National Institute for Disaster Management

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

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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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Acronyms

Acronyms	
BASICS	British Association for Immediate Care
CRED	Centre for Research on the Epidemiology of Disasters
CVM	Cruz Vermelha de Moçambique (Mozambique Red Cross)
DANIDA	Danish International Development Agency
DFID	United Kingdom Department for International Development
VDRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DRI	Disaster Risk Index
EM-DAT	Emergency Event Database
ENSO	El Nino Southern Oscillation
FEWS-NET	Famine Early Warning System Network
GCM	Global Climate Model or General Circulation Model
GDP	Gross Domestic Product
GGI	Greenhouse Gas Initiative
GIS	Geographic Information System
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)
HDI	Human Development Index
ICT	Information Communications Technology
IIAM	Institute of Agricultural Research of Mozambique
IIASA	International Institute for Applied Systems Analysis
INAHINA	National Institute for Hydrography and Navigation, Mozambique
INAM	National Institute of Meteorology of Mozambique
INGC	Instituto Nacional de Gestao de Calamidades (National Disaster Management Institute)
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
MICOA	Ministério para a Coordenação da Acção Ambiental (Ministry for Coordination of Environmental Affairs)
MINAG	Ministry of Agriculture and Rural Development
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPA	National Adaptation Plan for Action
NCAP	Netherlands Climate Assistance Programme
NGO	Non-governmental Organization
OND	October, November, December months
PARPA	Plano de Accao para a Reducao da Pobreza Absoluta (Action Plan for the Reduction of Absolute Poverty)
PET	Potential Evapotranspiration
PMI	Potential Moisture Index

Acronyms	
SADC	Southern African Development Community
SETSAN	Secretariado Técnico de Segurança Alimentar e Nutrição (Technical Secretariat for Food and Nutrition Security)
SLR	Sea level rise
SRES	Special Report on Emissions Scenarios
SVI	Social vulnerability index
SON	September, October, November months
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
VAC	Vulnerability Assessment Committee
WFP	World Food Programme

1

Climate Change Analyses

1.1 Climate change historical and baseline analysis

Dr. Antonio Queface, UEM

1.2 Historical overview of natural disasters

Dr. Antonio Queface, UEM

1.3 Climate change modeling and future analysis

Dr. Mark Tadross, UCT

Climate change historical and baseline analysis

Dr. Antonio Queface, UEM

1.1a Introduction

1.1b Past Trends in Mozambican climate

1.1a Introduction

Mozambique lies on the southeast coast of Africa between 10°S and 27°S. It has a long coastline which faces the tropical and sub-tropical Indian Ocean and which experiences a predominantly maritime climate. The climate of this coastal region is largely determined by the offshore warm waters of the Agulas current and the close proximity of tropical cyclones which pass mostly from the north to the south of the country. The mountainous region towards the northwest of the country, bordering Malawi, moderate the high temperatures usually found at these latitudes, whereas the deep wide valleys of the Zambezi and Limpopo rivers are regions of lower topography (see Figure 1.1). Generally temperatures are warmer near the coast (and the warm offshore ocean current) and cooler inland at higher altitudes.

Rainfall mostly falls in the summer warm season (November – April), especially when the Inter Tropical Convergence Zone (ITCZ) is in its most southerly position over the northern parts of the country. Over southern regions low intensity rainfall can also fall during the autumn, winter and spring seasons and may be associated with ridging anticyclones which bring moisture from the south. Rainfall is also influenced by local variations in altitude, with higher regions often experiencing more rainfall. Heaviest rainfalls are however associated with the passage of tropical cyclones which emanate from the tropical Indian Ocean and pass along the Mozambique channel usually from north to south, and can result in heavy floods such as those experienced in 2000.

Inter-annual variability of the climate of Mozambique is often associated with large scale global patterns of change such as the El-Niño Southern Oscillation (ENSO), the negative phase of which (El-Niño) usually results in drier conditions. Even so, Sea Surface Temperatures (SST) in the Indian Ocean (which sometimes are associated with El-Niño) exert a strong influence on the climate of Mozambique. Whilst warm SSTs in the Indian Ocean can lead to drier conditions inland (due to the offshore displacement of dominant rainfall producing systems), over coastal regions high SSTs in the Mozambique channel may increase humidity and rainfall.

This report details changes observed in the seasonal climate of Mozambique during the 1960-2005 period and presents downscaled future scenarios of climate over Mozambique, focusing on the mid-century (2046-2065) and late-century (2080-2100) periods. As such it provides additional information to that provided in other sources. These scenarios were used as a basis for this report, as well as the flood and crop-suitability modelling undertaken as other components of this project. Whilst the results of the flood and crop-suitability modeling are presented elsewhere, details of the data production and enabling process is presented here as it involved significant time and resources. However, the main purpose of this report is to understand how the climate of Mozambique may already be changing and how it may be expected to change in the future. It therefore serves as necessary background and context for the other studies undertaken as part of this project.

1.1b Past Trends in Mozambican climate

General Climate

Mozambique is located on the eastern coast of southern Africa between 10°S and 26°S, 30°E and 40°E. The climate is mostly tropical, characterized by two seasons; a cool and dry season from May to September and a hot and humid season between October and April. The rainfall distribution in the country follows a east-west gradient, with more abundant rainfall along the coast, where the annual average varies between 800 and 1200mm, reaching as high as 1500mm on the coastal areas of Beira and Quelimane. The inland high altitude areas in the north and central regions receive approximately 1000mm, whereas the inland central and south areas receive about 600mm of rainfall (Table 1). The South of Mozambique is generally drier, more so inland than towards the coast, with an average rainfall lower than 800mm, decreasing to as low as 300mm in Pafuri District, Gaza province (INAM, 2009).

Mozambique's coastal regions are in the path of highly destructive tropical cyclones that occur during the wet season, and which are often associated with heavy rainfall events that may contribute a significant proportion of annual rainfall in a very short period. Considering the 1980-2007 period the number of landfalling cyclones in Mozambique was fifteen (15), eight (8) of which made landfall in the central districts of the country while 4 and 3 made landfall respectively in the northern and southern regions. This clearly indicates that the central districts of Mozambique are more vulnerable to tropical cyclones than the northern and southern regions. On the other hand heavy rainfall associated with these cyclones at landfall may cause flooding that can impact several activities, damage to road and rail infrastructure. Rainfall totals in excess of 100-200mm are common with tropical cyclones that move over land. In March 2008, intense tropical cyclone Jokwe moved over northern Mozambique and its radial cloud bands with their high rainfall intensity caused rainfall in excess of 200mm in Nampula (some 150km inland). Other examples of wettest cyclones are found during TC Eline in 2000 (~500 mm), TC Delfina in 2003 (~281 mm), TC Japhet in 2003 (~190 mm) among others (Mavume et al., 2008).

Inter-annual variability in wet-season rainfall in Mozambique is very high, particularly in the central and southern regions, often with negative effects on rainfed agriculture. The most well documented cause of this variability is the El Niño Southern Oscillation (ENSO) which causes warmer and drier than average conditions in the wet season of Eastern Southern Africa in its warm phase (El Niño) and relatively cold and wet conditions in its cold phase (La Niña). The usual Tahiti minus Darwin sea level pressure (SLP) difference is used for Southern Oscillation Index (SOI). Negative SOI is correlated with El Niño events and the positive SOI with La Niña events. Evidence of an association between ENSO and rainfall in southern Africa has been documented in many studies (Miron and Tyson, 1984; Lindesay 1988, Rocha and Simmonds, 1997; Richard et al, 2000; Reason et al., 2000; Reason and Jagadheesha, 2005).

Monthly Total Precipitation (mm)								
	North		Central			South		Coastal
	Inland & high altitude north	Coastal north	Inland central	Inland high altitude central	Coastal central	Inland south	Coastal south	
Jan	239	154	167	221	249	123	151	184
Feb	215	166	150	237	266	121	140	186
Mar	214	219	84	150	245	81	118	177
Apr	91	101	19	56	137	40	71	98
May	28	38	6	22	72	27	63	62
Jun	3	25	3	13	52	16	41	42
Jul	3	13	3	20	68	15	42	46
Aug	1	8	1	18	35	16	27	26
Sep	9	2	1	20	23	24	37	27
Oct	22	8	15	47	41	45	48	39
Nov	89	33	48	89	92	73	86	79
Dec	202	110	137	199	213	98	124	151
Total	1 116	877	634	1 092	1493	679	948	1 117

Table 1.1: Baseline climatological values of monthly total precipitation (mm) for Mozambique
Source: Adapted from the online database of Mozambican National Meteorological Institute.

The influence of ENSO (as measured by the SOI) on late summer rainfall (JFM) has been found to be important in southern Africa (Rocha and Simmonds, 1997). The association is such that during the El Nino low phase of the Oscillation the cloud-band convergence zone moves offshore and with it the highest rainfalls. During the high phase cloud bands locate preferentially over southern Africa and rainfall is higher (Tyson and Preston-Whyte, 2000). The severe droughts of 1982-83 and 1991-92, which spread famine across the southern and central Mozambique including most of the southern Africa region was related with strong El Nino events. This relationship between ENSO and late summer rainfall can explain about 20% of rainfall inter-annual variability (Lindesay and Vogel, 1990).

Country-wide temperatures are warmest near the coast, compared with colder temperatures inland at higher elevations (Table 1.2). Typical average temperatures in these coastal parts of the country are 25-27°C in the summer and 20-23°C in winter. The inland and higher altitude northern regions of Mozambique experience cooler average temperatures of approximately 20-22°C in the summer, and 15-20°C in winter (INAM, 2009). The central region experience averages temperatures between 25-27°C in summer with exceptional high values reaching 29°C in Tete province. In winter the average temperatures of this region range from 22-25°C. The average temperatures in south region are 24-26°C in summer and 20-22°C in winter. The following table gives more details of the average temperatures values for different regions.

Monthly Minimum Average Temperatures (°C)

	North		Central			South		Coastal
	Inland & high altitude north	Coastal north	Inland central	Inland high altitude central	Coastal central	Inland south	Coastal south	
	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax
Jan	15	23	24	20	24	22	22	23
Feb	16	23	24	20	24	22	22	23
Mar	15	23	24	19	23	21	22	22
Apr	14	22	22	17	21	18	19	21
May	11	20	18	14	18	15	17	18
Jun	9	18	19	12	16	13	14	16
Jul	8	18	17	12	16	13	14	15
Aug	10	18	18	13	16	14	15	16
Sep	12	20	21	15	18	16	17	18
Oct	13	22	23	17	20	18	19	20
Nov	15	23	24	18	22	19	20	21
Dec	16	24	24	19	23	21	21	22

Monthly Maximum Average Temperatures (°C)

	North		Central			South		Coastal
	Inland & high altitude north	Coastal north	Inland central	Inland high altitude central	Coastal central	Inland south	Coastal south	
	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax	Tmax
Jan	26	31	34	29	32	33	31	31
Feb	27	31	34	28	32	32	31	31
Mar	26	31	33	28	31	31	30	30
Apr	25	30	33	26	30	30	29	29
May	24	29	30	25	28	28	27	28
Jun	23	28	29	23	27	26	25	26
Jul	22	27	29	23	26	26	25	26
Aug	24	27	30	24	27	27	26	26
Sep	27	28	35	27	29	29	27	28
Oct	29	29	36	28	30	30	28	29
Nov	30	30	35	29	31	31	29	30
Dec	28	31	34	29	32	32	30	31

Table 1.2: Baseline climatological values of monthly minimum and maximum averages temperatures for Mozambique. ***Source: Adapted from the online database of Mozambican National Meteorological Institute.***

Mean Climate and Observed Variability

Daily observed meteorological data for a period of forty six years (1960-2006), from twenty seven meteorological stations around Mozambique were used to set the baseline climate scenario. More information about station codes and location will be given in the next chapters. The data consisted of daily minimum and maximum air temperatures and rainfall. The data were supplied by the Mozambican National Meteorological Institute (INAM) as part of an agreement with the National Institute of Disaster Management (INGC). This study required a regional perspective for analysis of the different components; therefore the climatological information will be given for four geographical areas; North, Centre, South and Coastal as shown in Table 1.3.

Region	Provinces
North	Cabo Delgado, Nampula and Niassa
Central	Manica, Sofala, Tete, and Zambezia
South	Gaza, Inhambane and Maputo
Coastal	Maputo, Gaza, Inhambane, Sofala, Zambezia, Nampula e Cabo Delgado

Table 1.3: Regions and related provinces used in this study

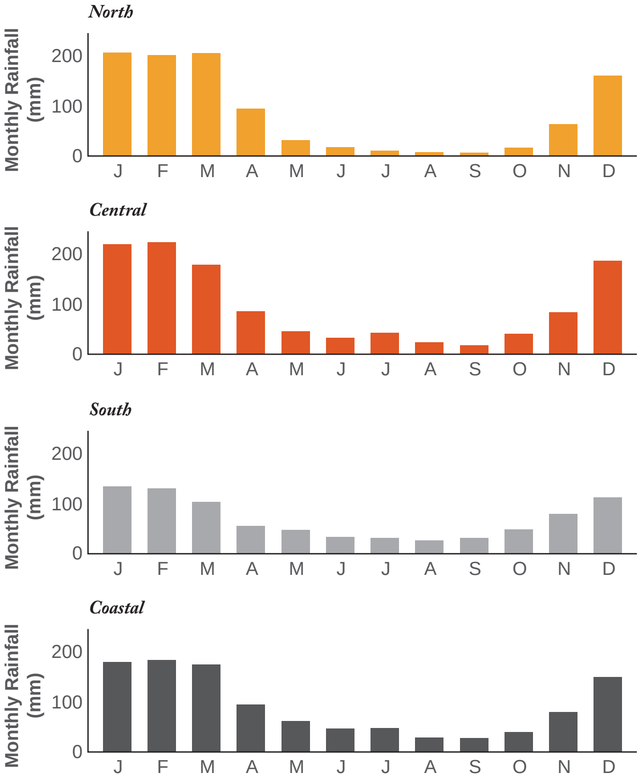


Figure 1.1: Seasonal variation of monthly mean rainfall in Mozambique.

Rainfall variability

Rainfall seasonal variation

Most of the rainfalls in Mozambique occur during the Southern Hemisphere summer, from October to April. Two seasons are usually distinguished early summer (October to December) and late summer season (January to March). During the rainy season, the highest values in amount of rainfall occur in January, February and March (Figure 1.1), corresponding about 45% of the total annual rainfall. Such precipitation is generally caused by migration and activity of the Inter-tropical Convergence Zone (ITCZ).

In north region typical values of monthly average rainfall are 20–200 mm/month in wet season and 5–30 mm/month in dry season. The central has approximately 30–200 mm/month for wet period and 20–40 mm/month in dry period. The south has the lowest recorded values of about 40–130 mm/month in wet season and 20–40 mm/month in the dry season. It is important to note that the dry season has relatively high rainfall values compared to the previous two regions due to the influence of active cold fronts in winter, which contribute to the rainfall in this region. The coastal region has significant rainfall of about 40–200 mm/month in wet season and 20–60 mm/month in dry season.

Along the coastal region in central Mozambique and inland high elevations areas of the central and north regions exceptional values well above 200 mm/month can be observed.

Rainfall spatial variability

The following map obtained from the Mozambican Meteorological office, illustrates the spatial distribution on the rainfalls annual mean across the country (Figure 1.2). It is noted that the majority of the country receives about 1000mm of rainfall per year. The rainfall amount decrease towards the inland areas in most regions of the Zambezi Valley and the region south of the Save River, where the low level of the fields does not cause relevant orographic influence. In these regions, in most of the areas of the Tete, Inhambane, Gaza and Maputo Provinces, as well as in parts of northern Manica and Sofala, the climate type is sub-humid, with a mean annual rainfall between 550 and 800mm. The region with the lowest mean annual rainfall is the area of Pafúri, in Gaza province with values below 400mm. Where the orographic influence becomes larger, across the higher outcrops in western Manica and Zambezia, northern Tete and Niassa, the rainfall values increase reaches an annual mean of 1300-1750mm. It should, however, be referred that Upper Zambezia records the highest mean annual rainfall, with values sometimes above 2000mm, in particular on the Namúli mountains.

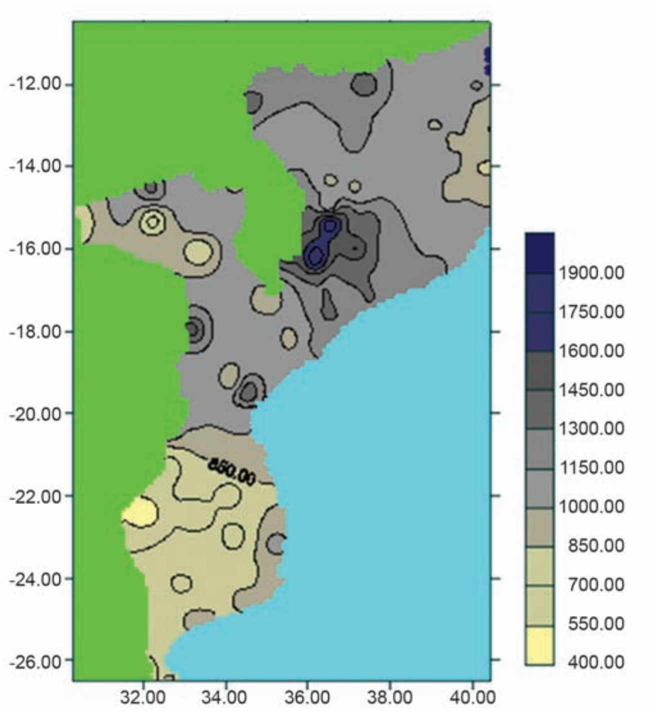


Figure 1.2: Spatial distribution of the annual mean rainfalls in Mozambique (Source INAM)

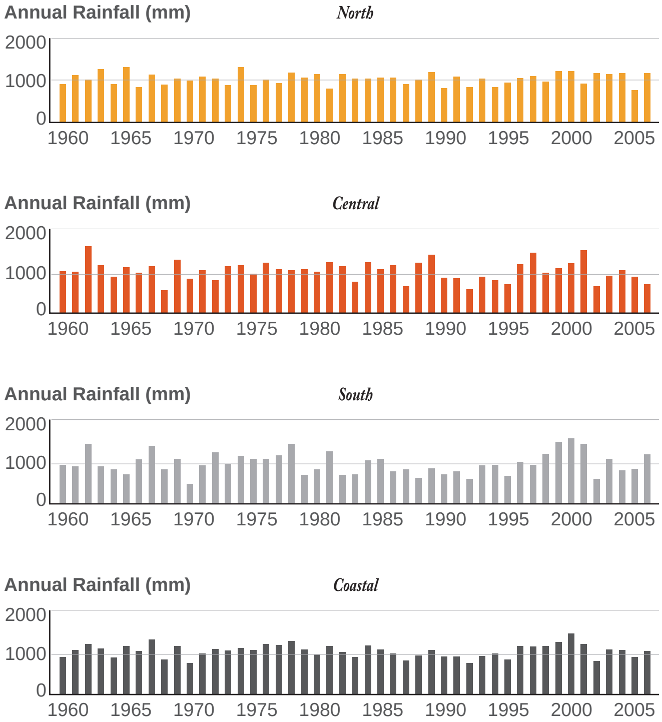


Figure 1.3: Annual observed precipitation for four different regions: North, Central, South and coastal represented by the four panels respectively.

Rainfall inter-annual variability

Figure 1.3 shows annual mean values of precipitation observed in four different regions from 1960-2006. The mean annual rainfall in north region is characterised by low inter-annual variability with annual means between 800 – 1200mm per year. The central region has higher spatial variability with the coastal provinces Sofala and Zambezia receiving the most rainfall – exceptionally high annual values as 1500mm can be recorded. In contrast Tete province which is inland receives the lowest amount - approximately 600mm per year. Southern Mozambique with an average rainfall of approximately 800mm is characterized by high inter-annual variability, with annual means of 400 mm (e.g. 1970) and well above 1000mm (e.g. 1962, 1967, 1978, 1999, 2000, 2001) being recorded in this region. Gaza province has the highest spatial variability in south, with the coast receiving frequently 800–1200mm of annual rainfall as recorded in Xai-Xai station, whereas the middle inland station of Chókwé receive about 400–800mm per year. The coastal region receive around 800 –1200mm/year, with the central coast receiving an exceptional values well above 1500mm. An inter-annual variability is also evident in this region with annual means of about 700mm (e.g. 1970, 1992, 2002) and well above 1000mm (e. g. 1967, 1978, 1999, 2000) being recorded.

Extremes of interannual climate variability can often create stress in many aspects of human life (Rocha and Simmonds, 1997). Floods and droughts have been recognized as a common occurrence in central and southern regions of Mozambique respectively. These can be observed by the rainfall deviations from the climatological average (between 1971 and 2000) for each region (Figure 1.4), which indicates whether extreme events, such as floods and droughts, occurred in each year and each region. In northern region the magnitude of floods and droughts is small compared with central, south and coastal regions. The central region is characterized by high frequency of floods, while the south has high frequency of droughts with extensive drought periods during the early 80's and late 90's. It is important to note that whilst droughts are more common in the south, the magnitude of floods in this region can be very high and cause high damages. Coastal rainfall deviations characterized by the similar signature of the south region, may be due to high data density in the South compared with the Centre and North.

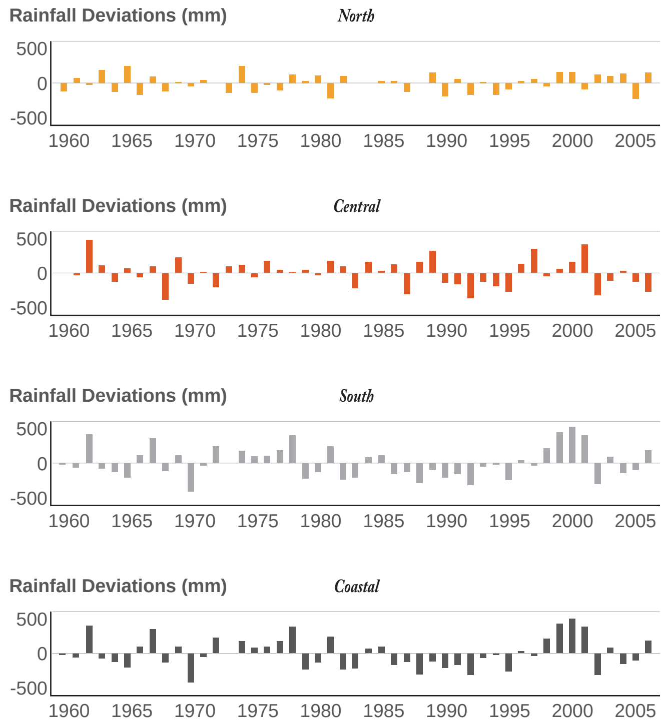


Figure 1.4: Rainfall deviations showing the likelihood for occurrence of floods and droughts in the four different regions: North, central, south and coastal.

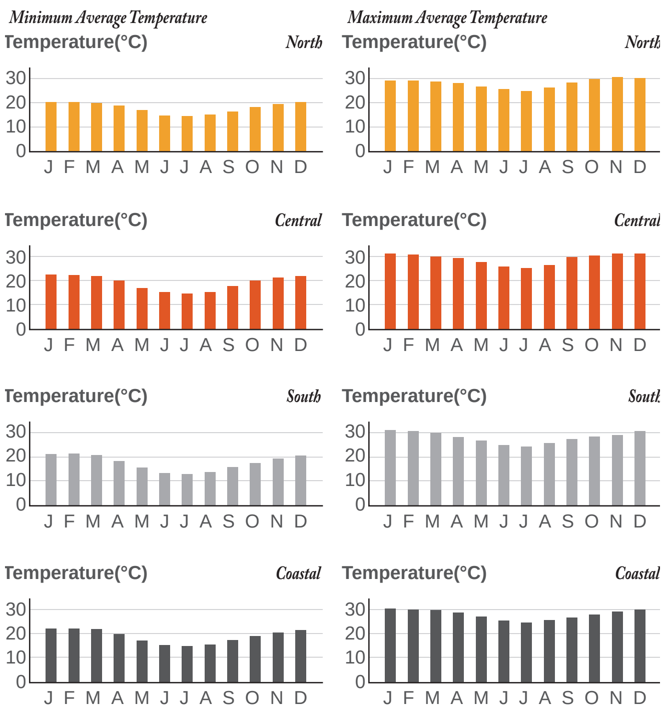


Figure 1.5: Seasonal variation of minimum and maximum averages temperatures in Mozambique

Temperature variability

Temperature seasonal variability

Monthly means of minimum and maximum temperatures for north, central, south and coastal regions are presented in figure 5. It is noted that between May and September is the period with lower temperatures (winter), October and April with high temperatures (summer). In general country wide monthly minimum average temperatures range between 18 - 22°C in summer and 14-18°C in winter. Furthermore the northern region has the lowest recorded minimum temperatures. Monthly maximum average temperatures are typically between 28-32 °C in summer and 24-28°C in winter. The central and coastal has the highest maximum temperatures along the country.

Temperature inter-annual variability

Annual means of both minimum and maximum temperatures from 1960 to 2006 shows significant changes in all regions, particularly from the early 1990's (Figure 1.6). In the North the annual maximum average temperatures where often below 30°C before the 90's and constantly above 30 °C after 1990 (Figure 1.6 left). The Centre has recorded average temperatures around 31°C before 90's; with sharp increase after this year. However, this increase should be taken carefully due to very low meteorological data coverage in central Mozambique, where the upgrade of the meteorological network is matter of urgency. The south region has typical annual maximum average temperatures around 31°C with a slight increase over the period 1960-2006.

Annual mean minimum temperatures show noticeable increase in north and south regions (Figure 1.6 right). The sharp change beyond 1995 in the Centre should be viewed with caution. However, it is evident that minimum average temperatures are often around 21°C. The increase in minimum temperature will lead to decrease on cold days. For instance, McSweeney et al. (2008) report that the frequency of cold days and nights have decreased significantly since 1960 in all seasons except SON. The average number of 'cold 'days per year has decreased by 14 (3.9% of days) between 1960 and 2003 and the average number of 'cold' nights per year has decreased by 27 (7.4% of days).

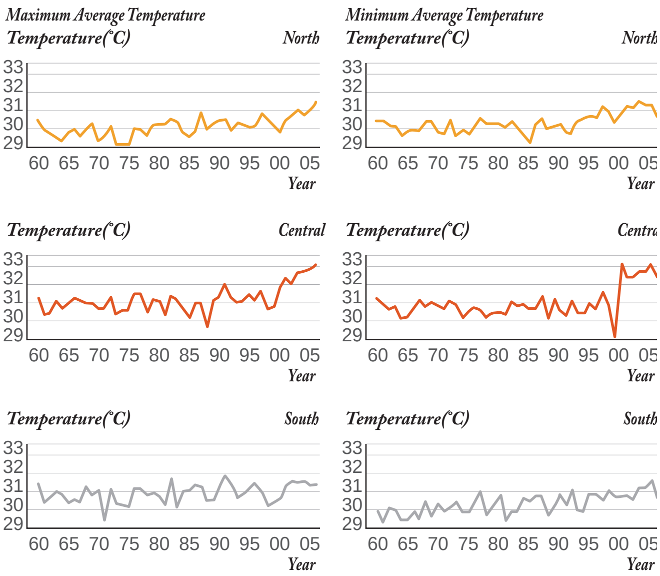


Figure 1.6: Annual mean maximum temperature (left) and annual mean minimum temperature (right) for north, central and south Mozambique.

Observed historical trends

Rainfall

Figure 1.3 (upper panel) shows how rainfall patterns in northern Mozambique have tended to increase in the last two decades. The Centre reveals unstable climate condition where droughts and floods of variable magnitude have been affecting the region and no clear trend can be detectable. It is relevant to note that central Mozambique represents the biggest area of the subdivision for this study, but it is hampered by lack of availability of historical meteorological data. The south was dominated by consistent long drought periods with a sudden shift to high magnitude floods around year 2000.

Temperature

Averages temperatures tend to increase country wide by different magnitudes depending on the location. If these trends are to remain in near future it seems that some places in the North will experience floods more frequently. The Centre requires greater monitoring for all type of natural disasters and weather related parameters in this region needs to be extended and improved as matter of urgency as climate change is happening. For southern Mozambique an integrated effort to deal with droughts and shorter wet seasons is needed. Finally, based on possible trends where there are uncertainties, it can be concluded that community preparedness in disaster risk reduction should be the front line in the next few years.

Historical overview of natural disasters

Dr. Antonio Queface, UEM

The following sections summarizes the available and accessible data about natural disasters affecting Mozambique. The objective is to provide as comprehensive a view of current disaster data to better understand their impacts and trends in Mozambique.

Criteria for selecting databases

Setting the criteria for selecting natural disaster databases for analysis was required but proved to be a challenging exercise as there exists no agreed central definition for "natural disaster". The lack of detailed methodological information that is publicly available raises issues of the transparency of databases and also makes comparability difficult.

The criteria for inclusion of an event as disaster for this study followed the current methodology of the Emergency Disasters Data Base (EM-DAT) as follows: ≥ 10 people killed, and/or ≥ 100 people reported affected, and/or a declaration of a state of emergency, and/or a call for international assistance (http://www.em-dat.net).

The national natural disaster database for Mozambique is compiled by event type and recorded information includes number of people killed/affected and economic losses. There is an effort to classify the magnitude of events when possible or if clear methodologies thus exist.

