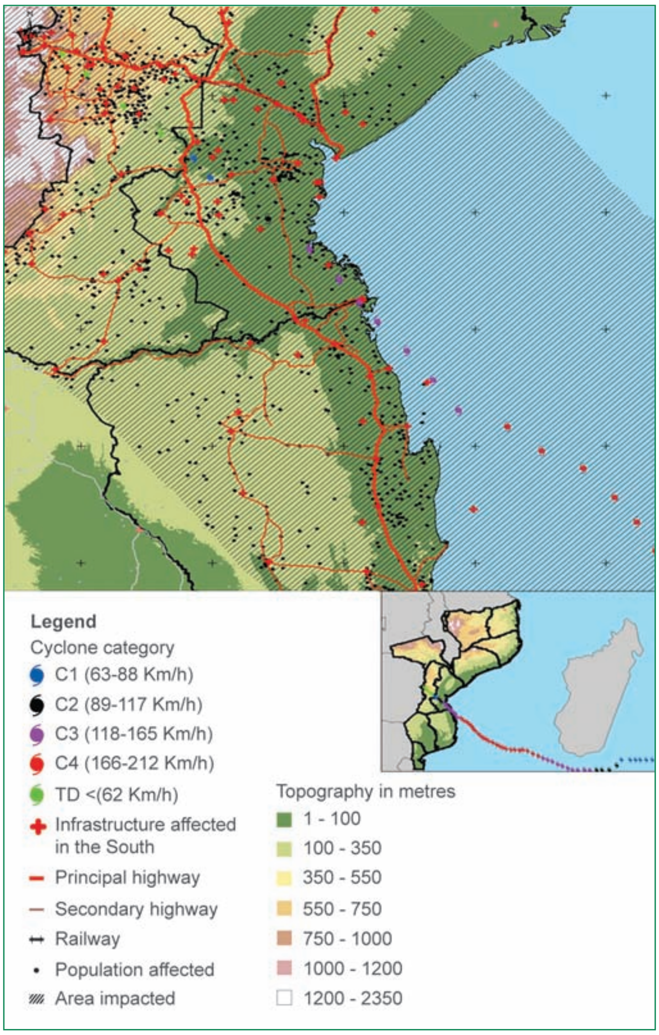
Map 5: The impact of a Category 4 cyclone in the Centre.
Source: Bundrit and Mavume, 2009.



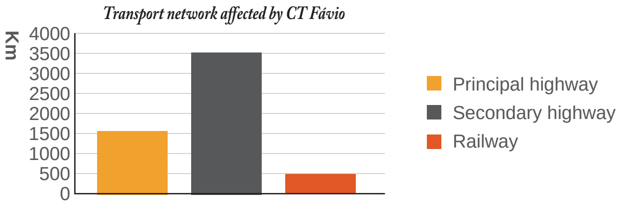


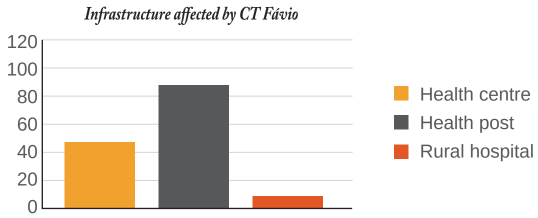


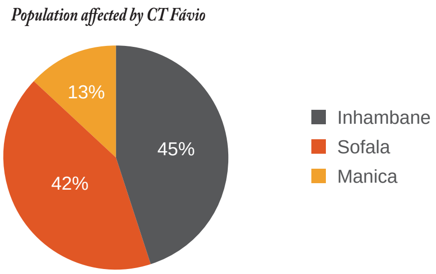
2.1 Observed trends in tropical cyclones (period 1980-2008) ***Continued***

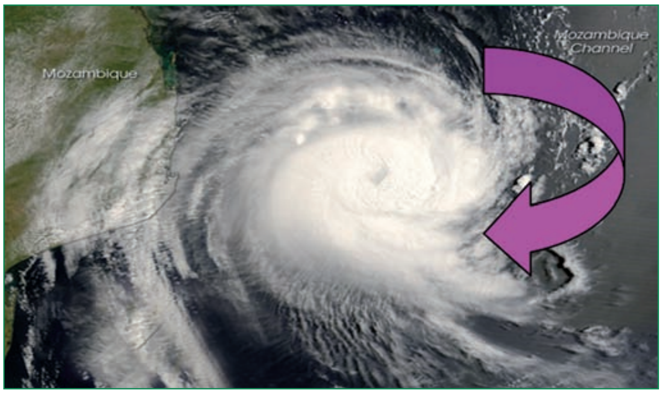


Map 6: The impact of a Category 4 cyclone in the northern part of the South. ***Source: Bundrit and Mavume, 2009.***









2.2 Observed sea level rise (period 1960-2001)

There is very little sea level data available for the forty year period from 1960-2001 of the quality needed for sea level rise analysis, and nothing in recent years. At best it can be said that records from Maputo (Figure 6) are not inconsistent with estimates of regional trends (e.g. Church et al, 2004) and identified global trends (e.g. IPCC, 2007). Thus recent past trends in global rates of sea level rise can be cautiously used for the coast of Mozambique, as reflecting the best estimates available. These global rates have risen since 1961 at an average rate of 1.8mm per year and since 1993 at an accelerated average rate of 3.1mm per year.

A long and representative observational record of sea level has not yet been assembled to test whether or not the acceleration will be sustained into the future, nor at what rate (IPCC AR4, 2007). However, with changing emissions and increased temperatures, there is likely to be further acceleration of sea level rise through the links to climate change processes.

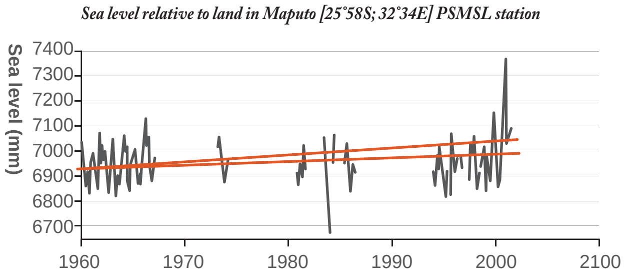


Figure 6: Mean sea level records relative to land height in Maputo, 1960-2002. ***Source: INAHINA, 2008.***

2.3 Future cyclone and sea level rise scenarios (period 2030–2100)

Both recent trends in observations and long term modeling outcomes suggest that climate change will affect the characteristics of tropical cyclones in the south-western Indian Ocean. Observations show that there is an indication in increase of both frequency and intensity of cyclones; however, the number of events in this period is too limited to base statistically significant trends on. Models suggest that for the Indian Ocean there is an overall tendency toward decreasing frequency of tropical cyclones but increasing cyclone intensity (Emanual, 2008).

There appear to be two groups of sea level rise scenarios:

- The Low Sea Level Rise (Low SLR) scenario, which includes the IPCC[3] and the SRES scenarios. These models are based largely on thermal expansion and exclude rapid dynamical changes in ice flow due to continental ice melting in the Polar Regions, which is an important reservation.

- The High Sea Level Rise (High SLR) scenario, which represents the 'worst case' scenarios with a substantial contribution from polar ice melt.

Scenario	2030	2060	2100
Low Sea Level Rise Scenario –'best case' (Low SLR)	10cm	20cm	30cm
High Sea Level Rise Scenario- 'worst case' (High SLR)	10cm	100cm	500cm

High SLR Scenario: Polar Ice Melt

Ice Melt available for Sea Level Rise

• Temperate/tropical glaciers	0.5 m
• Greenland Ice Sheet	7 m
• West Antarctic Ice Sheet	5 m
• East Antarctic Ice Sheet	55 m

- Non-linear acceleration of polar ice melt
- No time scales available

Figure 7: Sea level rise scenarios. ***Source: Brundrit and Mavume, 2009.***

Figure 7 illustrates the two hypothetical scenarios used in the sea level rise analyses that follow. It must be emphasized that the timing for the High SLR scenario is highly uncertain, as the future rates of melting of the polar ice caps are largely unknown.

- In the Low SLR scenario, tropical cyclones will remain the principal threat to the coast of Mozambique. Their damage potential will increase steadily as this modest sea level rise is experienced along the coast. Coastal erosion is likely to be episodic and associated with extreme storm events, with impact accumulating over time. With a low SLR of 30cm by 2100, coastal set-back will gradually reach approximately 30m (Bruun's rule).

- In the High SLR scenario, it is the permanent inundation of the coast and the low-lying areas behind which forms the principal threat, particularly to large estuaries and subsiding deltas. Coastal set-back by erosion will reach approximately 500m. Overall, this scenario is likely to be catastrophic to Mozambique.

Note 3

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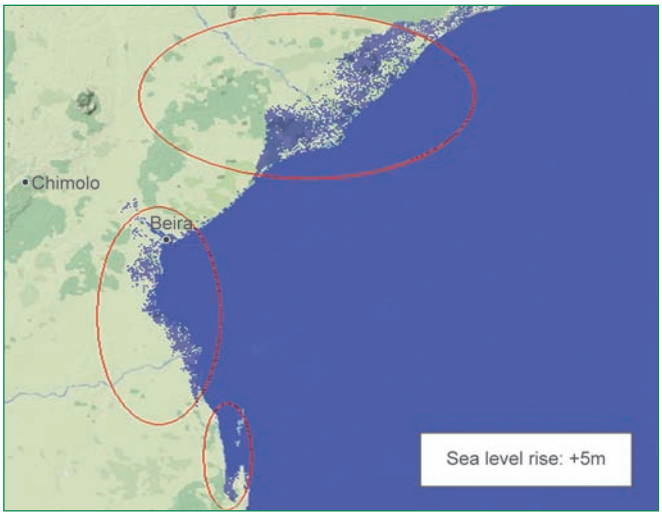
[3] In its projections of future changes in climate over the 21st century, the IPCC WG1, in its Fourth Assessment Report of February 2007, predicts a rise in the range 180mm to 590mm by 2100, depending on the particular emissions scenario used. This figure was greeted with disbelief by some leaders in the climate change community, who felt that it did not give enough credence to the future contribution from polar ice melt. In November 2007 in the AR4 Synthesis Report, the IPCC consequently withdrew the upper bound. The IPCC also declined to replace the upper bound with any other figure as they felt that not enough was known about likely rates of polar ice melt. The recent modest global sea level rise of 18mm per decade, with a spread from 13-23mm per decade, is now showing a (non-linear) acceleration, probably due to the onset of polar ice melt. Forecasts of sea level rise to the end of the century await a greater understanding of the future contribution of polar ice melt, but are very likely to be higher than earlier forecasts.

2.3.1 Future sea level rise and cyclone scenarios: Central zone

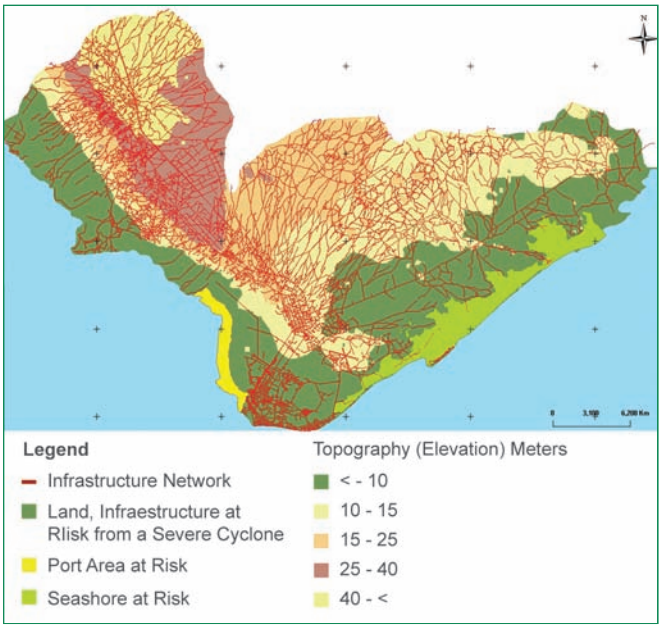
Map 7 indicates the areas at risk in the Centre both from a sea level rise of 5m and/or from the impact of an intense tropical cyclone.



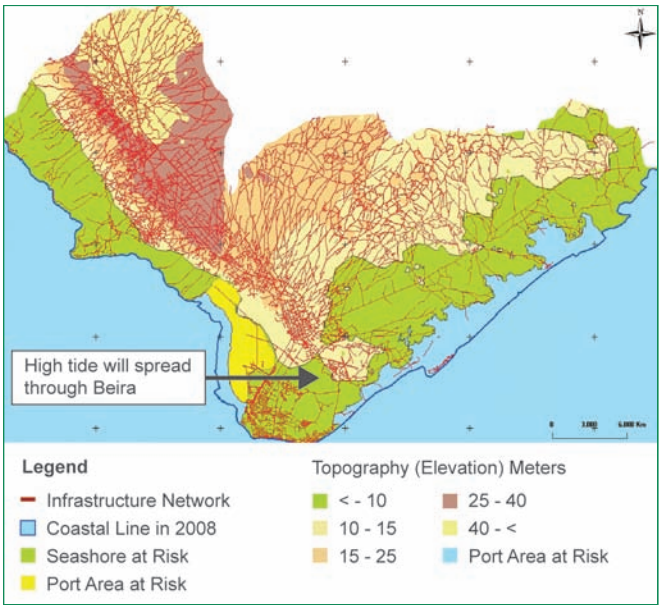
Map 7: Elevation map with the 5m contour line indicating areas at risk from a sea level rise of 5m and/or extreme cyclone and storm surge. ***Source: Bundrit and Mavume, 2009.***

Map 8 depicts areas vulnerable to flooding in Beira by 2030. It appears that the present seawall is only built to the height of the one-year return period at approximately 3.4m. Thus on occasion each year, the seawater spills over onto the road and flows through the fissures of the wall protecting the port. If no additional height is provided to cope with future sea level rise, every present day fixed coastal defense will be breached at decreasing intervals, overwhelming the population and infrastructure at risk. An extreme event of 3.8m now returning on average every 5 years in Beira will have a return period of 3 years when adjusted for low sea level rise by 2030. An event of 4.4m with a present day return period of 100 years will return on average every 60 years by 2030. The thousand-year extreme sea level event, probably associated with a tropical cyclone making landfall in the vicinity, would overtop the seawall and flood all land that lay at an elevation below 4.9m. This area of land is extensive and covers the entire area between the Beira city and the airport.

Even in a scenario of low and gradual sea level rise, i.e. 30cm by 2100, the present coastal defenses around the port city of Beira will need to be strengthened, so as to protect its high levels of economic and social investment. A favorable economic climate in Mozambique as a whole will be needed if this adaptation strategy of coastal protection is to be affordable and to be effective against climate change.



Map 8: Beira by 2030; gradual sea level rise and more intense cyclone risk. Red lines represent existing infrastructure; yellow the port zone at risk; light green the sea shore at risk and dark green the area at risk in the event of a severe cyclone.
Source: Bundrit and Mavume, 2009.



Map 9 depicts vulnerable areas in Beira in a High SLR scenario due to polar ice melting, reaching 5m in the late second half of the century. The city will be cut off from the interior and will likely become an island, and the port will need to be relocated to a safer environment. A strategy of managed retreat from the rising sea will need to be investigated and implemented.

Map 9: Beira in the High SLR scenario, after polar ice-melt (timing uncertain). Red lines represent existing infrastructure; yellow the port zone at risk; light green the sea shore at risk; blue the old coastline. ***Source: Bundrit and Mavume, 2009.***

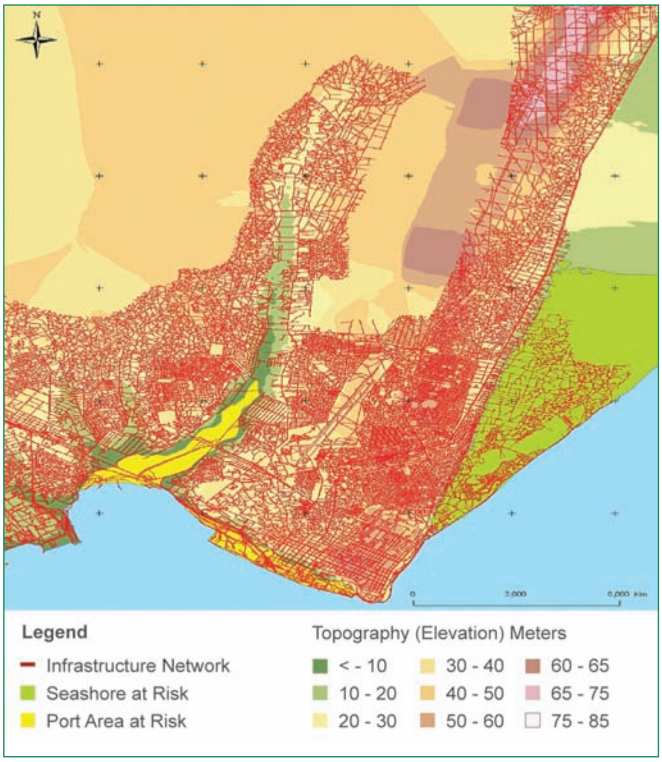
The existing vegetated dune barrier to the east of Beira is intended to prevent flooding of the low-lying land on the coastal plain behind, but is neither high nor wide enough to be effective against more intense future cyclones; this would require a barrier of approx 9m high x 30m wide, for a mean spring tide level of 2.9m. It is not easy to decide to build and maintain such a formidable barrier, on the chance of a tropical cyclone making landfall on this coast. The alternative to investing in such a formidable barrier is to accept the consequences of the impact of a tropical cyclone on the infrastructure behind. Once the dune barrier has been breached, the land at risk will be the land below 4.9m now and 5.17m in 2030; much more after 2040.

Dune barriers may not be needed for the modest levels of the Low SLR scenario. However, the loss of the protection from the offshore islands and the coral reefs in the High SLR scenario will certainly require the construction and maintenance of massive dune barriers. The alternative is gradual relocation of coastal developments in a managed retreat from the coast.

2.3.2 *Future sea level rise and cyclone scenarios: Southern zone*

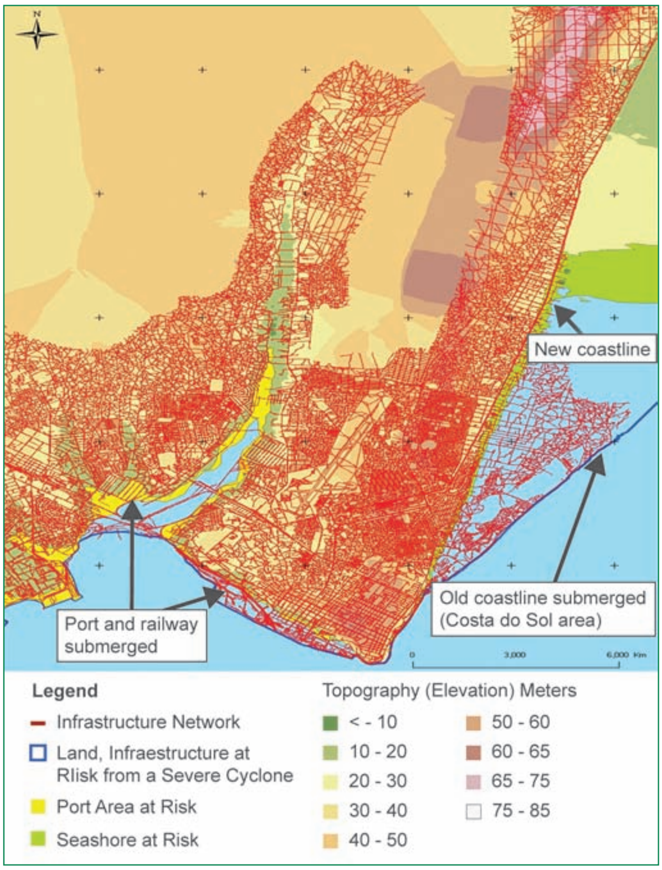
Maps 10 and 11 show the vulnerable areas in Maputo by 2030 and in the High SLR scenario. Whilst most of the city is situated on high ground, the Port of Maputo, its rail links and oil facilities are situated on the nearby estuary. The estuary is sheltered from the impact of a tropical cyclone making landfall from the sea, but is subject to flooding.

- In both the High and Low SLR scenario, by 2030, the coastal land in Maputo and the people living and working there are under threat from extreme sea level events, and will need to be appropriately protected. The extreme sea levels at Maputo used to design coastal defense works, must be adjusted upwards immediately to take account of sea level rise and the likely increase in intensity of tropical cyclones. At a minimum, the coastal defenses need to be raised to protect against 100 year return events by 2030 under the Low SLR scenario.
- In the Low SLR scenario, the Marginal and Costa do Sol areas of Maputo will suffer increased coastal erosion, and will need better protection through fortified seawalls, dunes or beach nourishment.



Map 10: Maputo by 2030. The yellow shows the port and railway area at risk; green represents the land at risk from an intense cyclone coupled with storm surge and (still) gradual sea level rise (below 10m); red is existing infrastructure.
Source: Bundrit and Mavume, 2009.

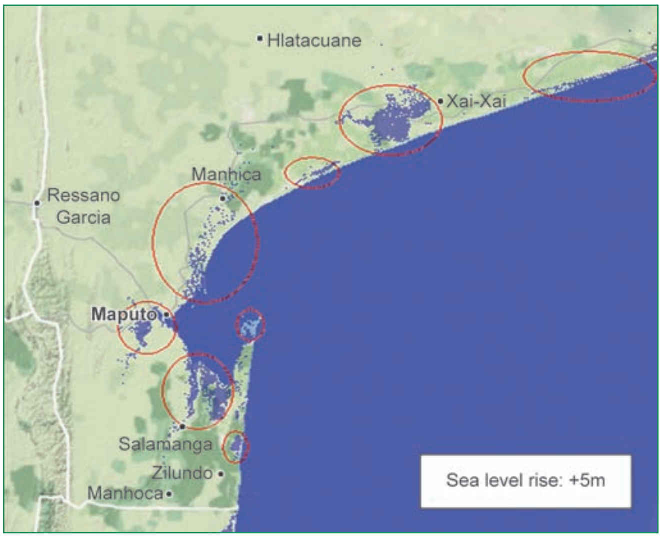
- In the High SLR scenario, the Marginal and the Costa do Sol will be below sea level and the Maputo will then need to rely on the steep barriers along the new coast. This will also be the case for the port and all its facilities, which will need gradual relocation as the water rises. The new coastline will be dominated by steep cliffs, which will make the development of new coastal infrastructure difficult and expensive. However, the city itself will remain safe on high ground.



Map 11: Maputo in the High LSR scenario, in the case of polar ice melt (timing uncertain) leading to a sea level rise of 5m. The yellow depicts the port and railway area which will be submerged; green represents the land at risk (below 10m) and the new coastline; the blue line is the old coastline; the red lines show existing infrastructure.
Source: Bundrit and Mavume, 2009.

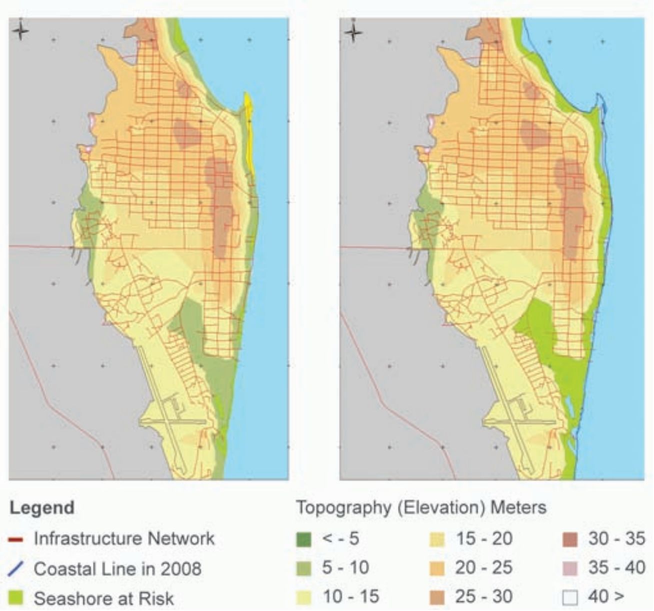
Map 12 indicates the areas at risk in the South both from a sea level rise of 5m and from the impact of an intense tropical cyclone.

- Though the rivers in the South are not as big as those in the Centre, there is the possibility of disruption of communication links with the rest of the country by flooding, through a combination of cyclone and storm surge at high tide, aggravated by sea level rise notably after 2030. Inhaca Island is also at risk of inundation. The flood plains of the lower Limpopo River south-east of Xai Xai, the lower Incomati River north-east of Maputo, the estuary at Maputo and the lower Maputo River are likely to be particularly affected. The widening of the lower flood plains at Limpopo and Incomati estuaries will increase their vulnerability to tropical cyclones through the narrowing of the natural coastal spits where the rivers enter the sea.



Map 12: Elevation map indicating the 5m contour line for the coastal zone of the South. ***Source: Bundrit and Mavume, 2009.***

- Vilanculos is a small port in the northern sector of the South. It was built on higher land (approximately 10m) which makes it less vulnerable to inland inundation. It is also protected by low offshore islands with coral reefs. Coral bleaching might damage the offshore corals and reduce their protective function from storms. Map 13 shows the effects of sea level rise and more intense storms on Vilanculos by 2030 (left) and in the high sea level scenario, timing uncertain (right). These will lead to coastal erosion and affect beach facilities, which must be taken into account with any future (tourism) development.



Map 13: Vilanculos by 2030 (left) and in the high sea level scenario, timing uncertain (right). Red lines show existing infrastructure. Yellow is the port area at risk of an intense cyclone with storm surge at a time of gradual sea level rise. Seashore marked in bright green is at risk below the 5m level. The blue line on the right marks the old shoreline. Portions of the port area are under water. ***Source: Bundrit and Mavume, 2009.***

2.3.3 *Future sea level rise and cyclone scenarios: Northern zone*

Map 14 illustrates the lower vulnerability of the North to future sea level rise and cyclone scenarios. Only very few areas along this coast are at risk, specifically the low-lying offshore islands close to the border with Tanzania. Compared to the Centre and the South, the coastal zone of the North is backed by higher ground and fewer rivers, and suffers from fewer tropical cyclones.

Map 14: Elevation map indicating the 5m contour line for the coastal zone of the North. ***Source: Bundrit and Mavume, 2009.***

Map 15 demonstrates that Nacala is protected from the brunt of extreme events by virtue of its geographical position.

- In the Low SLR scenario existing protection in Nacala will continue to be effective through the 21st century. Coastal defenses are in place to guard against inundation from an extreme event (cyclone coinciding with spring tide) of 3.12m above mean sea level, which currently has a return period of 1,000 years. It is only a narrow strip of coastal land within the 3m contour, holding the port and railway links, which would be at risk, as the town itself is located on much higher ground. Even this narrow strip of land and the port facilities are sheltered from the full brunt of the storm, because of its position.

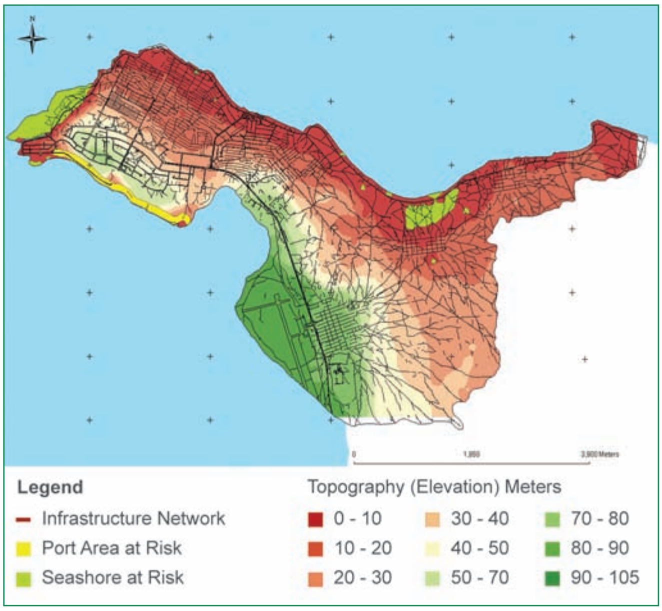
- In the High SLR scenario, the narrow strip of coastal land at Nacala is likely to inundate, requiring relocation of the port facilities. The extreme sea level construction standards at Nacala would need to be adjusted upwards to take account of the sea level rise and the likely increase in intensity of the most intense tropical cyclones. The coastal defenses would also need to be raised, as the sea level rises through the 21st century.

(a)

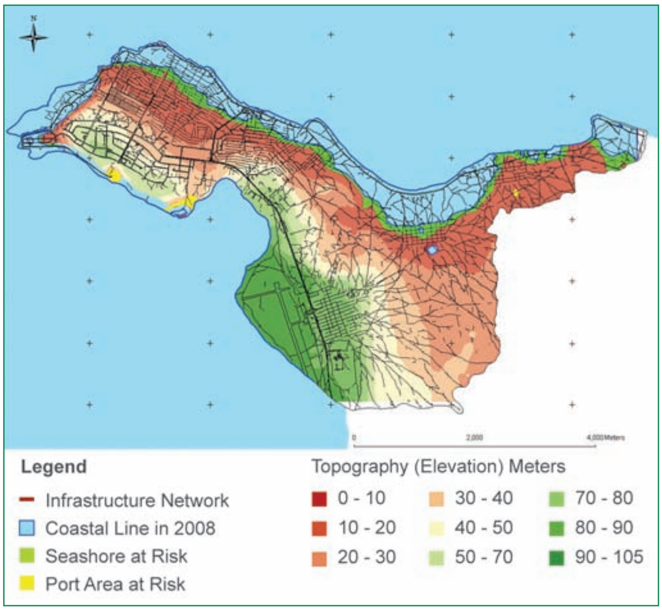
(b)

Map 15: Google Earth map of (a) Nacala on deep estuary (b) Nacala port. ***Source: Google Earth.***

The city of Pemba is also exposed to increased risk. Maps 16 and 17 reveal the areas at risk by 2030 from more intense cyclones, and beyond 2050 in the event of polar ice melt (timing uncertain).

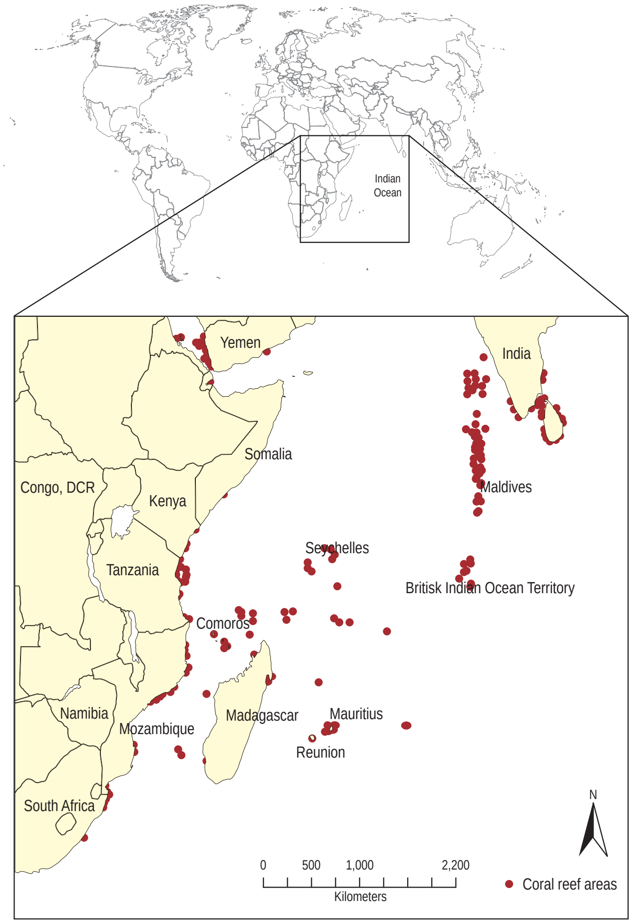


Map 16: Pemba: areas at risk by 2030 from more intense cyclones. The light green represents the seashore at risk; the darkest red the 10m contour at risk in the event of an intense cyclone and storm surge, on top of gradually rising sea levels. *Source: Bundrit and Mavume, 2009.*



Map 17: Pemba: areas at risk beyond 2050 in an extreme sea level rise scenario, (timing uncertain). Black lines represent existing infrastructure; the blue line is the old coastline; the bright green area shows the new coastline and seashore at risk. *Source: Bundrit and Mavume, 2009.*

A new impact from climate change will be increased levels of coastal erosion, which will threaten investment in beach resorts. This will arise from the gradual inundation of the offshore islands and increased damage to the coral eco-systems, which will reduce their effective capacity for protection of the coast. Map 18 shows the existing coral-ecosystem.



Map 18: Coral ecosystems along the Eastern coast of Africa. *Source: ESRI world map.*

Obura (2005) reported on high coral bleaching in both southern and northern Coastal zones in Mozambique resulting from sea surface temperature increases during 1998, with highly varying mortality rates ranging from 20% to 80%. Acidification of ocean waters through increased dissolved CO_2 will provide serious issues for corals. Startling consequences for coral reef health are predicted under all IPCC SRES future world scenarios by 2100.

2.4 Cost of coastal protection

The impact of the estimated changes in cyclones and sea level rise on the Mozambique coast in economic terms needs assessing. It has already been noted that the fast-developing coastal zone of the Centre is particularly vulnerable to such impacts.

2.4.1 *Cyclones*

The consensus of opinion is that climate change will mean that the propensity for intense tropical cyclones to make landfall is set to increase from the present day situation. The impact of such individual intense tropical cyclones will be greatly magnified. With increased intensity, cyclones will travel inland, affecting a larger area of land. The impact on the socio-economic infrastructure will be felt more widely, extending to new developments in areas such as tourism, minerals exploitation and fishing, industry and housing. The Saffir-Simpson Hurricane Scale suggests that the potential damage from the high category tropical cyclones is overwhelming compared to that of the low category cyclones. The impacts will be made even worse if the cyclone frequency also increases.

> The damage experienced in recent global events has increased substantially, as the size and intensity of the tropical cyclones have increased. This trend is also confirmed by the global re-insurance industry, where the increases in the losses experienced per individual event have threatened the viability of the entire industry. The re-insurance industry has recognized the need to increase the probability of tropical cyclones making landfall on vulnerable coasts in its calculations of risk. Risk carriers believe they cannot wait until science has provided answers to all the relevant questions, but must already make substantial upward adjustments to the cost of cover in such risk portfolios (Munich Re, 2006).

In Mozambique investments are being made in areas where the threats from cyclones are increasing and the cost of insurance, even when borne by the government, is becoming very unattractive.

A re-evaluation of the storm surge and flood risk from intense tropical cyclones is urgently required, as well as a greater appreciation of all the aggravating factors associated with mega-catastrophes that might impact on particularly vulnerable localities on the coast of Mozambique. Such studies should be a priority in future climate change impact investigations.

2.4.2 *Sea level rise scenarios*

As to sea level rise, the key question is whether or not Mozambique can afford to protect its coastal assets in Beira, Maputo and other coastal cities, both now and under the modest sea level rise envisaged in the near future. As to the High SLR scenario, what should the strategic approach be? Should Beira for example, build the massive coastal defenses to try to protect the port and city from the sea, and to build new road and rail links to the interior? Or should the strategic approach be a managed retreat, with entry to the city limited beforehand, new urban areas developed on high ground, and the port and its facilities relocated upstream on the river?

The affordability of added future protection has been studied by Nicholls and Tol (2006), who linked four protection classes to an economic model to determine which particular protection class should be adopted as the optimal protection strategy, noting additional expenditure involved for countries with delta coastlines (such as Mozambique).

- The ‘low protection class’ had a seawall designed to a height of the 1 in 10 year storm surge, with affordability which they linked to an economy of below US$600 GDP/capita in general but below US$2,400 GDP/capita for delta coasts.

- The ‘medium protection class’ had a seawall designed to a height of the 1 in 100 year storm surge, which they linked to an economy of between US$600 and US$2,400 GDP/capita in general but between US$2,400 and US$5,000 GDP/capita for delta coasts.

- Finally, the ‘high protection class’ had a seawall designed to a height of the 1 in 1000 year storm surge, which they linked to an economy of over US$2,400 GDP/capita in general but over US$5,000 GDP/capita for delta coasts.

For Mozambique, for all scenarios, the high protection class would require a seawall to a height of 5.17m, to cope with the added sea level rise by 2030. On a delta coast, Nicholls and Tol (2006) estimate that this can only be afforded by a country with a GDP per capita in excess of US$5,000.

In 2000 GDP stood at US$98 per capita in Mozambique. Depending on socio-economic development, under good economic growth as depicted by the IPCC B1 scenario, this could grow to approximately US$4,897 per capita by 2060; under poor economic growth, GDP could reach only approximately US$222 per capita by 2060 (Metzger, 2008). However, Mozambique needs to invest now in protecting its vulnerable delta coastline against climate change. This illustrates the difficulty faced by Mozambique as a poor country, already subject to the impact of climate change on a delta coast.

3 Past trends and future changes in river hydrology

Approximately 103 hydrographic basins have been identified across Mozambique, 13 of which represent a drainage area of more than 10,000km². Total surface runoff is approximately 216km³/year, of which some 116km³/year or 56% is generated in neighboring countries. This makes Mozambique vulnerable to changes in the water dynamics of neighboring countries too. There are 15 dams in Mozambique (DNA) for flood control, water and power supply (MICOA, 2007).

The hydrological analysis looks at future river flow behavior, saline intrusion and river water demand versus supply, incorporating future rainfall projections, population growth, and topographical, soil and land cover parameters. Per capita water use for agricultural, domestic and industrial water demand is subtracted from the river flow for each person in the upstream sub-basins. In the future scenarios, this water use is multiplied by the increased population. Increases in peak rainfall, caused by cyclones and increases in rainfall intensity are not captured by the models, which may lead to under-estimation of flood peak magnitudes.

As the models give varying results a probability classification is used to indicate likelihood of outcomes. Map 19 provides a description. In short, the outcomes give an indication of impact of climate change on river flows. However, any adaptation recommendations must take into account the effects of regional water management plans.