Description of databases sources
Natural disasters types included in this analysis cover the following: Droughts, Floods, Tropical Cyclones, Wind storms, Epidemics and Earthquakes.

The information presented in this document is derived from a variety of sources. Two national sources covering the period of 1980 up to 2008 and four international sources covering more extend period. The cumulative databases cover the period 1956-2008.

National databases
National data was derived from the National Institute for Disaster Management (INGC) and the FEWSNET Mozambique.

International databases
Internet searching for disaster databases produced an innumerate number of references thus inclusion criteria were employed to identify references most useful to Mozambique as follows:

Centre for Research on the Epidemiology of Disasters (CRED): EM-DAT
The Emergency Disasters Data Base (EM-DAT) is a publicly accessible international database collecting information on natural and technological disasters, and is managed by the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, Belgium. The data can be accessed at http://www.em-dat.net.

Under the EM-DAT methodology, an event is commonly considered a disaster when, ≥ 10 people killed, and/or ≥ 100 people reported affected, and/or a declaration of a state of emergency, and/or a call for international assistance. Because of the ambiguity or absence of definitions in other sources this criteria was used to compile the entire national database.

Global Disaster Identifier Number (GLIDE)
GLIDE is a project initiated and maintained by the Asian Disaster Reduction Center (ADRC). A GLIDE number is generated for all disaster events. The aim is to attach the number to all databases documenting the same disaster thereby linking the various information sources. The GLIDE database is available online at http://www.glidenumber.net. It is searchable by date, disaster type, country, and GLIDE number.

British Association for Immediate Care (BASICS)
The British Association for Immediate Care (BASICS) is a U.K. based charity, which maintains a database of natural and technological disasters. The database is searchable by accessing the following URL http://www.basedn.freeserve.co.uk/. It is also possible to access the website via another URL on an associated webpage: http://www.basics.org.uk/data/searchPage.php. There is no methodology provided to suggest sources of information or inclusion criteria.

Münich Reinsurance Company: NatCat
NatCat is a private international level disaster database maintained by Munich Reinsurance Company. NatCat collects information on natural disasters (excluding technological disasters) and entries cover a period from 79AD to the present (although only major events are recorded prior to 1980). Data can be accessed at http://mrnathan.munichre.com

Historical overview of past natural disasters affecting Mozambique

The main disasters events affecting Mozambique are weather related phenomena's, associated with an outbreak of epidemics. Annex I, shows the major disasters occurred and registered in Mozambique. This information is sorted by decade, by event and includes number of people killed, affected and damage as economic losses. The available data used in this study cover the period from 1956 up to 2008, comprising 67 entries.

Country wide the most common events affecting Mozambique are floods, epidemics and tropical cyclones. Figure 1.7 shows that floods count for about 30%, epidemics for 27% and 19% for tropical cyclones of natural disasters affecting Mozambique.

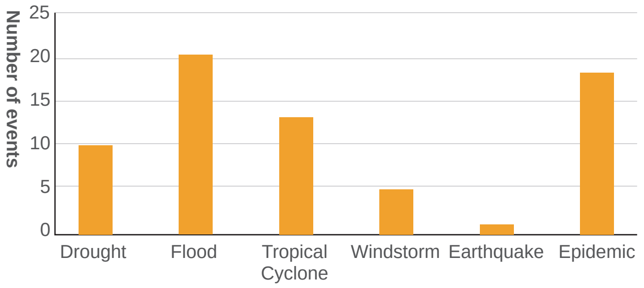


Figure 1.7: Frequency distribution of total number of natural disasters occurred from 1956 to 2008.

One crucial question alongside the climate change issue is whether or not the number of natural disasters is growing? The answer to this question needs a careful analysis due to lack of homogeneity on collected data about natural disasters. Since the 80's data collection methods have improved worldwide, one can observe an increasing number of events during the last three decades. Figure 1.8 shows a significant increase in the number of disasters since the 80's, with the growing rate of floods and epidemics dominating the last two decades of 20th and early 21st centuries.

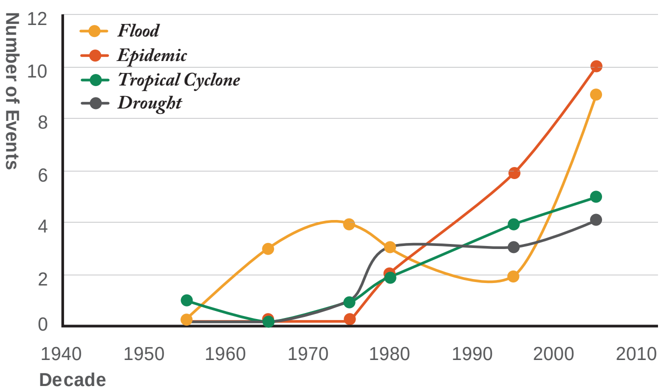


Figure 1.8: Historical trend of natural disasters in Mozambique (1956 -2008).

Overview of past natural disasters by region

The historical database shows that the four events that are the most likely to occur in Mozambique, namely: Floods, Tropical Cyclones, Droughts and Epidemics. For a better understanding of the level of vulnerability by region (South, Central and North) a total number of events by disaster type are described for different regions (Figure 1.9). It is observed that the Centre is the most disaster prone followed by the South, while the North is likely to have fewer disasters.

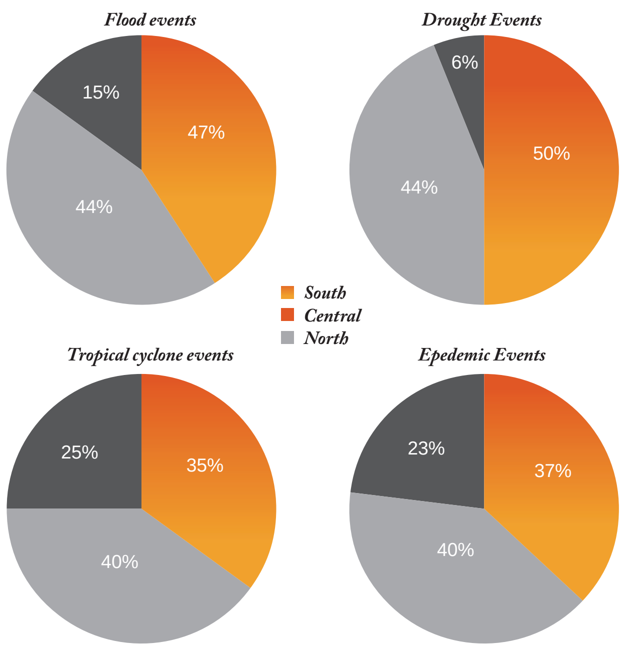


Figure 1.9: Total number of the four common events occurred in the different regions.

According to the database, floods are much common in the Centre and South; tropical cyclones affect more of the Centre and South. Droughts occur more frequently in South and Centre of the country. Epidemics are likely to affect the Centre and the South. However, the North is less prone compared to other regions it is noted that tropical cyclones and epidemics are matter of concern in this region.

The main impacts of natural disasters

The main impacts of natural disasters are expressed by the number of people killed, affected and damage as economic losses. It is important to stress the lack of information and reliability of the economic losses included in the database. Most of the time this figure is measured by the amount of aid requested by the country, to cover the basics needs, after the disaster has occurred.

Table 1.4 shows the top ten deadiest disasters occurred in Mozambique between 1956 and 2008. It is evident that, the long-lasting drought between 1981 and 1985 has killed thousand of thousands of people across the central and south Mozambique. This single event was the deadiest disaster ever affected the country. It is important to note that during the same period Mozambique was under a civil war with many people displaced, limited access country wide and deficient food production system. All these constraints may aggravate the impact of this particular disaster. On the other hand floods and epidemics are the most frequent killer around the country.

Table 1.5 shows the top ten natural disasters sorted by number of people affected, which reveal that drought events are the number one in terms of number of people affected. Nevertheless a single flood event in 2000 occurred in short period (few weeks) have affected millions of people compared to the prolonged drought of 1981/1985. These facts need a careful consideration from the disaster management actors, for better identification of priorities on population assistance.

N°	Disaster type	Year	Location	Number of Killed
1	Drought	1981/1985	Maputo, Gaza, Inhambane, Manica, Sofala and Zambezia	100,000
2	Flood	2000	Maputo (Matutuine, Manhiça, Magude and Marracune), Gaza (Mabalane, Chokwé, Chibuto, and Xai-Xai), Inhambane, Sofala, Manica and Tete	800
3	Epidemic	1997/98	Maputo City, Maputo, Gaza, Inhambane, Manica, Sofala, Tete and Zambezia	619
4	Epidemic	1990		588
5	Epidemic	1992		587
6	Flood	1971	Zambezia Region	500
7	Flood	1977	Gaza	300
8	T. Cyclone	1994	Nampula, Zambezia, Manica and Sofala	240
9	Epidemic	1983	Maputo, Gaza, Inhambane, Manica, Sofala and Zambezia	189
10	T. Cyclone	1984	Maputo, Gaza, Inhambane	109

Table 1.4: Top ten natural disasters: Number of killed.

N°	Disaster type	Year	Location	Number of Killed
1	Drought	1981/1985	Maputo, Gaza, Inhambane, Manica, Sofala and Zambezia	5,750,000
2	Flood	2000	Maputo (Matutuine, Manhiça, Magude and Marracune), Gaza (Mabalane, Chokwé, Chibuto, and Xai-Xai), Inhambane, Sofala, Manica and Tete	4,500,000
3	Drought	1991/1992	South and Central Mozambique	3,300,000
4	Drought	1998/99	Maputo, Gaza and Inhambane	3,300,000
5	T. Cyclone	1994	Nampula, Zambezia, Manica and Sofala	2,000,000
6	Drought	1994/95	Central and South	1,500,000
7	Drought	2005/2006	Maputo, Gaza, Inhambane, Sofala, Manica, Tete and Zambezia	1,400,000
8	Drought	2002/2003	South and Central provinces	600,000
9	Flood	2001	Zambezia, Tete, Sofala, Manica and Gaza	549,326
10	Drought	2007	South and Central provinces	520,000

Table 1.5: Top ten natural disasters sorted by number of people affected.

A general understanding of the impacts caused by all disasters accounted in our data base can be viewed in Table 1.6.

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 1.6: Summary of the impacts of natural disasters between1956 and 2008.

Droughts and floods are the main events affecting the majority of the population in disaster prone areas in Mozambique. Floods and epidemics are the most common events followed by tropical cyclones.

The number of people killed is very high for droughts; a single event with duration of five year (1981 to 1985), killed about 100,000 people. If this information is presented graphically it gives an idea that only droughts count for deaths (Figure 1.10a), because other numbers in the same field became insignificant.

Looking at the same results without the terrible events, if we consider that this occurred during the civil war and the ability to assist the population or to produce food was limited. Therefore the number of deaths was aggravated by war. Under these circumstances it is noted that epidemics and floods count for more deaths due to natural disasters (Figure 1.10b).

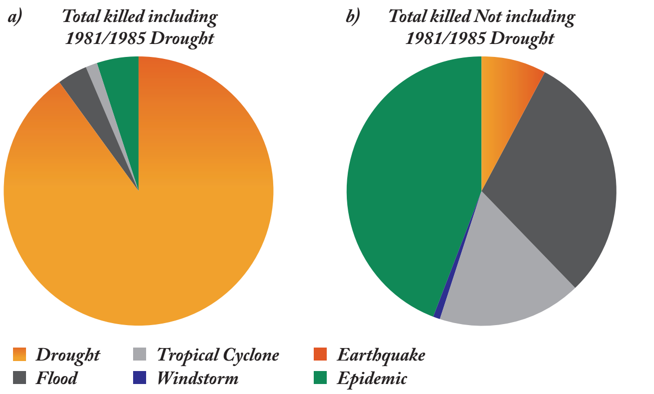


Figure 1.10: Total of people killed by natural disasters from 1956 and 2008, with severe 1981/1985 drought (4a) and without this event (4b).

Another question of concern when we look at the way Mozambique is managing the natural disaster could be: Are the impacts of natural disasters growing?

Given the fact that floods are the most common disaster affecting the country, we can draw some information related to the trends on number of people killed or affected along the many decades of data collection.

Figure 1.11 reveals that prior to year 2000 around half a million people where frequently affected by each flood event. The worst case occurred in 2000 when 4.5 million people were affected and eight hundred killed. For visualisation purpose of the number of people killed and affected in the same scale a log scale was applied to the y axis. The year 2000 was a significant turning point and important lesson for disaster management related institutions. Since 2000 a lot of effort has been made to reduce the number of victims killed as demonstrated in Figure 1.11 .

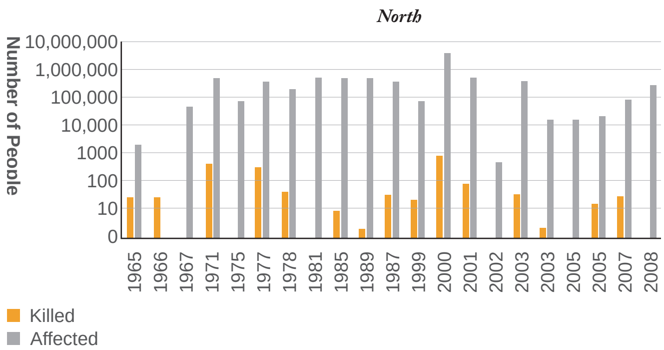


Figure 1.11: Number of people affected and killed by floods along the recorded database.

Climate change modeling and future analysis

Dr. Mark Tadross, ICT

1.3a	*Global and regional climate trends*
1.3b	*Station data used for the climate analyses*
1.3c	*Observed trends in the historical record*
1.3d	*Projected changes for 2046-2065 from downscaled GCMs*
1.3e	*Changes in regional climate*
1.3f	*Climate change scenarios for flood and crop-suitability modelling*
1.3g	*Reconciling observed and expected future change*
1.3h	*Recommendations for further work and analyses*

1.3a Global and regional climate trends

It is widely recognized that there has been a detectable rise in global temperature during the last 40 years and that this rise cannot be explained unless human activities are accounted for[1]. However, the regional distribution of temperature increases are not uniform and some regions have experienced greater change than others, especially the interior of continental regions such as southern Africa (see Figure 1.12). This is consistent with detected increases in annual temperatures found over southern Africa since 1900[2]. Additionally these changes in temperature are associated with decreases in cold extremes accompanied by increases in hot extremes[3]. Furthermore, the global average temperature indicates an increasing rate of change, such that temperature is rising quicker during the latter half of the 20th century (see Figure 1.12). Importantly, this increase in the rate of change is expected to continue, potentially resulting in more rapid changes of climate in the future.

Changes in rainfall are typically harder to detect due to its greater variability, both in time and space. Even so, changing rainfall patterns have been detected for many parts of the globe, including moderate decreases in annual rainfall over southern Africa. Where records are of sufficient length there have been detectable increases in the number of heavy rainfall events[4] and within the southern hemisphere there is evidence for a moistening of the tropics and subtropics[5]. This is consistent with regional studies over continental southern Africa which have shown trends for an increasing length of the dry season and increases in average rainfall intensity[3]. This has important implications for the seasonality of regional rainfall and together suggests a shorter but more intense rainfall season.

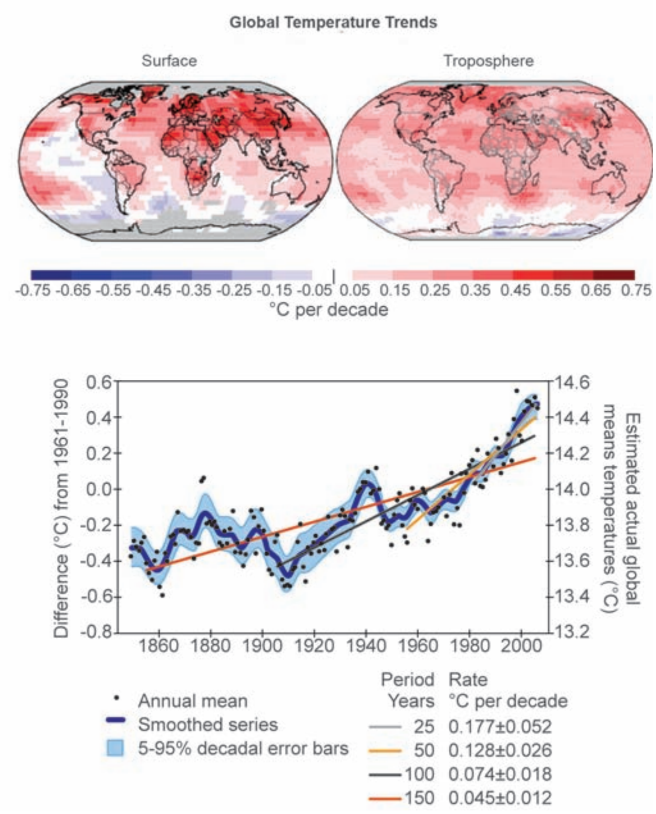


Figure 1.12: Distribution of global temperature trends (1979-2005) for the surface (left) and troposphere (right) from satellite records. Below: the average global temperature since 1850 indicating the increased rate of change during the later part of the 20th century4.

Besides changes in temperature and rainfall, other aspects of global change are notable1:

- Increases in intensity and spatial extent of droughts since the mid-1970s
- Decreases in northern hemisphere snow cover
- Increases in the duration of heat waves during the latter half of the 20th century
- Shrinking of the arctic sea ice pack since 1978
- Widespread shrinking of glaciers, especially mountain glaciers in the tropics
- Increases in upper-ocean (0-700m) heat content
- Increases in sea level at a rate of 1.8 mm yr^{-1} between 1961 and 2003, with a faster rate of 3.1 mm yr^{-1} between 1993 and 2003.

There is therefore compelling evidence for climate change at the global level, attribution to human activities, as well as its effects on continental southern Africa. However, understanding how global climate change may affect individual countries and small regions within a country is still a matter of research and is inherently linked to issues of uncertainty (see Box 1). So whilst the observed global level changes serve to highlight that climate change is a reality and that we have confidence in continuing and potentially accelerating change, it is necessary to explore how local climates may already be changing as well as how they are expected to change in the future.

Notes

[1] IPCC (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, New York, US, Cambridge University Press.

[2] Hulme, M., R. Doherty, T. Ngara, M. New and D. Lister (2001). African Climate Change: 1900-2100. Climate Research 17(2): 145-168.

[3] New, M., B. Hewitson, D. B. Stephenson, A.Tsiga, A. Kruger, A. Manhique, B. Gomez, C. A. S. Coelho, D. N. Masisi, E. Kululanga, E. Mbambalala, F. Adesina, H. Saleh, J. Kanyanga, J. Adosi, L. Bulane, L. Fortunata, M. L. Mdoka and R. Lajoie (2006). Evidence of trends in daily climate extremes over southern and west Africa. Journal of Geophysical Research 111. D14102, doi:10.1029/2005JD006289

[4] Solomon, S., D. Qin, M. Manning, R. B. Alley, T. Berntsen, N. L. Bindoff, Z. C. A. Chidthaisong, J. M. Gregory, G. C. Hegerl, M. Heimann, B. Hewitson, B. J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T. F. Stocker, P. Whetton, R. A. Wood and D. Wratt (2007). Technical Summary. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manning et al. Cambridge, UK. New York, US, Cambridge University Press

[5] Zhang, X., F. W. Zwiers, G. C. Hegerl, F. H. Lambert, N. P. Gillett, S. Solomon, P. A. Stott and T. Nozawa (2007). Detection of human influence on twentieth-century precipitation trends. Nature 448: 461-465

1.3b Station data used for the climate analyses

The data and analyses within this report show some of the changes noted in the historical records (trends) of climate in Mozambique and those changes projected for the future 2046-2065 and 2080-2100 periods from a suite of 7 downscaled GCMs. Both the historical trends and future projections were derived from daily (maximum and minimum) temperature and rainfall measurements since 1960 from 32 synoptic weather stations within Mozambique. These data were supplied by the Instituto Nacional de Meteorología de Mozambique (INAM). A list of the 32 stations, as well as their geographical locations, is provided in Table 1.7.

Due to constraints requiring a minimum of 10 years of daily data post-1979 for the statistical downscaling there were only 30 stations with sufficient rainfall data and 27 stations with sufficient temperature data. Therefore only the 27 stations with sufficient data for rainfall and temperature are used in the following analyses. Those stations provided by INAM and not meeting these criteria are highlighted in red in Table . Given Mozambique's land area of 784,090 km^2 this provides an approximate station density of 1 station every 29,000 km^2, which is much less than South Africa which has approximately 1,200 stations over a land area of 1,221,040 km^2 (approximately 1 station every 1,000 km^2).

Box 1: Understanding uncertainty and risk

The issue of uncertainty is crucial to understanding past and future climatic change, especially when designing adaptation strategies that will benefit both present and future socioeconomic situations. Uncertainty does not mean that we have no confidence in our projections of future climate. Indeed all climate projections, including seasonal forecasts, are couched in terms of probability of certain climate conditions appearing in the future. This is the framework within which humans often operate, allowing an assessment of future risks, e.g. consideration of financial and investment opportunities.

To be able to assess risk, one needs to consider all sources of information. It is therefore essential that a probabilistic framework is used to develop projections which should incorporate different sources of information. The IPCC define four sources of uncertainty that currently limit the detail of the regional projections:

1. Natural variability. Due to the limiting factor of observations (both in time and space) we have a limited understanding of natural variability. It is difficult to characterize this variability and the degree to which it may exacerbate or mitigate the expected background change in climate. This variability itself may change due to anthropogenic factors, e.g. increases in the frequency of droughts and floods;
2. Future emissions. Much of future projected change, at least in terms of the magnitude of change, is dependent on how society will change its future activity and emissions of greenhouse gases. Even so, the world is already committed to a degree of change based on past emissions (at least another 0.6ºC warming in the global mean temperature). Human responses to managing emissions may result in a projected global mean temperature change of between 1.5º and 5.6ºC;
3. Uncertainty in the science. This is complicated within Africa because current understanding of the regional dynamics of the climate of the continent is limited. There may be aspects of the regional climate system, which could interact with globally forced changes to either exacerbate or mitigate expected change e.g. land-use change. This could possibly lead to rapid nonlinear change, with unforeseen and sudden increases in regional impacts;
4. Downscaling – the term used to define the development of regional scale projections of change from the global models (GCMs) used to simulate the global response of the climate system. Downscaling tools can introduce additional uncertainty e.g. between downscaling using regional climate models and statistical techniques. Usually this uncertainty limits the confidence in the magnitude of the projected change with the pattern and sign of change often interpreted with greater certainty.

The location of the 27 stations meeting the criteria for downscaling are shown in Figure 1.13a. The stations are spread throughout Mozambique though they have a noticeable bias to be situated along the coast. Whilst this is not so noticeable in the north, the southern inland regions and to a lesser extent the central inland regions, have large areas without station measurements. This restricts how representative the following results can be for these inland regions, and for this reason it was necessary to use some station data from countries bordering Mozambique for both the preparation of the data for crop suitability modelling (see section 1.6.1) and the analysis of regional variations (see section 1.5).

Figure 1.13b shows the topographical variation within Mozambique, clearly showing the low lying coastal plain covering much of the country in the south and central regions (coloured green/blue). The higher mountains/plateaux inland and to the north are also clearly visible. Comparing Figure 1.13a and b indicates that the station network used in this anlysis misses potentially key areas such as the highland areas in Tete province (central west) and the low lying regions in Gaza province (southern inland). Figure 1.13c shows the regional zoning of Mozambique according to the Instituto de Investigação Agrária de Moçambique (IIAM), which was adopted for this study and is used for the regional analysis in section 1.5. It clearly shows that most of the stations are located in the coastal region, especially in the south where nearly all of the stations are in or close to the coastal region.

StationID	StationName	Latitude (°S)	Longitue (°E)	Elevation (m)
CD000013	MOCIMBOA DA PRAIA	-11.35	40.37	27.0
CD000014	MONTEPUEZ	-13.13	39.03	534.0
CD000022	MECUFI	-13.28	40.57	10.0
CD000034	PEMBA	-12.98	40.53	101.0
GZ008007	MANJACAZE	-24.72	33.88	65.0
GZ008010	MACIE	-25.03	33.10	56.0
GZ008032	XAI-XAI	-25.05	33.63	4.0
GZ008035	MANIQUENIQUE	-24.73	33.53	13.0
GZ008050	CHOKWE	-24.52	33.00	33.0
IB007003	INHAMBANE	-23.87	35.38	14.0
IB007004	INHARRIME	-24.48	35.02	43.0
IB007007	PANDA	-24.05	34.72	150.0
IB007010	VILANCULOS	-22.00	35.32	20.0
MN005015	CHIMOIO	-19.12	33.47	731.0
MN005032	MESSAMBUZI	-19.50	32.92	966.0
MN005045	SUSSUNDENGA	-19.33	33.23	620.0

StationID	StationName	Latitude (°S)	Longitue (°E)	Elevation (m)
MP009005	UMBELUZI	-26.05	32.38	12.0
MP009010	MANHICA	-25.37	32.80	35.0
MP009044	MAPUTO/MAVALANE	-25.92	32.57	39.0
MP009052	CHANGALANE	-26.30	32.18	100.0
NP002001	ILHA DE MOCAMBIQUE	-15.03	40.73	9.0
NP002006	RIBAUE/AGRICOLA	-14.98	38.27	535.0
NP002008	ANGOCHE	-16.22	39.90	61.0
NP002049	LUMBO	-15.03	40.67	10.0
NP002051	NAMPULA	-15.10	39.28	438.0
NS001002	CUAMBA	-14.82	36.53	606.0
NS001003	LICHINGA	-13.30	35.23	1,365.0
SF006053	BEIRA/AEROPORTO	-19.80	34.90	8.0
TT003002	TETE	-16.18	33.58	149.0
TT003053	ULONGUE	-14.73	34.37	1.0
ZB004001	QUELIMANE	-17.88	36.88	6.0
ZB004029	PEBANE	-17.27	38.15	25.0

Table 1.7: INAM synoptic weather stations for which daily rainfall and temperature measurements after 1960 were acquired.

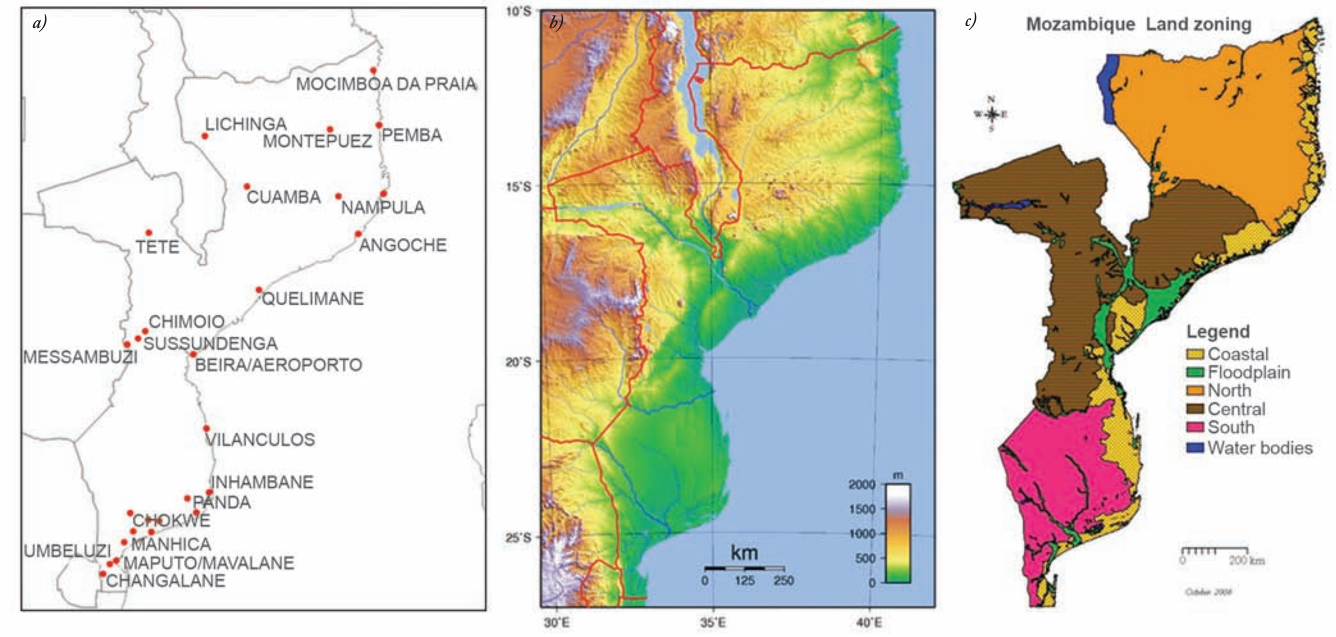


Figure 1.13: a) Location of synoptic weather stations used in the analysis of historical trends and for downscaling the future climate; b) Topographic map of Mozambique[6]; c) Land zoning map of Mozambique
Source: Instituto de Investigação Agrária de Moçambique

Quality control testing of station data

The data from each of the 27 stations underwent rigorous quality control, including checking for unrealistic rainfall and temperature values, as well as testing each timeseries for homogeneity. Suspicious data were set to missing values before proceeding with the tests for trends and using the data to downscale the future climate scenarios (see section 1.4).