3.1 Historical trends (period 1950-2008)

Analysis of the period 1950-2008 shows that floods have occurred on average every 2.8 years in the Maputo basin, 2.6 years in the Umbeluzi, 4.8 years in the Incomati, 1.6 years in the Limpopo, 1.6 years in the Pungue and 2.6 years in the Licungo. This implies that on average, Mozambican rivers are currently expected to exceed the flood alert level every 2 to 3 years. Very large floods exceeding 1.5 times the flood stage occur much less frequently, about once every 15 to 20 years.

The 1950s were generally devoid of large flood peaks. A period of large floods was observed from the mid-1960s through the mid-1980s. Half of all these twenty major flood events analyzed in this study occurred during the decade from 1970 to 1980. This active period is followed by minimal flood activity during the late-1980s and most of the 1990s. Major floods return again at the beginning of 2000. This cycle of wetness and dryness is also observed in rainfall datasets such as the Global Historical Climate Network.

3.2 Future trends (period 2030–2060)

The study found that ocean tides are the largest natural forcing affecting sea water intrusion into river systems. This salt water intrusion is already occurring now. The influences of sea level rise and storm surge appear to be of much smaller magnitude, certainly until 2030.

Table 2 shows the affects of sea water intrusion on river systems. In terms of area impacted, the Zambezi is the largest but the Save could be more serious because of its long annual period of low river flows. In terms of distance inland, the Limpopo is the worst affected followed by the Incomati and Zambezi.

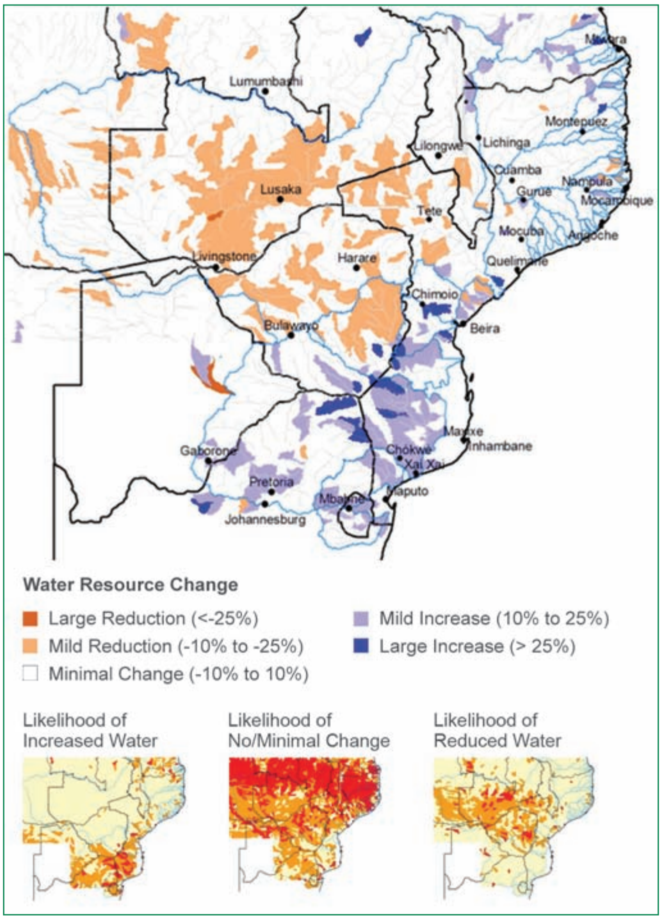
Rivers	Distance Inland in km	Area Impacted in km²
Ligonha	5	6
Zambezi	28	240
Buzi	20	19
Save	16	170
Limpopo	29	83
Incomati	28	9
Maputo	11	5

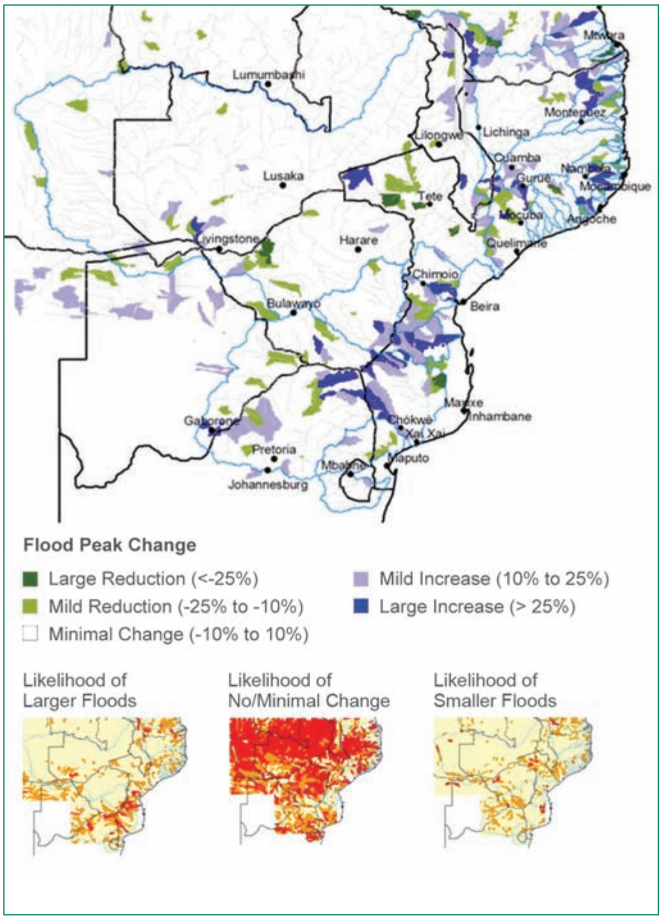
Table 2: Area impacted by salt water intrusion as a result of sea level rise and storm surge, by approximately 2030. ***Source: Brundrit and Mavume, 2009.***

Salt intrusion can go much further inland as a result of tidal activity, as is exemplified for the Pungue river, which is the main source of drinking water for the cities of Beira and Dondo and of irrigation water for a major sugar estate in Mozambique. In dry years the intrusion of salt water reaches the raw water intake at some 82km from the estuary mouth, causing it to be interrupted. This problem has already greatly affected the water supply to Beira, the second largest city of Mozambique, as well as the production of the Mafambisse sugar estate (Lamoree and Nilsson, 2000). An increase in the salinity intrusion will lead to a more frequent closing of the water intake.

Salt intrusion is also presently a problem in the Incomati and Limpopo rivers which have large developments in irrigation, as well as in the Zambezi. Vast areas of the South and Central interior (Incomati, Umbeluzi, Limpopo and Pungue) suffer from loss of land caused by salt water intrusion, resulting from the low discharges of effluents (Tauacale, 2002).

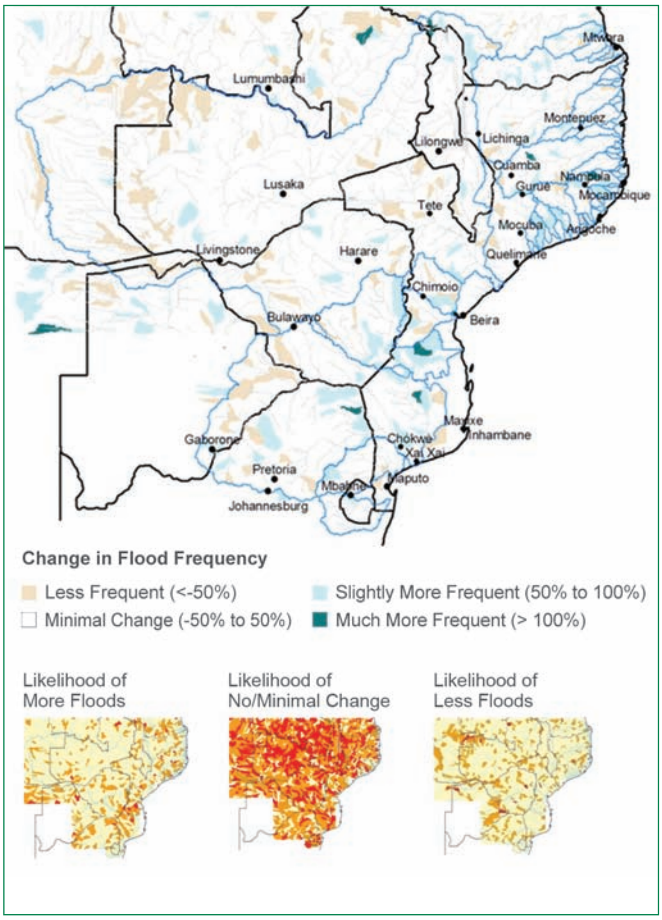
Maps 19, 20, 21 and 22 show the impacts of climate change on river flows and water availability and are described per zone, following the section on salt water intrusion discussed in the following three sections.



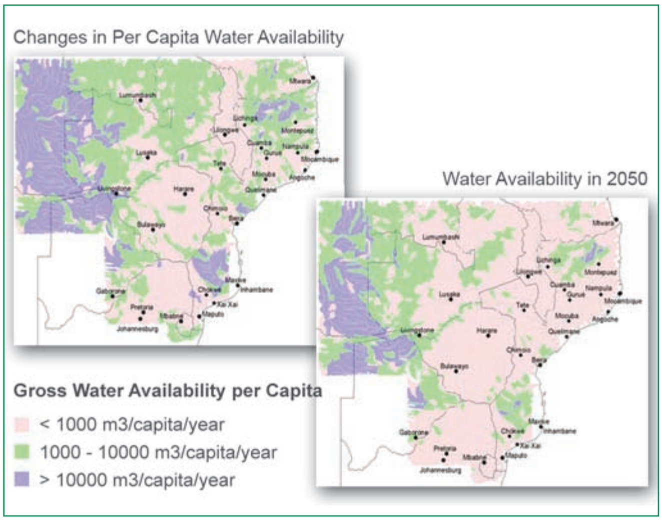


Map 19: Average changes in the average river flow from the seven GCMs and associated likelihoods. The map on the right shows that a large increase (>25%) in water resources is likely to happen only in the South, in the Limpopo and Save rivers. The 3 small maps below indicate that an outcome is unlikely to happen if 2 or less models projected that outcome (pink shade); likely to happen if 3-4 models projected it (orange shade); and very likely to happen if 5-7 models projected it (red shade). For example, the likelihood that water flows will increase is regarded as unlikely by the models except for the South, where 5-7 models are projecting increases (top left map). ***Source: Asante, 2009.***

Map 20: Average changes in the magnitude of floods from the seven GCMs. The majority of models predict little or no change in flood peak magnitude (left middle), except for the Limpopo which shows high likelihood for higher flood peaks. These estimates will underestimate changes in the magnitude of floods due to the climate data used to force the streamflow model. *Source: Asante, 2009*.



Map 21: Average changes in flood frequency from the seven GCMs. Most models predict minimal change and increased risk in the coastal basins of the South and North.
Source: Asante, 2009.



Map 22: Changes in per capita water availability. By 2050, most of Mozambique will experience water stress.
***Source: Asante, 2009*.**

3.2.1 Southern zone

- Six of the seven climate models indicate a tendency towards increased average annual rainfall of about 25% for the South. The biggest increase in rainfall and river flow appears to occur in the January-February-March (JFM) months, which is when the risk of flooding is greatest. The projected increases generally extend inland through the entire drainage area of the Limpopo and basins to its south. However, the increase in temperature also results in a 10% increase in evapotranspiration and higher crop water requirements, leading to some of the rainfall gains being lost, particularly in the warmer portions of the drainage area in Botswana and parts of South Africa.

- For the main growing season in the JFM months, five of the seven models indicate that the risk of drought, damage to crops, and crop failure in southern Mozambique remains unchanged.

- Drought risk in the South for the October-November-December (OND) months also remains unchanged, according to the median model. Risk of complete crop failure shows minimal change, but there is greater uncertainty in this result, as two models show widespread increased risk and one model shows patches of increased and reduced risk. This result indicates that changes in crop failure patterns during the OND months seem sensitive to small perturbations, and should be monitored closely.

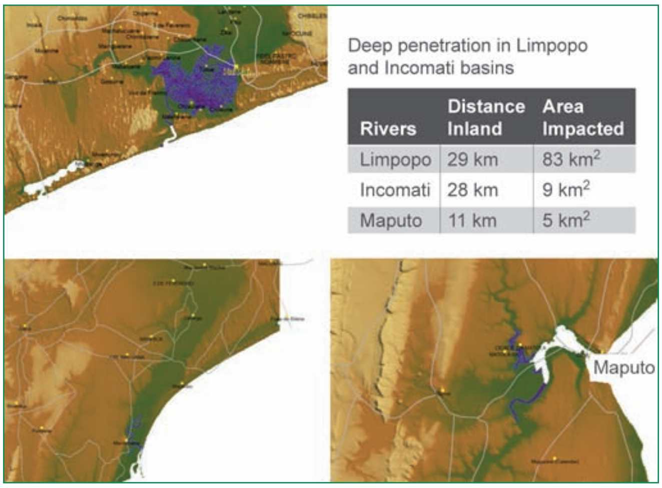
- A 25% increase in the magnitude of large flood peaks is expected along the main stems of both the Limpopo and Save rivers in the South. These increases were observed in five out of seven GCM models. The frequency of floods tends to remain unchanged, with three models predicting only a slight increase in frequency in smaller sub-basins away from the main stem of the Limpopo.

- While river flows are expected to increase in all basins in the South, when water usage is taken into account the situation becomes much less attractive. The population of the Limpopo basin is expected to rise from about 14 million in 2000 to about 46 million in 2050. Even with a 15% increase in natural river flows, this would imply a 64% drop in per capita water availability by 2050.

- A similar three-fold increase in population and 60-70% decrease in water availability are also predicted for the Incomati, Umbeluzi and Maputo basins. A smaller decrease of about 40% would be experienced in the Save because of lower population growth rates in Zimbabwe.

- If the current uneven usage rates are maintained or uniform high usage rates are adopted across the zone, the Limpopo would become dry most of the year because extraction rates would exceed the water available from natural river flows. The Limpopo flows can only be maintained with water usage at less than 250m³/capita/year, while the Umbeluzi and parts of the Incomati can only be maintained with usage at less than100m³/year. The internationally used water scarcity threshold is 1000m³/capita/year (below this, water stress would occur). These results emphasize the need to reduce reliance on these rivers by developing alternate water sources, while avoiding the development of new agricultural uses in these basins.

Map 23 shows the rivers in the South which are highly susceptible to salt water intrusion. These are characterized by long, wide floodplains. The length of inland salt water penetration is almost identical for the Limpopo (29km) and Incomati (28km) rivers. However, the area inundated by salt water in the Limpopo basin is much larger at 83km^2 than the Incomati where only 9km^2 is impacted. The Maputo River is also impacted with a depth of penetration of 11km and inundation extent of 5km^2.



Deep penetration in Limpopo and Incomati basins

Rivers	Distance Inland	Area Impacted
Limpopo	29 km	83 km^2
Incomati	28 km	9 km^2
Maputo	11 km	5 km^2

Map 23: Inundated areas and salt water intrusion in the Limpopo, Incomati and Maputo rivers. ***Source: Asante, 2009.***

3.2.2 Central zone

- Upstream rainfall reductions in Zimbabwe and Zambia could translate into significant reductions in river flows in Mozambique; notably for the Zambezi and Save, which originate in the interior of the continent. This may have implications for the Cahora Bassa hydro-electric power supply. Additional research is needed to assess how the changes in the timing or reliability of flows could impact hydropower production, the economy and strategies to mitigate impacts.

- Reductions in Zambezi river flows of about 15% are predicted by six out of seven models. Actual flow reductions in the Zambezi could be much larger given the increasing risk of droughts and the growing population within its drainage area. The Buzi and Pungue are within the 'transition zone' of the models, showing no strong trends in flow change in any direction.

- The Central zone is the most likely to experience increased risk of droughts and crop failure, although there is some disagreement between models about the exact locations of increased crop failure. The extent and severity of the drought risk increases notably during the OND months. The zone of increased drought risk covers most of Zimbabwe, Zambia and the areas of Mozambique around Cahora Bassa. During the JFM months a zone of increased drought risk is centered over Zimbabwe and probably stretching into Mozambique, which can have important implications for transboundary water usage and agricultural trade in the zone. It should be noted that the Centre has experienced the greatest agricultural expansion over the past decade (notably maize, rice), boasting relatively high yields and providing more than 30% to the value of production. Given that large portions of the interior of Zambia and Zimbabwe are predicted to experience decreases in magnitude of flood peaks, a significant increase in flood magnitude (i.e. flood peaks) does not appear to be a high risk in most of central Mozambique. However, it should be noted that the models do not capture the effect on flood magnitude resulting from cyclone rainfall. Cyclone intensity is expected to increase, and trend analysis has shown an increase in cyclone frequency over the past 13 years with the majority making landfall in the Central region.

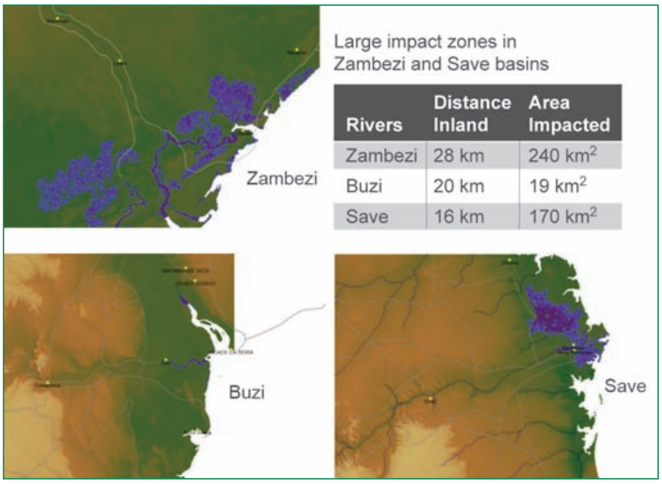
- The frequency of flooding is generally expected to reduce slightly across the zone except for a few isolated patches of slightly enhanced frequency in coastal watersheds in the Pungue and in the middle Zambezi near the Caprivi Strip.

- Assuming current population growth rates, per capita water availability is predicted to fall from about 1900m^3/capita/year in 2000 to about 500m^3/capita/year by 2050. Using current national per capita water usage rates, it is estimated that actual discharge entering Mozambique could be reduced by about 25% by 2050. Under the high (250m^3/capita/year) and medium (100m^3/capita/year) water usage scenarios, water discharge would drop by 44% and 14%, respectively. These water usage scenarios do not include future mega projects for the Centre or in neighboring countries, which would significantly increase water usage.

- In 2050, the Shire Valley of the Zambezi river will have water demands in excess of water supply under current, high or medium water usage scenarios. Elsewhere in the Zambezi, there appears to be enough water to meet water usage needs in spite of the impacts of climate change and population growth. The Buzi and Pungue both have adequate water resources to meet demand from expected population and climate changes under current water use regimes. The Pungue can also support the low and medium water use scenarios in future, but not the high scenario. Buzi has adequate water to meet all four water use scenarios in future.

Map 24 shows the Centre. This is the worst impacted in terms of area of inundation by salt water intrusion. In the Zambezi delta, over 240km^2 of land could be impacted with inland salt water penetration of about 28km. The marshland vegetation in the delta could provide some natural resistance to this intrusion. High flows from annual flooding of the Zambezi could also help to wash back some of the salt water. Conservation of marshland vegetation and eco-hydraulic management of the Cahora Bassa reservoir releases are required to ensure that these restorative processes occur.