Any data collected at a weather station must undergo quality control procedures. Such quality control procedures are generally flexible and there are no hard and fast guidelines as to what should be implemented. For example, complex statistical techniques that detect discontinuities in timeseries (usually indicating the relocation or deterioration of a sensor) can be used with historical data. Or alternatively, some relatively simple quality control tests can be used:

- Remove negative rainfall, or rainfall above station-specific unrealistic values;
- Remove where maximum temperatures and less than minimum temperatures or either are within 3 – 6 standard deviations of the long-term mean.

In this analysis it was decided to use the following tests and data was removed if it failed any of them:

- checking for negative rainfall;
- rainfall > 500 mm in one day;
- minimum temperatures greater than maximum temperatures;
- minimum and maximum temperatures greater than 6 standard deviations from the long-term (full dataset) mean value
- in-homogeneities due to changing instruments or location.

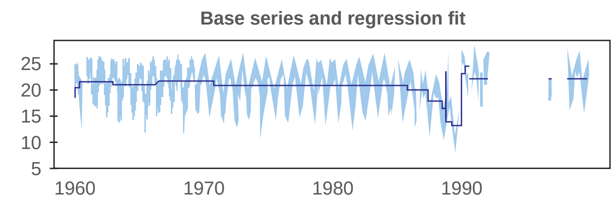


Figure 1.14: Timeseries of minimum temperature from Pebane station. Note the gradual degradation of the recordings from 1985 to 1990.

The first 4 steps were completed before undertaking the 5th step. The 5th test utilised software distributed by ETCCDMI[7,8]. Even so there were still a number of identified problems. These mostly appear to relate to sensor degradation an example of which is given in Figure 1.14. In this figure the measurements deteriorate between 1985 and 1990 – if the change was immediate and occurred only once then it could be due to a change of sensor or location but in this case it seems the sensor gradually degraded during the period. Whenever changes such as those in Figure were discovered the data was set to NA (not available or not recorded).

Notes

[6] http://en.wikipedia.org/wiki/Geography_of_Mozambique

[7] http://cccma.seos.uvic.ca/ETCCDMI/software.shtml

[8] Wang, X. L., Q. H. Wen, and Y. Wu (2007) Penalized maximal t test for detecting undocumented mean change in climate data series. J. Appl. Meteor. Climatol., 46 (No. 6), 916-931. DOI:10.1175/JAM2504.1

1.3c Observed trends in the historical record

Studies of recent historical changes in climate within Mozambique are complicated by the significant regional variations in climate mentioned earlier, as well as natural variability on time scales of 10 years or longer. However, there is clear evidence that temperatures have increased, following the global trend and that the character of rainfall has changed appreciably. Whilst past trends are no guarantee of future change, especially in the context of uncertainty (Box 1), they are the foundation from which to assess current adaptation strategies to climate change and how they may be appropriate given future expected change.

To assess changes in climate the suite of seasonal and annual indices, developed under the STARDEX project, were calculated at each of the 27 INAM stations. These indices represent a broad range of rainfall and temperature characteristics that capture most aspects of the climate that are likely to be affected by climate change. They do not, however, capture changes in seasonality associated with changes in the start/end of the rains which is dealt with in section 1.3.3. Average trends between 1960 and 2005 were calculated for each index, geographically located, and then interpolated (kriged) to a 0.5 degree grid. The suite of 57 indices for which these calculations were performed (annually and for each of the SON: September to November; DJF: December to February; MAM: March to May; JJA: June to August and seasons are given in Annex 1. Given that this represents for each of the 27 stations a set of 285 indices, only those indices representing significant and spatially consistent trends are presented here.

Temperature

Not surprisingly the most consistent trends were found for indexes related to temperature; Figure 1.15 indicates trends in mean minimum temperatures for the four seasons (DJF, MAM, JJA and SON) whereas Figure 1.16 indicates the same for mean maximum temperatures. Significant trends (greater than 90 % confidence interval or p-value of less than 0.1) at each station are indicated by a "+"/"-", otherwise no symbol is used.

It is clear from these figures that most stations indicate significant increases in both mean minimum and mean maximum temperatures. The trends from individual stations were grouped according to the four regions defined in

The North, South, Central and Coastal areas and are shown in Table 1.8.

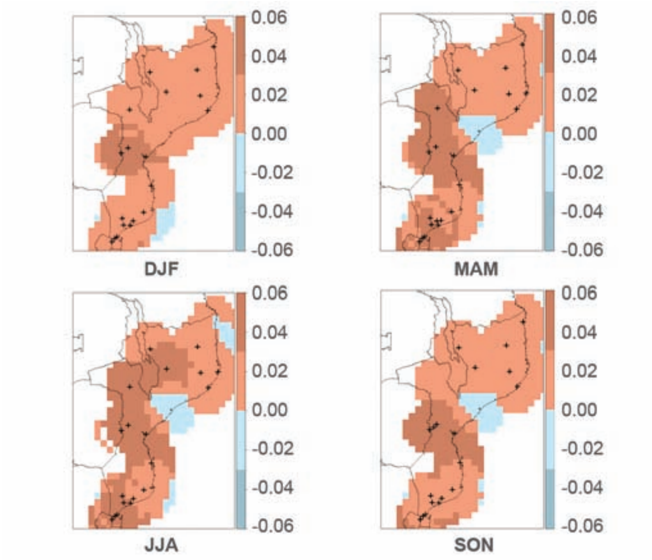


Figure 1.15: Trends in mean minimum temperature (1960-2005) for the four seasons DJF, MAM, JJA and SON (°C year^{-1}). "+"/"-" indicates positive/negative trends significant at the 90% confidence level.

Highest trends were greater than 0.03°C per year resulting in the highest average increase of 1.62°C during the 45 year period and over the central regions during JJA. Trends are particularly high for minimum temperatures during the late summer (MAM) and winter (JJA) periods, especially over the central and southern regions. Maximum temperatures indicate highest changes over the northern regions, particularly during the early (SON) and late (MAM) summer periods. Similar increases were also noted for the coldest (10th percentile) and hottest (90th percentile) nights (minimum temperatures) and days (maximum temperatures).

Spatially extensive and statistically significant increases in the duration of the longest heat waves were also noted, especially over the northern regions during SON (trends up to +0.2 days year^{-1} ≈ increase of 9 days between 1960 and 2005). It was also noted that the number of coldest nights and coldest days has been decreasing for all regions and all seasons (as much as 14% in MAM over central regions), whereas the number (frequency) of hot nights and hot days has been increasing (Table 1.19).

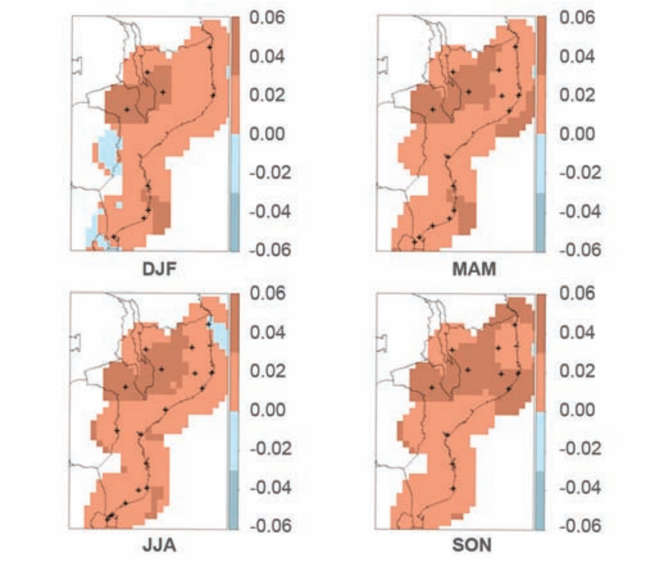


Figure 1.16: Trends in mean maximum temperature (1960-2005) for the four seasons DJF, MAM, JJA and SON (°C year-1). "+"/"-" indicates positive/negative trends significant at the 90% confidence level.

Broadly speaking the highest increases have been in the number of hottest nights, with annual increases greater than 12% in the north and central regions and the highest increase of 25% in the north during DJF. Even so the number of hottest days has also increased significantly over the whole of Mozambique, with the highest increases of 17% in the north during SON. This ties in with the changes in rainfall noted in the next section and is likely in part due to decreases in cloud cover, rainfall and evaporation, as well as increases in solar heating (due to less cloud cover).

Rainfall

Trends in rainfall indices were much more heterogeneous than those for temperature. Whilst there are statistically significant increases in some intensity related indices at specific locations and for specific periods, the most spatially consistent changes were found for indices related to rainfall frequency. Figure 1.17 shows trends in mean dry day persistence (the probability of having one dry day following another) for the spring and autumn seasons. The figure indicates that during these seasons over the north-eastern regions (Cabo Delgado/Nampula) the probability of consecutive dry days has been increasing. Consistent with these trends increases were also noted in mean dry spell length over these same regions. Trends in dry spell length are greatest in SON (Figure 1.18), increasing by as much as 20 days between 1960 and 2005, and which likely reflect a delay in the end of the dry season.

	Average maximum temperatures					Average minimum temperatures				
	DJF	MAM	JJA	SON	Annual	DJF	MAM	JJA	SON	Annual
North	0.76	1.16	0.93	1.15	1.02	0.88	0.84	0.88	0.80	0.91
Central	0.40	0.98	1.11	0.95	0.92	1.12	1.38	1.62	1.15	1.21
South	0.50	0.98	0.90	0.65	0.77	0.69	1.27	1.35	1.14	1.17
Coastal	0.74	1.01	0.82	0.91	0.84	0.52	0.65	0.62	0.61	0.67

Table 1.8: Mean changes (per region) in average maximum and minimum temperatures (°C) between 1960 and 2005 for each of the four seasons and as an annual average.

	Frequency max. temp. above 90th percentile					Frequency min. temp. above 90th percentiles				
	DJF	MAM	JJA	SON	Annual	DJF	MAM	JJA	SON	Annual
North	8.29	13.82	15.11	17.29	14.08	25.20	16.46	7.84	14.01	17.04
Central	4.89	6.17	9.32	6.88	7.26	17.61	10.41	11.06	10.54	12.21
South	1.52	7.03	8.69	3.39	5.12	6.44	10.25	11.49	9.66	9.38
Coastal	5.03	8.70	9.79	7.73	7.50	11.25	8.21	3.60	7.76	8.70

Table 1.9: Mean changes (per region) in the frequency with which maximum and minumum temperatures are in the hottest 10%. Changes are the difference (as a percentage) between the average frequency in 1960 and the average frequency in 2005.

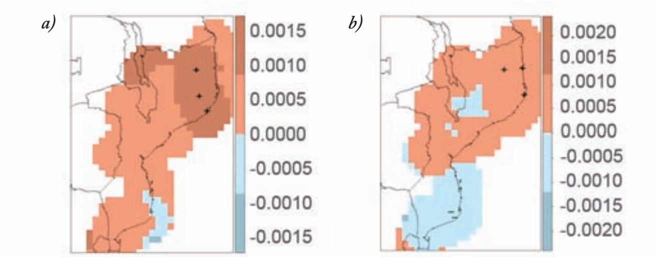


Figure 1.17: Trends in mean dry day persistence (1960-2005): a) MAM; b) SON (days year-1).

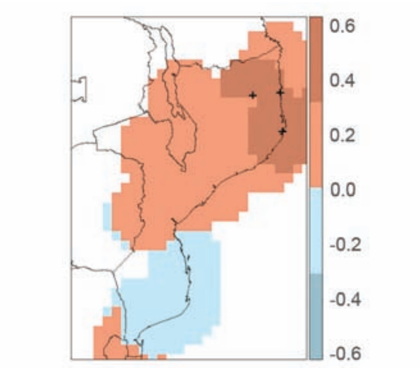


Figure 1.18: Trends (1960-2005) in mean dry spell length during SON (days year-1).

Changes in seasonal boundaries

As mentioned previously the STARDEX indices do not present information on potential changes in seasonal boundaries. We therefore developed indexes related to the start, end and duration of the season, based on rainfall as well as rainfall and potential evapotranspiration (PET; a measure of the evaporative potential of the atmosphere which increases as temperature increases). The rainfall only criteria assumed the season to have started when 45mm of rain fell in 30 days after August 1st and ended when less than 60mm fell in 30 days. The combined rainfall and PET criteria assumed that the start/end of the season was when the ratio of rainfall/PET was consistently above/below 0.5 for 30 days. Two criteria for defining seasonal boundaries were used as it is currently often the practice to use a rainfall only criteria whereas the rainfall/PET ratio more accurately reflects changes in moisture availability due to temperature changes, which will likely be a significant component under climate change. There are several methods for calculating PET, though due to data availability we were restricted to those approximate methods using only temperature. Both a modified Thornthwaite and Priestley-Taylor (P-T) method were tested with the P-T method eventually being used for the analysis (see discussion in section 1.4).

Very few spatially extensive and significant changes were detected in the seasonal boundaries. However, consistent with the changes noted in dry day persistence and dry spell length during SON there has been a trend for later starts to the rainfall season over the northern regions (see Figure 1.19). These trends are as high as 1 day year-1 leading to changes of up to 45 days between 1960 and 2005. Whilst there were less obvious and consistent changes in the end and duration of the rainfall season, a simple index of moisture availability (rainfall – 0.5PET summed for each day between the start and end of the season), which approximately measures the potential rainfall–evaporation during the season, indicates that these northern regions have had steady increases in rainfall – 0.5PET, despite increases in temperature/PET and later starts to the season. This indicates that either the rainfall season has shifted later to a period when convective rainfall is normally more intense or there have been increases in the average intensity of daily rainfall. Consistent with other studies3 we found non-statistically significant positive trends in mean daily rainfall intensity, but these were not clearly associated with the main rainfall season. Therefore it is likely the positive trends for moisture availability are mostly due to a shift of the rainfall season to a wetter period.

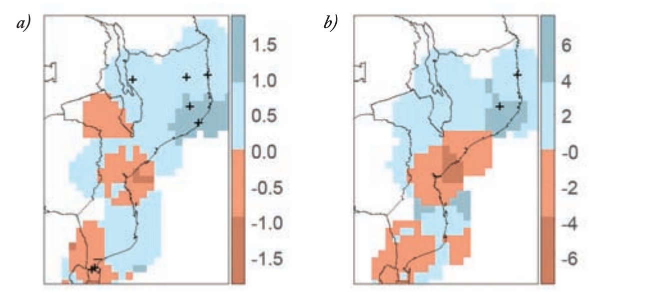


Figure 1.19: Trends in: a) start of the rainfall season (days year^{-1}). Trends in some northern regions suggest that the start of the rains fell up to 45 days later in 2005 than in 1960; b) rainfall – 0.5PET (mm day^{-1} year^{-1}) during the rainfall season.

Box 2: Is one GCM better than another at projecting future change?

Whilst some GCMs are better at simulating the present observed climate, this does not necessarily mean that they are better at simulating future change. Evaluating one GCM against another is also not an easy task; whilst one GCM may better simulate monthly mean rainfall and temperature it may not better simulate the daily frequency or diurnal cycle of rainfall. Another problem when trying to use a single GCM is that only a limited number of future scenarios can be used and this can sometimes create the impression of a narrowly determined future, which may not fully span the range of potential future change. It is therefore recommended that future change is expressed either as a range of future change or as an average statistic (e.g. median) with some measure or recognition of the spread of possible future states.

1.3d Projected changes for 2046-2065 from downscaled GCMs

General Circulation models (GCMs) are the fundamental tool used for assessing the causes of past change and projecting change in the future. They 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. In making projections of climate change, several GCMs and scenarios of future emissions of greenhouse gasses are used to predict the future (see Box 2). This leads to a suite of possible futures, each of which is a valid representation of what the future climate may be. That there is a range of future possibilities is an important concept to understand clearly as it means that we can only suggest futures that may be more likely than others.

GCMs typically work at a spatial scale of 200-300km, with the scales at which they have skill, i.e. at which they can usefully project the future, typically greater. Whilst this problem is greatest for projections of rainfall, it limits the application of GCM projections for assessments of change at the local scale. Therefore, the technique of 'downscaling' is typically used to produce projections at a finer spatial scale. Downscaling works because the GCMs are generally good at projecting changes in atmospheric circulation (high and low pressure) but do a poor job of translating that information into changes in rainfall. The projected changes in rainfall and temperature used in this project are therefore taken from the statistical downscaling of 7 GCMs downscaled to each of the station locations presented in Table 1.10. All 7 GCMs were used in the IPCC 4th assessment report and forced with the SRES A2 emissions scenario[9] (which assumes that society will continue to use fossil fuels at a moderate growth rate, there will be less economic integration and populations will continue to expand). Details of the GCMs are provided in Table 1.10. It was decided to initially concentrate on a range of GCMs from one emissions scenario as this range is mostly larger than the range between scenarios, certainly until mid-century. The reason for this is that the concentration of greenhouse gases, especially CO_2, will continue to grow under all scenarios and will largely only change towards the middle of the 21st century[9].

Originating Group(s)	Country	I.D.
Canadian Centre for Climate Modelling & Analysis	Canada	CGCM3.1(T63)
Météo-France/Centre National de Recherches Météorologiques	France	CNRM-CM3
CSIRO Atmospheric Research	Australia	CSIRO-Mk3.0
Max Planck Institute for Meteorology	Germany	ECHAM5/MPI-OM
US Dept. of Commerce/NOAA/Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.1
NASA/Goddard Institute for Space Studies	USA	GISS-ER
Institut Pierre Simon Laplace	France	IPSL-CM4

Table 1.10: GCMs used to downscale the projected climate for the 1960-2000, 2046-2065 and 2080-2100 periods[10]

The statistical downscaling used in this report is based on Self Organising Maps[11], the results of which have been used by the IPCC over Africa[12], and which will be referred to as the SOMD method[13]. The following figures show the differences in climate between the 1960-2000 and 2046-2065 periods, as simulated by the GCMs and downscaled via the SOMD method. Given the sparsity of stations in some regions, especially close to the borders with other countries, we included a range of stations from South Africa (provided by the Water Research Commission of South Africa), Swaziland, Zimbabwe, Zambia, Malawi and Tanzania (provided by the World Meteorological Organisation), all as close to the Mozambique border as was found in the relevent databases. Details of these extra stations are provided in Annex II.

Rainfall

Figure 1.20 shows the median change in rainfall from the 7 GCMs and for the 4 seasons: DJF, MAM, JJA and SON (changes for each individual GCM are shown in Annex III). The changes are interpolated (kriged) between stations. Any changes less than 0.1 mm day^{-1} are masked out as they are less than the increases in evapotranspiration (see section 1.4.3). The "+"/"-" symbol at each station location indicates if the median absolute deviation (a robust measure of standard deviation) of the variability from year to year increases or decreases in the future climate. This provides an approximate indication if seasonal rainfall variability can be expected to increase in the future.

Notes

[9] IPCC (2000) IPCC special report emissions scenarios: Special report of IPCC working group III. Intergovernmental panel on climate change. pp 20.

[10] http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php

[11] Hewitson, B. C. and R. G. Crane (2006). Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa. International Journal of Climatology 26(10): 1315-1337.

[12] Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R. K. Kolli, W.-T. Kwon, R. Laprise, V. M. Rueda, L. Mearns, C. G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton (2007). Regional Climate Projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manninget al. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press

[13] climate data downscaled via SOMD is available via the website http://data.csag.uct.ac.za

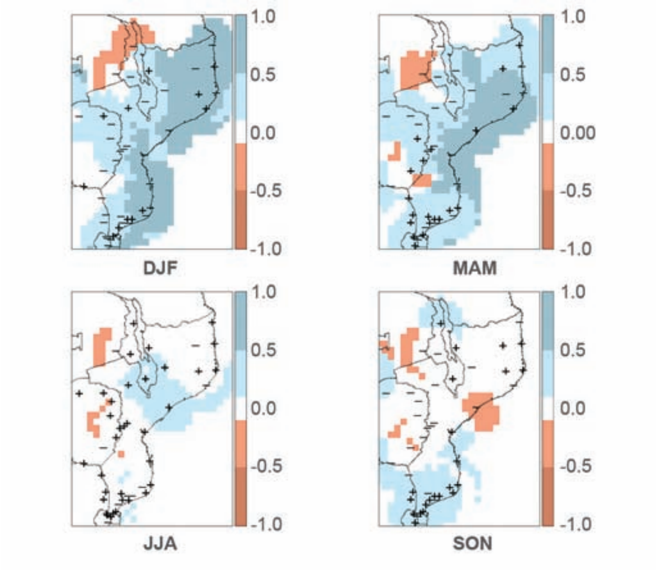


Figure 1.20: Median changes in future rainfall (mm day-1) from 7 GCMs. "+"/"-" indicates whether seasonal variability is expected to increase/decrease in the future.

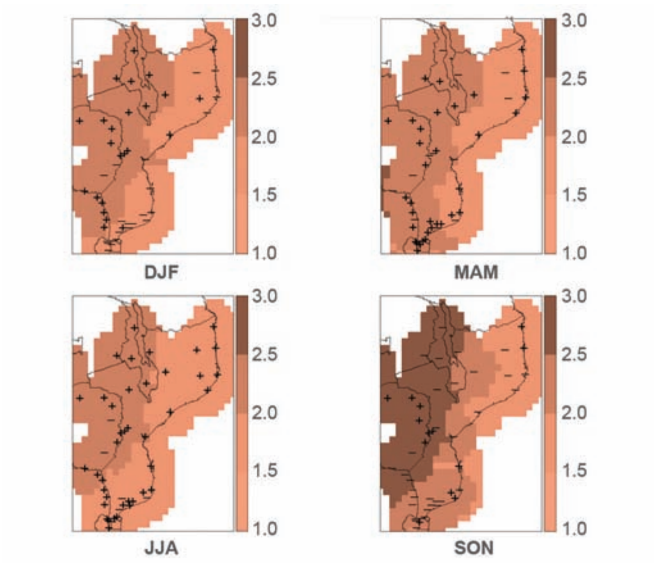


Figure 1.21: Median changes in future maximum temperature from 7 GCMs (2046-2065 period). "+"/"-" indicates whether seasonal variability is expected to increase/decrease in the future.

Figure 1.20 suggests that rainfall can be expected to increase over most of Mozambique during the DJF and MAM seasons whilst these increases are often less than approximate increases in evapotranspiration (0.1 mm day-1) during the JJA and SON seasons. Higher increases in rainfall are simulated towards the coast, especially during the DJF season, with similar increases in coastal regions as well as towards Malawi during the MAM season. Seasonal variability both increases and decreases depending on location; over southern coastal regions there is often an increase in seasonal variability during all four seasons (though this is not true for all stations); most stations suggest an increase in variability over the whole country during JJA.

Temperature

Both minimum and maximum temperatures are projected to increase in all seasons by all 7 GCMs. Figure 1.21 shows the median model changes in maximum temperature (similar plots of changes in minimum temperatures can be found in Annex IV) for each of the 4 seasons, which clearly demonstrates that temperatures are expected to rise by 1.5-3°C by the 2046-2065 period. In all four seasons, maximum temperatures rise more towards the interior and less at the coast, partly due to the moderating influence of the ocean. Similar spatial patterns are present for changes in PET, highlighting that the interior regions will also suffer greater evaporation changes than those regions near the coast. It is also clear that the largest increases occur during the SON season, before the onset of the rains over much of the country. Changes in variability are mostly positive with clear suggestions that variability in maximum temperatures will decrease in the north during SON but increase over most of the country during MAM and JJA. Changes in variability in minimum temperatures (Annex IV) suggest increases in variability in the north during MAM and JJA, with increases during SON in the south.

Potential evapotranspiration

As mentioned earlier the calculation of PET with data only for temperature requires the use of approximate methods. Both a modified Thornthwaite[14] (TW) and Priestly-Taylor[15] (P-T) method were tested with the TW method projecting greater increases in PET than the P-T method. However, given that the TW method is more appropriate for humid climates and that the P-T method is used more widespreadly within crop models over southern Africa, we use the P-T method in all calculations of PET in this report, though they may be considered conservative estimates. Even so, being temperature-only methods both TW and P-T do not account for potential changes in humidity and wind which would affect PET calculations using a standard Penman-Monteith method.

Notes

[14] Pereira, A. R. and W. O. Pruitt (2004). Adaptation of the Thornthwaite scheme for estimating daily reference evapotranspiration. Agricultural Water Management 66: 251-257.

[15] http://www.civil.uwaterloo.ca/Watflood/Manual/02_03_1.htm

Figure 1.22 shows the expected changes in PET for each season. It is clear that similar to increases in temperature, PET increases more inland away from the coast and that highest increases are found during SON, particularly over the Limpopo and Zambezi river valleys. This suggests that evaporation will increase significantly in these regions before the onset of the rainfall season, which, depending on changes in rainfall, could result in decreases in soil moisture before the main cropping season starts (this is investigated further in the following section). Besides these high increases in PET (which are also found during DJF in the western regions), increases in variability are suggested in the north during MAM and JJA, with increases in the south during DJF, MAM and JJA.

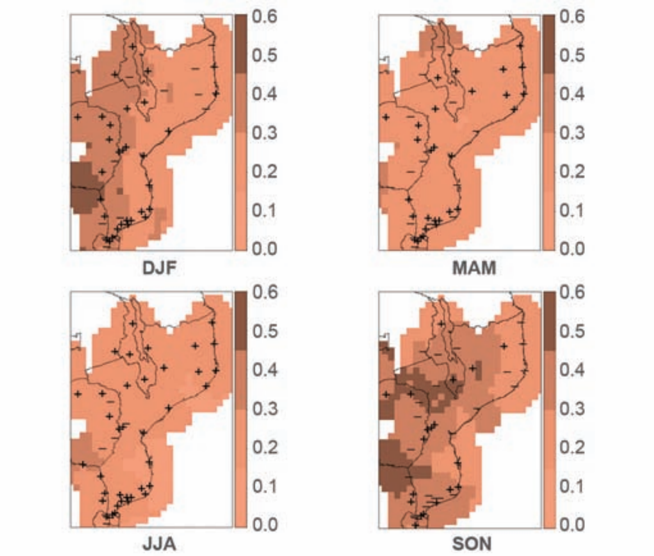


Figure 1.22: Median changes in future potential evapotranspiration (mm day-1) from 7 GCMs (2046-2065 period). "+"/"-" indicates whether seasonal variability is expected to increase/decrease in the future.

Seasonal and agro-meteorological conditions

As mentioned in section 1.3.3 the start, end and duration of the season was calculated for the historical record, based on both rainfall-only and rainfall/PET criteria. These same criteria were used to calculate the projected changes in the start/end and duration in the future climates of the 7 downscaled GCMs. Because the rainfall/PET criteria (rainfall/PET > 0.5 marks the rainfall season boundaries) is more robust to climate change (due to increases in evaporation) we only show the results of these calculations which are presented in Figure 1.23.

Figure 1.23a demonstrates that according to these criteria the rainfall season may be expected to start earlier over most of the country, though it is also expected to end earlier in the south and later in the far north (Figure 1.23b). This results in longer rainfall seasons in the north and southern regions towards the coast, but decreases in seasonal duration over the central regions and Zambezi valley (Figure 1.23c). Whilst this provides an indication of these seasonal changes in the start, end and duration of the season it should be noted that the results are highly dependent on the calculation of PET – here we have used the method which estimates the least increases in PET and therefore provides the most favourable estimates of changes in these seasonal characteristics. The following section provides further information on these modelled changes.

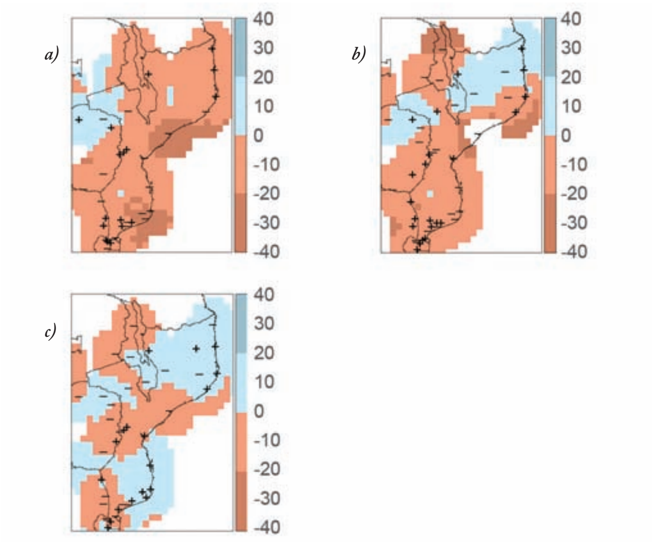


Figure 1.23: Median changes in future a) start, b) end and c) duration of the rainfall season from 7 GCMs (2046-2065 period). "+"/"-" indicates whether interannual variability is expected to increase/decrease in the future. Changes are given in days with negative values indicating an earlier start/end and reduced duration, whereas positive values indicate late start/end and longer seasons.

1.3e Changes in regional climate

Given the shifting changes in climate demonstrated for different locations in the previous section and the need to understand change from a more regional perspective we calculated rainfall, minimum and maximum temperature, PET as well as indices for the start, end and duration of the season for the four regions identified in Figure 1.24 (“North”, “Central”, “South” and “Coastal”). These data were taken as the means of all stations that fell in the following latitude bands: -15.5°S > North, -21°S < Central< -15.5°S, -21°S > South, with the Coastal region compromising a subset of the 27 stations found only on the coast. This led to the grouping of stations shown in Table 1.11.