- The Save basin would also be heavily impacted with an area of 170km^2 stretching 16km inland. The northern bank of the Save River, extending from Machanga to Divinhe, could be the most impacted by the salt water intrusion. In the Buzi, the intrusion covers a small area (19km^2) but it extends far inland (20km).



Large impact zones in Zambezi and Save basins

Rivers	Distance Inland	Area Impacted
Zambezi	28 km	240 km^2
Buzi	20 km	19 km^2
Save	16 km	170 km^2

Map 24: Inundated areas and salt water intrusion in the Zambezi, Buzi and Save rivers. ***Source: Asante, 2009.***

At least 334 families (about 1670 people) were forced into displacement camps in neighboring Malawi, after flooding of the Chire river, one of the main tributaries of the Zambeze river in January 2008. © Mark Rigby 2008

3.2.3 Northern zone

- As indicated in section 1 of this report, rainfall is expected to increase in the North, notably in the period from January to May. Four out of seven models indicate an average annual rainfall increase of about 15%, while three indicate only localized or minimal changes in total annual rainfall.

- All seven climate models indicate that there will be no change in drought risk or risk of crop failure in the North during the JFM months. No special adaptations are needed to account for the effects of climate change. However, changing populations could increase pressures for land conversion to agriculture from other existing land uses.

- For the OND months, median predictions are similarly devoid of changes in drought risk, with only one model indicating some increased drought risk along the Malawian border.

- The situation is considerably less certain with regards to the frequency of crop failure, with three models predicting increased failure, three predicting decreased failure and one predicting minimal changes and isolated patches of failure. Taken together, the findings seem to point to mild reductions in frequency of crop failure in coastal areas during the OND months, and no change elsewhere in the zone.

- Since most of the river basins in this zone are internally draining, the zone offers the best opportunity for Mozambique to benefit from the positive impacts of climate change independent of the actions of neighboring countries. However, without enforcing sustainable development mandates any positive impacts from climate change in this zone will not be of major significance, and will be overwhelmed by the negative impacts and environmental degradation resulting from exploitation of natural resources.

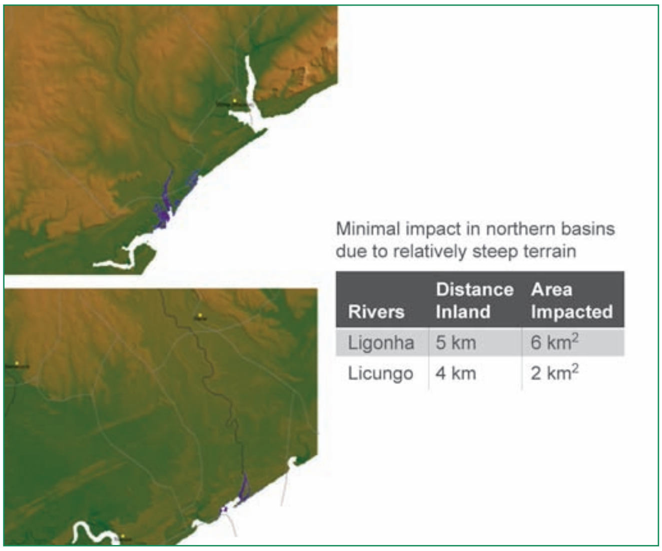
- No changes in magnitude of flood peaks were simulated in the interior part of the zone, though this may be partly due to the inability of the climate data to simulate increases in peak rainfall amounts. By contrast, most coastal watersheds recorded large changes in flood peaks. The changes were a patchwork of both increased and reduced flood peaks, with a higher number of watersheds showing increases. This indicates that while the models have some difficulty in determining exactly where rainfall events will occur, there is a general expectation of increased flood peaks in small watersheds wherever storms make landfall.

- The frequency of flooding shows a similar patchwork of increasing and decreasing frequencies in isolated watersheds. More watersheds show increases in frequencies than decreases, however the clustering needed to confirm a consistent trend of change is absent.

- There appears to be no change in stream flow. Two small areas show minor deviations from this trend: the southern portion of the zone shows reduced stream flow (two models), while the northern tip of the country near the mouth of the Rovuma River shows increased water resources (three models).

- At current per capita usage rates, all river reaches have adequate water to meet demands until 2050. However, with projected population growth, about 60% of river reaches could become water scarce by 2050.

Map 25 shows that salt water intrusion does not pose a major problem for the river systems in the North. This is because the terrain is generally more rugged with steeper slopes along the river channel. The distance of inland penetration is only 4km for the Licungo river, with an inundated area of 2km^2; and 5km for the Ligonha river, with an inundated area of 6km^2. These impacts are relatively mild compared to other parts of the country.



Minimal impact in northern basins due to relatively steep terrain

Rivers	Distance Inland	Area Impacted
Ligonha	5 km	6 km^2
Licungo	4 km	2 km^2

Map 25: Inundated areas and salt water intrusion in the Ligonha and Licungo rivers. *Source: Asante, 2009.*

4 Past trends and future changes in agricultural land use and crop suitability

4.1 Historical trends (Period 1986-2007)

- Over 95% of the food crops in Mozambique are produced under rain-fed conditions (IIAM, 2008). Average household yields per zone over the period 1986-2007 for the major cereal crops (maize, rice, sorghum) as well as cassava, groundnuts and beans, are very low at approx 1 ton/ha, and show no trends of increasing. The period 1997/98 to 2003/04 saw virtually no yield increase for the country as a whole. Most of the production growth has been primarily the result of increases in cultivated area, rather than increases in yield (IIAM, 2008).

- Over a 20 year period (1986-2007), cultivated land has increased by 23% from approximately 20,801,600ha in 1986 to approx 25,537,200ha in 2007. The total land surface of Mozambique is approximately 76,500,000ha (IIAM, 2008).

- Of the 25,537,200ha of cultivated land, some 39% (9,988,800ha) is found in the Centre; 38% in the North and 23% in the South. Some 25% of the cultivated soils are located in low-lying soils, which during floods are largely inundated. For the floodplain zone, the Central floodplain contributes 60% of the cultivated land.

- The greatest increase (47%) in area cultivated took place in the fertile floodplains, notably in the Centre. Combined with a population growth of 2% this has considerably increased the stress on these soils, and a continuation of this expansion will not be sustainable. Significant results will need to be attained in increasing yields per ha, but under worsening conditions of increasing temperatures, rainfall variation and soil degradation.

Table 3 summarizes the observed extreme values of yields (highest and lowest) for the relevant crops for this study, and their potential yields under rain-fed crop production. The current gap between actual and potential yields in Mozambique is large.

Crop	Lowest observed yield	Highest observed yield	Potential yields [(1)]
Maize	0.1	2.0	10.9 – 8.7
Sorghum	0.02	0.87	8.8 – 6.2
Cassava	0.1	7.0	13.6 – 10.9
Groundnut	0.01	0.9	3.3 – 2.6

(1) Adapted from “Generalized Agro-Climatic Suitability for Rain-fed Crop Production”.

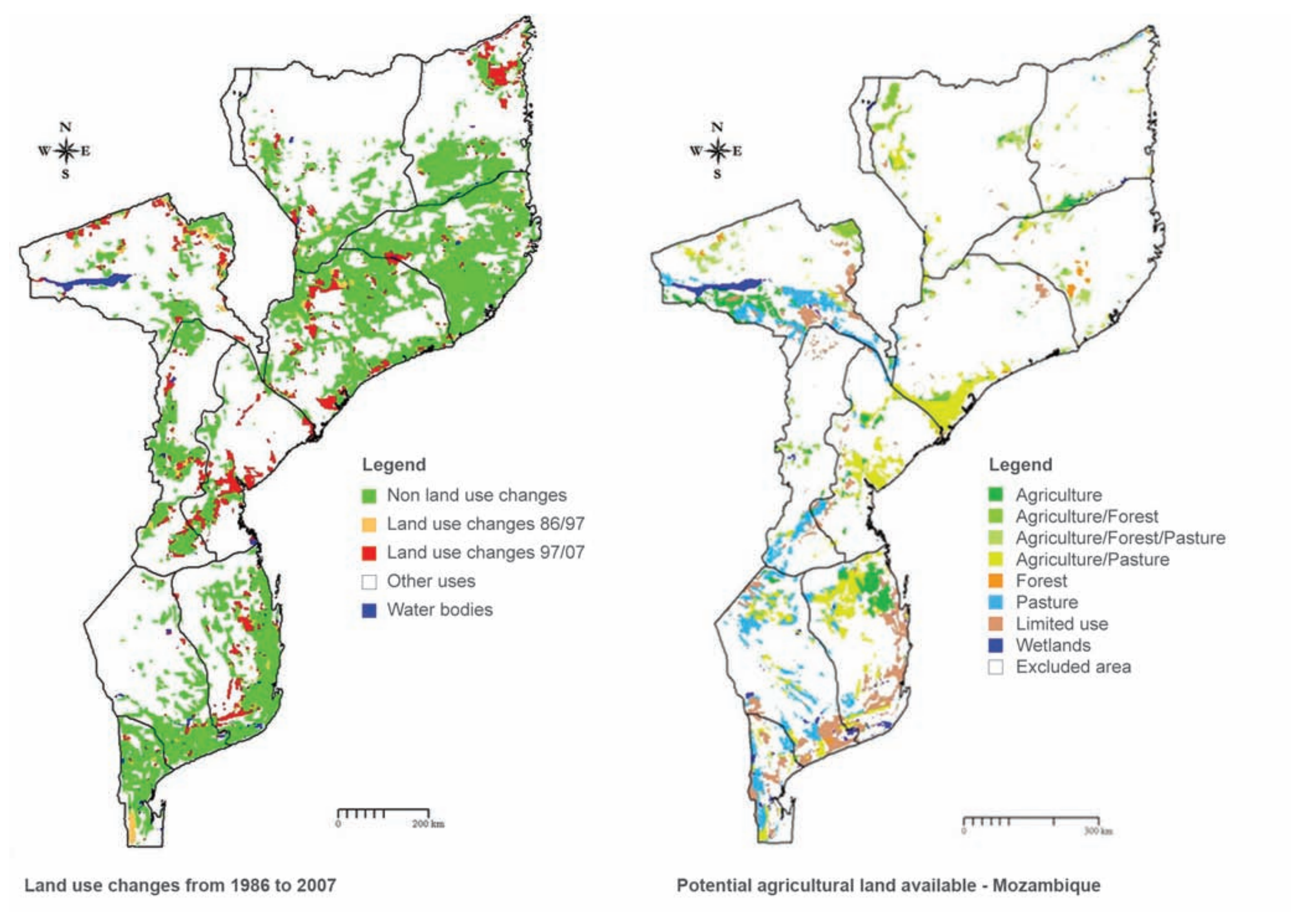
Table 3: Lowest and highest observed crop yields, and potential yields in ton/ha. *Source: Marques, 2009.*

A simple calculation on land requirements for a growing population shows the crucial importance of increasing yields per ha in Mozambique. Cereal needs for the current population of 20.5 million is approx 2,542,000 tons which, at the current average 2006/7 cereals yield of <1 ton/ha (MINAG, 2008), requires a cultivated area of approximately 2,800,000ha. If the population grows at 2% annually to approximately 29.6 million by 2030, needs will rise to 4,300,000 tons of cereals which, assuming the same yield/ha, requires an area of approximately 4,700,000ha. By 2060 this will have risen to 10,250,000ha for 35.3 million people and 9,500,000 tons of cereals. Even in a scenario of slower population growth which levels off after 2030, needs would still approach some 4,500,000ha by 2060 for cereals alone, for approximately 29.3 million people. The question is how much suitable additional land is available to cover these future needs, given other evolving land uses.

The single most important source of risk for crop failure nation-wide is drought. According to a study by IIAM (2006) on maize, rice, sorghum and groundnut, drought constitutes between 48-73% of the risk of crop failure in Mozambique.

Expansion of cultivated land in Mozambique is often linked to the various stages of vegetation re-growth of fallow land in the traditional shifting cultivation system. Historically, areas of forest were only disturbed to the extent necessary to ensure food supply for the extended family. However, rapidly increasing populations, have put considerable pressure on available crop land to produce more food, resulting in shorter fallow cycles. This, in turn, leads to reductions in soil fertility and increased soil and environmental degradation and erosion. As the pressure continues to increase, this traditional shifting cultivation system will not be able to survive.

Map 26 shows the major temporal land use changes for the last two decades, as well as the present potential available land for different land uses.



Land use changes from 1986 to 2007

Potential agricultural land available - Mozambique

Map 26: Land use changes from 1986-2007 (left) and potential available land for different land uses (right). In the left map, orange gives the changes from 1986-1997 and red the changes from 1997-2007 (much larger than the changes in the previous decade). The right-hand map shows available land suitable for various types of cultivation in green shades and yellow, forests on orange, marginal lands in pink. Light blue is suitable for grazing and dark blue is water. The white areas represent unavailable land, after deduction of land allocated to or suitable for forests/concessions and tree plantations, conservation, mangroves, existing agriculture, uncovered land, eco-tourism, aquaculture, humid land with limited use, resettlement areas, DUATs, population centres, local initiatives, areas with mining prospects. ***Source: IIAM, 2008.***

Coastal Region from 1986 to 2007

	Year 1986	Year 1997	Year 2007	Available Land
North	1,073,200	1,149,200	1,260,800	85,600
Central	524,400	582,400	815,200	161,600
South	1,852,000	1,932,000	2,103,600	330,400
Total	3,449,600	3,663,600	4,179,600	577,600

Floodplain Region from 1986 to 2007

	Year 1986	Year 1997	Year 2007	Available Land
North	137,600	155,200	208,600	118,000
Central	699,600	747,200	1,181,600	709,600
South	424,800	442,400	467,200	35,200
Total	1,262,000	1,344,800	1,857,400	862,800

Inland Region from 1986 to 2007

	Year 1986	Year 1997	Year 2007	Available Land
North	7,250,400	7,645,600	8,134,600	2,065,200
Central	5,954,000	6,799,600	7,992,000	1,704,800
South	2,885,600	3,208,000	3,373,600	1,586,000
Total	16,090,000	17,653,200	19,500,200	5,356,000

Mozambique from 1986 to 2007

	Year 1986	Year 1997	Year 2007	Available Land
Coastal	3,449,600	3,663,600	4,179,600	577,600
Floodplains	1,262,000	1,344,800	1,857,400	862,800
Inland	16,090,000	17,653,200	19,500,200	5,356,000
Total	20,801,600	22,661,600	25,537,200	6,796,400

Table 4: Summary of Land Use Changes (ha) by zone and currently available land for agricultural expansion. *Source: IIAM, 2008.*

Table 4 provides the present available land for crop production, excluding productive forest and conservation areas. It shows that only 26.6% of the total land or 6,796,400ha is currently available for the expansion of agriculture, without interfering with other land uses (IIAM, 2008). Most of this is in areas currently difficult to access, or susceptible to flooding, or with limited water resources.

Given the above estimates, if the present situation in the sector is maintained, Mozambique will run into conflicting situations to the detriment of the people and the economy. If Mozambique opts for agricultural intensification, around 30% to 50% of the present land used for agriculture will be reduced once almost half of the land in the rural environment is put under fallow cultivation. In addition, if effective land reform and reduction in yield gaps are achieved, a lot of land will be saved.

Zoning	Changes in Risk	Cassava (5% area)			Maize (% area)			Soya (% Area)		
		Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
North	Significant Reduction Risk	0.93	0.93	0.93	0.00	0.00	0.00	0.00	0.00	0.00
	Slight Reduction Risk	1.87	1.87	1.86	27.82	28.35	26.79	1.25	1.88	0.00
	No Significant Change	56.60	58.57	53.48	71.94	72.91	71.27	77.73	85.07	73.45
	Slight Increase Risk	40.12	43.22	38.32	0.10	0.31	0.00	19.77	23.65	12.82
	Significant Increase Risk	0.31	0.31	0.31	0.00	0.00	0.00	1.35	2.50	0.63
Zoning	Changes in Risk	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Central	Significant Reduction Risk	2.76	5.63	1.18	1.48	2.07	0.59	2.07	2.37	1.77
	Slight Reduction Risk	16.28	21.60	9.76	22.26	25.15	19.45	5.63	5.91	5.33
	No Significant Change	74.09	79.58	70.12	70.32	71.60	68.96	66.63	70.10	62.66
	Slight Increase Risk	5.13	6.51	3.55	5.81	10.90	1.48	11.75	13.60	10.10
	Significant Increase Risk	1.58	3.55	0.59	0.00	0.00	0.00	14.02	15.96	12.48
Zoning	Changes in Risk	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
South	Significant Reduction Risk	0.00	0.00	0.00	10.40	16.20	0.00	22.31	45.00	1.26
	Slight Reduction Risk	6.43	13.72	1.86	19.14	47.36	0.62	38.37	51.14	28.75
	No Significant Change	89.66	93.13	82.96	68.87	95.53	36.14	36.08	60.32	21.88
	Slight Increase Risk	2.70	3.12	1.88	1.46	3.75	0.00	3.13	3.75	2.49
	Significant Increase Risk	1.04	1.86	0.00	0.00	0.00	0.00	0.21	0.63	0.00
Zoning	Changes in Risk	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Coastal	Significant Reduction Risk	6.60	11.18	4.27	3.72	5.98	0.00	1.98	3.42	0.00
	Slight Reduction Risk	22.66	30.77	10.40	17.17	21.49	9.47	5.95	8.61	4.27
	No Significant Change	56.23	66.76	48.18	75.54	80.09	73.06	65.22	71.95	55.56
	Slight Increase Risk	13.48	16.47	48.18	3.43	10.33	0.00	17.86	27.35	10.88
	Significant Increase Risk	0.86	1.73	0.00	0.00	0.00	0.00	9.07	10.04	7.75
Zoning	Changes in Risk	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Floodplain	Significant Reduction Risk	6.27	12.48	3.13	9.41	10.94	6.34	3.61	6.15	1.54
	Slight Reduction Risk	10.98	17.19	6.33	21.44	24.93	15.86	4.64	6.28	1.54
	No Significant Change	72.13	77.54	68.61	64.31	65.63	62.31	64.50	67.46	61.54
	Slight Increase Risk	7.32	7.91	6.25	4.71	12.69	0.00	10.84	12.55	9.22
	Significant Increase Risk	3.14	4.75	1.56	0.00	0.00	0.00	16.51	20.00	10.96

*Changes are expressed as a % of the total land surface per zone. Significant Reduction in Risk is equivalent to a change to a better suitability class by two levels; Slight reduction risk is equivalent to a change to a better suitability class by one level; No Significant Change is equivalent to no change in the suitability class; Slight Increase Risk is equivalent to a change to a worse suitability class by one level; Significant Increase in Risk is equivalent to a change to a worse suitability class by two levels.

Table 5: Average, maximum & minimum changes in land suitability for cassava, maize and soya, resulting from climate change*.
Source: Marques, 2009.

4.2 Future change (period 2030/40-2060)

Changes in land suitability for six important crops were estimated using three GCMs (GFDL representing dry conditions; IPSL representing wet conditions; and ECHAM simulating intermediate conditions) out of a total of seven. Due to the limited number of climate models used, results can only be considered as tentative and more research is recommended for more robust statements on likelihood and probability of change. In the absence of other results, the median model (in the middle of the three mentioned GCMs) is closest to the centre of all seven projected climate futures, accessed through the main report, and therefore represents the most likely change.