As nearly all the stations in the southern region are found towards the coast it was found that the results for the coastal region closely resembled those for the south, though this is clearly inconsistent with the different climate found in the inland regions of Gaza province. Therefore to better represent these regions in the results for the south it was decided to add those stations from South Africa and Zimbabwe, shown in Annex II, which lay between 21°S and 26.2°S.

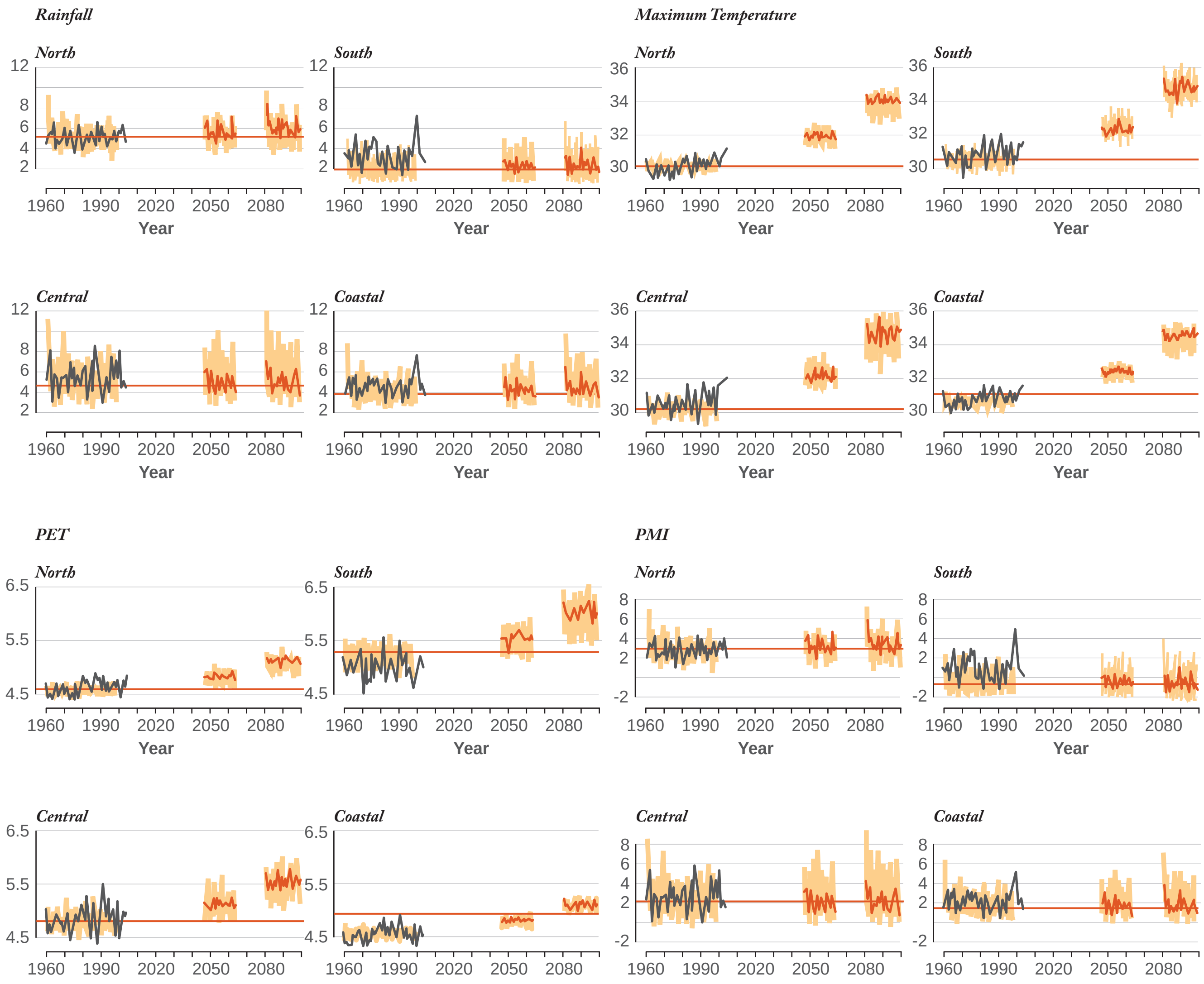


Figure 1.24: Interannual variability for the November-April season for each of the 4 regions: a) Rainfall (mm day^{-1}); b) Maximum temperature (°C); c) PET (mm day^{-1}) and d) Rainfall – (0.5*PET) (PMI) (mm day^{-1}). Orange shading is the GCM intermodel range, dark orange is the median of the models and the black line is the station observations. The horizontal orange line is the mean of the 7 GCM control climate simulations.

Region	Stations
North	Cuamba, Lichinga, Mocimboa da Praia, Montepuez, Pemba, Lumbo, Nampula
Central	Angoche, Beira Aeroporto, Chimoio, Messambuzi, Quelimane, Sussengenga, Tete
South	Changalane, Chockwe, Inhambane, Inharrime, Macie, Manhica, Maniquenique, Manjacaze, Maputo Mavalane, Panda, Umbeluzi, Vilanculos, Xai-Xai
Coastal	Mocimboa da Praia, Pemba, Lumbo, Angoche, Quelimane, Beira Aeroporto, Vilanculos, Inhambane, Inharrime, Xai-Xai, Manhica, Maputo Mavalane

Table 1.11: Grouping of INAM stations into regions.

Changes in rainfall, temperature, PET and potential moisture index

Figure 1.25 presents regionally averaged rainfall, maximum temperature, PET and (Rainfall – (0.5*PET)) (taken as an index of potential surface moisture "PMI") for the station observations (black line), modelled range (orange shading) and modelled median change (dark orange line) for the November-April season during the past (1960-2000) and for two future periods (2046-2065) and (2080-2100). When looking at the 1960-2000 period, the modelled range of climates can be seen to correspond to the observed climate (black line) providing confidence that the downscaled models are simulating the most important aspects of Mozambique climate (besides a detectable bias for simulating too little rainfall in the south). Most of the noticeable trends in the observations (black lines) are related to temperature, with obvious increases in maximum temperatures and PET in the central region. These changes are simulated to increase in the future with higher increases for the 2080-2100 period than the 2046-2065 period, consistent with the observed trends. There are no obvious changes in mean rainfall (Figure 1.25a) during the 1960-2000 period, though there is noticeably higher interannual variability in the southern and central regions. In the future periods it can be seen that the median simulated change is close to the mean of the control climate simulations (horizontal orange line), indicating that both negative and positive rainfall changes are simulated. PMI (Figure 1.25d) clearly shows that most regions have 6 month means that are positive during the 1960-2000 period, demonstrating that during this period there is mostly more rainfall than evaporation (negative values indicate potentially more evaporation than rainfall, whereas positive values indicate potentially more rainfall than evaporation). The exception is the south which is clearly a region that often has negative PMI and therefore is more prone to drought. Again however, these calculations rely on the method of calculating PET and so are likely to be an optimistic estimate. Furthermore these changes are shown for the November-April main rainfall season (similar figures for the four main seasons are given in Annex V and ignore seasonal fluctuations which change how rainfall, temperature and PET interact at different points in the seasonal cycle. In particular, evaporation is often greater than rainfall in the winter and early summer period. The following section therefore looks in closer detail at the timing of these rainfall increases/decreases and when the water balance is likely to be positive/negative.

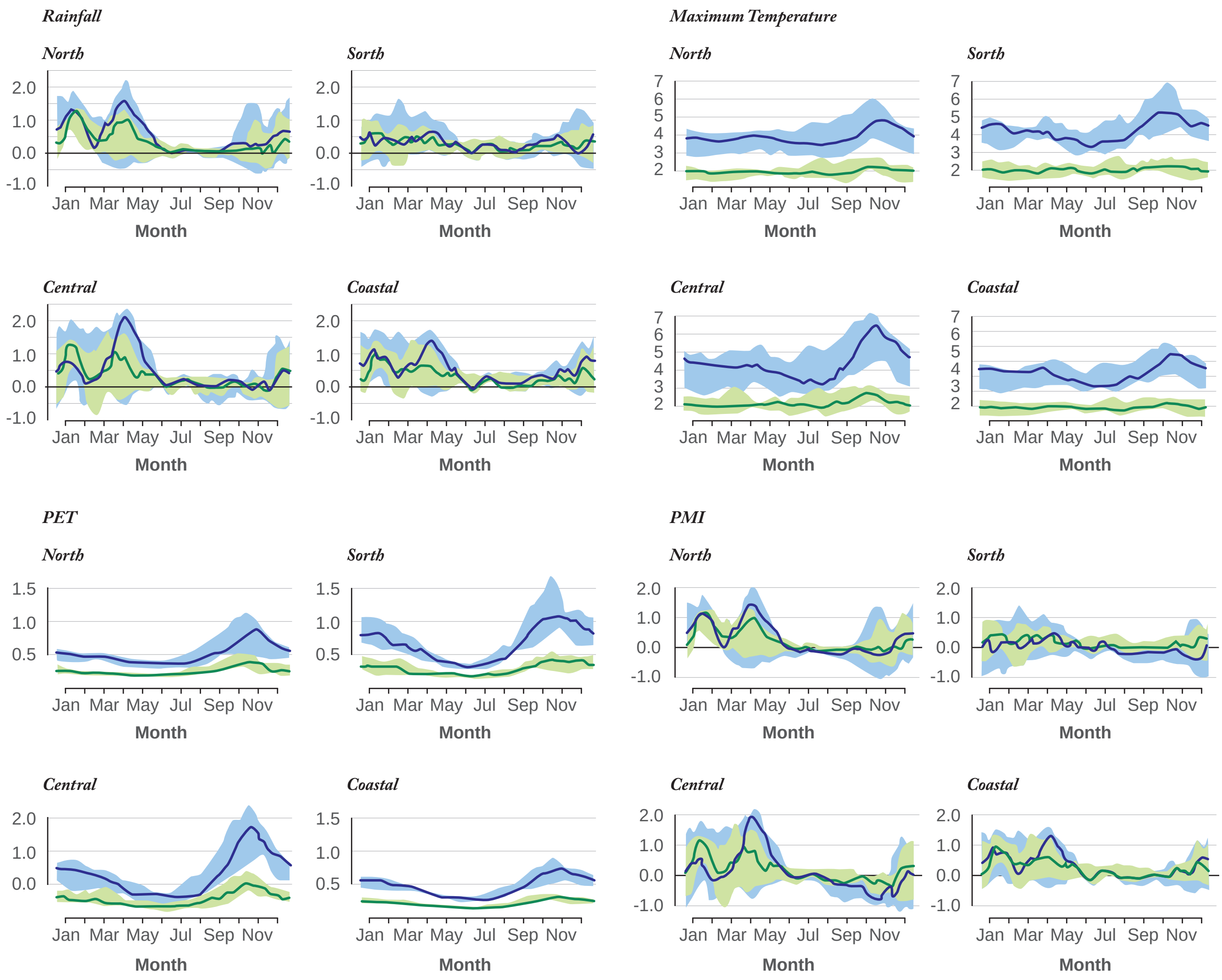


Figure 1.25: Changes in the annual cycle of a) Rainfall (mm day^{-1}); b) Maximum temperature (°C); c) PET (mm day^{-1}) and d) Rainfall – (0.5*PET) (PMI) (mm day^{-1}) simulated by 7 GCMs for the north, central, southern and coastal regions. Green shading indicated the range (olive line the median) for the 2046-2065 period, blue shading the range (blue line the median) change for the 2080-2100 period.

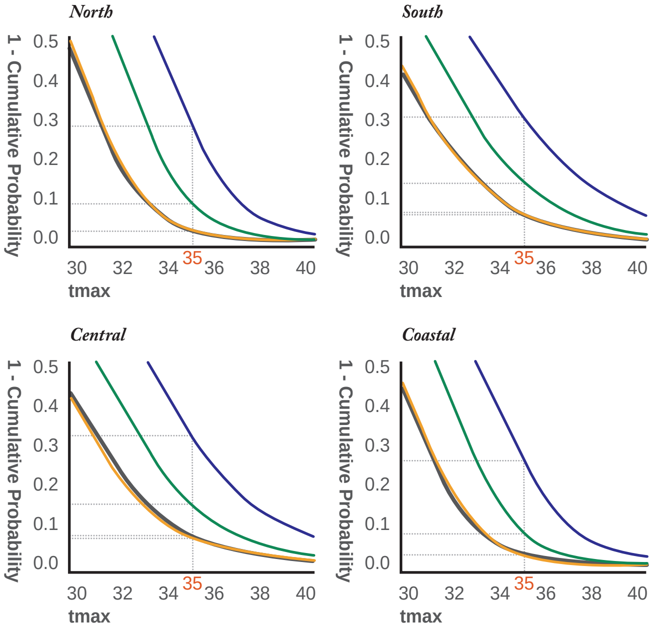


Figure 1.26: Frequency (1 – cumulative probability) with which maximum daily temperature exceeds 35°C in the observations (black line), simulated 1960-2000 (orange line), 2046-2065 (green line) and 2080-2100 (blue line) periods, for each of the four regions. The cumulative distributions are an amalgamation of the downscalings from all 7 GCMs.

Thresholds and frequencies of extreme temperatures

Given the increases in average temperature simulated for the future climates it is expected that the frequency with which daily maximum temperatures will exceed critical thresholds will increase in the future. This is clearly demonstrated in Figure 1.26 which shows for each region and period the simulated frequency (1 minus the cumulative probability) with which maximum daily temperature exceeds 35°C. In each plot the observations for the region are shown as the black line and in each case this can be seen to closely follow the simulated control periods of the GCMs (orange line), providing confidence that the GCM simulations are realistic during this period. The probability/frequency with which this critical threshold is exceeded ranges between 0.02 (for the coastal and northern regions) and 0.07 (for the central and southern regions). There is an approximate increase between 0.08 and 0.14 respectively during the simulated 2046-2065 period, representing an increase in the likelihood of this extreme temperature by approximately 7%. In the far future 2080-2100 period the increase in the likelihood of attaining this temperature is greater than 25% in all regions (as high as 33% in the central region). Given the seasonal cycle of these changes presented in the previous section and that maximum temperatures often occur during the September-November period before the rains, it is to be expected that many of these exceedance days will occur during this period in the future.

1.3f Climate change scenarios for flood and crop-suitability modelling

The scenarios developed as part of this component of the INGC project are not a standalone component and the expectation was that they would be used downstream as inputs into further impact modelling. This impact modelling had two components: 1) crop-suitability modelling undertaken by IIAM and 2) flood risk modeling undertaken by Ara-Sul and another international consultant. Both of these components had specific requests when it came to data requirements and formats to run the flood-risk and crop-suitability models. This aspect of the project took a long time to work out and required a lot of consultation via emails and telephone conversations for the author to understand the specific requirements of the impact modellers, as well as for the impact modellers to understand the peculiarities of the climate science, models and data. It should be noted that the author is not an expert in either of these models and therefore may (accidently) misrepresent some of the complexities. Here we provide a summary of the pertinent points that came to light during the course of the project for future reference when undertaking this type of work.

Crop-suitability modelling

The crop suitability modelling undertaken by IIAM utilised an agroecological model based on principles established by the United Nations Food and Agricultural Organisation. These are in some ways similar to the ways in which the start and end of the season has been defined in this report (using a ratio of rainfall/PET of 0.5 to define the seasonal boundaries). However, the model uses monthly mean data and uses crop-specific coefficients and soils data to define water use and land suitability. Whilst the end product and information is presented in the form of GIS maps, most of the calculations are done in excel using baseline data from 135 agromet and synoptic stations scattered around Mozambique. This presented a problem in that the climate change scenarios were only for the 27 INAM stations mentioned previously. Therefore the initial step was to take the INAM stations and interpolate (using a kriging algorithm) their projected changes in monthly mean rainfall, maximum and minimum temperatures and PET to the locations of the 135 IIAM stations. As the baseline data from the 135 stations wasn't readily available, the projected changes in climate were added to a baseline created by interpolating the INAM observations. However, it was realised at a late stage that this baseline data was unrealistic (largely because there are no INAM stations in the central southern regions and so the created baseline largely reflected the coastal stations used to create the data). Therefore it was decided that IIAM should digitise the baseline data for the 135 stations (shown in Figure 1.27), which was sent to the author who then added the climate change data to this original baseline.

Even so this still presented a logistical problem of running the crop-suitability model with 135 stations for each of 7 downscaled GCMs (representing data for 945 stations). IIAM indicated that this was not feasible and so it was decided to run with only 3 GCMs representing a dry, medium and wet model. This is a very crude approximation as each model will only be dry, medium or wet at specific times of the seasonal cycle and so may miss some of the major impacts. Even so there was no real alternative and so this is how the modelling proceeded. Finally, the last hurdle was to import all the climate change scenarios into excel as manually importing the data was not feasible. This was accomplished via a routine written using the R software.

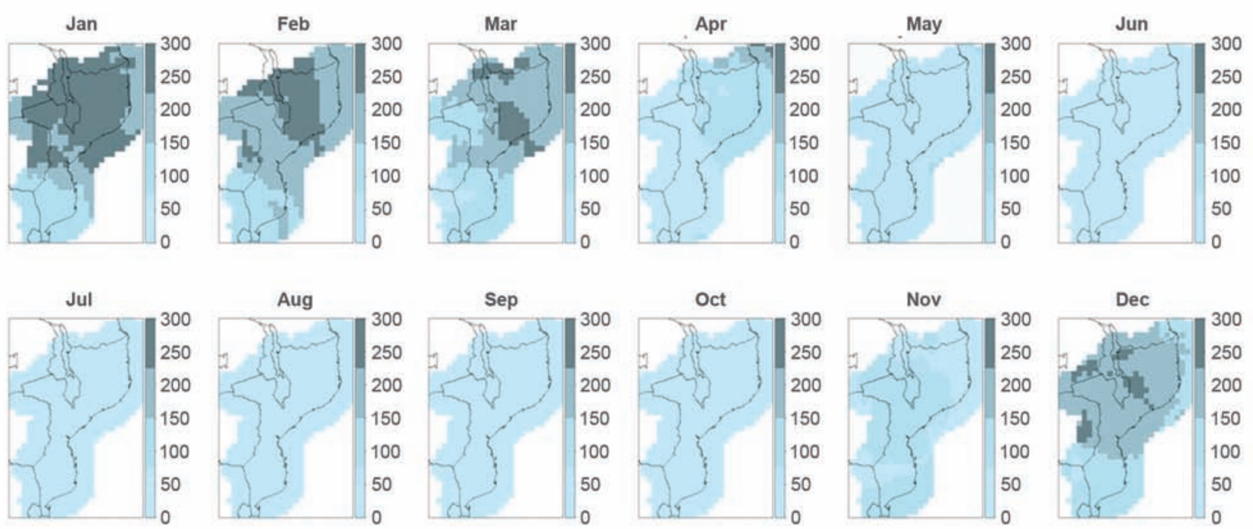


Figure 1.27: IIAM baseline rainfall for each month, created from the 135 IIAM stations.

Flood risk modelling

The flood risk modelling represents a major step forward in the modelling of climate change impacts in southern Africa. It was mostly feasible as it builds on much of the work implemented by FEWS-NET within the region for flood risk monitoring – largely a response to the 2000/1 floods in Mozambique. Even so developing a downscaled climate change dataset for this work was a challenge. Station data could not be used as the flood model requires gridded data and for larger regions e.g. the watersheds of the Limpopo and Zambezi rivers which stretch across large parts of southern Africa.

Eventually it was decided to try and downscale the GCMs using the satellite based Rainfall Estimates (RFE) as the observed training data. This satellite data is currently used by the model for monitoring purposes. However, data available for a long enough daily timeseries has only just become available for use as the training data (a minimum of 10 years of data is required). The main problem was adapting the data and/or downscaling the code to work with the geographic projection that the data was supplied on. To get around this problem the flood modellers took the RFE estimates and used them to produce daily estimates of rainfall at each sub-basin centroid, as well as the geographic location of each sub-basin centroid. These data were then used in the downscaling in a similar manner to the station data, though due to the large dataset it took 48 hours of continuous calculations to run the downscaling. Whilst the rainfall data used for this modelling is a different observational source than the INAM (+ other country) station data used for the analysis in this report and the IIAM modelling, it can be expected to produce estimates of change that will be spatially consistent with these other downscaled data. This stems from the fact that the same spatial patterns in the GCM data are used to resample the observed data in each case. There may be differences in the magnitude of estimated changes, especially where the satellite-based RFE data may be biased with respect to observations on the ground, but the RFE observations have the advantage that they are valid for spatially gridded regions. Assumptions regarding the spatial representivity of point measurements, such as are made when kriging the station data, are not required for the RFE data.

The output downscaled data files were then reformatted to the same format that the data were given as and then sent back to the flood modellers. It was decided that the flood modelling would undertake to use all 7 downscaled GCMs to get a clear handle on the range of projected changes.

One important drawback of this proposed modelling approach was that the statistical downscaling methodology is currently based on historical observations and so is unable to project daily rainfall intensities beyone what is currently experienced at a particular location. It therefore underestimates the maximum potential floods in a future climate, though it can capture changes in the frequency of large floods. Current research is seeking to address this issue in the near future.

1.3g Reconciling observed and expected future change

The projected changes in rainfall and temperature for the middle and end of the 21st century that have been presented here are linked to physical changes in the regional climate system, which offers a way to reconcile observed trends and future projected change where they are different. Consistently projected future change is a consequence of the following physical changes:

1. Increase in temperature, which promotes convective activity, especially during mid-late summer

2. Increase in humidity, which increases the amount of moisture available for rainfall once it is triggered.

3. Retreat of the mid-latitude storm systems and increases in the continental high pressure system during winter (and potentially autumn and spring)

However, these changes in the physical system will interact and couple in a non-linear manner and individually manifest themselves at different periods in the future. The regional expression of change is therefore dependent on which mechanisms, which may compete with each other (e.g. increases in rainfall may offset decreases in rain days), are dominant at any particular time. Unlike the temperature signal due to climate change, which is currently observable, the rainfall signal (as estimated from low variability GCM data and therefore likely a conservative estimate) is not expected to be observable for several decades.

Reconciling these past and future changes is a difficult, yet necessary challenge, if climate science is to better inform those involved in planning disaster risk reduction and adaptation activities. Where current (statistically significant) trends are in line with projected change, and the physical mechanism related to both is understood, planning and adaptation related to such changes have firm grounds for moving ahead. However, where there are observed statistically significant trends at most stations within a given area, but future projections (all models) either disagree on the sign of the change or are inconsistent, then further investigation is required as observed changes may be due to natural variability. In the case when there are no consistently observed significant trends, but projections suggest a change that is physically plausible, further monitoring is necessary to detect any such changes if and when they happen in the future.

From the data presented in this report, increases in temperature are already apparent across Mozambique and much of this increase has happened since 1990. Changes in rainfall are, however, much harder to detect due to it's spatial and temporal heterogeneity. Indeed it is possible that multidecadal variability will dominate any climate change signal in the rainfall record in the near future. Even so this does not mean that human and ecological systems are not moving beyond critical thresholds and many of the changes noted here need to be evaluated within their specific social, economic and/or ecological settings. A good example of this would be cropping/farming systems which are currently close to critical thresholds of either water availability or seasonal duration (for growing specific crops). Increases in temperature alone (with no significant change in rainfall) could make the cultivation of particular crops unviable. This may be an immediate problem facing farmers in semi-arid regions. The projected increases in rainfall which are simulated by the climate models in the far future and which could offset some of these difficulties are not immediately relevent as these beneficial changes have yet to occur. Therefore the scenarios presented in this report are quite possibly optimistic from this standpoint.

1.3h Recommendations for further work and analyses

One obvious recommendation for future work would be to use more downscaled GCMs to better capture the potential range of climate changes in the future (including using data for another scenario e.g. the B1 SRES emissions scenario). However several other important aspects of the modelling process, as well as the scientific limitations and application of the data for the purposes required by INGC, present themselves. To summarise the most pressing problems:

1. There is a lack of information regarding the vulnerability of society to critical climate thresholds. If such thresholds are provided then the climate information can be tailored to be more relevant to particular sectors and impacts;

2. Use the output of a dynamical regional climate model to better understand changes in maximum rainfall and hence maximum floods;

3. Determining when in the future rainfall increases may offset the negative impacts of increases in temperature. This is unlikely to resolve itself with more climate change modelling, therefore it is recommended that the project look at developing scenarios of near-term climate change based on existing trends and knowledge of how the climate may change in the next 20 years. These should be developed as scenarios, rather than explicitly using GCMs to model the future climate;

4. Linked to the previous point it would be useful to identify specific regions and sectors for more detailed analyses and for which ‘extreme’ or ‘outlier’ scenarios of change (not the median change) may be important.

Whilst some of these issues have been touched on during the course of the project, much more work is needed to adequately address the information requirements of INGC.

2

Sea level rise and cyclone analysis

2.1 Cyclone historical and baseline analysis

Dr Alberto Mavume, UEM

2.2 Future impacts of climate change on cyclone, storm sturge and sea level rise activity

Prof. Geoff Brundrit, UCT and Dr Alberto Mavume, UEM

Cyclone historical and baseline analysis

Dr Alberto Mavume, UEM

2.1a Introduction

2.1b Technical Assessment

2.1a Introduction

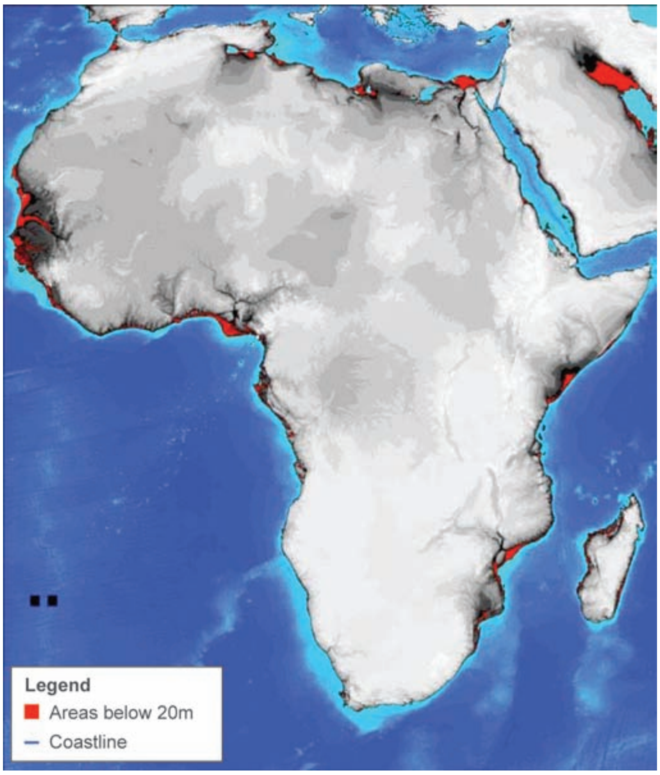
The coastal region of Mozambique is home to over half the population of the country, with many choosing to live and to work in its towns and villages. However, the coastal region of Mozambique is most susceptible to the natural disasters, which has devastating effects on the economic development of the country as a whole. Recent examples include the floods of the year 2000 and the impact of Tropical Cyclones (TC) Eline and Hudah. This led to damage to infrastructure and services amounting to 12% of the GDP of Mozambique, Stern (2006). These events have set back the economic development of the country by several years.

Tropical cyclones, storms and depressions are an ever present feature of the summer season in the South West Indian Ocean and the Mozambique Channel. In the period, 1980-2007, 56 cyclones were tracked by satellite to have entered the Mozambique Channel. This is an average of two cyclones per year for this period, Mavume (2008). Only 16 of the 56 cyclones made landfall on the coast of Mozambique, and moved inland. Of these 16, 3 made landfall in the North, 9 made landfall in the Centre and 4 made landfall in the South. The more intense cyclones were accompanied by extreme weather with widespread rain, leading to major flooding and damage to infrastructure along the rivers and the coast.

Much of the coastline of Mozambique is soft, comprising of muddy river sediments and sand, backed by land with low relief and extensive low-lying coastal plains. This is particularly true of the central provinces, which are characterized by major rivers, such as the Zambezi, Save, Buzi and Pungoe, draining the continental interior, and prone to flooding on an annual basis. The coastline has a series of estuaries and deltas, which shift in response to the frequent floods and deposits of large amounts of sediment. Coastal erosion is a problem along the dynamic coastline. People, infrastructure and services in harbour cities such as Beira are in constant need of protection (MICOA ,1998).

Map 2.1 illustrates the extent of the 20m contour along the coast of Africa, where large estuaries and deltas form low lying land. The map illustrates the extent of Mozambique's vunerablity to climate change along its coasts, one of the highest in Africa.

The risk of disaster is high when the chance of occurrence of a hazard is high, when the vulnerability to damage from that hazard is high and when the capacity to cope with the consequences of the occurrence is low, Benessene (2008). This is applicable with respect to disasters arising from tropical cyclones along the coast of Mozambique. The chance of a tropical cyclone is high, with landfall likely on a vulnerable coastline. The capacity of the country to cope with such an occurrence was certainly low in the year 2000. It also demonstrates the value of Disaster Risk Management. The lessons learnt from the year 2000, and incorporated into Disaster Risk Management Action Plans by the INGC, have meant that the country is in a better state of readiness to withstand the onslaught of a severe tropical cyclone. Thus the impact of the Category 4 TC Favio (mean wind speeds in excess of 59m/sec) in February 2007 was not as great as for the tropical cyclones of 2000. This was due in part to features of the Action Plan, such as the development of an early warning system, disaster preparedness and communication to local communities, (Benessene, 2008). As extreme weather events continue to hit Mozambique, the Government of Mozambique will increasingly face decisions about how to manage people at risk and on the move due to environmental factors, Forced Migration Review 31 (2008).