Table 5 summarizes the average findings on land suitability for crop change, as well as maximum and minimum values, giving some insight into cassava, maize and soya behavior in response to climate change across the different zones of Mozambique. More detailed information and other crops are presented in the main report. Annex III maps the results for some of the main crops.

- The table shows that "*no significant change*" in suitable area is the dominant category for all crops (cassava, maize, sorghum, soya, groundnut, cotton) in all zones, although the percentages of area affected vary by crop and zone. Cassava is the main root crop in Mozambique and has a relatively high tolerance for seasonal and extended moisture stress and poor soil fertility conditions. Maize shows "*no significant change*" in some 76% of the Coastal zone area, 69% of the South and 70% of the Centre, showing little variation among zones. For Soya, the dominant class is "*no significant change*" in all zones except for inland South.

- Overall, suitable areas may increase in the Centre and the North, whilst the zones most affected by loss of suitable area will generally be those that already struggle from the impacts of irregular and extreme climate events. These include the mixed arid-semiarid systems in the Gaza and semiarid systems in parts of northern Inhambane and south of Tete, the coastal zones of the South and southern Central zones, and many of the drier zones of major river systems like Limpopo, Save and Zambeze.

- The North is not likely to experience major reduction in river flows so irrigation potential is higher assuming water availability for irrigated crop production.

The above analysis indicates that the increases in yields attainable with the intensification of agriculture and technological development are higher than the expected decreases in yields caused by climate change. It is reiterated that the crop suitability findings reported here are only based on three climate change models, and additional research to reduce uncertainty is recommended.

5 Potential future changes in Health

- Mozambique is among the ten nations in the world most affected by malaria, causing between 44,000 to 67,000 deaths annually in all age groups. Approximately 682,000 pregnant woman and 2.8 million children under age five are at risk from malaria (Bradbury and Edward, 2005).

- Warmer temperatures may extend the range and prolong the seasonality of transmission of vector-borne diseases, especially malaria. The frequency and intensity of extreme weather events influences the incidence of water-and rodent-borne diseases (Epstein, 2008).

- Long-term data sets are incomplete in Mozambique, making it difficult to apply models to quantify the potential impact of climate change on disease risk in the country. However, a focus on extreme weather events can reveal spikes in disease incidence associated with extreme events. Figure 8 depicts a four-fivefold increase in malaria following the 2000 floods over non-disaster periods, reported by a Japanese relief team working in Gaza (Kondo et al., 2002; Epstein and Mills, 2005). As explained elsewhere in this report, extreme events in Mozambique are expected to become more frequent and intense.

- The temperature cut-off point for epidemics versus non-malarious zones is 18°C, and a temperature of 22°C allows for stable transmission when coupled with 80mm of monthly rainfall for at least 5 months of the year (Craig et al., 1999). In Mozambique, malaria occurs both through stable transmission and epidemics. While many different models (not Mozambique specific) exist and results vary, they generally agree that the future spread of malaria is likely to occur at the edges of its current geographical distribution. Annex IV indicates the prevalence of malaria and other diseases by zone (Epstein, 2008).

- Other diseases are also expanding or re-emerging. The IPCC (2007) projections for an increase of 5-8% in arid and semi-arid land in Africa could increase transmission and favor the expansion of the meningitis belt (Epstein, 2008). There were several epidemics of meningococcal meningitis in Mozambique in the late 1990s (J. Cliff, pers. comm., 2008). The Chikungunya fever (transmitted by Aedes albopictus, the Asian tiger mosquito) appeared from 2004-2006 in Kenya, La Reunion, Seychelles and Comoros. (Chretien et al., 2007). Cholera periodically reappears, especially following flooding and with warm temperatures. During the 1997/98 El Niño event, the (unexpected) flooding and elevated sea surface temperatures (SSTs) led to epidemics of cholera in Mozambique and neighboring Tanzania (WHO, 1998). Drought can also be associated with cholera and other water-borne diseases, due to the associated decline in personal hygiene and lack of adequate drinking water. The 1993 outbreak was associated with the 1992/93 El Niño-associated drought (Epstein, 2008).

The largest killer of Mozambican children, malaria poses an enormous threat to those affected by the floods. The mosquitoes thrive in stagnant pools left behind when the flood waters recede. © Douglas Allen 2007

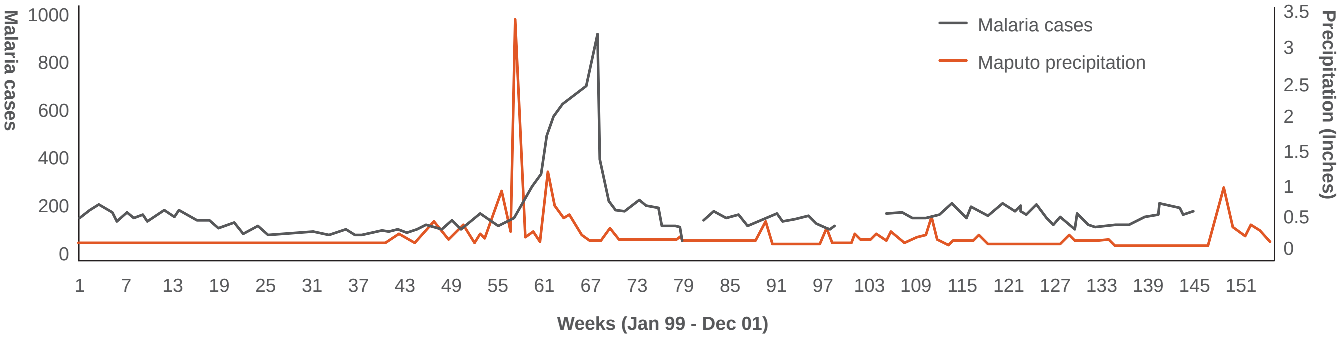


Figure 8: Malaria cases and Maputo precipitation. ***Source: Epstein, 2009.***

6 Uncontrolled fire – baseline analysis

- The intricate traditional balance between humans and fire as a tool for agriculture, hunting, charcoal production and woodland management, has been upset in Mozambique in recent decades due to population growth, conflict and a breakdown in traditional management practices. The result has been a perceived rise in the number of wildfires affecting rural communities and an associated increase in crop and property damage, as well as the loss of human lives (Hoffman et al., 2008).

- The on-going process of climate change has the potential to exacerbate this situation by altering the frequency, intensity, severity and seasonality of fires in Mozambique. The exact relationship between climate change and fire risk in Mozambique is difficult to establish due to lack of historical data and the role of human interventions such as livelihood practices and land cover change. The main report provides a baseline of uncontrolled fire risk for Mozambique, including a brief policy overview and fire risk maps per zone based on current climatological conditions; humidity and fuel material; topographic characteristics; vegetation coverage and demographic density. A trend analysis of the frequency, location, intensity and impact of uncontrolled burnings in Mozambique is provided over the time span in which precise data exists (2002-2008). Three existing integrated models (not Mozambique-specific) were applied to compare fire risk based on actual heat occurrences (MODIS sensor) to fire risk as projected by the models.

- Approximately 6-10 million hectares of forest (11-18% of total forest area) and 9-15 million hectares of other lands are burned yearly in Mozambique (DNFFB, 2002). The vast majority of fires are caused by human activity.

Figure 9 shows the distribution of fire occurrences per year since 2002. Niassa province in the North shows the highest average values of fire occurrences, followed by Tete and Zambezia provinces in the Centre. Manica and Sofala provinces in the Centre show significant spatial repetition, increasing the risk of irreversible loss of natural ecosystem and biodiversity.

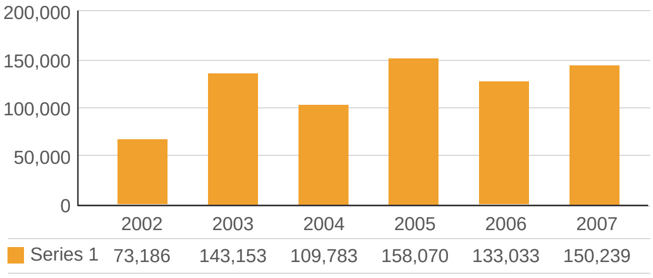
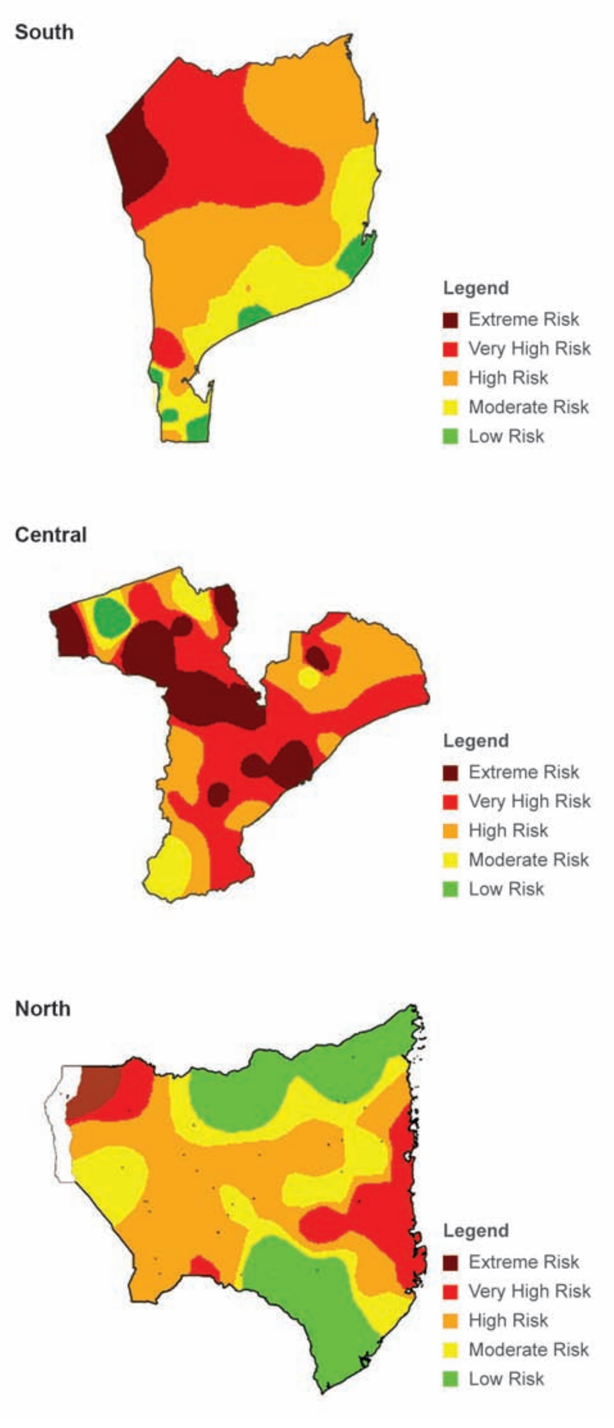


Figure 9: Fire occurrences per year in Mozambique, 2002-2007. ***Source: Fernandes, 2009.***

Map 27 represents the Fire Danger Index for each zone, based on rainfall and evapotranspiration.



Map 27: Risk Map According to current Climate Conditions per zone, South, Central and North. ***Source: Fernandes, 2009.***

- According to the categories used in the SAMPAIO (1991) model, adapted for this research, it can be observed that 6% of the South was classified as “extreme risk” and 30% as “very high risk”; the Centre shows 24% at extreme risk and 37% at high risk, whereas the North shows 4% at extreme risk and 13% at high risk (Fernandes, 2009). Almost all types of forest in Mozambique are affected by the phenomenon (Fernandes, 2009).

- Three integration models were used in this study (Table 6). The methodology and detailed findings are described in the main report.

Model	Equation Used	Source
I	[0,655*DD + 0,655*SV] + [(0,29*D% + 0,11*OE0,1*AL) + (0,305*CC+0,305*HMC) + 0,4*CV]	Oliveira (2002)
II	2*DD + 2*SV + 4*D% + 3*CV + 2*OE-AL	Salas & Chuvieco (1994)
III	2,5*DD + 2,5*SV + 4*CV + 3*D%*OE	Ferraz & Vettorazzi (1998)

Whereby: DD – Risk index due to demographic density; SV –Risk index due to road system distribution; D% - risk index due to land slope; OE – risk index due to slope orientation; AL – risk index due to altimetry; CC – risk index due to climate conditions; and HMC – risk index due to vegetal coverage.

Table 6: Data Integration Models *Source: Fernandes, 2009.*

Comparison of the above models with the MODIS sensor data for Mozambique (period 2002-2007), show that models II and III best explain fire risk in the South. Model III (which attaches the heaviest weight to demographic density) best fits the Centre and model II (which emphasizes slightly more the geographic characteristics), the North. While the models capture a significant portion of the risk, the differentiation between the model results is not very large. More work using remote sensing techniques and liaison with existing efforts[4] is planned in Phase II to better understand the possible impact of climate change on risk to rural livelihoods through damage to crops, infrastructure and health; and to achieve improved early warning and response capacity.

Uncontrolled wild fires, often triggered by smallholders, remain a serious environmental problem threatening both agricultural land and natural parks. © Valeriy Kirsanov 2007

Note 4

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[4] Currently there are efforts underway by the fire unit of the Global Observation of Forest and Land Cover Dynamics (GOFC GOLD) to develop a prototype Fire-Early Warning System for Africa. The system will be comprised of three components: a fire danger rating system, a fire risk assessment, and a fuels assessment. The prototype shall operate at the sub-Saharan Africa, and West Africa regional levels. An example of the implementation of the South African Fire Danger Index and the Canadian Fire Weather Index modified for grasslands exists in neighbouring countries such as Botswana (Hoffman et al., 2008).

7 *Government response and role of the private sector*

An analysis of the existing legal framework from a climate change perspective shows that Mozambican laws, policies, strategies, and programs focus on natural disasters, the impacts of HIV Aids and food insecurity as the main risks to poverty reduction. Many aspects of climate change are covered by the existing legal framework, and inter-institutional coordination mechanisms exist. However, there is no systematic institutional focus on climate change. An important obstacle to this is the lack of awareness of the consequences of climate change for Mozambique specifically, and implications in the short term for key ministries such as transport, tourism, energy.

Considering the impacts climate change will have on people, ecosystems and the economy, institutional response will require a revision of the legal framework, as well as secondary legislation determining roles and competencies including information management (Sanchez del Valle, 2009).

Efforts to date by the government and international community have not led to the clarification of ministries' roles and responsibilities, to minimize overlap in mandates and mainstream climate change into the government's five year plans. The current arrangement for the co-ordination of adaptation strategies is for the ministry of environment to assume overall responsibility for climate change. Experience to date suggests that this arrangement leads to weak inter-sectoral co-ordination as its importance has not been acknowledged or accepted by key senior figures in the government. It is critical that ministries who will play a key role in development and adaptation to climate change - such as the ministries of transport, public works, energy, trade, tourism, agriculture and health, understand the magnitude and timing of risks and the implications for their own ministries, so that they take climate change into consideration in their multi-year budget planning and engage in the development of adaptation implementation strategies.

Without the capacity to implement and monitor policies and legislation, the signing of conventions and passing of laws and revision of standards and environmental impact assessment regulations will have very little effect on the actual adaptation of Mozambique to climate change and the sustainable development of the country.

Whilst understanding the increasing value of its natural resources, the government of Mozambique currently has neither the capacity nor the financial resources to ensure the organized and consistent implementation of an integrated adaptation strategy. Until this is in place, the implementation of adaptation is likely to be ad hoc and slow, leading to an immediate risk of exploitation of natural resources for quick financial gains. The rural poor will see few real benefits, yet suffer the consequences of environmental degradation. The private sector therefore has a crucial role to play in properly kick-starting adaptation. It is vital to understand and eliminate the perceived and real barriers to attracting the 'serious' companies to Mozambique.

The main report on policy analysis and institutional response relevant to climate change lists all the Mozambican government studies, recommendations, strategies and interventions put in place to date, notably through (MICOA INGC, 2009). This includes the National Adaptation Plan for Action (NAPA), approved by the government in December 2007, which outlines four priority actions: strengthening of early warning systems; strengthening of adaptation capacity of farmers; reduction of impacts in coastal areas; and water management in relation to climate change. This study provides scientific support for the priorities outlined in the NAPA, as well as additional proposals on how to achieve them in light of the most recent information and developments.

The extent to which decision-makers make use of improved scientific understanding, to achieve sustainable development goals in the face of climate change, depends in large part on the coherence of the science base and effective channels of communication to fast track new knowledge to policy makers in terms they can understand. Annex V provides an innovative proposal towards achieving this.

Decisions made now will directly affect the extent to which Mozambique will be able to cope with the impacts of climate change by 2030 and beyond.

Table 7 below shows the effect of different socio economic pathways on the ability of the country to adapt to climate change[5].

Note 5

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[5] The scenarios are based on the IPCC SRES B1 (left column) and A2 (right column), with regional indicators provided by the Institute for Applied Systems Analysis (IIASA) Greenhouse Gas Initiative (GGI) as well as the integrated assessment model IMAGE. The framework of drivers of change is adapted from the Millenium Ecosystem Assessment.