Map 2.1: 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.

The continued effectiveness of Disaster Risk Management in the future will depend upon the response to the challenges of climate change.

How will climate change impact on the risks currently facing the coastal provinces of Mozambique?

Given the breakdown of disaster risk into hazard, vulnerability and coping capacity, and the recognition of the continuing danger posed by tropical cyclones, the key questions which arise are:

- Will climate change intensify the tropical cyclones that form the key hazard along the coast of Mozambique?
- Will climate change, through the expected consequence of sea level rise, increase the vulnerability of the coastline to tropical cyclones to any appreciable extent?
- What impacts from climate change are to be expected, and what measures should be taken to minimize the risks and economic losses?

The detailed knowledge arising from the investigations into these key questions will form the response to climate change for Disaster Risk Management in the coastal regions of Mozambique. The insights will then need to be properly incorporated into the relevant Action Plans.

2.1b Technical Assessment

Tropical Cyclones

Underlying Rationale

During 2005 two highly publicized scientific papers appeared documenting evidence from the observational records for an increase in tropical cyclone activity.

IWTC-6, San José, Costa Rica, November 2006

Evidence for a substantial increase in power of tropical cyclones (denoted by the integral of cube of the maximum winds over time) for the West Pacific and Atlantic basins during the last 50 years were documented.

Emanuel (2005)

This result is supported by findings showing that there has been a substantial global increase (nearly 100%) in the proportion of the most severe tropical cyclones (Category 4 and 5 on the Saffir-Simpson scale), from the period from 1975 to 2004, which has been accompanied by a similar decrease in weaker systems.

Webster et al. (2005)

A number of authors attribute the reported increase as being due primarily to data reliability issues, in that the strong tropical cyclones are more accurately monitored in recent years. Numerous tropical cyclones may have been missed and not counted even in the Atlantic basins, especially prior to 1910.

Landsea et al. (2006)

Other authors extended the analysis of Webster et al., for the Northwest Pacific basin back to earlier years and argued that the trend in that basin is part of a large inter-decadal variation, similarly to what have been occurring for the Atlantic basin.

Golthenberg et al. (2001)

The scientific debate concerning the Webster et al. and Emanuel papers is not as to whether global warming can cause a trend in tropical cyclkone intensities. The more relevant question is how large a chang: a relatively small one several decades into the future or large changes occurring today?

IWTC-6, San José, Costa Rica, November 2006

Tropical cyclones, hurricanes or typhoons; all are common names, used to describe the same natural phenomena – one of the most deadly, costly, and destructive weather systems on the Earth (Gill, 1982). Intensive tropical cyclones produce destructive winds, coastal storm surges, torrential rains and severe floods, usually resulting in serious property damage and loss of human lives. Hurricane Andrew's strike on Florida during August of 1992 caused in excess of $30 billion in direct economic losses, while Hurricane Floyd in 1999 disrupted the lives of 2.5 million of its residents who had to be evacuated (Elsener and Jagger, 2006). On the other hand, tropical cyclones may also have positive impacts. Rainfall, if not torrential, in connection with a cyclone is often regarded as a positive effect (Sugg, 1968). Another positive impact has been proposed by Imberger et al. (1979). Imberger et al. have suggested that cyclones, which affect the waters northwest of Australia on average four times per year, induce upwelling and mixing and thus bring additional nutrients to otherwise nutrient poor surface waters.

Mozambique has a coastline of about 2,700 km. More than 60% of its population lives in coastal areas, which in many places consist of lowlands with sandy beaches, estuaries and mangroves. Survival and everyday life in these areas depend to a large extent on local resources, such as farming and fishing, whilst the infrastructure is weak or even non-existent. In summary, the conditions mean a high vulnerability of both people and landscape to tropical cyclones. Accurate predictions and forecasts of tracks and intensities of tropical cyclones are therefore highly important issues. Knowledge on cyclone behaviour, including areas of landfall and possible future changes are needed to undertake countermeasures such as evacuation of densely populated areas under threat, but also in the long run, for proper land use, for hazard mitigation, for insurance reasons, and in order to build up efficient warning systems.

Since 2000 Mozambique has been hit by five intense tropical cyclones [in 2000 by TC Eline and TC Hudah, in 2003 by TC Japhet, in 2007 by TC Favio and TC Jokwe in 2008], all of which stand as vivid examples of the large social and economic consequences they bring about. In Mozambique, for example, floods in the wake of TC Eline caused approximately 2 million people to be displaced or otherwise severely affected. About 600 people died. The estimated cost of the Mozambique floods in the year 2000 stood at more than US$167 million in terms of emergency aid funds and in immediate activities in order to rehabilitate the infrastructure and relocate displaced persons (IPCC, 2001).

What are the present day impacts of tropical cyclones along the coast of Mozambique?

Saffir-Simpson Scale Hurricane Classification	Maximum Wind Speed [knots:mph:km/h]	Storm Surge [metres : feet]	Damage Level
Tropical Depression	< 34:< 39:< 61	Not Applicable	None or Minimal
Tropical Storm	34-63 : 39-73 : 61-117	Not Applicable	Minimal
Category 1: Cyclone	64-82 : 74-95 : 118-153	1.0 - 1.7 : 4 - 5	Minimal
Category 2: Cyclone	83-95 : 96-110 : 154-177	1.8 - 2.6 : 6 - 8	Moderate
Category 3: Major Cyclone	96-113 : 111-130 : 178-209	2.7 - 3.8 : 9 - 12	Extensive
Category 4: Major Cyclone	114-135 : 131-155 :210-248	3.9 - 5.6 : 13 - 18	Extreme
Category 5: Major /Super Cyclone	> 135: > 155: > 248	> 5.6 : > 18	Catastrophic

Table 2.1 :The Saffir-Simpson Scale for Hurricane Classification.

The South Western Indian Ocean is an area which is a genesis region for tropical storms which occasionally develop into tropical cyclones. Some of these intense weather systems enter the Mozambique Channel and make landfall on the coast of Mozambique. Since 1980, these storms have been observed by satellite, and their movements and life histories carefully monitored and comparative statistics assembled. The Saffir-Simpson scale (Table 12) is used to characterize the intensity of tropical storms and tropical cyclones in terms of their maximum wind speed, associated storm and damage level.

Table 2.1 characterizes the intensity on the Saffir-Simpson scale and month of occurrence during the cyclone season of the tropical storms and cyclones entering the Mozambique Channel. During the period 1980-2007, 56 tropical storms and cyclones entered the Mozambique Channel.

	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Nov	2	0	0	0	0	0
Dec	4	1	0	0	2	0
Jan	9	6	0	2	1	0
Feb	8	2	4	0	2	0
Mar	3	3	2	0	0	0
Apr	1	1	1	1	1	0
Total	**27**	**13**	**7**	**3**	**6**	**0**

Table 2.2: Numbers of occurrence of tropical storms and cyclones in the Mozambique Channel, by Saffir-Simpson Scale and by month during the period 1980-2007.

Most weather systems in the Mozambique Channel remain undeveloped as tropical storms or low category cyclones, with the cyclone season covering the summer months between November and April. The strongest tropical cyclones experienced in the Mozambique Channel reached Category 4 on the Saffir-Simpson scale.

Figure 2.1 the exceedance diagram, shows the return period, plotted on a logarithmic scale, for the tropical storms (designated as Category 0) and the tropical cyclones of Categories 1-4, which were observed in the Mozambique Channel for the period 1980-2007.

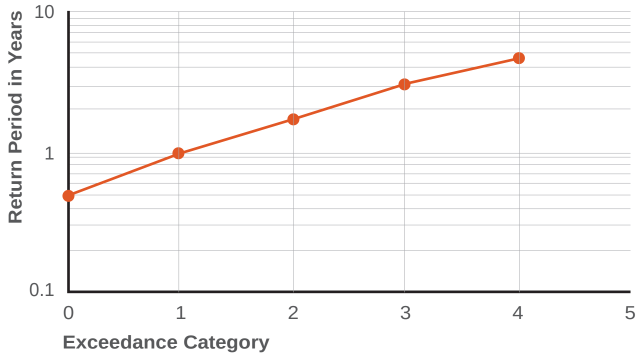


Figure 2.1: Exceedance Categories for Cyclones in the Mozambique Channel.

For storms and cyclones of Category 0 or above, the expected return period was 0.5 years, or the equivalent of twice per year for storms and cyclones of all categories. Tropical cyclones of Category 1 or above would occur every year, while Category 3 or above tropical cyclones would occur every three years. The slightly concave, downward shape to the curve in this exceedance diagram means that, in these observed cyclones for this period, there is a tendency for the more intense Category 4 cyclones to occur rather more frequently than would be expected on the basis of the log-linear law of extreme value analysis.

The damage caused by tropical cyclones depends to a large extent on whether they make landfall and when storm surge, high winds, and heavy rainfall combined with high waves cause severe impacts. However, high waves from near or remote tropical cyclones which don't make landfall, but reach hurricane strength and then track southward along the coast as they weaken are likely to cause severe coastal erosion and significant economic impacts. TC Boloestes is a good example that occurred in the 2005-2006 SWIO season. TC Boloetse crossed the island of Madagascar as a tropical storm in late January 2006 with moderately strong rains. The storm intensity declined to a tropical-depression as it crossed the mountainous ridgeline that runs along the eastern shore of Madagascar. However, once the storm system reached the warm waters of the Mozambique Channel, the tropical depression reorganized and built up enough strength to become a tropical cyclone. The cyclone had sustained winds of around 165km/hr, classifying it as a Category 2. Although it seemed inevitable that it would hit the coast north of Beira, the system experienced a sudden southward track direction. There was no significant wind damage on the Mozambique coast, but significant wave heights of 2-3m associated with the cyclone were reported to cause considerable coastal erosion.

Of the 56 tropical cyclones and tropical storms in the Mozambique Channel in the period 1980 to 2008 only 16, a quarter of the total number, made landfall (Tables 2.3 and 2.4) on the coast of Mozambique. Five of these made landfall in the North, 8 in the Centre and 3 in the South. Of greater concern has been the increase in the frequency of these storms as only 4 occurred in the period 1980 to 1993, whilst the other 12 occurred in the period of fourteen years from 1994 to 2007. The intensity upon landfall of the cyclones occurring in the second period also increased. Tables 2.4a and 2.4b show the comparative details.

Year	Category and Name	Landfall	Date	Strength	Wind speed
1984	(TS) Domoina	South	28 Jan	TS	102 km/h
1986	(TS)	Central	9 Jan	TS	83 km/h
1988	(Cat 2) Filao	Central	2 March	Cat 1	121 km/h
1988	(TS)	North	25 Nov	TS	74 km/h

Table 2.3: Tropical cyclones of Categories 1-4, storms (TS), and depressions (TD) making landfall on the coast of Mozambique in the period 1980-1993.

Year	Category and Name	Landfall	Date	Strength	Wind speed
1994	(Cat 4) Nadia	North	24 March	Cat 1	139 km/h
1995	(TS) Fodah	Central	22 Jan	TD	37 km/h
1996	(Cat 4) Bonita	Central	14 Jan	Cat 1	130 km/h
1997	(Cat 1) Lisette	Central	2 March	TS	111 km/h
1998	(TS)	North	17 Jan	TD	56 km/h
2000	(Cat 4) Eline	Central	22 Feb	Cat 4	213 km/h
2000	(Cat 4) Hudah	Central	8 April	Cat 1	148 km/h
2003	(Cat 4) Japhet	South	2 March	Cat 2	167 km/h
2003	(TS) Atang	North	13 Nov	TD	46 km/h
2004	(TS) Delfina	Central	1 Jan	TS	93 km/h
2007	(Cat 4) Favio	South	22 Feb	Cat 3	185 km/h
2008	(Cat 4) Jokwe	North	08 Mar	Cat 3	180 km/h

Table 2.4: Tropical cyclones of Categories 1-4, storms (TS), and depressions (TD) making landfall on the coast of Mozambique in the period 1994-2008.

Figure 2.2 shows TC Eline moving into the interior on 23 Feb 2000, the strongest tropical cyclone to make landfall on the coast of Mozambique in recent years.

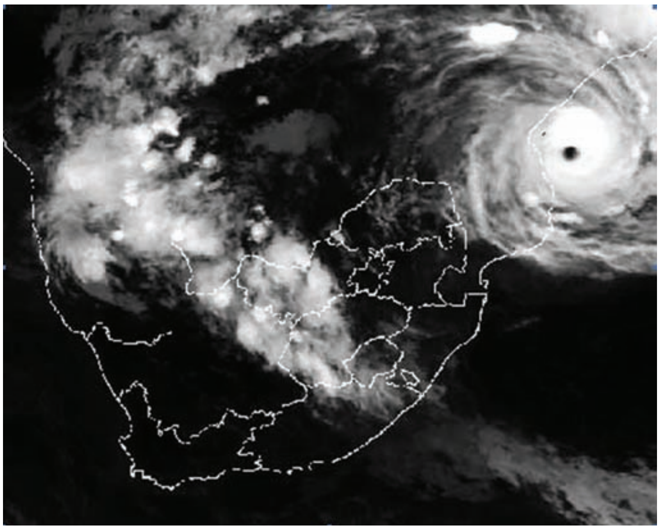


Figure 2.2: Satellite image of TC Eline prior landfall on the 21 nd February 2000.

On landfall TC Eline was still classified as Category 4 on the Saffir-Simpson scale, with wind speeds in excess of 114 knots (131mph or 210 km/h) and an accompanying storm surge likely to have been in excess of 4m in height. The damage caused by TC Eline was extreme and estimated to be in excess of 12% of the GDP of Mozambique.

Will climate change intensify the tropical cyclones?

The prevalence of tropical cyclones in the South Western Indian Ocean is thought to be due to their association with the high sea surface temperatures in summer that provide the heat to drive the formation and development of the cyclones. This is borne out by the following figures showing the cyclone trajectories of the South Western Indian Ocean during the cyclone season of the period 1980-2007.

Figure 2.3 shows the genesis locations of the tropical cyclones and their association with a sea surface temperature greater than a threshold of 28°C. It is worth noting that the tropical cyclones of the Mozambique Channel can have their genesis in the warm waters of the northern Mozambique Channel, or cross Madagascar from the South Western Indian Ocean. In the latter case, the cyclones will have weakened in their passage across Madagascar, but can intensify markedly as they cross the Mozambique Channel. In March, the sea surface temperature threshold reaches so far south as to encompass the entire Mozambique Channel.

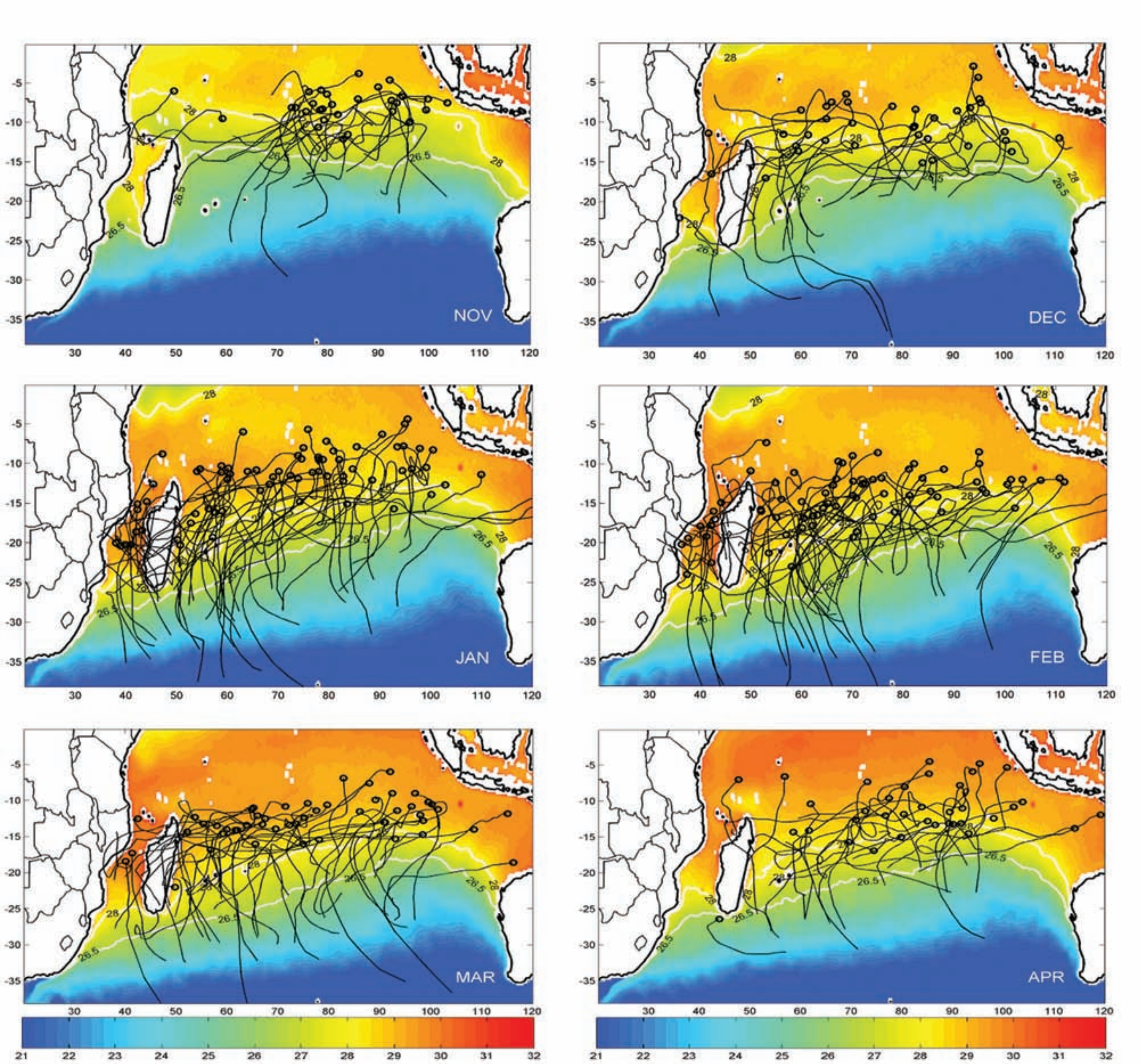


Figure 2.3: Tropical cyclones trajectories for the months of November–April (1980-2007).TC genesis locations are indicated as circles. TMI monthly mean SST (1998-2005) highlights two isotherms. The lower isotherm, 26.5°C is the typical SST cut-off in cyclone formation as suggested by Palmén (1948). The upper isotherm 28°C is the proposed threshold value for the South-West Indian Ocean under the current investigation.

The proposed direct link between climate change and cyclone intensification is through the wider geographic spread of this threshold of warmer sea surface temperature as global warming begins to make its impact. There is already some evidence of this in the cyclone statistics, from the Mozambique Channel between 1980 and 2007. Dividing these statistics into the early and late years of the period, demonstrates the differences in occurrence, particularly of the more intense cyclones.

Period	TS	Cat 1-2	Cat 3	Cat 4	Cat 5	ITC	TC	All
1980-1993	15	8	0	2	0	2	10	25
1994-2007	12	12	3	4	0	7	19	31

Table 2.5: Number of cyclones in the Mozambique Channel, separated by category for the periods 1980-93 and 1994-07, respectively. ITC = Category 3-5.

However, the numbers of cyclones are too small to draw any significant conclusions regarding trends. Rather than being due to climate change, these differences may just be due to natural variability. A longer record of observation is needed before any definitive conclusions can be drawn about trends in the occurrence of intense cyclones. The record has to be long enough for the natural variability to be averaged out and the trend due to climate change revealed.

An alternative approach is to use climate modeling to try to identify future trends in the characteristics of tropical cyclones. Various climate models can be used in the simulation, and different emission scenarios may be adopted. Again, the results of the simulation will contain inherent variability from the forcing of the changing scenarios, and comparisons are only really possible after the scenarios have had time to settle down, which may well take many decades. Thus these model studies provide ultimate outcomes rather than projections into the near future.

Global climate models have been used to directly simulate cyclone patterns into the future, even though they may not possess sufficient horizontal resolution to simulate the inner core of intense cyclones. While there is a wide variation in the results of these studies, there is a tendency toward decreasing frequency of tropical cyclones, but an increase in their intensity and associated precipitation, as in the study by Bengtsson et al. (2007), comparing the situations at the ends of the 20th and the 21st century.

Emanual et al. (2008) describe a technique for downscaling tropical cyclone climatologies from global analyses and models, which aims to avoid the resolution issue. Simulated storms driven by re-analysis of data between 1980 and 2006 concur with the data on observed storms, including their spatial variability and temporal variability on time scales from seasons to decades. The technique is then applied to the output of seven global climate models run in support of the most recent IPCC AR4 report. 2,000 tropical cyclones in each of the 5 ocean basins were simulated using global model data from the last 20 years of the 20th century, and the 22nd century as simulated by assuming IPCC emission scenario A1b. The results for the Indian Ocean show that there is again an overall tendency toward decreasing frequency of tropical cyclones, consistent with the direct simulations using global climate models, and a general increase in storm intensity increase, as expected from theory and prior work with regional tropical cyclone models.

Thus both recent trends in observations and long term modelling outcomes suggest that climate change will affect the characteristics of tropical cyclones in the South Western Indian Ocean in two distinct ways. Figure 2.4 shows an exceedance diagram for return periods of tropical cyclones in the Mozambique Channel, amended to include these future trends. Tropical cyclones are likely to become less frequent (as shown by the green arrows), but their intensity and associated precipitation is likely to increase (as shown by the red arrows). Overall, the future changes are less easy to pin down.

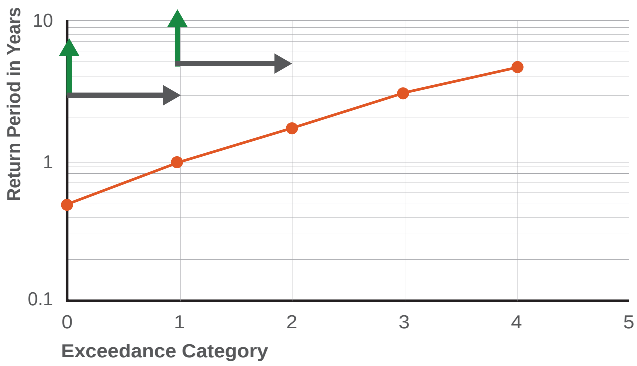


Figure 2.4: Future Trends in Cyclone Exceedance.

Finally, the question arises as to the future impact of tropical cyclones on the Mozambique coast in economic terms. If tropical cyclones are to become less frequent and their return periods become longer, their overall impact might be decreased as the number of potential disasters will be fewer. However, if the proportion of intense tropical cyclones is set to increase, then the impact of individual intense tropical cyclones will be much greater whenever they do occur. The Saffir-Simpson Scale suggests that the impact of the high category tropical cyclones is overwhelming, compared to the impact of the low category cyclones. This is confirmed by the global re-insurance industry, where the losses experienced per individual event increase substantially with the return period of the event. In the future, the re-insurance industry has recognized the need to adjust the probability of tropical cyclones making landfall on vulnerable coasts. While storm activity is known to be subject to natural fluctuations, there is a likely superimposed trend towards more frequent and more intense cyclones. This will require a re-evaluation of the storm surge and flood risk, as well as the aggravating factors associated with mega-catastrophes, with an even greater loading on intense cyclones. As these changes to the risk environment become increasingly apparent, risk carriers believe they cannot wait until science has provided answers to all the relevant questions, but must already make substantial adjustments to risk portfolios (Munich Re, 2006).

Storm Surges

What are the characteristics of observations of extreme sea level events along the coast of Mozambique, and how are they used by engineers and planners?

Much of the coastline of Mozambique is soft, comprising of muddy river sediments and sand, backed by land with low relief and extensive low-lying coastal plains. The Centre is characterized by major rivers, such as the Zambezi, Save, Buzi and Pungoe, draining the continental interior, and prone to flooding on an annual basis, while rivers such as the Limpopo, Incomati and Maputo enter the sea in Maputo Bay in the South. The coastline has a series of estuaries and deltas, which shift in response to the frequent floods and the deposit of large amounts of sediment. Such soft coastlines are vulnerable to coastal erosion, especially when extreme sea level events such as tropical cyclones prevail.

It is possible to examine the root causes of this vulnerability through the observational record of sea level which is available from the tide gauges maintained by the Instituto Nacional de Hidrografia e Navigação (INAHINA) in Mozambique. The influence of storm surge is examined at three harbors on the coast of Mozambique where records of extreme sea level are available from the tide gauge records. The extreme sea levels are given in centimetres above mean sea level, to enable comparison with topographic maps of elevation on land. The harbors are Maputo, Beira and Nacala, representative of the South, Centre and North, respectively. Port diagrams are constructed from observed annual maximum sea levels over a ten year period, using a logarithmic ordinate for the return period. Their stable linear trend enables extrapolation of a return period well beyond the observational record.

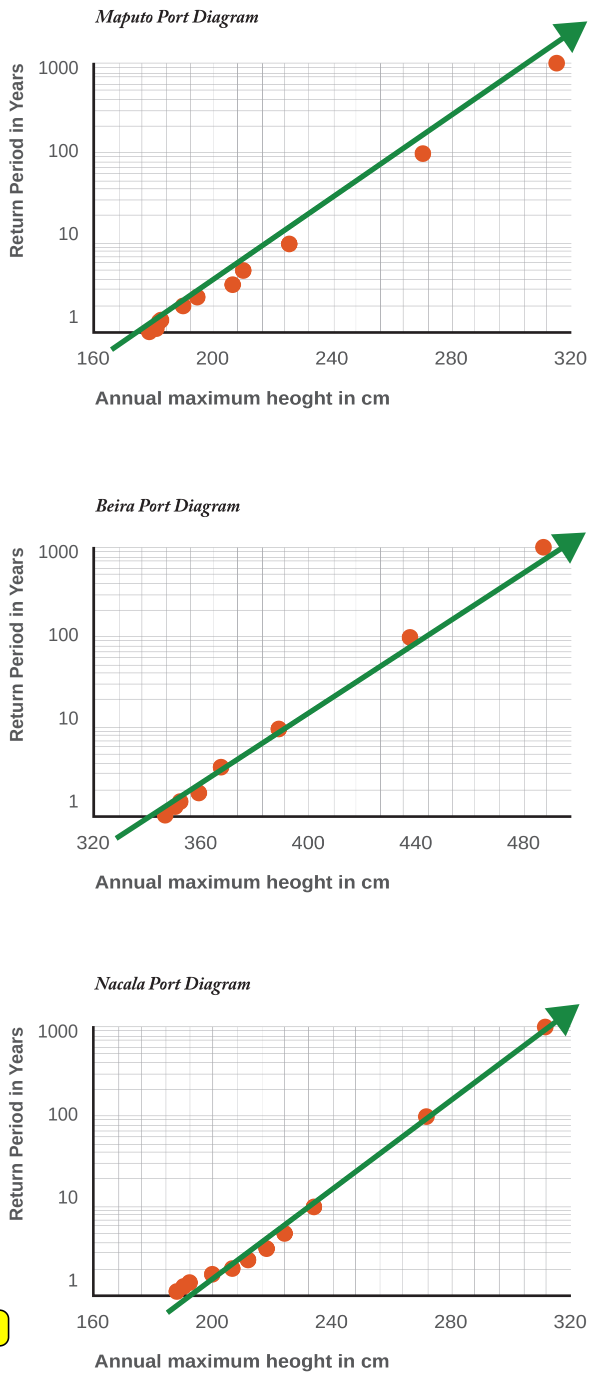


Figure 2.5: Port diagrams from observed annual maximum sea levels over a 10 year period.

Port	1 year	10 years	100 years	1000 years	HAT
Maputo	178cm	225cm	270cm	315cm	178cm
Beira	346cm	390cm	440cm	490cm	340cm
Nacala	185cm	234cm	272cm	312cm	205cm

Table 2.6: Annual Maximum Height in centimetres above Mean Sea Level against Return Period in years, with Highest Astronomical Tide for comparison.

Each year the annual maximum sea level is expected to approximate or even exceed the highest astronomical tide, even though such a tide may not be predicted for that year. It is expected that bad weather will bring a storm surge, which will build onto the predicted tide to produce an extreme sea level. The higher values of the annual maximum sea level heights at Beira are principally due to the much greater tidal range, approaching 7m between spring low and spring high tides, in the central provinces of Mozambique. In addition, the general contribution of storm surge to the maximum sea level height, as measured by the difference between the annual maximum sea level at a return period of 1,000 years and the highest astronomical tide, also increases from Nacala to Maputo to Beira.

To investigate the effect of tropical cyclones the record of sea level observations along the coast of Mozambique has been studied. The following conclusions can be drawn:

1. The effect of tropical cyclones can only be investigated if the tide gauges are operational at the time. Damage to the infrastructure, both observational or communications, from the tropical cyclone may well be an issue (Eline, 2000).

2. Only when the tropical cyclone is close enough will there be a noticeable effect in the sea level record (Bonita, 1996).