Drivers of Change	Mozambique Development Trajectory 1	Mozambique Development Trajectory 2
Regional Context[1]	• Strong, effective regional governance	• Ineffective governance in most countries in the region
	• Regional cooperation and integration	• Regional fragmentation
	• Strong formal economic sector	• Informal sector dominates
	• Rapid technological development and modernization	• Slow technological development and modernization
	• Significant reduction in poverty	• Little reduction in poverty
National Governance	• Political stability	• Political instability
	• Long-term government strategies, focusing on attracting foreign investment to increase development levels sustainably	• Ad hoc changes in policies, lacking consistent strategies, leading to unsustainable development and depletion of natural resources
	• Significant investment in health and education	• Little investment in health & education
National Economy	• Large foreign investments in agriculture, bio-energy crops, fossil fuel extraction, and mining, resulting in economic benefits for all of society	• Limited foreign investment with a restricted number of countries, that benefit only the influential elite
	• Mozambique quickly becomes self-sufficient in energy supply	• Mozambique slowly becomes self-sufficient in energy supply
	• Continued rapid economic growth (6-8% per year)[2] result in growing employment opportunities and a strong rise in GDP per capita rises from US$98 in 2000 to US$4,897 in 2060[2]	• Slow economic growth (2-3% per year)[2] has little effect on employment opportunities and GDP per capita rises slowly from US$98 in 2000 to US$222 in 2060[2]
	• Strong advances in ICT, agricultural productivity, technology, infrastructure, education, mainly as a result of positive externalities form economic growth	• Most of the population does not benefit from advances in ICT, agricultural productivity, technology, infrastructure and education
	• Affordable foreign products and a growing tourism sector	• Foreign imports are expensive and restrict the tourism sector
	• Human development index (HDI) reaches 0.5-0.6 by 2030-2040[7].	
Population, health and well-being	• Population grows slowly until 2030 and then levels off at 29 million[2]	• Population grows steadily to 35 million in 2060
	• Rapid urbanization until 2030. From 2030 urbanization levels off and by 2060, 65% of the population lives in urban centres[2]	• Very rapid urbanization, because rural regions offer limited prospects. By 2060 85% of the population lives in urban centres[2]
	• Advances in bio-energy technology allow large parts of the population access to electricity, including rural regions, reducing dependency on fuel wood	• Access to energy remains too expensive for many people in rural areas who remain dependant on fuel wood
	• Investment and advances in ICT greatly improve telephone and internet connectivity	• Private companies restrict investment in ICT to urban centers
	• Large public investment in health and education is initially concentrated in growing cities, but later extended to rural regions. These include effective vaccination programs, reduction in HIV/Aids, secondary education available to large parts of society	• Public funds are consumed by ad hoc efforts to cope with negative aspects of poverty and minimize impacts of disasters, leaving limited funds for structural improvements. Large parts of the population remain very poor and have limited access to education, health care and sanitation
Agriculture and food security	• Foreign investment in agriculture focuses on large scale plantation producing exportable commodities	• Foreign investment in agriculture focuses on large scale plantation producing exportable commodities
	• Greater wealth and better education leads to better technology and management for local food crops as well. There is a gradual increase in productivity and by 2030 Mozambique is self sufficient	• Productivity increases are small and climate change impacts have serious implications for food security, especially in dry years
	• Despite increases in productivity, there is considerable regulated expansion of farmland, to accommodate the growing population	• There is dramatic and relatively uncontrolled expansion of farmland to meet food demands of the growing population, while yields remain low
	• Smallholder farming decreases, and larger cooperatives emerge	• Smallholder farmers remain dominant, although plantations and cooperatives are formed in some regions
	• Bio-energy crops are increasingly important as an export product and for local energy supply. Extensive plantations are set up in marginal regions, while more intensive production is regulated strongly in more favorable agro-ecological zones	• Bio-energy crops are increasingly important, especially as export products. Large plantations are set up in favorable agro-ecological zones, competing with the production of staple foods

Drivers of Change	Mozambique Development Trajectory 1	Mozambique Development Trajectory 2
Environment	• Although economic development is the key focus of government and society, there is a general attempt to limit environmental degradation and ensure a sustainable use of natural resources, e.g. through improved land use planning • The reduction in small holder farms results in a strong decrease in uncontrolled forest fires, while the general availability of electricity reduces deforestation for firewood • There is a considerable expansion of agricultural land for domestic food provision, export of cash crops and the production of bio-crops • Intensification and expansion of agriculture and mining leads to local pollution and environmental and ecological degradation	• There is little attention for environmental issues due to the high levels of poverty and limited economic development, resulting in widespread land degradation and a decrease in soil productivity • Uncontrolled wild fires remain a serious environmental problem, while fuel wood remains the most important energy source in rural regions, resulting in continued deforestation • There is considerable expansion of agricultural land, mainly for domestic food provision • Intensification and expansion of agriculture and mining gives little consideration for environmental and ecological degradation
Vulnerability to natural hazards and climate change	• The government incorporates climate change in its contingency planning, and is well prepared to cope with hazards when they occur • Rising temperatures, more frequent droughts[3] and more severe flooding[4] will cause for continued variability in agricultural productivity, despite improved natural resource management and appropriate government policies. Water stress occurs as a result of increased irrigation demands and human consumption, However, government regulations minimize risk of conflict • By 2060 Mozambique, with a GDP per capita of US$4897[2], can afford high category coastal protection from tropical cyclones[5,6], protecting the most vulnerable coastal areas despite global sea level rise and more intense cyclones. • By mid century, socio economic development could cancel out risk due to increases in extreme event frequency or intensity for the climate change projected by the seven GCMs[7]	• The government has limited resources for preparation and mitigation, and is often ill prepared when hazards occur • Rising temperatures, more frequent droughts[3] and more severe flooding[4] combined with poor natural resource management and lacking government policies (e.g. to control fire hazard) will result in recurrent food shortages and income loss. Greater water demand for agriculture and human consumption leads to frequent conflict due to lack of government regulations • By 2060 Mozambique, with a GDP per capita of only US$220[2], cannot afford coastal protection[5, 6]. Global sea level rise is likely to lead to huge land loss and will seriously impact urban centers, tourism and other economic activity along the coast • By mid century, a continuation of observed trends in disaster frequency could lead to disaster risk levels several times higher than they are today, in the absence of sustainable development and policies specifically targeting disaster risk and climate change[7]

Table 7: Impact of socio-economic drivers on vulnerability to climate change by 2030 and 2060. ***Source: Metzger et al, 2009.***

Footnotes in table:

[1] Scholes, R.J. and Biggs, R. 2004. Ecosystem services in Southern Africa: a regional assessment. A contribution to the Millennium Ecosystem Assessment, prepared by the regional-scale team of the Southern African Millennium Ecosystem Assessment.

[2] A. Grubler, B. O'Neill, K. Riahi, V. Chirkov, A. Goujon, P. Kolp, I. Prommer, S. Scherbov, E. Slentoe 2007. Regional, national, and spatially explicit scenarios of demographic and economic change based on SRES, Technological Forecasting and Social ChangeVolume 74, Issue 7: 980-1029.

[3] Tadross et al., this project

[4] Mavume et al., this project, Asante et al., this project

[5] Nicholls, R. and Tol, R. 2006. Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Philosophical Transactions of the Royal Society, A, 364 (1841): 1073-1095

[6] Hoozemans F, Marchand M, Pennekamp H.A. 1993. A global vulnerability analysis, vulnerability assessments for population, coastal wetlands and rice production on a global scale, 2nd edn. Delft Hydraulics and Rijkswaterstaat, Delft

[7] Patt et al, this project

In sharp contrast to Mozambique, neighboring South Africa has moved climate change out of the policy margins to a national priority. South Africa is the world's 14th most important emitter of CO_2 and faces both strong mitigation and adaptation requirements.

Recognizing the cross cutting nature of climate change, an Inter-Ministerial Committee on Climate Change was created in 2005, supported by an Intergovernmental Committee on Climate Change and a National Committee on Climate Change (a multi-stakeholder information sharing forum).

The government's vision, approved in July 2008, states that the 'South African climate response policy will be informed by what is required by science, namely to limit global temperature increase by 2°C above pre-industrial levels.' The government has set a trajectory which requires South African emissions to peak by 2020-25; plateau by 2025-30, decline by 2030-35 and reach the levels required by science by 2050-60.

To achieve this, South Africa has formulated six policy pillars, namely: (i) Greenhouse gas emission reductions; (ii) Building on and scaling up current initiatives; (iii) Implementing the 'Business Unusual' Call for Action; (iv) Preparing for the future; (v) Vulnerability and adaptation; and (vi) Alignment, coordination and cooperation.

A Greenhouse Gas Inventory was updated in 2000; long Term Mitigation Scenarios (LTMS) were developed for the country in 2007, formulating a range of strategies for different mitigation trajectories; a National Technology Needs Assessment was conducted; the South African Climate Change R&D Strategy was approved; and the Second National Communication is underway. The Transportation sector (DoT) is developing its climate change strategy and the Department of Trade and Industry is developing an Industry Response Plan.

The most recent initiative from the Department of Environment and Tourism and the Department of Science and Technology was the Climate Change Summit held from 3-6 March 2009, calling together over 900 representatives from government, business, the scientific community and civil society. The aim was to obtain input for developing the South African Climate Change Response Policy, taking as basis a draft framework document and discussing latest findings and developments. The South African National Climate Change Response Policy is to be approved by the end 2010 and translated into legislative, regulatory and fiscal packages by 2012. At the summit, concern was expressed about this late timeline, given the peak-plateau-decline trajectory and the Bali statement that greenhouse gas emissions of developing countries must be significantly (-25 to -45%) reduced by 2020. Immediate action proposed at the summit therefore focused on the energy sector, by far the heaviest contributor to South African greenhouse gas emissions[6].

While the above indicates that South Africa is well underway in its preparations for mitigation, adaptation is still at a distant second place. The outline of the National Climate Change Response Policy recognizes that climate resilience by the poor will require institutional, fiscal and policy adjustments in order to shift from 'coping' to 'adaptation' mode; calls for national and regional adaptation plans; and states the importance of municipal initiative in implementing adaptation. The business community, while eager to contribute to adaptation, is searching for ways to do so. In this regard an opportunity exists for Mozambique, if an enabling environment and framework for business is created.

Like Mozambique, South Africa still faces many questions about the specific impacts of climate change for South Africa, which will determine adaptation requirements. However, it is better equipped to deal with these questions than Mozambique, and important opportunities for collaboration exist. The South African Department of Science and Technology has recently launched a Global Grand Challenge[7] to answer a series of climate change questions of national importance, and to serve as a framework for all climate change related projects. South Africa has well-developed early warning systems at municipal level, and new remote sensing techniques are being acquired for upgrading early warning. Furthermore, it has advanced Earth Observation Systems (relevant for fires, earthquakes etc.), and a Technological Innovation Centre with globally competitive expertise on renewable sources of energy. Mozambique will explore collaboration on early warning, risk analysis and capacity building during the next INGC project phase.

Decentralisation of awareness creation and action is taking place through the mainstreaming of climate resilience in municipal planning. A number of municipal plans have been upgraded recently to include climate change risks. The flagship of which is the response plan of the municipality of Western Cape, organized by theme rather than by sector. Resettlement of communities and 'climate change refugees,' spatial planning and land use rights are issues already faced by municipalities, and being addressed through strategic, multi-sectoral assessments. Mobilization of the media and education for awareness creation at community level is still at starting levels.

Note 6, 7

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[6] Action proposed includes the retiring of old coal power stations, diversifying the energy mix, investing in clean energy, feed in tariffs, adjust regulatory framework, mandatory energy efficiency standards for business, creation of green jobs and the need for in-depth green jobs business models, technological development opportunities, capacity building etc), modal shifts in transport etc..

[7] The Global Change Grand Challenge is one of five Grand Challenges set by the Government of South Africa as part of their ten year innovation strategy to shift South Africa to a knowledge based economy. The other Challenges address other major changes brought about by human intervention, such as pollution, altered fire and hydrological regimes, the over-exploitation of natural resources, habitat destruction and fragmentation, and the introduction and spread of diseases and invasive alien species (Annex V).

8 Conclusions and Recommendations

8.1 Conclusions

As a result of climate change, the exposure to natural disaster risk in Mozambique will increase significantly over the coming 20 years and beyond. It is vital that the government is made aware of this and acts now to incorporate climate change risks in its infrastructural planning and investments and establishes a national response plan to climate change.

In the event of low global mitigation results ('too little, too late'), according to the projections of the modeling:

- Temperatures in Mozambique may rise by as much as 2-2.5˚C by 2050 and 5-6˚C by 2090 (depending on the region).
- Rainfall variability will increase; there will be likely shifts in the start of rainy seasons, wetter rainy seasons and drier dry seasons.
- Flood risk will increase notably in the South
- The Centre will be most heavily impacted by more intense cyclones and sea level rise, as well as drought risk around the Cahora Bassa area.
- Upstream rainfall reductions in Zimbabwe and Zambia could translate into significant reductions in river flows in Mozambique, notably for the Zambezi and Save; this may have implications for the Cahora Bassa hydro-electric power supply, but further research is needed.

- In the North, whilst increased flood peaks are expected in coastal basins, no changes in river flows are projected. Since most of the river basins in this zone are internally draining, the North offers the best opportunity for Mozambique to benefit from any positive impacts of climate change (for example increased rainfall) independent of the actions of neighboring countries. However, any such potentially positive impacts will be overwhelmed by the negative impacts and environmental degradation resulting from exploitation of natural resources where sustainable development mandates are not enforced.

- Up to approximately 2030, more severe cyclones will pose the biggest threat to the coast; beyond 2030, the accelerating sea level rise will present the greatest danger especially when combined with high tides and storm surges. The city of Beira is already in a very vulnerable situation, with inadequate coastal protection for yearly return events. Parts of Maputo, as well as other coastal areas such as Pemba and Vilankulos and nearby islands, are also at risk. In an extreme but possible scenario, resulting from polar ice melt (timing unknown), it is the permanent inundation of the coast and the low-lying areas behind which forms the principal threat, particularly to large estuaries and subsiding deltas. Coastal set-back by erosion would reach approximately 500m. Overall, this scenario is likely to be catastrophic for Mozambique.

- Salt water intrusion will increase as a result of lower river flows combined with ocean tidal activity, probably aggravated by sea level rise after 2030, impacting on agricultural land. The largest affected areas occur in the Zambezi, Save and Limpopo estuaries.

- Investments are being made in areas where the threats are increasing and the cost of insurance, even when borne by the government, is becoming very unattractive. This is a bleak picture that needs to be carefully assessed. A re-evaluation is urgently required of storm surge and flood risk from intense cyclones, as well as of all factors associated with mega-catastrophes that might impact on particularly vulnerable localities on the coast of Mozambique.

- In terms of agriculture, the modeling undertaken here suggests that suitable areas may increase in the north of the Centre and the North, while the zones most affected by loss of suitable area will generally be those that already struggle from the impacts of irregular and extreme climate events. These include the mixed arid-semiarid systems in the Gaza and semiarid systems in parts of northern Inhambane and south of Tete, the coastal zones of the South and southern Centre, and many of the drier zones of major river systems like Limpopo, Save and Zambezi. Although it is suggested that drought occurrence will increase slightly, the agricultural modeling undertaken here is limited in the number of climate models used and should only by undertaken as an indication of future change.

- Relatively few areas show significant decreases in crop suitability as a result of climate change, but current problems resulting from climate variability are likely to intensify. If the present situation of predominantly low yields is maintained, population growth and increasing demands on land and diminishing water supplies may create conflicting situations by as early as 2030, which will be detrimental to the people and the economy. Food deficits will increase as expansion of cultivated land becomes increasingly problematic. The current gap between actual and potential yield for rain-fed production is so large that overall, the increases in yields attainable with intensification of agriculture and technological development are likely to be higher than the expected decreases in yields caused by climate change. If Mozambique opts for agriculture intensification, around 30% to 50% of the present land used for agriculture can be allocated otherwise, given that almost half of the land in the rural environment is under fallow cultivation. If in addition effective land reform and reduction in yield gaps are achieved, a lot of land will be saved.

- Vulnerability is expected to increase over the next two decades, as climate impacts reduce peoples' livelihood assets (health, water, infrastructure) and impinge on food production, thus undermining Mozambique's overarching goal of reducing extreme poverty. However, the extent to which the vulnerability of Mozambique will increase with increased exposure, depends on its adaptive capacity. This in turn depends in large part on the socio-economic and technological development trajectory Mozambique will take, and on the adaption measures, i.e. protection and planning it will put in place in the coming 5-10 years. In terms of health, this could mean capturing heightened disease risk through early warning systems using remote sensing and strengthening the resilience of communities through a multi-sectoral approach involving the measures mentioned in Annex V.

- If successful by mid-century adaptive capacity could have improved to the extent that vulnerability decreases to below current risk levels (excluding extreme polar ice melts). The key issue is one of timing: Mozambique cannot wait.

- Currently, Mozambique cannot afford the requisite coastal protection. For both Low and High SLR scenarios, a high protection class (protection against a 1 in 1,000 year storm surge) would require a seawall built to a height of 5.17m along the coast, to cope with the added sea level rise by 2030. On a delta coast, Nicholls and Tol (2006) estimate that this can only be afforded by a country with a GDP in excess of US$5,000 per capita. GDP in 2000 stood at approximately US$98 per capita in Mozambique. Depending on socio-economic development, under good economic growth, as depicted for example by the IPCC B1 scenario (IPCC, 2000), Mozambican GDP could grow to approximately US$4,897 per capita by 2060, in which case it could afford the highest protection class; under poor economic growth as depicted for example by the IPCC A2 scenario (IPCC, 2000), GDP could reach only approximately US$222 per capita by 2060 (Metzger, 2008), in which case Mozambique could not even afford proper protection against 1 in 10 year events. However, Mozambique cannot wait until 2060 and needs to invest now in protecting its coastal areas against climate change. This illustrates the difficulty faced by Mozambique as a poor country, already subject to the impact of climate change on a delta coast.

- Implications for INGC in the event of no action are severe. Its current response capacity will be wholly inadequate by 2030/40 in the possible scenario of sea level rise, more intense cyclones, land right conflicts due to permanent inundation, water shortages, degrading land and salt water intrusion, escalating food shortages, more epidemics and an exponential increase in wildfire spread and damage. If in such a context a tipping point (threshold) is reached in an ecosystem, causing major and irreversible change, INGC will be overwhelmed.

8.2 Recommendations

It is recommended that INGC:

- Upgrade its emergency response planning to deal with climate change risks, well beyond current preparedness levels; review resettlement plans from a climate change perspective; actively engages with relevant ministries to ensure adequate adaptation measures are included in 5 year plans and budgets, according to a national adaptation strategy; and plays a lead role in ensuring implementation of infrastructural and non-infrastructural adaptation.

- Create an information system which integrates information on climate hazards (cyclones, floods and droughts), their expected changes in the future, as well as information related to both physical and social vulnerabilities (roads, infrastructure, poverty levels, sector dependencies). This information should be continually reviewed based on the latest research (incorporating the IPCC 5th assessment report) and should actively pursue research that is needed to fill critical gaps in current knowledge. This activity will underpin subsequent assessments and provide easily accessible information that can help coordinate future efforts.

- Harness the capacity of the private sector to help translate Mozambique's obligations under conventions, laws, policies and regulations, into actual adaptation and sustainable development on the ground. The responsible private sector, i.e. companies who are committed to invest in sustainable development while doing business with Mozambique, have a crucial role to play in properly kick-starting adaptation. It is vital to understand and eliminate the perceived and real barriers to attracting these companies to Mozambique.

- Engage ministries. It is critical that ministries who will play a key role in development and adaptation to climate change, such as the ministries of transport, public works, energy, trade, tourism, agriculture, health, state administration and planning and finance, understand the magnitude and timing of risks, implications for their own ministries, their own role and responsibilities and funding options available. These ministries must take climate change into consideration in their multi-year budget planning and actively engage in the development of adaptation strategies, ideally on the basis of strategic assessments of priority areas (as opposed to fragmented sectoral approaches), a coherent, organized science base and effective channels of communication. Currently these are not in place.

An effective response of the government must include the following:

- The formulation and approval of a national response strategy to climate change, which will serve as the basis for all subsequent negotiations and channeling of projects and allocation of budgets
- A systematic institutional focus on climate change, by all key ministries (see Table 7 below)
- A revision of the legal framework and secondary legislation to adjust fiscal policies, roles and responsibilities per ministry, to facilitate the implementation of adaptation
- Leadership in the implementation of infrastructural and non-infrastructural adaptation and early warning, thus moving away from today's ad hoc, project-based and donor-driven activities
- Engagement of the serious private sector and mandatory adaptation standards and requirements for investors
- Effective awareness creation and education at provincial and district level
- Creation of the capacity to receive and manage large scale and complex international funding for climate change adaptation, with a 'one-stop-shop' to deal with all queries
- Ensuring performance monitoring and accountability through the establishment of an independent audit company, with immediate penalties for illegal practices and poor performance and award systems and incentives for good performance.