3. The tidal range in the Centre is so large that it can dominate the effect of a tropical cyclone when the cyclone occurs at the time of a neap tide. The real danger is when the tropical cyclone coincides with a spring tide, so that the two events combine together to create an extreme sea level.

4. Records of sea level are often made in sheltered locations within harbours. The effect of a tropical cyclone may be much greater on an open coast.

The influence of TC Bonita on the sea level at Beira in the year 2000 illustrates these points. TC Bonita added a 50cm storm surge to the sea level record at Beira, which is lost in the dominant tidal record.

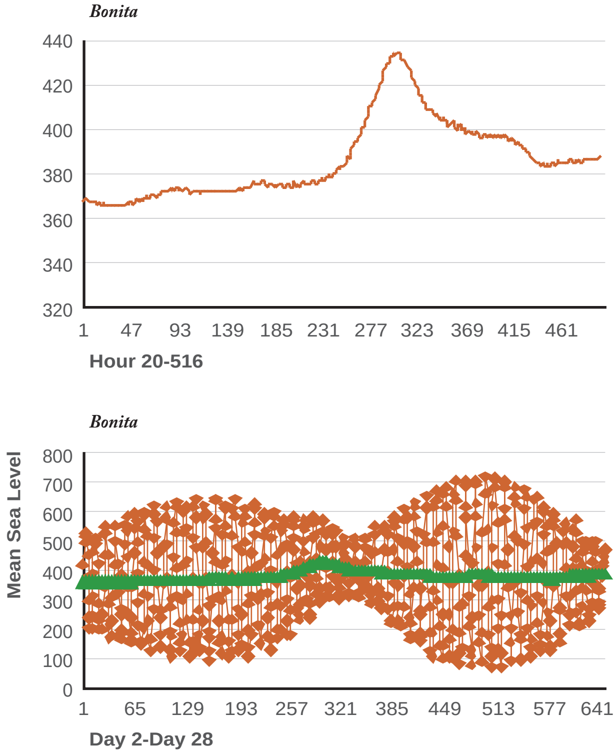


Figure 2.6: The influence of TC Bonita on the sea level at Beira in the year 2000.

The estimates of extreme values to be expected at return periods of 1, 10, 100 and 1000 years are used by coastal engineers in their design of coastal defenses, and by coastal planners for estimates of land areas which are at risk of inundation. Coastal protection built at the lowest level of the one year return period will provide minimal protection. Water will breach the defenses and will flow landward at the time of an extreme event with a ten year return period. If sustained in time, such an event will flood all the land lying below the 10 year return period elevation. The 1,000 year extreme sea level event, probably associated with a tropical cyclone making landfall in the vicinity at a spring high tide, will overtop the defenses and flood all land which lies at an elevation below the level of the 1,000 year return period event. Greater protection can be gained by building the coastal defenses upward to the heights of the 10 year or the 100 or even the 1,000 year return periods.

The maximum sea levels at long return periods correspond to extreme value analysis estimates of the levels of storm surge that can be expected under present day conditions. It should be remembered that the underlying conditions will be influenced by climate change, through changes in the characteristics of tropical cyclones and through sea level rise. Amendments to the elevations expected at long return periods, to the corresponding port diagrams, to the protection levels, and to land areas and populations at risk, will be needed to account for the effect of climate change.

Sea Level Rise

Will climate change, through the expected consequence of sea level rise, increase the vulnerability of the coastline to tropical cyclones?

Dasgupta et al 2006, investigated the comparative impacts on developing countries of coastal inundation due to sea level rise (without storm surge augmentation) through the 21st century. Using such measures as land area, population, agriculture and local economies, they noted that, of all the regions worldwide, sub-Saharan Africa is expected to suffer the least impact. Mozambique appears as one of the sub-Saharan countries most affected when the sea level rise reaches extreme levels of 4 to 5m but not at more modest levels of 1m. The World Bank study uses existing populations, socio-economics and land use patterns as a basis for examining the effects of sea level rise, as if it were to happen overnight and affect each country under existing circumstances.

By contrast, Nicholls and Tol 2006 looked at both the impacts and responses to sea level rise over the 21st century, and included the effect of storm surge augmentation on sea level rise by extending the Global Vulnerability Analysis of Hoozemans et al (1993). They carried out a global analysis using the Special Report on Emission Scenarios (SRES), with the contrasting levels of economic development and commitment to mitigation, and added adaptation strategies dependant on relative wealth. In their comparative economic analysis of coastal impacts globally, they emphasize that it is the small island states and countries with extensive coastal deltas, such as Mozambique, that will suffer the most land loss and need to set aside the greatest proportion of their GDP for adaptation costs. The inclusion of Mozambique reflects its exposure to the hazard of tropical cyclones, the vulnerability of long sections of its coastline, and its inability to respond due to its poor economic status.

Observations of sea level globally show a statistically significant sea level rise as part of human-induced climate change. The underlying causes of sea level rise at present are thought to be:

- Thermal expansion of the oceans in response to global warming
- Continental ice melting in temperate and high tropical regions

At present, the rate of sea level rise is slow, but it does appear to be accelerating. What is the situation along the coastline of Mozambique?

Any analysis of sea level rise requires careful and consistent observations of sea level over several decades. Such records are not really available in Mozambique nor in Africa as a whole (Woodworth, Aman and Aarup, 2007). A relatively long record of annual mean sea level is available for Maputo from the Permanent Service for Mean Sea Level (PSMSL), which applies rigorous quality checks on the original observations supplied by INAHINA in Mozambique.

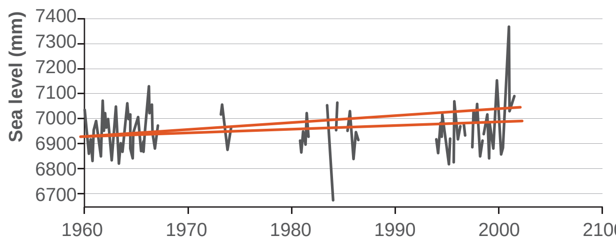


Figure 2.7: Mean sea level records relative to land height in Maputo, 1960-2002. Source: INAHINA, 2008.

The PSMSL uses a Revised Local Reference sea level rather than the more usual Land Levelling Datum.

It can be seen that there is very little high quality data available for portions of the period 1960-2001, and nothing in recent years. No trend can be detected as the early section and the end section cannot really be reconciled. To be fair it should be pointed out that the original objective in collecting this data was to enable effective tidal predictions to be made, which has been achieved. With the focus of climate change studies moving towards sea level trends, different and more stringent quality controls have become necessary. This requirement will test INAHINA in the future.

In order to make progress, it is necessary to turn to regional and global studies. Church et al. (2004) identified regional patterns of sea level rise from global tide gauge records between 1950 and 2000. For southern Africa, they estimated sea level rise of about 1.0 to 2.5mm per year. These rates agree with earlier studies of observations from the west coast of South Africa by Brundrit (1995) and recent analysis of tide gauge records from Durban by Mather (2007). The best that can be said is that the admittedly poor sea level record from Maputo is not inconsistent with the two estimates of regional trends from Church et al (2004), which are marked in red on the sea level record from Maputo.

Turning to global records for tectonically stable areas, the limited records from Mozambique and from southern Africa are consistent with more refined recent global trends of sea level rise of 1.3 to 2.3mm per year. These global rates of sea level rise can be applied, with caution, to the coast of Mozambique, to reflect the best available estimates of recent trends from global observations.

The IPCC in its Fourth Assessment Report has provided a Summary for Policy Makers within its Climate Change Synthesis Report, IPCC-Syn (2007). In discussing observed changes in climate and their effects, the IPCC report the following:

"Rising sea level is consistent with warming. Global average sea level has risen since 1961 at an average rate of 1.8 [1.3 to 2.3] mm per year and since 1993 by 3.1 [2.4 to 3.8] mm per year".

"Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer term trend is uncertain".

The observational record shows a shift in intensity, this time in the form of an acceleration in sea level rise. Again there is uncertainty as to whether this shift is due to climate change or to natural variability. A long and representative observational record of sea level has not as yet been assembled to test whether or not the acceleration will be sustained into the future, nor at what rate.

If the 1993 to 2003 sea level rise is sustained through the 21st century, it will result in a rise of 240mm to 380mm over the century. With changing emissions and increased temperatures, there is likely to be some further acceleration of sea level rise through the links to climate change processes. Again, it is possible to use global climate modeling, this time to identify future trends in sea level rise.

In its projections of future changes in climate over the 21st century, the IPCC WG1, in its Fourth Assessment Report of February 2007 (IPCC-WG1 2007), draws on a set of models of sea level rise for 2090-2100 relative to 1980-1999, and predicts a rise in the range of sea level rise from 180mm to 590mm by 2100, depending on the particular emissions scenario used.

The low estimate reflects a scenario in which mitigation efforts have successfully restricted sea level rise to the levels of the last century, while the high estimate reflects the influence of increasing ocean warming and temperate and tropical continental ice melting.

Of particular interest are the global sea level rise scenarios used by Nicholls and Tol (2006) for the SRES future worlds, which reflect alternative pathways of political, economic, technical and social development through the 21st century.

SRES	A1FI	A2	B1	B2
2030	80mm	80mm	80mm	80mm
2060	180mm	160mm	120mm	160mm
2090	340mm	280mm	220mm	250mm

These sea level rise scenarios provide levels at 2030, 2060 and 2090 through the 21st century which are consistent with lower projections from the IPCC.

All the sea level rise models introduced so far exclude rapid dynamical changes in ice flow due to continental ice melting in the Polar Regions. This is an important reservation. The recently documented ice melting, both at sea and on the polar ice-caps, has led the IPCC to abandon its earlier projections. In its Synthesis Report of November 2007, IPCC-Syn (2007), it states that:

"because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or upper bound for (future) sea level rise".

In order to provide some perspective on the gravity of the situation, the IPCC stresses that:

"Current models suggest virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level of about 7 metres if global average warming were sustained for millennia in excess of 1.9 to 4.6 degrees Celsius relative to pre-industrial levels".

It should be noted that no time scale is provided for this contribution to sea level from the Greenland ice sheet. The time scale awaits better understanding of the linkages between climate processes and continental ice melt, confirmed by an observational record of some reasonable relevance and length. It should also be noted that there are other polar ice caps that could potentially contribute to massive sea level rise.

Polar Ice Melt Scenario

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 2.8: Sea level rise scenarios.

In a review of coastal impacts and responses to sea level rise, Brooks, Nichols and Hall (2006) explore a number of scenarios for the possible rates of sea level rise over the next century. These include:

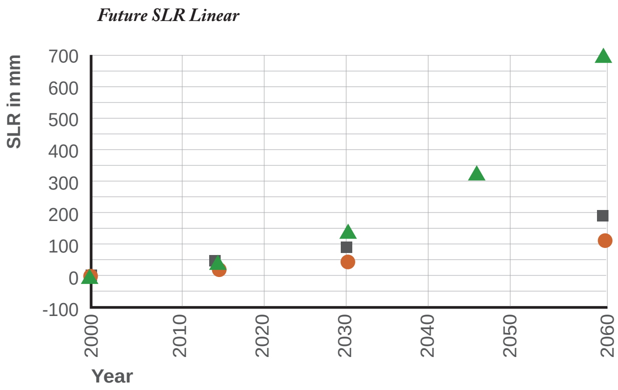
- A low rate of 10cm per century, which assumes that Greenhouse Gas concentrations will not rise above the levels of 380ppm experienced in the year 2000. This is not realistic but can provide a lower bound to sea level rise scenarios.
- A modest rate of 25-50cm per century, which keeps Greenhouse Gas emissions at the levels of the year 2000, and is more realistic. The eventual stabilization of Greenhouse Gases will then be roughly 450ppm, which is associated with an eventual temperature increase of 1.5°C and an eventual sea level rise of 2m. However, such a temperature increase could well lead to the risk of the onset of the melting of the Polar Ice Caps.
- Rates of over 1m per century are associated with the complete loss of the Greenland Ice Cap, as well as contributions from the West Antarctic Ice Cap. These require local increases of temperature exceeding 3°C in order to provide sustained melting.

It appears that there are two groups of sea level rise scenarios. The first group includes the IPCC and the SRES scenarios, and can be represented by a Low Sea Level Rise Scenario (Low SLR). In order to represent the group of scenarios which include a substantial contribution from polar ice melt, a High Sea Level Rise Scenario (High SLR) needs to be introduced.

	2030	2060	2100
Low Sea Level Rise Scenario	10cm	20cm	30cm
High Sea Level Rise Scenario	10cm	100cm	500cm

These two hypothetical scenarios will be used in the sea level rise analyses that follow. It must be emphasized that the High SLR Scenario is very speculative, as the future rates of melting of the polar ice caps are largely unknown.

Caution should be exercised when making projections of sea level rise based on extrapolations of current trends. Depending on whether sea level rise is maintained at a constant rate or accelerates in the future, the extrapolations would cover a wide range of values. Figure 2.9 illustrates this by charting sea level rise through the 21st century, which reverts to its earlier slow rate of 1.8mm per year (blue points), maintains its new modest rate sea level rise of 3.1mm per year (red points), or accelerates strongly by doubling the rate of sea level rise every 15 years (yellow points). The last doubling projection is intended to illustrate the High SLR Scenario, which includes rapid polar ice melt.



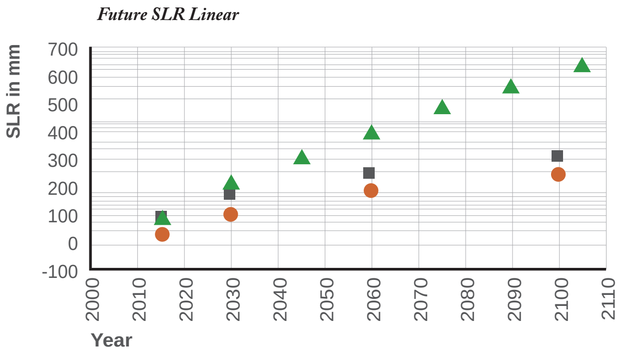


Figure 2.9: Sea level rise through the 21st Century.

At the first waypoint of 2030, both the linear and the doubling models give essentially the same estimates of sea level rise around 100mm. 54mm, 93mm and 139mm respectively. This is also true of the models used in the IPCC and the SRES analysis and even in simple models of polar ice melt. By the second way point of 2060, the levels begin to separate, reaching 108mm, 186mm and 697.5mm in the three cases. The very rapid acceleration only has an appreciable effect, leading to a clear differentiation between the between the linear and doubling models of 180mm, 310mm and 4900mm later in the 21st century.

The Low SLR Scenario and the High SLR Scenario introduced above are used, together with the extreme sea levels established before, to generate the future expected extreme sea levels at return periods of 1, 10, 100 and 1,000 years, depending on the location and the particular sea level rise scenario. Subsidence in delta environments and a gradual increase in the intensity of tropical cyclones are included in the calculations.

Nacala	Scenario	1 year	10 years	100 years	1000 years
Present		185cm	234cm	272cm	312cm
2030	**All**	195cm	244cm	282cm	330cm
2060	**Low SLR**	205cm	254cm	292cm	349cm
	High SLR	285cm	334cm	372cm	429cm
2100	**Low SLR**	215cm	264cm	302cm	370cm
	High SLR	585cm	634cm	672cm	740cm

Beira	Scenario	1 year	10 years	100 years	1000 years
Present		346cm	390cm	440cm	490cm
2030	**All**	361cm	406cm	455cm	517cm
2060	**Low SLR**	376cm	420cm	470cm	545cm
	High SLR	456cm	500cm	550cm	625cm
2100	**Low SLR**	391cm	435cm	485cm	576cm
	High SLR	761cm	805cm	855cm	946cm

Maputo	Scenario	1 year	10 years	100 years	1000 years
Present		178cm	225cm	270cm	315cm
2030	**All**	188cm	235cm	280cm	335cm
2060	**Low SLR**	198cm	245cm	290cm	355cm
	High SLR	278cm	325cm	370cm	435cm
2100	**Low SLR**	208cm	255cm	300cm	378cm
	High SLR	678cm	625cm	670cm	748cm

Table 2.7: Extreme sea levels expected at long return periods, at various ports and for the representative low and high sea level rise scenarios. ***Notes: All heights are in centimeters above present day mean sea level.***

Extremes are derived from observed and extrapolated sea levels at the various harbors, with subsidence of 15cm per century included at Beira.

Storm surge at the 1,000 year return period, corresponding to an intense tropical cyclone, is increased by 20% over the century, before being added to the sea level.

Before considering the question of future protection in detail, the case of no action beyond the present situation is explored. With no additional protection, the effect of future sea level rise will appear to reduce the return periods of extreme sea level events. This can be illustrated through a composite Port Diagram for extreme events at present and for the extreme events expected in 2030, with the sea level rise of 10cm from all sea level rise scenarios. The port of Beira is chosen to illustrate this phenomenon.

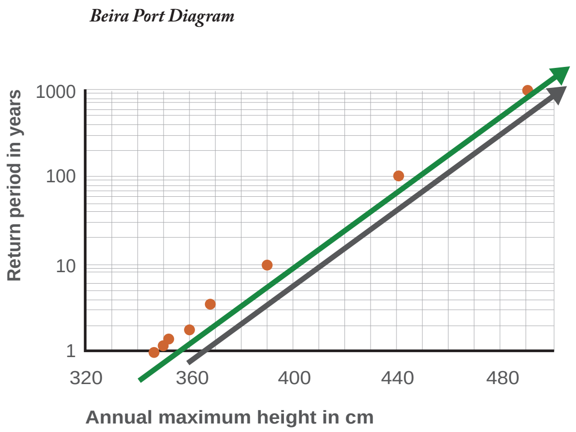


Figure 2.10: Beira Port diagram.

The present day annual maximum height for various return periods is marked in blue on the Beira Port Diagram. The maximum heights, after the sea level rise of 10cm in 2030, are marked in red on the amended Port Diagram. The extreme event of 380cm with a present day return period of 5 years (blue line), will have a return period of 3 years (red line) when adjusted for the sea level rise in 2030. In the same way, the extreme event of 440cm with a present day return period of 100 years (blue line), will have a return period of 60 years (red line) in 2030. Every present day, fixed coastal defense, will be breached at decreasing intervals and the population and infrastructure at risk will be overwhelmed, if no additional height is provided to cope with future sea level rise.

Coastal Adaptation Strategies

The principal threat to the coastline of Mozambique, its people and its economy at the present time, comes from the damage potentially caused by the impact of a tropical cyclone. This was the case in the year 2000 when TC Eline and TC Hudah caused damage amounting to 12% of GDP, from which the country took several years to recover. With the onset of climate change in the early years of the 21st century, tropical cyclones will remain the principal threat, and their potential impact will possibly grow though an increase in their intensity and their interaction with the expected modest rates of sea level rise.

Vulnerability to tropical cyclones depends on the nature of the coastline, whether the coast is hard or soft, rigid or yielding. In the same way, coastal infrastructure and services are protected from the sea in different ways for hard rocky coasts, for dynamic sandy coasts and for soft muddy coasts. Here two categories of coastal protection are considered; fortified seawalls and vegetated dune barriers. Each category of protection has its own engineering design characteristics to provide appropriate degrees of cost effective protection from extreme storm surge events. For the High SLR Scenarios associated with polar ice melt, protection becomes less affordable and a new adaptation strategy of Coastal Retreat has to be investigated.

Fortified seawalls are designed to protect valuable infrastructure and services, often in an industrial and an urban environment. Protection classes based on the return periods of storm surges have often been used as part of the seawall design. An overview can be given for the South, Centre and North in turn, using the extreme sea level heights expected at return periods of 1, 10, 100 and 1,000 years, from representative ports in the three zones.

Port	1 year	10 years	100 years	1000 years	HAT
Maputo	178cm	225cm	270cm	315cm	178cm
Beira	346cm	390cm	440cm	490cm	340cm
Nacala	185cm	234cm	272cm	312cm	205cm
Protection Classes	*Minimal*	*Low*	*Medium*	*High*	

Table 2.8: Extreme sea level heights expected at return periods of 1, 10, 100 and 1,000 years, from representative ports in the three zones.

These heights can be used as design heights for fortified sea walls offering minimal protection, low protection, medium protection and high protection in the three zones. Decisions have to be taken as to which level of protection to afford each area at risk. What is the risk, expressed in terms of the economic loss of infrastructure and services from temporary flooding of the area, against the cost of building or raising the height of a seawall to provide proper protection? In a real sense, this means comparing the cost of building up and maintaining the seawall against insuring against the losses from the unlikely occurrence of an extreme sea level event like a tropical cyclone with a return period of 1,000 years, even if it is the government that carries the insurance.

It should be borne in mind that climate change will alter the heights of the extreme sea level events at long return periods, and also increase the design heights for the seawalls that are protecting the investment in infrastructure and service in the ports and cities and in the communication links along the coast. Sea level rise will increase the base level for the seawalls, typically by 10cm at the 2030 way point, and much more by the end of the century. It is also anticipated that there will be an added effect from the more intense tropical cyclones in the South Western Indian Ocean. Minimal, low, medium and high protection levels for coastal defences can be set directly from the extreme sea levels expected at return periods of 1, 10, 100 and 1000 years, under the various sea level rise scenarios, as given in Table 2.8 above. These levels will be used as the basis for protection levels in the regional studies that follow in section 2.3, and for land elevation maps to estimate areas at risk, and hence population, infrastructure, communication links and services at risk.

The affordability of added future protection has been addressed by Nicholls and Tol (2006) in their investigation of the SRES scenario as typical of the LSR Scenarios. They link the four protection classes to an economic model to determine which particular protection class should be adopted as the optimal protection strategy, and noted the added expenditure involved for countries with delta coastlines. Their low protection class has a seawall designed to a height of the 1 in 10 year storm surge, with affordability which they link to an economy of below US$600 GDP/capita in general but below US$2,400 GDP/capita for delta coasts. Their medium protection class has a seawall designed to a height of the 1 in 100 year storm surge, which they link 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, their high protection class has a seawall designed to a height of the 1 in 1000 year storm surge, which they link to an economy of over US$2,400 GDP/capita in general but over US$5,000 GDP/capita for delta coasts.

At the present time, these affordability levels mean that much of the protection along the Mozambique coastline is at the minimal or low protection level. As the economy gradually grows, improvements can be contemplated, though there will always be the added burden of a vulnerable delta coastline. Nicholls and Tol (2006) emphasise that, if these protection classes are adopted as the adaptation strategy against sea level rise, and there is favourable economic growth, future additional impacts from sea level rise and storm surges can be contained at manageable levels. In fact, the danger of severe impacts may even be reduced from present levels. On delta coasts, vulnerability can be further reduced by managing human-induced subsidence such as groundwater withdrawal.

Coastal engineering design criteria that need to be considered in use of dune barriers to protect coastal infrastructure.. In contrast to the fortified seawalls, where design features such as dolosse fronting the seawall dissipate the force of ocean waves, the dune barriers are exposed to the full erosive potential of the waves in the surf zone. The extreme sea levels on the open coast will exceed values gathered from observations in harbours, as they will include dramatic wave effects in the surf zone. This can be seen from the Saffir-Simpson storm surge levels, which reach over 4m for the most intense tropical cyclones, as against the storm surges associated with the extreme sea levels which remain less than 2m. Dune barriers must be high enough and wide enough to withstand the erosive potential of the storm surges on the open coast associated with tropical cyclones. The experiences of the extreme storm of March 2007 along the nearby east coast of South Africa led Theron (2008) to recommend that dune barriers used along the coast of Mozambique should be designed at heights in excess of 6m above the mean spring tide. This same storm eroded beaches by 30m in just six hours. These are the sizes of the dune barriers that are needed to afford effective protection against tropical cyclones on soft coasts.

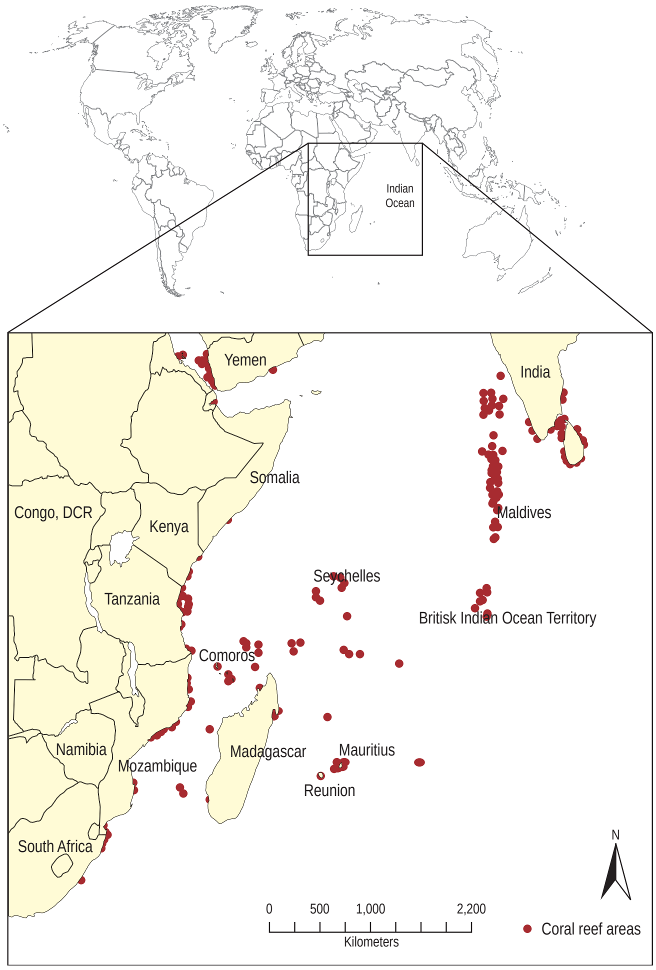
Studies on the impacts of sea level rise on soft coasts need to account for land lost directly through inundation, but also indirectly through coastal erosion. Erosion events are likely to be episodic and associated with extreme storm events such as the one described above. In the long term, there will be an accumulative impact and Bruun's Rule provides an order of magnitude estimate of erosion and coastal set-back at 100 times the rise in sea level. Thus the LSR Scenario, with its rise of 30cm by 2100, will be associated with a gradual coastal set-back estimated at 30m. Along certain sections of the coastline, such a loss of beach amenity will be unacceptable and dune protection measures, or beach nourishment schemes, will need to be considered to counter the effects of long term erosion.

Meanwhile, it is possible to explore some of the consequences of such a large scale polar ice melt, by way of an extreme climate scenario, even though its full impact may not be felt for many decades. Whilst protection through various forms of fortified sea walls and dune barriers is the preferred adaptation approach for the low sea level rise expected in the near future, the question arises as to whether or not such an approach will continue to be as economically attractive with sea level rise of the order of magnitude of metres rather than centimetres. The results of studies addressing this question elsewhere in the world can be of some relevance to Mozambique. Of particular interest are the possible societal responses to a 5m rise in sea level within a century, starting in 2030, as reported by Tol et al. (2007). They report on the outcomes of a series of workshops of regional experts and stakeholders, convened to consider the cases of three large and well-populated European estuaries. The most likely response in the Rhone estuary would be retreat, with economic losses, perhaps social losses, and ecological gains as wetland areas increase in size. In the Thames estuary, the outcome would be less clear, but would probably be a mix of accommodation and retreat, with parts of the city centre turned into a Venice of London. In the Rhine delta, the Netherlands, the initial response would be protection, followed by retreat from the economically less important parts of the country and probably from the Amsterdam-Rotterdam metropolitan region as well.

These three case studies by Tol et al. (2007) make it clear that adaptation would be difficult even in well developed countries. If the Netherlands does not expect to be able to cope, even with its extensive experience in the protection from the sea and in flood management technology, countries with similar river deltas are not expected to be able to use protection as a viable option either. The remaining option of the evacuation of large populations from tropical deltas in developing countries would be a national calamity for those countries. Whilst, this conclusion of the catastrophic potential effects of polar ice melt lends strong support to efforts leading towards the mitigation of climate change, it is also important to investigate the situation in threatened delta environments in developing countries through an approach, similar to that used by Tol et al. (2007).

Coral Coasts

In common with the islands of the Western Indian Ocean, much of the coastline of Mozambique, away from the major rivers, is fringed with coral reefs. This is particularly true of the North. These reefs comprise tough, algal-clad intertidal bars composed largely of coral rubble derived from their ocean front, and provide protection from wave attack to the inshore areas with their sediment veneers and beach sands that are susceptible to erosion (Arthurton 2003). Their continued function is under threat from various aspects of climate change and human interference. These negative effects include coral bleaching from high sea surface temperatures, submergence from sea level rise and reduced calcification from ocean acidification. Marine pollution is the general threat from human activities on the coast.



Map 2.2: Coral ecosystems along the Eastern coast of Africa.
Source: ESRI world map.

The impact of climate change through coral bleaching on coral reefs of the Western Indian Ocean has been well documented. Obura (2005), reported on high coral bleaching in both southern and northern Mozambique resulting from sea surface temperature increases during 1998, with highly varying mortality rates from the expulsion of the coral's symbiotic algae ranging from 20% to 80%, whilst Maina et al 2007 have modelled the susceptibility of these coral reefs to such environmental stress. The long-term impact of such widespread coral death episodes on the continuity of the supply of detrital coral rubble to fringing reef bars and platforms is yet unclear.

A fundamental question is whether the upward growth of the reef bars – the principal first line of sea defence - could keep pace with the predicted rate of sea-level rise. Assuming such a capability, there would be a prospect of increased accommodation for back-reef sediment accumulation on the platforms. Any deepening of the waters over the platforms would favor the translation of ocean swell and lagoon-generated waves onto the beaches, a condition that would be exacerbated if upward reef growth fails to keep pace with sea-level rise. Existing beach and beach plain deposits would then become increasingly vulnerable to wave erosion.

Additional stress on the health of the carbonate - fixing biota of the reefs and their platforms will arise over the long term from another consequence of global climate change - the increased levels of atmospheric carbon dioxide. The resulting acidification of ocean waters through increased dissolved CO_2, which will impede biogenic calcification. This will provide serious issues for corals, as omega levels in excess of 3.5 are required for optimal coral growth, so that growth will be limited under these conditions. The present day pH levels of 8-8.2 in the surface ocean are anticipated to fall to much lower pH levels by 2100 as atmospheric CO_2 levels increase. Startling consequences for coral reef health are predicted under all SRES future world scenarios by 2100.

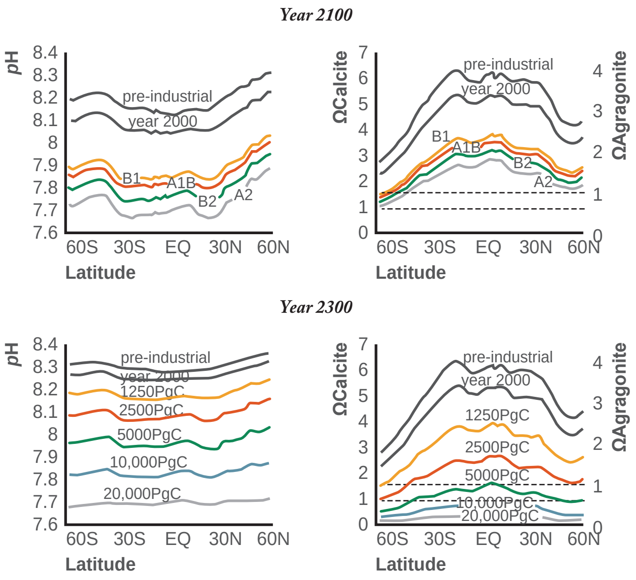


Figure 2.11: Ph levels in the surface ocean.
Source: Caldeira & Wickett, 2005, GRL.

Turbidity in coastal waters produced by high levels of suspended sediment discharged by rivers is another pressure of natural, often seasonal occurrence, usually related to monsoonal flooding. Human activities in the region's catchments and coastal zone increasingly impact on the health and biodiversity of the reef and platform habitats, and contribute to physical shoreline change. These include:

- Industrial, agricultural and domestic discharges leading to the eutrophication and pollution of the coastal environment,
- Physical interventions such as water impoundment and abstraction in catchments, sand mining and coastal engineering affecting the supply and transport of sediment both to and within the coastal zone, and
- Physical disruption of the ecosystem by insensitive fishery and recreational practices.

The reef bars form the key ocean defense for the fringing reef coasts. Given the forecast global average sea-level rise, the long-term protection of the reef-front, sediment-producing biota (especially the hard corals) from degradation by pollution (both marine- and land-sourced) and eutrophication, as well as human-inflicted physical damage must be a management priority. Similar protection is also relevant to the platform ecosystems, so that the biogenic production of carbonate sediment - the substrate of the backreef seagrass nurseries - is maintained. Because of their mesotidal condition, the fringing platforms are well flushed, generally with little scope for a build-up of contaminants. The coral reef areas of Mozambique are thus very vulnerable to climate change impacts, with direct effect on the biota as well as on the important linked socio-economic sectors, through the tourism industry.

Future impacts of climate change on cyclone, storm sturge and sea level rise activity

Prof. Geoff Brundrit, UCT and Dr Alberto Mavume, UEM

2.2 Regional implications for Mozambique

The earlier parts of this report examined the challenges faced by Mozambique in respect of climate change along its long coastline. They assessed the hazards of sea level rise and the intensification of tropical cyclones, especially in those areas which are known to be particularly vulnerable, and where the capacity of the country to cope with these hazards is limited. After summarizing the earlier sections, this section will deal with the implications for Mozambique, taking a regional approach so as to highlight their different sensitivities, needs and priorities, and setting out recommendations for future action to cope with the challenges of climate change along the coast.

Tropical cyclones have been an ever-present threat to the livelihood of the people living on the coast of Mozambique. Over the past 30 years both the frequency and the intensity of tropical cyclones making landfall on the coast of Mozambique has increased. The floods and cyclones of the year 2000 were particularly damaging to the economy and social fabric of the country as a whole. The warming associated with climate change strongly suggests that the trend of increased intensity of tropical cyclones will continue. Of particular concern is the tendency for people to migrate into the coastal region, so placing more people, infrastructure and services at risk.

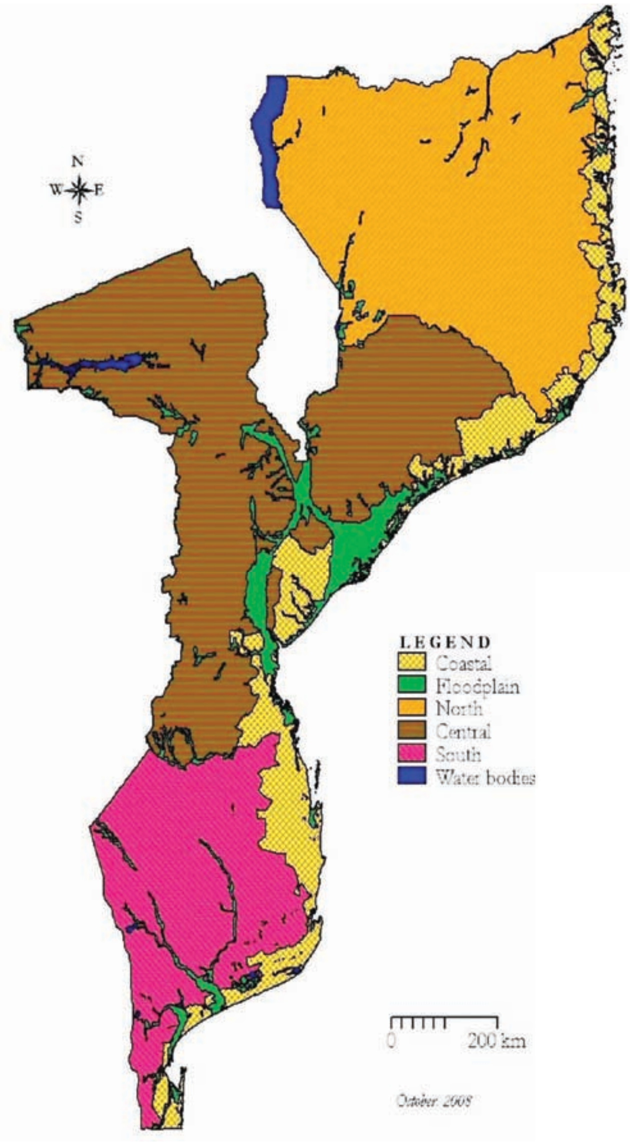
Much of the coast of Mozambique is vulnerable to attack from the sea, being particularly true of the Centre with their large rivers and deltas. The threat of inundation from tropical cyclones has meant that people and infrastructure at risk need to be properly protected through the construction and maintenance of coastal defenses. Sea level rise, accompanying global climate change, constitutes a threat in its own right, but is also a concern through its enhancement of the impact of tropical cyclones. Coastal defenses have to be strengthened further.

Global sea level rise scenarios fall into two categories:

	2030	2060	2100
Low Sea Level Rise Scenario	10cm	20cm	30cm
High Sea Level Rise Scenario	10cm	100cm	500cm

The Low SLR gives give a rise of up to 50cm by 2100. Under this scenario tropical cyclones will remain the principal threat to the coast of Mozambique. The potential for damage will increase steadily as this modest sea level rise is experienced along the coast. The scenarios under High SLR are quite different. This includes the rapid melting of polar ice caps, leading to sea level rise of the order of metres by 2100. In these circumstances, 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. Overall this threat to Mozambique is likely to be catastrophic.

All areas of the coast of Mozambique are subject to at least one of the impacts of climate change. However, each section of the coast has a distinct regional character, both in terms of their key threats and the extent of the vulnerability to these threats. This means that the implications of climate change are best dealt with on a regional basis; the North, the Centre and the South.



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).

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).

The Southern Region is characterized by a relatively narrow coastal plain, with some large rivers, a sandy coastline which becomes muddy close to the rivers, 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).

Map 2.3: Mozambique: land zoning. ***Source: ILAM, 2008.***

2.2 Regional implications for Mozambique

In the next section each zone will be examined as it relates to as it relates to climate change vulnerability. i.e the potential threat from tropical cyclones, based on the recent history of their occurrence and intensity, and an overall picture of the threat from sea level rise. The special threat to the coral ecosystems is dealt with where relevant.

The Northern Region of Mozambique

The North 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 the past 16 years).

Map 2.4 an elevation map provides a broad indication of vulnerability to climate change. The 5m contour along the coast can be used to indicate the areas at risk both from a sea level rise of 5m and from the impact of an intense tropical cyclone at present sea levels.

Map 2.4: Elevation map indicating the 5m contour line for the coastal zone of the North.

This suggests that only very few areas along this coast are at risk, specifically the low-lying offshore islands close to the border with Tanzania. The below details the risk of the impact of tropical cyclones in general, and the risk Nacala, the harbor town is exposed to.

The recent history of tropical cyclone occurrence shows the North was subject to four tropical storms or tropical cyclones in the past 15 years.

Year	Category and Name	Landfall	Date	Strength	Wind speed
1994	Cat 4 Nadia	North	24 March	Cat 1	139 km/h
1998	TS	North	17 Jan	TD	74 km/h
2003	TS Atang	North	13 Nov	TD	46 km/h
2008	Cat 4 Jokwe	North	08 March	Cat 3	180 km/h

Table 2.9: Tropical cyclones of Categories 1-4, storms (TS) and depressions (TD) making landfall on the coast of the Northern Region of Mozambique in the period 1994-2008.

The most intense cyclones were TC Nadia and TC Jokwe. TC Nadia was a Category 4 cyclone during its lifetime and remained a Category 1 cyclone at the time of its landfall close to Nacala. TC Jokwe made landfall as a Category 3 cyclone and remained at this intensity as it moved southwards down the coastal areas of the North. Both tropical cyclones turned back, to move off the land into the Mozambique Channel.

Figure 2.12 shows the impact of TC Jokwe on the coastal areas of the North, together with the damage to roads and health facilities, and the affect on the population.

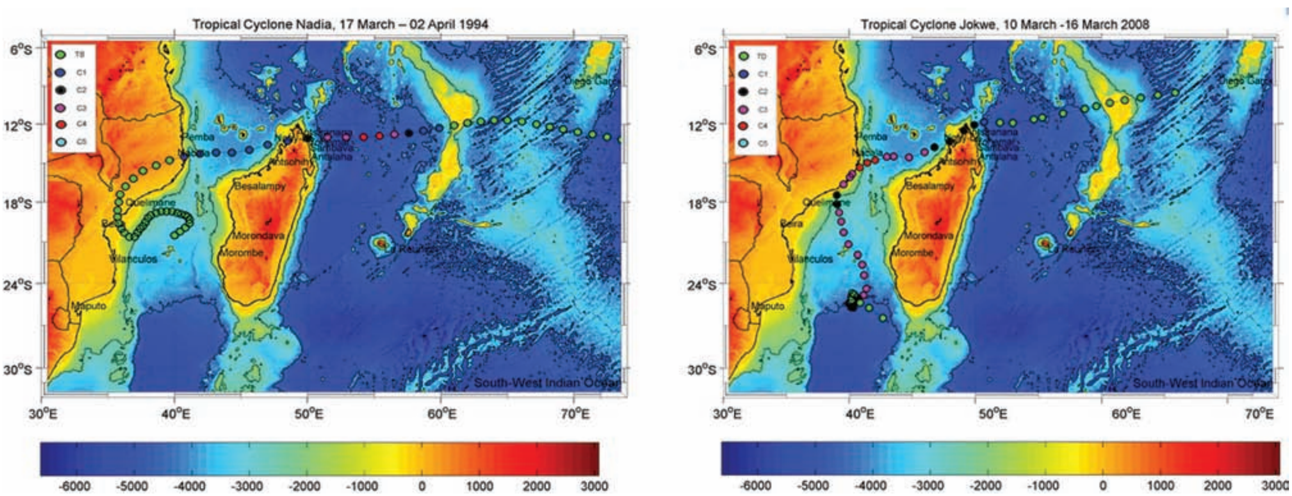
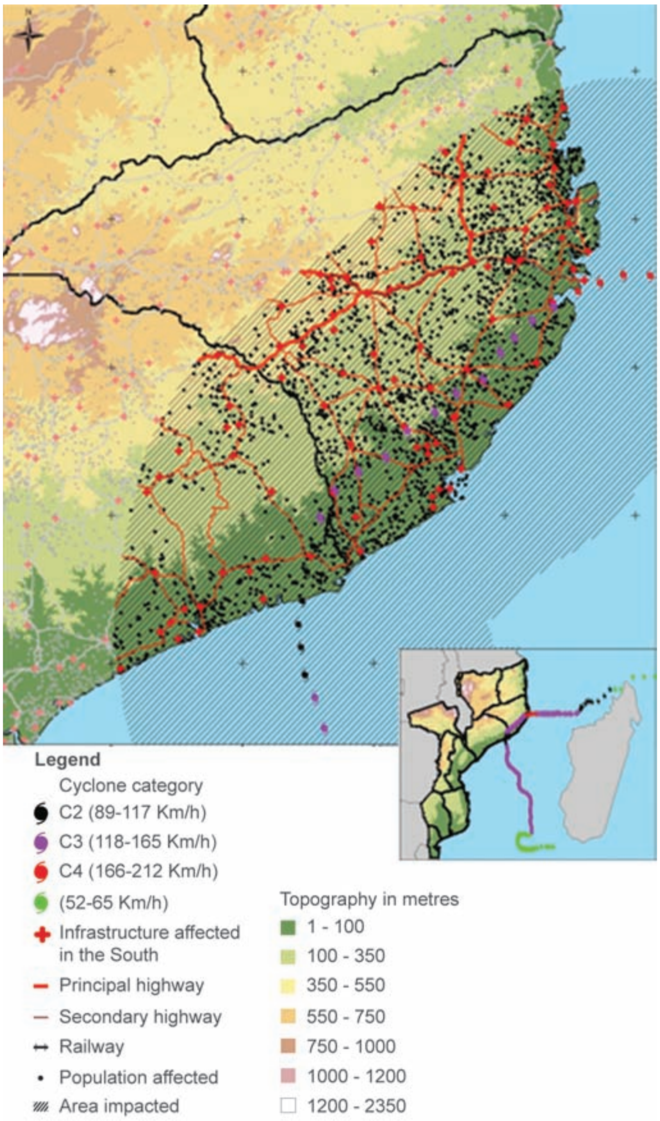
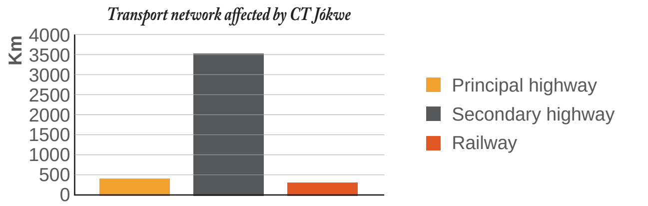
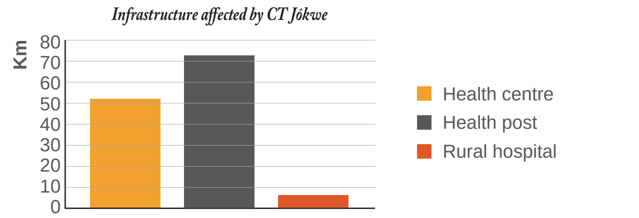


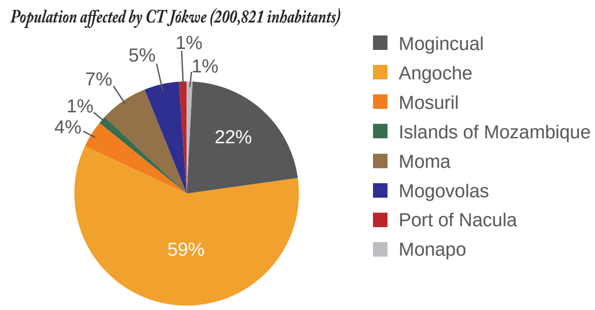
Figure 2.12: Trajectories of TC Nadia and TC Jokwe.

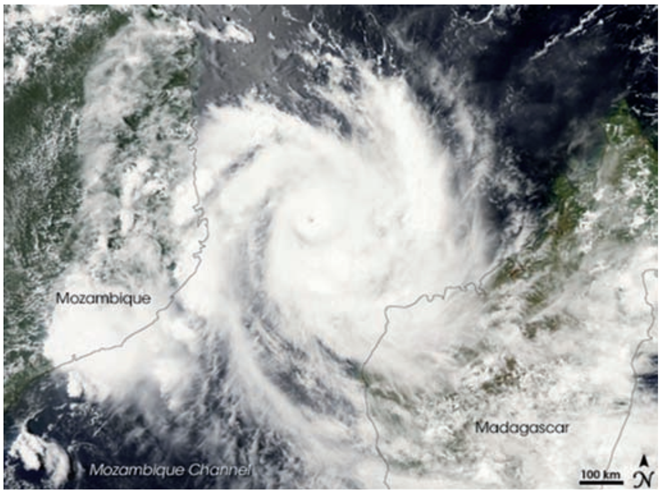


Map 2.5: The impact of a category 4 cyclone in the North. Area of impact is shaded, road network is shown in red lines, population in black dots.



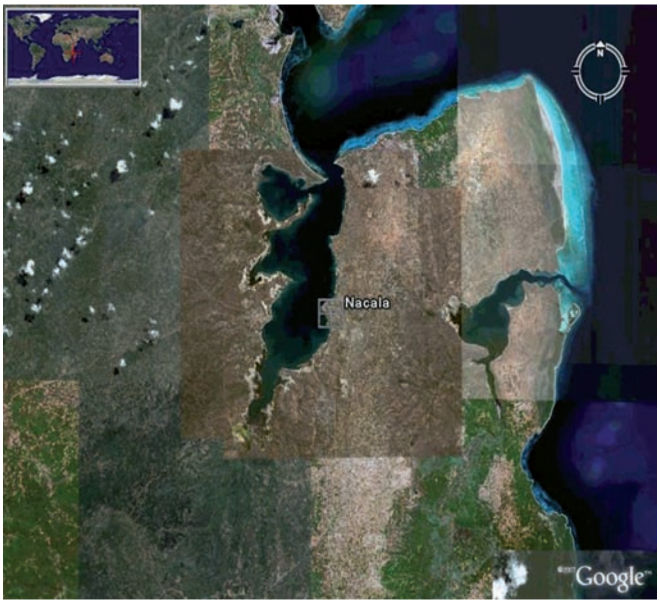






Climate change in the future is expected to lead to an increase in the intensity of tropical cyclones, and corresponding increase in the level of damage. There may also be an increase in their frequency of occurrence. Therefore the experience of the recent past can provide a valuable indicator of what might happen in the future.

The sea level observations made at the port of Nacala can be used to illustrate the exposure of the North to extreme sea level events and the need for coastal defenses. Nacala is situated on a deep estuary, and is sheltered from the open sea by high ground to the East.



Map 2.6: Google Earth map of Nacala on deep estuary.

Figure 2.13 show how observations of extreme sea levels over the past 10 years can be used to construct a port diagram of the expected return periods of extreme events as indicated by annual maximum heights.

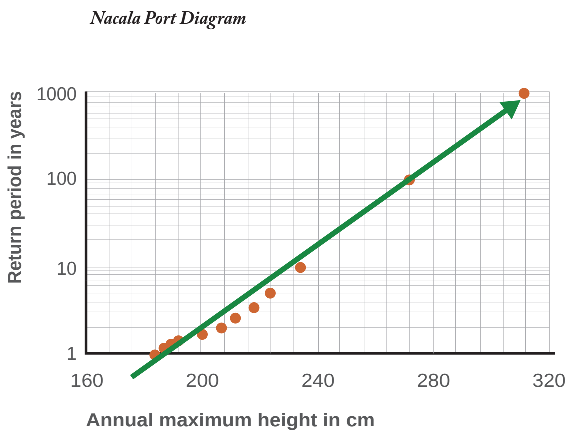


Figure 2.13: Nacala Port diagram.

Port	1 year	10 years	100 years	1000 years	HAT
Nacala	185cm	234cm	272cm	312cm	205cm

Table 2.10: Annual Maximum Height in centimetres above Mean Sea Level against Return Period in years, with Highest Astronomical Tide for comparison.

At present, the port and town of Nacala are normally subject to spring tides at a height of 2m above mean sea level. The 1,000 year extreme event from a tropical cyclone and coinciding with a spring high tide takes the sea level up to 3.12m. Coastal defenses are in place to guard against inundation from such an extreme event. Only a narrow strip of coastal land, holding the port and railway links, would be placed 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.

Map 2.7: Google Earth map of Nacala port.

These extreme sea levels at Nacala need to be adjusted upwards to take account of 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 over the 21st century.

Port	1 year	10 years	100 years	1000 years	Scenarios
Nacala	185cm	234cm	272cm	312cm	present
	195cm	244cm	282cm	330cm	2030
	205cm	254cm	292cm	349cm	2060 Low SLR
	215cm	264cm	302cm	370cm	2100 Low SLR
	285cm	334cm	372cm	429cm	2060 High SLR
	585cm	634cm	672cm	740cm	2100 High SLR
Protection Class	*Minimal*	*Low*	*Medium*	*High*	

Table 2.11: Extreme Sea Levels Expected at Long Return Periods At Various Ports and for the Representative Low and High Sea Level Rise Scenarios.

Protection will continue to be effective within the Low SLR Scenario through the 21st century, affording good protection from tropical cyclones and low levels of sea level rise. However, the radical difference expected from the polar ice melt contribution to the High SLR is clearly illustrated, with the likely inundation of the narrow strip of coastal land necessitating the relocation of the port facilities. The lack of a coastal platform may become an issue.

These levels can also be used to understand the vulnerability of Pemba and Angoche to climate change.

Map 2.8: Google Earth map of Angoche.

Map 2.4, the 5m contour map of the North, shows that the offshore islands will be at risk of inundation. A further impact of climate change is on the coral ecosystem, a striking feature of much of the coastline of Northern Mozambique. These reefs comprise tough, algal-clad intertidal bars composed largely of coral rubble derived from their ocean front, and provide protection from wave attack on the inshore areas - with their sediment veneers and beach sands that are susceptible to erosion. An important consequence of this gradual inundation is a reduction in the effectiveness of providing protection to the coast, which then becomes exposed to the full force of any extreme event.

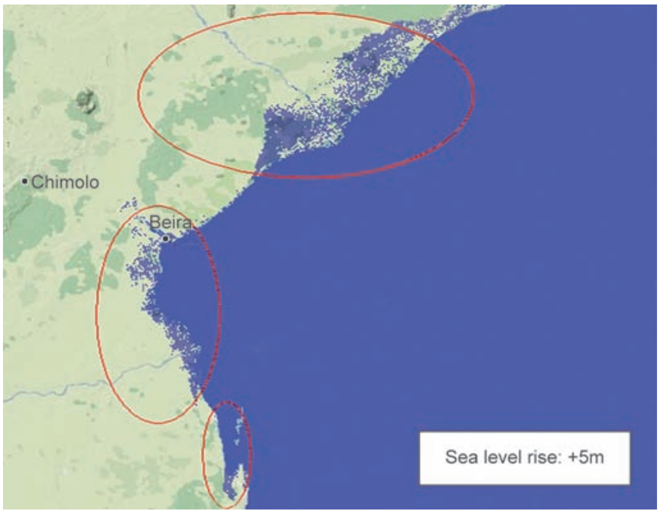
Such exposure would lead to increased erosion and set back of the coastline, equivalent to approximately 100 times the rise in sea level. The two scenarios used here are the modest rise of 30cm over the century and the high polar ice melt rise of 5m over the next century. This leads to rough estimates of erosion set-backs from Bruun's Rule of 30m in the first scenario and 500m in the polar ice melt scenario. If the erosion threatens existing coastal developments in, for example, the tourism industry, new coastal defenses will need to be put in place to afford adequate protection from future storm events. These defenses will need to be substantial. One recommendation is for dune barriers designed at heights in excess of 6m above level mean spring tide and with bulk widths of 30m.

Dune barriers may not be needed for the modest levels in 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 The Central Region of Mozambique

The Centre is characterized by a relatively 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).

In order to provide a broad indication of vulnerability to climate change, an elevation map indicating the 5m contour along the coast can be used to indicate the areas at risk both from a sea level rise of 5m and from the impact of an intense tropical cyclone.



Map 2.9: 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.

Map 2.9 shows the potential risk to people and communication links in the extensive estuary and delta areas of the Centre, particularly with regards to the Zambesi delta and the area around Beira. Offshore islands are under threat of inundation and, where there are coral reefs, climate change will again affect their protective character.

The North is most susceptible to tropical cyclones as illustrated by the four tropical storms and two tropical cyclones that have made landfall on the coast in the past 15 years.

Year	Category and Name	Landfall	Date	Strength	Wind speed
1995	TS Fodah	Central	22 Jan	TD	37 km/h
1996	Cat 4 Bonita	Central	14 Jan	Cat 1	130 km/h
1997	Cat 1 Lisette	Central	2 March	TS	111 km/h
2000	Cat 4 Eline	Central	22 Feb	Cat 4	213 km/h
2000	Cat 4 Hudah	Central	8 April	Cat 1	148 km/h
2004	TS Delfina	Central	1 Jan	TS	92 km/h

Table 2.12: Tropical cyclones of Categories 1-4, storms (TS) and depressions (TD) making landfall on the coast of Mozambique in the period 1994-2008.

The three most intensive tropical cyclones were TC Bonita, TC Eline and TC Hudah, whose paths across the coast of the Centre are shown below.

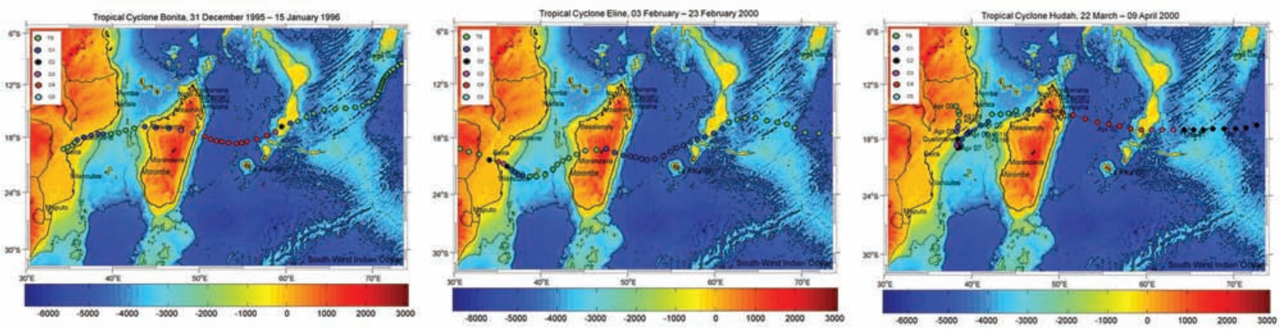
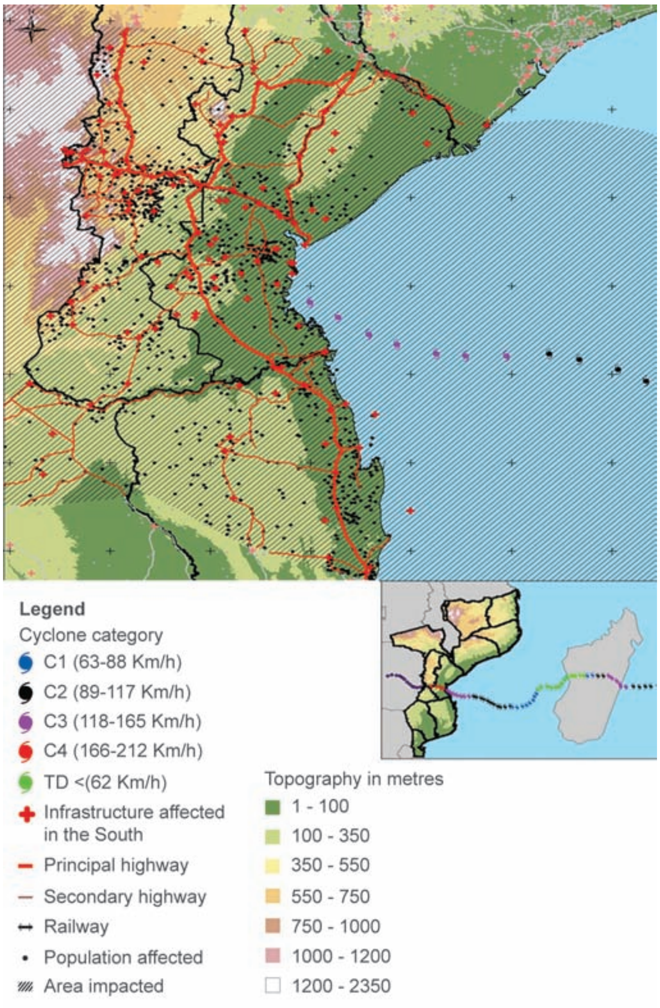
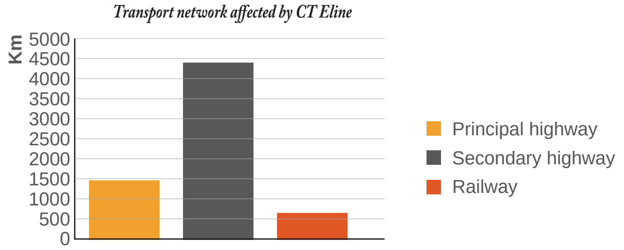
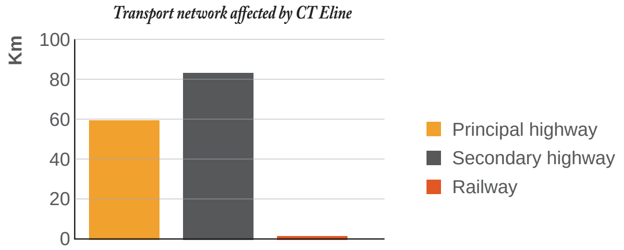


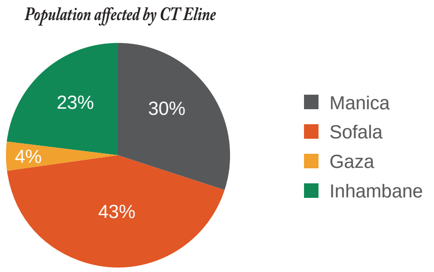
Figure 2.14: Trajectories of TC Bonita, TC Eline and TC Hudah.