To achieve this, the following milestones are proposed, some of which will need to be worked at simultaneously:

	Milestone	Timing	Participants, Lead, Responsible
1	**Government's Call for Action.** Creation of awareness and 'wake-up call' through the INGC study on the Impacts of Climate Change on Mozambique disseminated at ministerial level and through a workshop to the wider public.	May 2009	Proposed participants: MOTC, MAE, MST, MIC, MICOA, MITUR, MINAG, MPD, MEC, MISAU, MOPH, ME, MIREM, MINEC Workshop: UNDP Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)
2	**Government's Vision on National Response to Climate Change.** The vision should outline how the government wants Mozambique to be by e.g. 2050 in the face of climate change and what policy pillars must be set up to achieve this. For example, the Vision could include that Mozambique's development will be guided by: • The requirements set by science to protect our earth and our children. • The natural strengths and opportunities the country offers, following a climate-friendly pro-growth and pro-jobs strategy (becoming a leader in e.g. wave energy generation). • That Mozambique pro-actively build its knowledge base and its capacity to adapt to the inevitable impacts of climate change by: revising early warning and disaster response systems and infrastructure planning, in the roll-out of basic services, in agriculture, forest management, water resource management and in the health sector • That provinces are enabled to adequately protect themselves. Policy pillars will lay the basis for measurable and verifiable adaptation and mitigation outcomes, and could include: (1) 'Green infrastructure and green job creation' e.g. all road/ public and business buildings/ port and water works/ inner city development infrastructure from 2020 must be according to specific standards, to combine both adaptation and mitigation requirements. (2) 'Preparing for the Future' including e.g. new early warning systems, role of major cities in adaptation (provincial response plans, training, fiscal support for implementation, climate change in curricula). (3) 'Diversifying our Energy Mix,' reducing the dependency on the Cahora Bassa, fossil fuels and wood for energy, attracting investment in wind and wave and solar energy, becoming a leader in one renewable energy (e.g. waves) and achieving X% of energy supply from renewables by 2020. (4) 'Determining our Strengths and Weaknesses in the face of climate change,' including strategic assessments and outlining major opportunities for development per province. (5) Alignment, coordination and cooperation, building on and scaling up current initiatives and ensuring a thematic (integrated) approach as opposed to sectoral.	August 2009	Proposed participants: MOTC, MAE, MST, MIC, MICOA, MITUR, MINAG, MPD, MEC, MISAU, MOPH, ME, MINEC, Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)

	Milestone	Timing	Participants, Lead, Responsible
3	**Government's Announcement of the Mozambique Grand Challenge for Adaptation to Climate Change.** Based on the government's vision and policy pillars, the Grand Challenge sets forth ambitious targets and calls for proposals for implementation, nation wide and internationally. Targets can include: • An internationally recognized early warning system with remote sensing and regional links. • Coastal city protection in place for 100 year return events. • Mega projects for energy (coal), mining, tourism, factories and other major construction allocated in line with provincial Core Competency Profiles (following regional strategic SWOT analyses) and respecting mandatory standards and adaptation requirements by 2012 (Industrial Response Plan). • Provincial Response Plans based on risk assessment and SWOT analysis, with fiscal- and training support to implement and including a 'Veto channel' to CENOE in the case of observed unsustainable exploitation in their provinces. • Revamped Green Inner Cities, with starting from 2012 all new building of roads and buildings and waste management and water supply and recycling and energy supply done according to green standards, X percent of vehicles on flexi-fuel. • Expanded energy supply infrastructure, with X percent of new capacity coming from clean coal technologies, Y percent of total energy coming from renewable sources, and Z percent of the population supplied by clean energy grids by 2020. • Water: How to do more with less. Regional management • Agriculture: How to do more with less. Pilot projects involving serious biofuel companies and differing strategies, to double yield in conditions of more variable climate, soil degradation, less water, less fertilizers etc. • Skills Challenge: A total of 1000 Mozambican doctorates and 100 PhDs in climate change disciplines by 2015, and an optimal ratio of technology to science development. • The Design and Delivery of Global Change Education: primary and secondary education packages on global change, climate change. • The establishment of a Centre of Knowledge on Climate Change, applying thematic research to reply to key questions such as those in Annex V, and establishing a research base and improved information management and communication for a better science-policy interface. • The establishment of an independent Adaptation Auditing Authority for measuring the performance of adaptation implementation and applying an incentive / penalty system. Includes a One-Stop-Shop for all questions related to climate change regulations, financing, implementation, monitoring of international commitments. Main elements that must be covered by the Challenge: human capacity development; knowledge generation and exploitation (bridging the gap between research, policy and application); and infrastructure and early warning.	Challenge launched in Sept. 2009 Winners announced mid 2010	Proposed participants: MOTC, MAE, MST, MIC, MICOA, MITUR, MINAG, MPD, MEC, MISAU, MOPH, ME, MIREM Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)

	Milestone	Timing	Participants, Lead, Responsible
4	**Government's Fundraising for Implementation of Adaptation** • Based on the Grand Challenge results, financial cost of adaptation up to 2020 is established and the government mobilizes funds for implementation. • Internal government budgeting already starts with immediate effect, through the upcoming 5 year plans and budgets, as preparation and some adaptation must start now. • Capacity for the receipt and management of large scale, phased and complex funding is established, with one lead authority and accountability at ministerial level. • The winning Grand Challenge proposal for the Adaptation Auditing Authority is implemented.	2009	Proposed participants: MOTC, MOPH, MAE, MICOA, ... Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)
5	**Government's National Response to Climate Change Strategy** Based on the government's Vision, the Grand Challenge results and the outcomes of Copenhagen December 2009 Conference Of Parties, the National Response to Climate Change Strategy is published.	2010	Proposed participants: Committee? Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)
6	**Government's Implementation of Adaptation** Phased approach: immediate start through the INGC phase II programme (multi-ministerial), followed by the implementation of the winning proposals of the Grand Challenge and the drafting of legislative, regulatory and fiscal packages to enable implementation. The INGC phase II will focus on the following (2009-2010): • Revamped emergency response and planning to include impacts of climate change, 'climate change refugees,' resettlement and climate change, fire spread monitoring etc. • Identify and cost the best infrastructural (hard and soft) adaptation options for established priority areas. • Set up the Grand Challenge. • Start adaptation, through awareness creation at central and provincial levels; establishing revised standards for protective infrastructure (houses, seawalls, roads etc); determining the perceived and real barriers to attracting the serious private sector to help implement adaptation.	2009-2010 2010-2020	Proposed participants: MOTC, MOPH, MPD Lead: tbc Responsible: Co-ordinating council (chaired by the Prime Minister)

Annex I

Summary of Methodology

A total of eight teams, each consisting of one international expert and a national expert, have been established in the following fields: climatology, oceanography and cyclones, hydrology, agriculture, fires, health, global change, vulnerability, GIS, legal and disaster risk management. Annex II details the list of team members and their institutions.

The study uses historical data and climatological modeling of temperature and rainfall as a basis for understanding how the climate of Mozambique may already be changing and how it may be expected to change in the future.

Both the historical trends and future projections in the seasonal climate of Mozambique are derived from daily (maximum and minimum) temperatures and rainfall measurements between 1960 and 2005 from 27 synoptic weather stations within Mozambique. This data is supplied by the National Institute of Meteorology of Mozambique (INAM).

To project downscaled future scenarios of climate (temperature and rainfall) over Mozambique, focusing on the mid-century (2046-2065) and late-century (2080-2100) periods General Circulation Models (GCMs) are used.

GCMs are complex computer models, which represent interactions between the different components of the climate system such as the land surface, the atmosphere and the oceans. Seven different GCMs are used: CGCM3.1(T63), CNRM-CM3, CSIRO-Mk3.0, ECHAM5/MPI-OM, GFDL-CM2.1, GISS-ER, IPSL-CM4 As is the SOMD downscaling process developed at the University of Cape Town.

The scenarios from the seven GCMs are used to study the impact of climate change on water resources, and on agriculture.

Water resource conditions are determined by ingesting daily rainfall and evaporation data into the Geospatial Stream Flow Model (GeoSFM), derived from either historical data or the predictions from the seven GCMs, downscaled to the area of study. Given the need for projected changes outside Mozambique’s borders, satellite-based rainfall estimates (RFE) were used to downscale future projections for the water resource modelling.

The water supply is determined from average river flow conditions, whilst flood conditions are based on maximum flow during each year. The water demand analysis uses current population and water usage information to construct future condition assessments assuming current, high, medium and low usage scenarios.

For agriculture, the current and potential scenarios on land utilization types suitability classification are assessed with a dynamic and automated land evaluation system (ALES), which operates on the basis of a decision-tree model for each land utilization type, matching its eco-physiological and socio-economic requirements, with the relevant land/environment attributes, i.e. soil, terrain and climate characteristics/qualities. Such a system results in the simulation of crop yields/performance under different levels of management, where observed yields are associated with prevailing small holder traditional low input farming systems, and potential yields corresponding to limitation free highly managed commercial crop production systems.

For the cyclones GCMs are used to directly simulate cyclone patterns in the future, even though they may not possess sufficient horizontal resolution to simulate the inner core of intense cyclones. Impacts are accessed along the coastal area of Mozambique. Similarly, two different scenarios for sea level rise based on the current knowledge are modelled, and the impacts are accessed for the coast and coastal cities as well as the coral reefs along the coast.

Other components of the study include the baseline study for fires and most vulnerable areas; the impact of climate change on health; the vulnerability of Mozambique to natural disasters; legal and institutional aspects related to disasters and climate change; and socio-economic development scenarios.

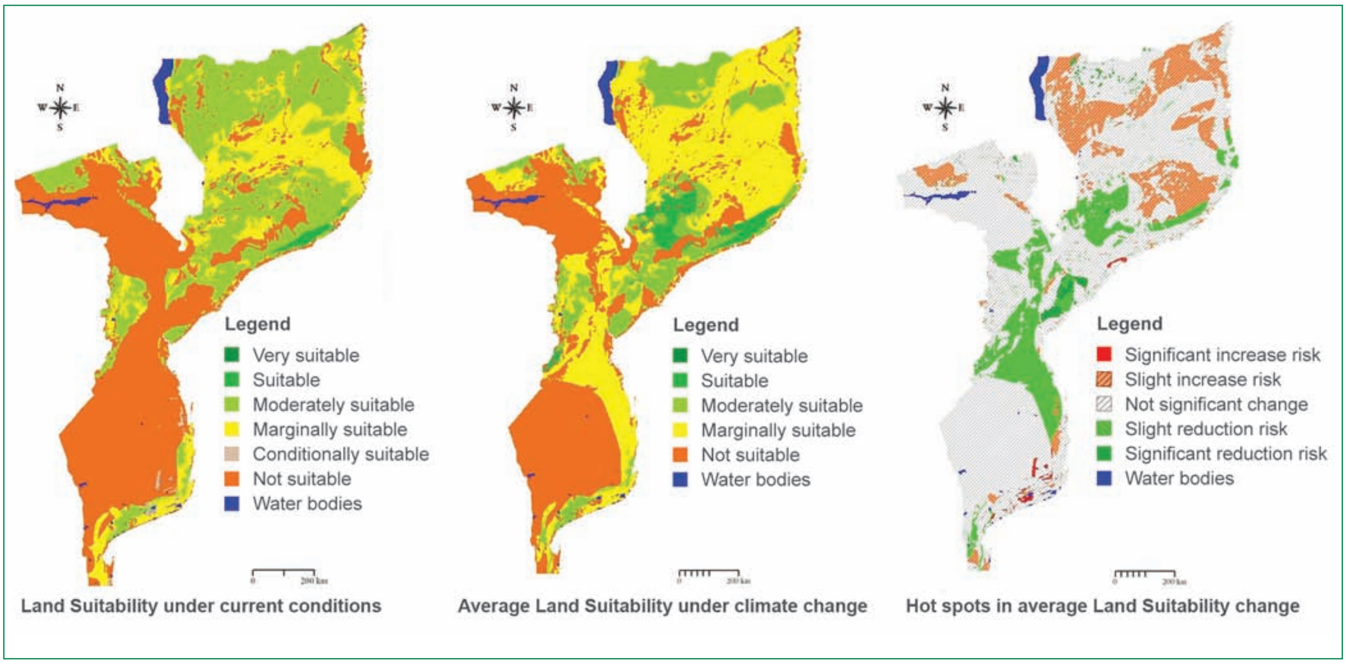
Annex II

Team Composition, INGC Climate Change Project, Phase I: May 2008 – April 2009

Ref.	Team Memebers INGC Climate Change Project Phase I	Institution	Area of Expertise	Main responsibility
1	Mark Tadross, Senior Research Fellow, Climate Systems Analysis Group, UCT Department of Environmental and Geographical Science. Tel. +27 83 5446354, +27 21 6502784; E-mail: mtadross@csag.uct.ac.za	University of Cape Town, Climate Systems Analysis Group, South Africa	Climatology	Downscaled GCMs, observed trends and climate hazards for Mozambique.
2	Marc Metzger, Senior Research Fellow. Tel. +44 131 651 4446; E-mail marc.metzger@ed.ac.uk	Centre for the Study of Environmental Change and Sustainability, University of Edinburgh, School of GeoSciences, Scotland	Global change	Storylines, socio economic impact analysis.
3	Geoff Brundrit, Emiritus Professor in Physical Oceanography, UCT, Chair of the Global Ocean Observing System (GOOS / WMO) in Africa. Tel. +27 833373924, +27 21 786 2308; E-mail: oceangeoff@iafrica.com	Global Ocean Observing System (GOOS / WMO), South Africa	Oceanography	Sea Level Rise and storm surge scenarios modelling.
4	Kwabena Asante, PhD., civil engineer, hydrologist, Climatus (former USGS). Tel. (+1) 605 415 4612 or 605 231 1594; E-mail: asante@alumni.utexas.net	USGS/Climatus	Hydrology	River flood risk modelling and water management tools and adaptation.
5	Paul Epstein, MD, MPH, Associate Director, Center for Health and the Global Environment, Harvard Medical School, Boston, USA. Tel: +1 6173848586; E-mail: paul_epstein@hms.harvard.edu	Harvard Medical School, Boston, USA	Health	Impact of climate change on health in Mozambique.
6	Anthony Patt, Research Scholar, Leader of Decisions and Governance Group, Programme on Risk and Vulnerability, International Institute for Applied Systems Analysis IIASA. Tel: +43 2236897306, +43 6644389330; E-mail: patt@iiasa.ac.at	International Institute for Applied Systems Analysis IIASA, Austria	Vulnerability analysis	Top-down vulnerability analysis and pathways.
7	Rosa Sanchez, PhD, GTZ Advisor on Disaster Risk Reduction. Tel. +502 24770707, +502 58979784; E-mail: rosa.sanchez.valle@gmail.com	Gesellshaft fur Technische Zusammenarbeit (GTZ), Mozambique/Guatemala	Disaster Risk Management	Bottom up vulnerability analysis and coping mechanisms.
8	Antonio Queface, Assistant Lecturer of Climatology, Physics dept, University Eduardo Mondlane, Tel. +258 827266350; E-mail: queface@uem.mz	University of Eduardo Mondlane, Mozambique	Climatology	Historical trend analyses, baseline, modelling assistance.
9	Jose Rafael, Docente assistente Ciencias Ambientais, Planificacao de Uso de Terra, Teledeteccao (GIS), dept. Geografia, University Eduardo Mondlane, Tel. +258 823100600; E-mail: Rafael@zebra.uem.mz	University of Eduardo Mondlane, Mozambique	GIS	Mapping, data collection, targeting.
10	Alberto Mavume, PhD candidate, Department of Oceanography UCT, Lecturer at Physics department University Eduardo Mondlane, amavume@uem.mz, Tel. + 258-82-8492180; E-mail: amavume@yahoo.co.uk	University of Eduardo Mondlane, Mozambique	Oceanography/ Cyclones	Cyclones. Data collection and modelling assistance.
11	Agnelos dos Milagres Fernandes, lecturer at department of Agronomy and Forestry Engineering, Eduardo Mondlane University. Tel. +258 823142600; E-mail: afernandes@uem.mz	University of Eduardo Mondlane, Mozambique	Wildfires	Link between climate change and wildfires in Mozambique.
12	Mario Ruy Marques, Environmental Soil and Water Management Scientist, Instituto de Investigacao Agraria de Mozambique (IIAM), Tel. +258 823032420; E-mail: mmarques@map.gov.mz	Instituto de Investigacao Agraria de Mozambique (IIAM), Ministry of Agriculture	Environmental Soil and Water Management	Impact on agriculture, food security.
13	Agostinho Vilankulos, Direccao Nacional de Aguas (Ara Sul), Tel. +258 825159091; E-mail: avilankulos@yahoo.com.br	Direccao Nacional de Aguas (DNA), Ministry of Transport and Communication, Mozambique	Hydrology	River historical trend analysis & baseline, flood risk modelling, data collection.
14	Moises Benessene, Director INAM. Tel. +258 823048745, Fax +258 21491150; Email: moises_b@inam.gov.mz	Instituto Nacional de Metereologia (INAM), Mozambique	Meteorology	Data provision and analysis, validation of results.
15	Telma Manjate, Director of Coordination, Ministry of Environment (MICOA). Tel. +258 823286210, E-mail: telmanjate@yahoo.com.br	Ministerio de Coordinacao do Ambiente, Mozambique	Environment, coordination	Data provision and analysis, validation, coordination.
16	Rui Brito, Assistant Professor Irrigation and Drainage, Eduardo Mondlane University, Water and Agriculture, Advisor, analysis, main report, input for synthesis report. Tel. +258 823093340; E-mail: ruibrito@tvcabo.co.mz	University of Eduardo Mondlane, Mozambique	Water and Agriculture	Consolidation and Interpretation, quality control.
17	Barbara van Logchem, INGC Climate Change project coordinator, synthesis report. Tel. +258 823093520; E-mail: barbaravanlogchem@gmail.com	Instituto Nacional De Gestao de Calamidades (INGC), Mozambique	Natural disasters prevention and response	Project coordination.

Annex III

Change in land suitability per crop resulting from climate change

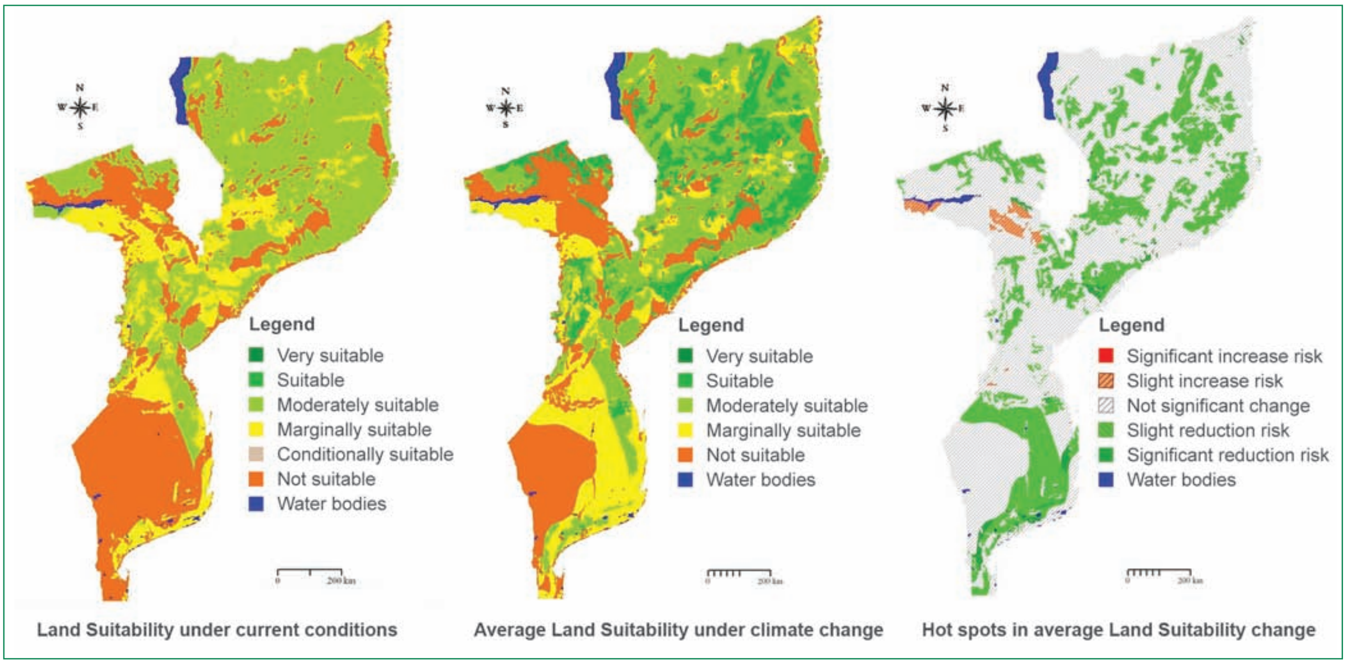


Land Suitability under current conditions

Average Land Suitability under climate change

Hot spots in average Land Suitability change

Maps of land suitability and hotspots resulting from climate change, for Cassava. The left map shows current suitability for the crop, the middle map the average suitability in the future (2030/40-2060), and the right map the difference between the two (whereby red is a significant reduction in suitability; pink a slight reduction in suitability; white shows no change; light and dark green show slight and significant increase in suitability, respectively). ***Source: IIAM, 2008.***

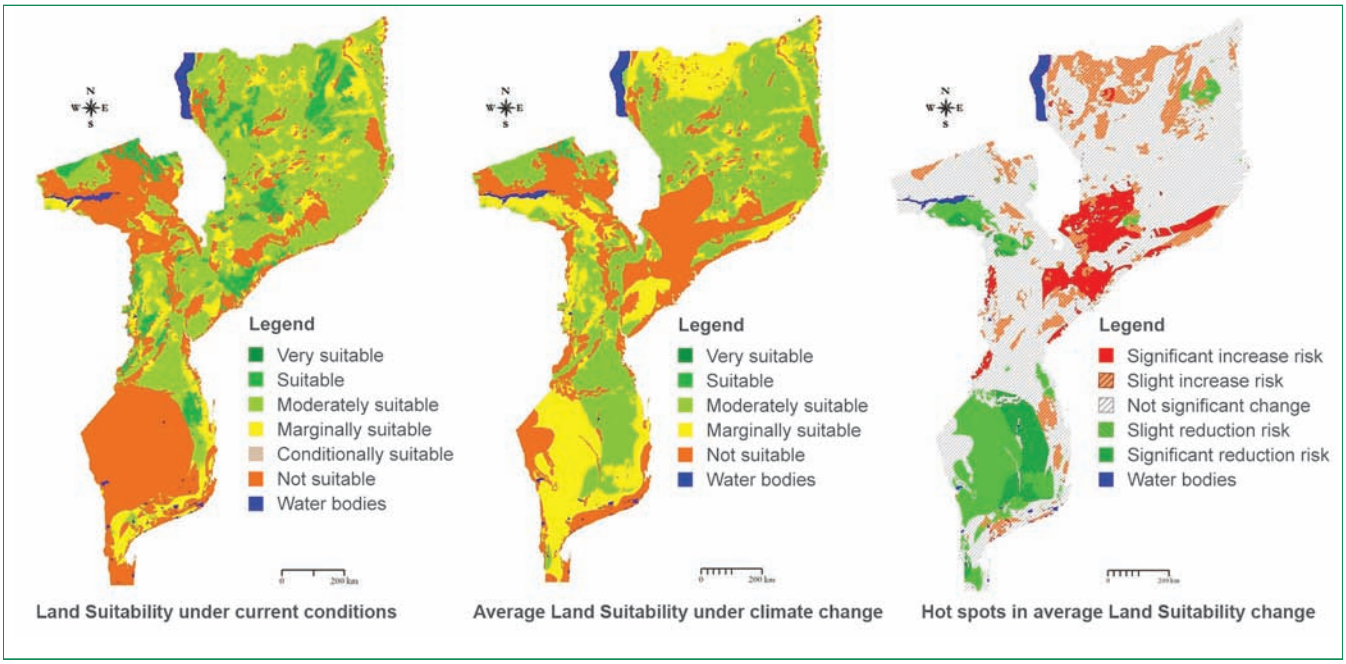


Land Suitability under current conditions

Average Land Suitability under climate change

Hot spots in average Land Suitability change

Maps of land suitability and hotspots resulting from climate change, for Maize. ***Source: IIAM, 2008.***

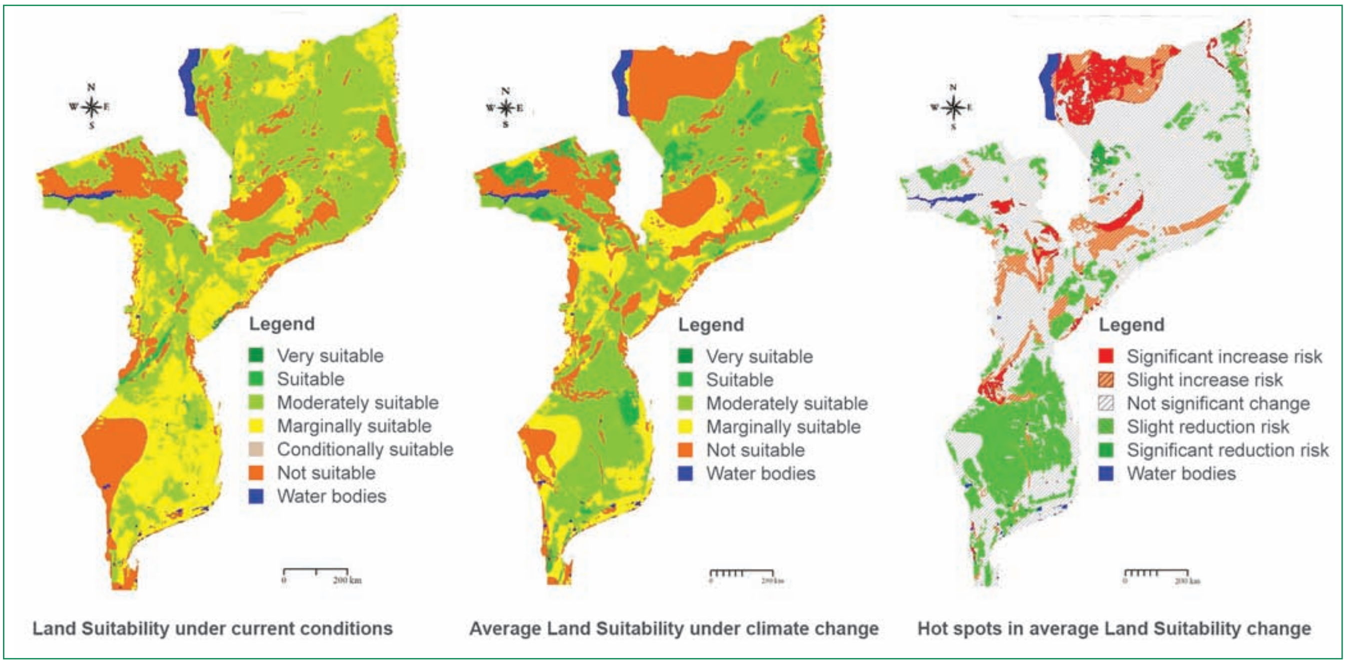


Land Suitability under current conditions

Average Land Suitability under climate change

Hot spots in average Land Suitability change

Maps of land suitability and hotspots resulting from climate change, for Soya. ***Source: IIAM, 2008.***



Land Suitability under current conditions

Average Land Suitability under climate change

Hot spots in average Land Suitability change

Maps of land suitability and hotspots resulting from climate change, for Sorghum. ***Source: IIAM, 2008.***

Annex IV

Most Prevalent Health Problems in Mozambique and possible adaptation measures by zone.

Zone	Weather extremes	Drought-prone	Most prevalent diseases	Diseases	Possible Adaptive Measures
Coastal	Most cyclone-prone		Malaria	Cholera	Wetland, barrier island and coral reef preservation Remote sensing for early warning
North		Drought-prone pockets Zambezia (2009)	Malaria	Meningitis Zambezia Plague Konzo: Nampula, Zambezia & Cabo Delgado	Community education Processing measures Food storage, supplies and supplements Remote sensing for early warning, other EW
Inland Highlands			Malaria: prolonged season & increased altitude is possible		Increased awareness in naïve areas Insecticide – impregnated bed net and medicine distribution Vector control Remote sensing early warning
Cente	Flood-prone	Tete: Drought prone	Malaria	Cholera Tete: Plague Tete: Trypanosomiasis	Insecticide – impregnated bed net and medicine distribution Vector control, remote sensing early warning Population screening Tsetse fly control Stocking Medicines Remote sensing (vegetation indices linked to precipitation and temp.)
South	Floods	Drought	Malaria: prolonged season & increased altitude possible	Cholera	Water chlorinisation Clean water supplies Decentralized treatment centers Trained personnel

Source: Epstein, 2009.

Annex V

Establishing the Mozambique Grand Challenge for Adaptation to Climate Change

Recognizing that climate change is a major threat to the country and its development and requires large scale, multi-sectoral response and recognizing the need to channel funding and initiatives into a framework, which addresses the priorities of the country, the government of Mozambique launches a Grand Challenge for Adaptation to Climate Change.**

Although it is known that climate change will have a significant impact on Mozambique and the Southern Africa region, many questions remain. For example:

1. What contingency and mitigation plans are needed to address flooding and inundation due to sea level rise and more extreme weather events, and how can we better forecast such events? How will these changes affect (resettlement) programs aimed at ensuring safety, water and food security for the poor?

2. What is the investment needed to ensure adaptation to climate change in high priority high risk impact areas? What are the specific implications for tourism and industry?

3. Are there critical thresholds or 'tipping points' of change which if exceeded, will have a disproportionately negative effect on our people and our economy? Does the risk of damage for key coastal cities and growth areas suddenly increase above a certain sea level? Can systems be developed to warn of the imminent approach of these thresholds? Given that our economy and urban systems depend on extensive use of natural resources, how do these systems need to change to avoid certain tipping points?

4. How will we safeguard water quantity and quality, given the threat of reduced rainfall in the catchment areas of major international rivers ending in Mozambique, increased rainfall variation and increasing (transboundary and domestic) pressure on our water resources? What are the absolute limits to this resource?

5. How can new transport infrastructure be optimized to reduce dependency on fossil fuels and reduce climate change impacts? What new standards are required to take into consideration climate change and protect people and infrastructure from the increasingly extreme weather events and sea level rise? How can urbanisation occur sustainably and lead to a reduction in poverty, for example, through the development of new green markets?

6. What will need to change with respect to extraction and use of primary natural materials, such as minerals, water and forest products to minimize greenhouse gas emissions and toxic waste? Should the National Institute for Disaster Management have a veto right over projects which will (demonstrably) drastically increase risk of exposure to natural disasters?

7. Given our population growth and increasing demands on our land and water, how can we increase agricultural yields under conditions of less water availability, more saline intrusion, higher temperatures, unpredictable rainfall, less fertile soils, more erosion?

8. How will coastal fishing and coral reefs be affected by changes in ocean currents, temperatures, acidity, and compounded by overfishing?

9. What are the key characteristics of successful market-based mechanisms and an enabling legal and institutional environment that will attract serious investors who are committed to helping Mozambique achieve sustainable development and adapt to climate change, and reject investors who are not? What are the existing barriers to attracting these investors? What incentive-based mechanisms need to be implemented? Who are the top 20 companies in Mozambique in terms of emissions and pollution and what measures will they need to put in place to mitigate these? What monitoring and auditing capacity is required to hold all stakeholders accountable to the Mozambican people who depend on sustainable development for their (future) survival?

10. How can we avoid the loss of skills, information and facilities through over-dependence on single individuals and disorganized databases scattered across spatially separated institutions?

11. Will Mozambique be able to place adaptation costs as a high enough priority so that implementation is carried out? Given that the Stern Review also emphasized early action will faltering now mean that Mozambique will ultimately fail?

All climate change related projects will need to fit into the agreed priority areas of research and all will be channelled through this Challenge, thus ensuring a coordinated and solid approach. Findings may serve as input for the formulation of an ambitious and challenging adaptation strategy for Mozambique, which should address the central question of how Mozambique should adapt to climate change while allowing for sustainable development. This will determine how Mozambique should position itself at international (negotiation) events such as the Conference of Parties in Copenhagen in December 2009. Such leadership in turn will be highly attractive to developed countries which are trying to determine where best to fund mitigation and adaptation.

**Other Challenges would address other major changes brought about by human intervention, such as pollution, altered fire and hydrological regimes, the over exploitation of natural resources, habitat destruction and fragmentation, and the introduction and spread of diseases and invasive alien species.

References

Asante, K. 2009. Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

Bradbury K, Edward A. 2005. Solutions for Effective Malaria Control: Lessons from Mozambique. CORE Group, March 2005.

Bundrit, G. and Mavume, A. 2009. Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

Church, J.A., White, N.J., Coleman, R., Lambeck K. and Mitrovica J.X. 2004. Estimates of the regional distribution of sea level rise over the 1050-2000 period. Journal of Climate. Vol.17: 2609-2624.

Chretien, J.P., Anyamba, A., Bedno, S.A., Breiman, R.F., Sang, R., Sergon, K., Powers, A.M., Onyango, C.O., Small, J., Tucker, C.J. and Linthicum, K.J. 2007. Drought-associated Chikungunya emergence along coastal East Africa. American Journal of Tropical Medicine and Hygiene. Vol. 76 (3), pp. 405-407.

Emanuel, K., Sundararajan, R. and Williams, J. 2008. Hurricanes and global warming: Results from downscaling IPCC AR4 simulations. Bulletin of the American Meteorological Society. Vol.89 (3), 347.

Epstein, P.R. and Mills, E. 2005. Climate Change Futures: Health, Ecological and Economic Dimensions, Center for Health and the Global Environment [Epstein PR, Mills E. (Eds.)]. Harvard Medical School. Boston. http://www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf

Epstein, 2009. Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

ESRI Website [online]. Available at: http://www.esri.com/ [Accessed January 2009].

Google Earth Website [online]. Available at: http://earth.google.com/ [Accessed January 2009].

Grubler, B. O'Neill, K. Riahi, V. Chirkov, A. Goujon, P. Kolp, I. Prommer, S. Scherbov, E. Slentoe,(2007) Regional, national, and spatially explicit scenarios of demographic and economic change based on SRES, Technological Forecasting and Social Change. Vol. 74, Issue 7: 980-1029.

Hoffman, A.A. and Parry, J. 2008. Climate change and wild land fires: the implications for Mozambique. 7th Southern Africa Fire Network (SAFNet) Conference, Katima Mulilo, South Africa, 22-26 September 2008. IISD: Manitoba.

Kondo H, Seo N, Yasuda T, et al. 2002. Post-flood –infectious diseases in Mozambique. Prehosp Disaster Med 17:126-133.

Instituto de Investigação Agrária de Moçambique (IIAM). 2006. Priority Setting for Public Sector Agricultural Research in Mozambique with National Agricultural Survey Data. Research Paper No. E3. IIAM, Maputo.

Intergovernmental Panel on Climate Change (IPCC). 2000. Summary for Policymakers. Emissions Scenarios. Available at: http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

Intergovernmental Panel on Climate Change (IPCC). 2007. Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change, Fourth Assessment Report (IPCC-AR4). 2007. Climate Change 2007: Synthesis Report, Summary for Policymakers. Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Lamoree, G. and Nilsson, A. 2000. A process approach to the establishment of international river basin management in Southern Africa. Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere. Vol.25, (3), 315-323

Mavume, A and Brundrit, G. 2009. Main Report: INGC Climate Change Report. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Rui (eds.)]. INGC, Mozambique.

Metzger, M. 2009. Main Report: INGC Climate Change Report. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Rui (eds.)]. INGC, Mozambique.

Ministry of Agriculture and Rural Development, Mozambique Website (MINAG) [online]. Available at: http://www.moa.gov.mz/

Ministry of Coordination of Environmental Affairs (MICOA). 2007. National Adaption Programme of Action (NAPA). Available at: http://unfccc.int/resource/docs/napa/moz01.pdf

Munich Re Group Website [online]. Hurricanes - More intense, more frequent, more expensive. Insurance in a time of changing risks. Available http://www.munichre.com/publications/302-04891_en.pdf

National Directorate for Forests and Wildlife (DNFBB). 2002.

Institute of Agricultural Research of Mozambique (IIAM). 2008.

National Institute for Hydrography and Navigation, Mozambique (INAHINA). 2008.

National Institute of Meteorology of Mozambique Website (INAM) [online]. Available at: http://www.inam.gov.mz/climatologia [Accessed in January 2009]

Nicholls, R. and Tol, R. 2006. Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century. Philosophical Transactions of the Royal Society, 364 (1841), 1073-1095.

Obura, DO (2005) Resilience and climate change: lessons from coral reefs and bleaching in the Western Indian Ocean. Estuarine, Coastal and Shelf Science 63 (3), 353-372.

Queface, A. and Tadross, M. 2009. Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

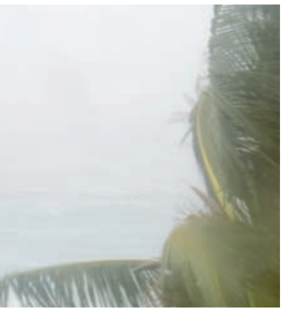
Sanchez del Valle. 2009. Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

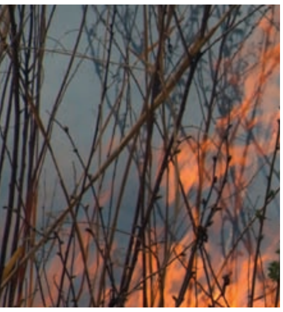
Scholes R.J. and Biggs R. (2004) Ecosystem services in Southern Africa: a regional assessment. A contribution to the Millennium Ecosystem Assessment, prepared by the regional-scale team of the Southern African Millennium Ecosystem Assessment.

Tadross, M. 2009. Climate change modelling and analyses for Mozambique in Main report: INGC Climate Change Report: Study on the impact of climate change on disaster risk in Mozambique. [Asante, K., Brito, R., Brundrit, G., Epstein, P., Fernandes, A., Marques, M.R., Mavume, A , Metzger, M., Patt, A., Queface, A., Sanchez del Valle, R., Tadross, M., Brito, R. (eds.)]. INGC, Mozambique.

Tauacale, F. 2002. Water Resources of Mozambique and the situation of the shared rivers.

World Health Organisation website (WHO) [online]. Available at: http://www.who.int/en/





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