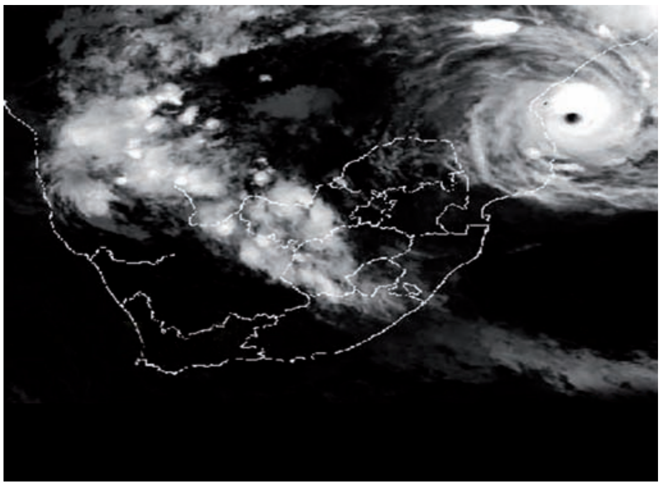


Map 2.10: The impact of a Category 4 cyclone in the Centre.









On landfall, TC Eline was still classified as Category 4 on the Saffir-Simpson scale, with wind speeds in excess of 210 km/hr and an accompanying storm surge likely to have been in excess of 4m in height. TC Eline caused extensive damage, estimated to be in excess of 12% of the GDP of Mozambique. Figure 2.14 shows the impact of TC Eline on the coastal areas of the Centre, together with the damage to roads and health facilities, and the affects on the population .

The sea level observations made at the port of Beira can be used to illustrate the exposure of the Centre to extreme sea level events and the need for coastal defenses. Beira is situated at the seaward end of the delta of the Pungoe River.

Map 2.11: Google Earth map of Beira.

These observations can be used to investigate the occurrence of extreme sea levels, and a corresponding Port Diagram for Beira.

Port	1 year	10 years	100 years	1000 years	HAT
Beira	346cm	390cm	440cm	490cm	340cm
Protection Classes	*Minimal*	*Low*	*Medium*	*High*	

Table 2.13: Annual Maximum Height in centimeters above Mean Sea Level against Return Period in years, with Highest Astronomical Tide for comparison.

The land at risk from the coincidence of a tropical cyclone and a spring high tide is all the land below the level of the storm surge with a return period of 1,000 years, which for Beira at present is at a level of 4.9m above mean sea level. Hoozemans et al (1993) noted that a 1,000 year storm surge of 1.9m should be added to a mean high tide level of 3m to obtain an appropriate 1,000 year extreme sea level, which gives the same level.

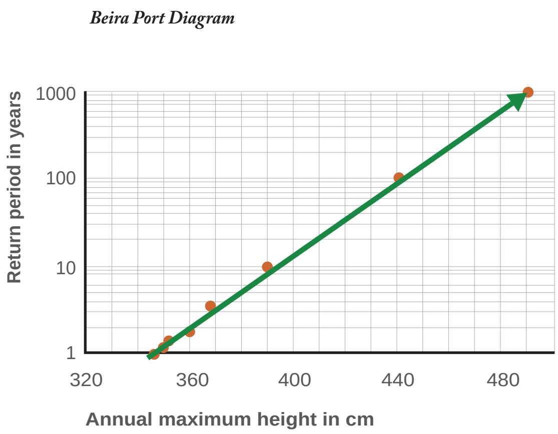


Figure 2.15: Beira Port diagram.

The estimates of extreme values to be expected on the basis of return periods of 10,100 and 1,000 years are used by coastal engineers in their design of coastal defences, and by coastal planners for estimates of land areas which are at risk of inundation. The study of the coastal defences of Beira in MICOA (1997), provides insight into the situation in Beira. 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”. More water breaches the seawall and flows landward through the drainage channels at the time of an event with a 10 year return period at 3.9m. If sustained, such a high water event would flood low lying land behind the seawall which lies below this elevation of 3.9m. The 1,000 year extreme sea level event, probably associated with a tropical cyclone making landfall in the vicinity, would overtop the seawall and flood all land which lay at an elevation below 4.9m. This area of land is extensive and covers the entire area between the city and the airport.

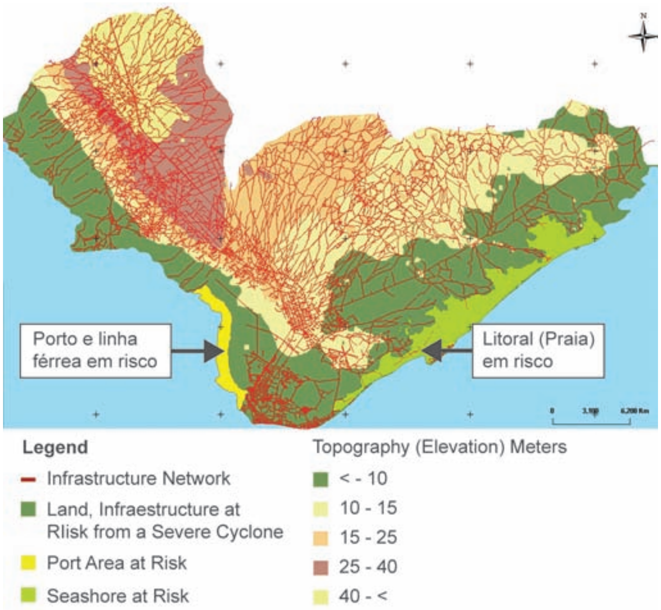
Greater protection can be gained by building the seawall upward to the heights of the 10, 100 or even 1,000 year return periods at Beira. Decisions need to be taken as to which level of protection to afford each area at risk. What is the risk, expressed in terms of the economic loss of infrastructure and services from temporary flooding of the area, against the cost of building or raising the height of a seawall to provide proper protection? In a real sense, this means comparing the cost of building up and maintaining the seawall against insuring against the losses from the unlikely occurrence of an extreme sea level event like a tropical cyclone with a return period of 1,000 years, even if it is the government that carries the insurance.

These sea levels need to be adjusted upwards to take account of sea level rise and the likely increase in intensity of the most intense tropical cyclones. The coastal defences would also need to be raised as the sea level rises over the 21st Century.

Port	1 year	10 years	100 years	1000 years	Scenarios
Beira	346cm	390cm	440cm	490cm	present
	361cm	406cm	455cm	517cm	2030
	376cm	420cm	470cm	545cm	2060 Low SLR
	391cm	435cm	485cm	576cm	2100 Low SLR
	456cm	*500cm*	*550cm*	*625cm*	2060 Ice Melt
	761cm	*805cm*	*855cm*	*946cm*	2100 Ice Melt
Protection Class	*Minimal*	*Low*	*Medium*	*High*	

Table 2.14: Extreme Sea Levels Expected at Long Return Periods At Various Ports and for the Representative Low and High Sea Level Rise Scenarios.

There is a clear difference between the two scenarios. Under all scenarios for Beira in 2030, the coastal land and the people living and working there are under threat from extreme sea level events, and will need to be appropriately protected.



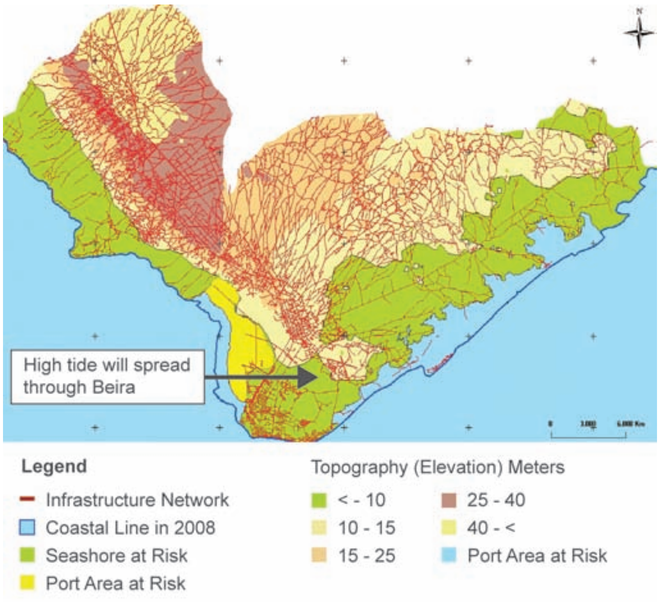
Map 2.12: Beira by 2030; gradual sea level rise and more intense cyclone risk. Red lines represent existing infrastructure; yellow the port zone at risk; light green the sea shore at risk and dark green the area at risk in the event of a severe cyclone.

Fortified seawalls are designed to protect valuable infrastructure and services, often in an industrial and an urban environment. Protection classes based on the return periods of storm surges have often been used as part of the seawall design, for example see Nicholls and Tol (2006) for an overview. They link the protection classes to an economic model to determine which particular protection class should be adopted as the optimal protection strategy, and noted the added expenditure involved for delta coastlines. This approach can be used for Beira. Under all sea level rise scenarios by 2030 , the high protection class would require a seawall to a height of 5.17m, to cope with the added sea level rise. On a delta coast, Nicholls and Tol (2006) believe that this can only be afforded by a country with a GDP per capita in excess of US$5000. This illustrates the difficulties faced by Mozambique as a poor country subject to the impact of extreme storm surges on a delta coast.

The vegetated dune barrier to the east of Beira is intended to prevent flooding of the low-lying land on the coastal plain behind. With a mean spring tide level of 2.9m, this means that the height of the dune barrier would need to approach 9m in height and 30m to be effective against the most extreme tropical cyclones. 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 this protection 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 is again the land below the level of the 1,000 year storm surge, 4.9m now and 5.17m in 2030.

The key question is whether or not Mozambique can afford to protect its coastal assets in Beira, both now and under the modest sea level rise envisaged in the near future?

The implications of the High SLR are much more serious for Beira. A sea level rise of 5m by 2100 will move the coastline far inland, if not prevented. In addition, a further 5m will be vulnerable from the impact of an extreme tropical cyclone. Much more land will be at risk.



Map 2.13: 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. The blue line is the old coast line.

Map 2.13 shows the coastal strip to the east of Beira, and the port and its facilities on the river. In a High SLR these will lie below the new sea level. It is assumed that the old city of Beira will remain protected. If the new coast is not protected, the tide will flow over the land behind the city. In such circumstances, the river will take a new course to the sea, and the city and port area of Beira will become an island separated from the mainland by the flooded low lying land.

As explained earlier, Mozambique might not be able to afford to attempt to protect the port and city of Beira from such an occurrence. It is the investigations by European authorities, responsible for the adaption of the major estuaries of the Rhone, Thames and Rhine to a 5m rise in sea level, that are of most relevance here. The adaptation strategy is one of managed retreat from the low lying areas along the coast, no matter whether they are industrialized or not. There are two important matters to be considered in Beira:

Should the strategic approach for Beira in the High Sea Level Rise Scenario be to build the massive coastal defences 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 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?

These points illustrate the vulnerability of Beira to catastrophic sea level rise. However, there are other locations along the coast that are also vulnerable.

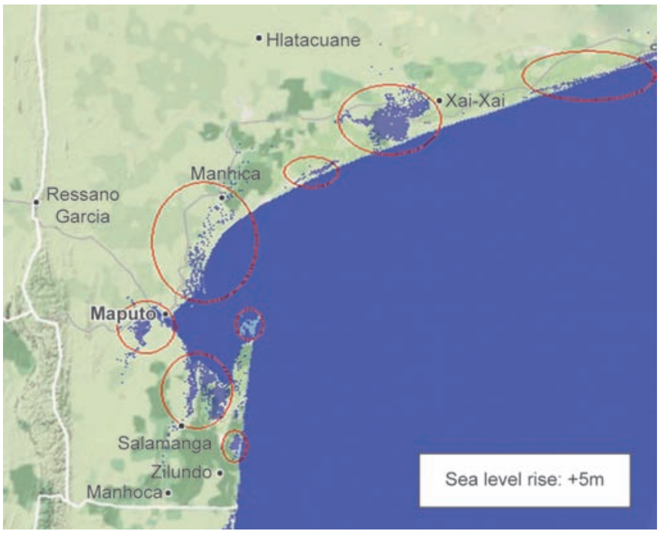
These levels can also be used to understand the vulnerability of Quelimane to climate change. Quelimane is well upstream in the lower reaches of the Sinais River. There is much low-lying land on the south bank.

Map 2.14: Google Earth map of Quelimane.

The Southern Region of Mozambique

The South is characterized by a relatively narrow coastal plain, with some large rivers, a sandy coastline which becomes muddy close to the rivers, and a shallow bight in Maputo Bay. The tides are moderate (2m in range), and the coast is subject to occasional tropical cyclones (2 in the past 16 years).

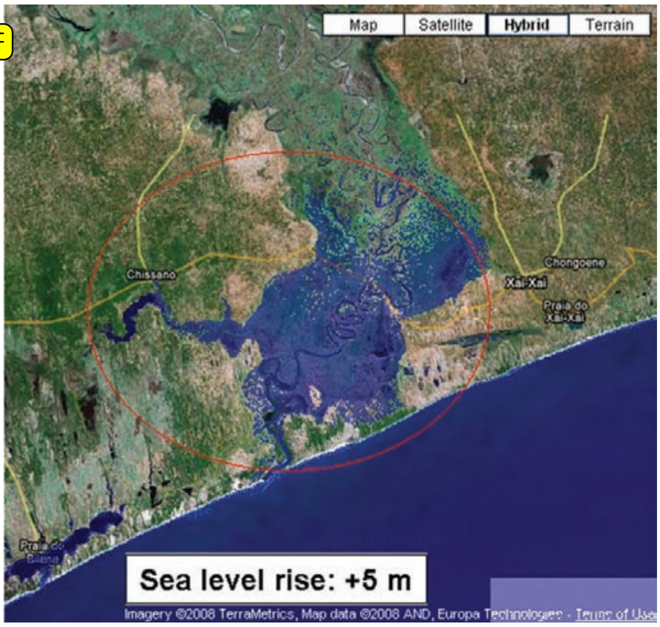
In order to provide a broad indication of vulnerability to climate change, an elevation map (Map 15) indicating the 5m contour along the coast can be used to indicate the areas at risk both from a sea level rise of 5m and from the impact of an intense tropical cyclone.



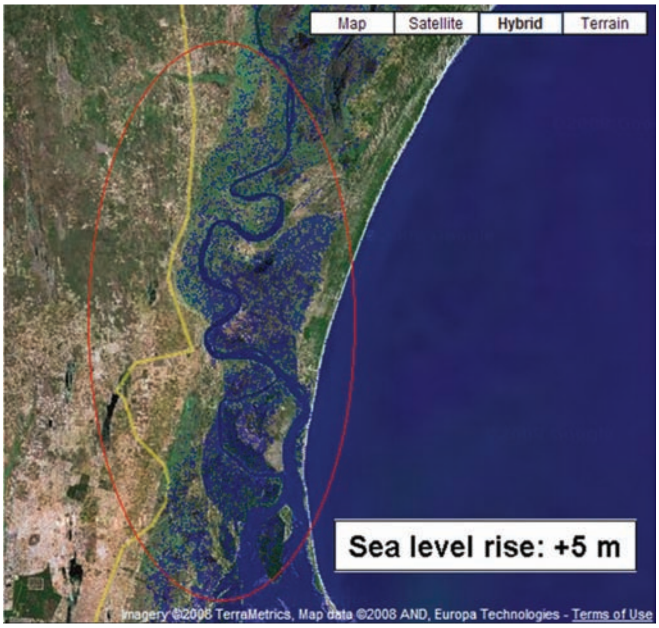
Map 2.15: Elevation map indicating the 5m contour line for the coastal zone of the South.

Though the rivers of the South are not as big as those of the Centre, there is the possibility of disruption of communication links owing to flooding. 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.

Maps 2.16a and b highlight the Limpopo and Incomati estuaries. In both cases, the widening of the lower flood plains will increase the vulnerability to tropical cyclones through the narrowing of the natural coastal spits where the rivers enter the sea.



(a)



(b)

Map 2.16: Google Earth map of the Limpopo (a) and Incomati (b) estuaries.

The South remains susceptible to tropical cyclones as illustrated by the two tropical storms and tropical cyclones that have made landfall on the coast in the past sixteen years.

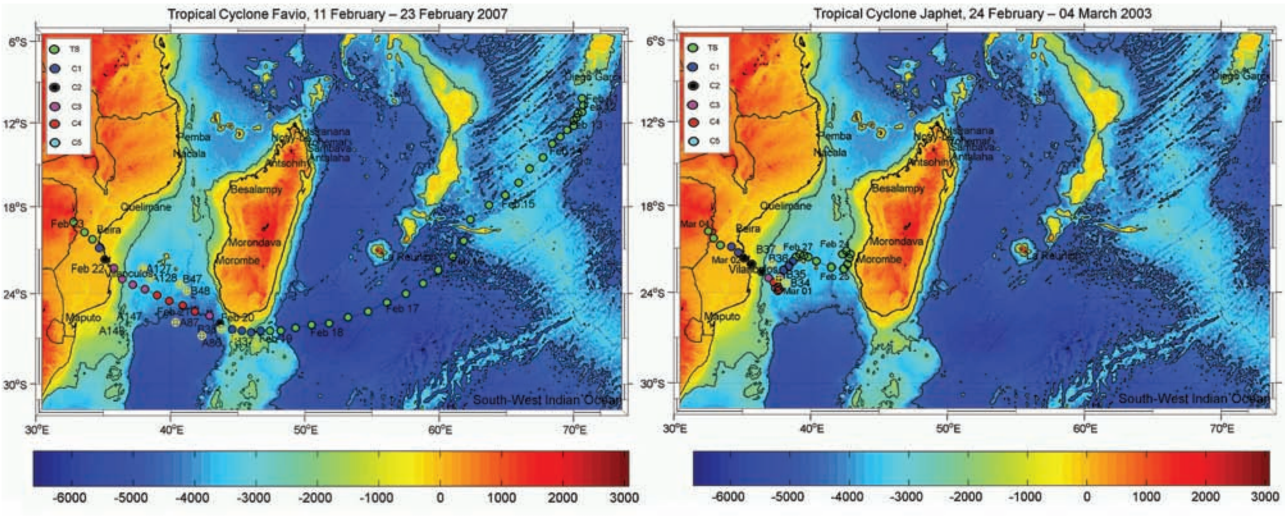


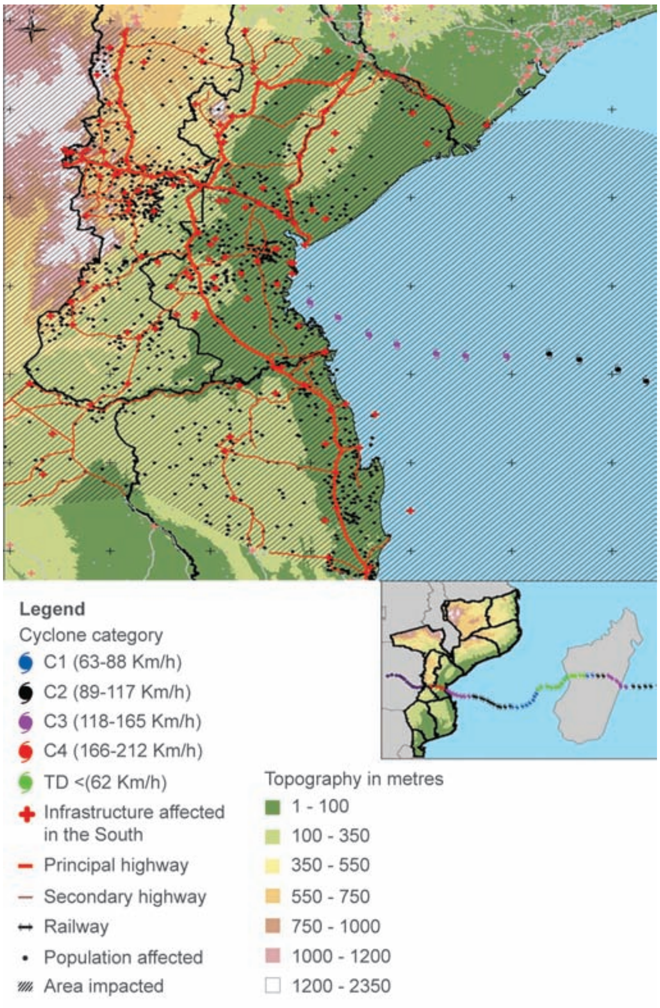
Figure 2.16: Trajectories of TC Favio and TC Japhet.

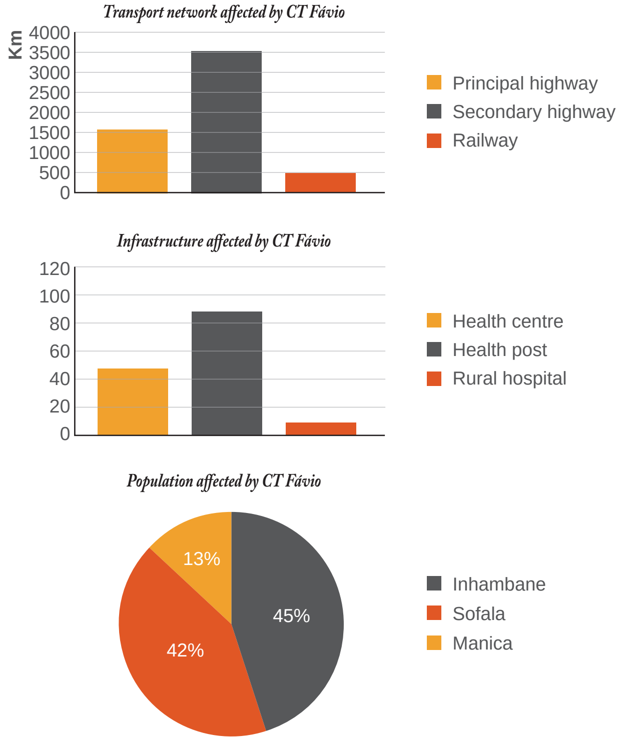
Year	Category and Name	Landfall	Date	Strength	Wind speed
2003	Cat 4 Japhet	South	2 March	Cat 2	167 kph
2007	Cat 4 Favio	South	22 Feb	Cat 3	185 kph

Table 2.15: Tropical cyclones of Category 1-4, storms (TS) and depressions (TD) making landfall on the coast of Mozambique in the period 1994-2008.

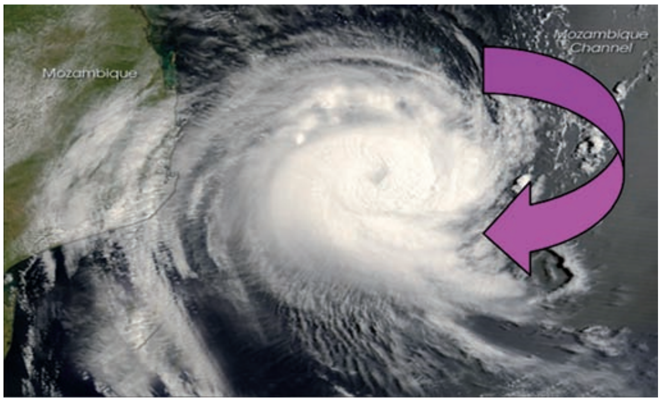
The two tropical cyclones, TC Favio and TC Japhet (Figure 2.16), were strong and both occurred very recently, raising concerns of a southward shift of the tropical cyclones affecting Mozambique. In addition, TC Favio approached the coast of Mozambique after passing to the south of Madagascar, which opens up a new pathway for tropical cyclones from the Western Indian Ocean to approach Mozambique without dissipating their strength over Madagascar. It should be noted that both tropical cyclones moved northward into the interior of the Centre after making landfall.

Map 2.17 illustrates the impact of TC Favio on the interior, and its effect on people, roads and health facilities. This provides an indication of the impact of future tropical cyclones on the South.





Map 2.17: The impact of a category 4 cyclone in the northern part of the South.



The sea level observations made for the port of Maputo can be used to illustrate the exposure of the South to extreme sea level events and the need for coastal defenses. Table 2.26 can be constructed of annual extreme sea levels.

Port	1 year	10 years	100 years	1000 years	HAT
Maputo	178cm	225cm	270cm	315cm	178cm
Protection Classes	*Minimal*	*Low*	*Medium*	*High*	

Table 2.16: Annual Maximum Height in centimetres above Mean Sea Level against Return Period in years, with Highest Astronomical Tide for comparison.

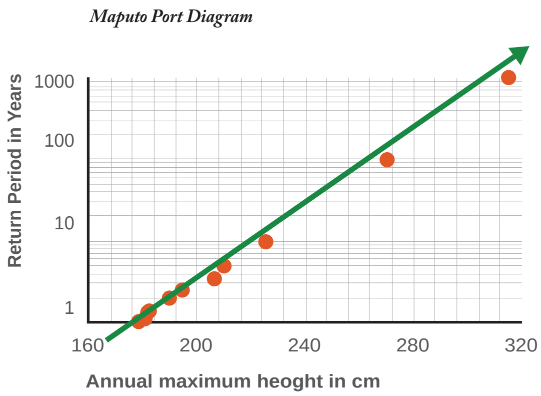


Figure 2.17: Maputo Port diagram.

The City of Maputo is situated on high ground. However, 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.

A low lying coastal strip, from the Marginal to the Costa do Sol, is being developed. This area is in need of protection as it is subject to coastal erosion, with roads and beach facilities under attack from storms.

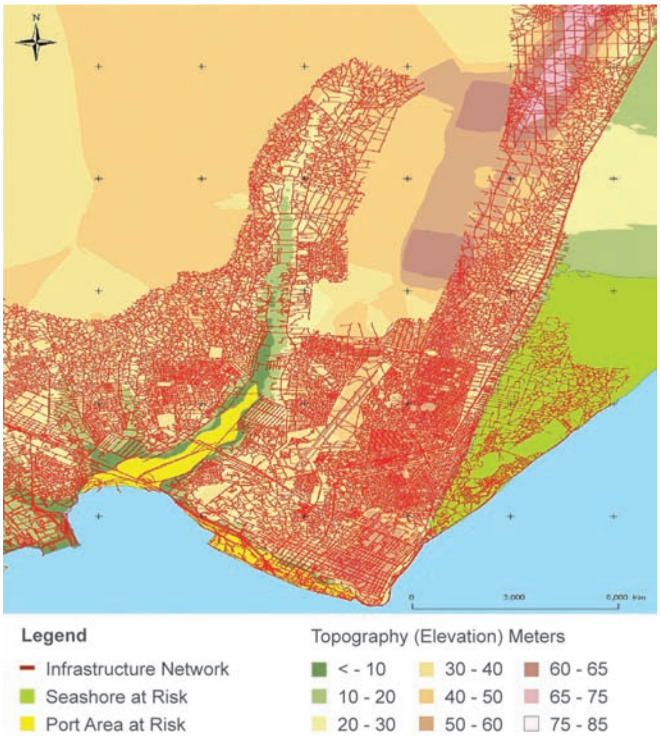
Map 2.18: Google Earth maps of Maputo.

The extreme sea levels at Maputo need to be adjusted upwards to take account of 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 over the 21st century.

Port	1 year	10 years	100 years	1000 years	Scenarios
Maputo	178cm	225cm	270cm	315cm	present
	188cm	235cm	280cm	335cm	2030
	198cm	*245cm*	*290cm*	*355cm*	2060 Low SLR
	208cm	*255cm*	*300cm*	*378cm*	2100 Low SLR
	278cm	*325cm*	*370cm*	*435cm*	2060 High SLR
	678cm	*625cm*	*670cm*	*748cm*	2100 High SLR
Protection Class	*Minimal*	*Low*	*Medium*	*High*	

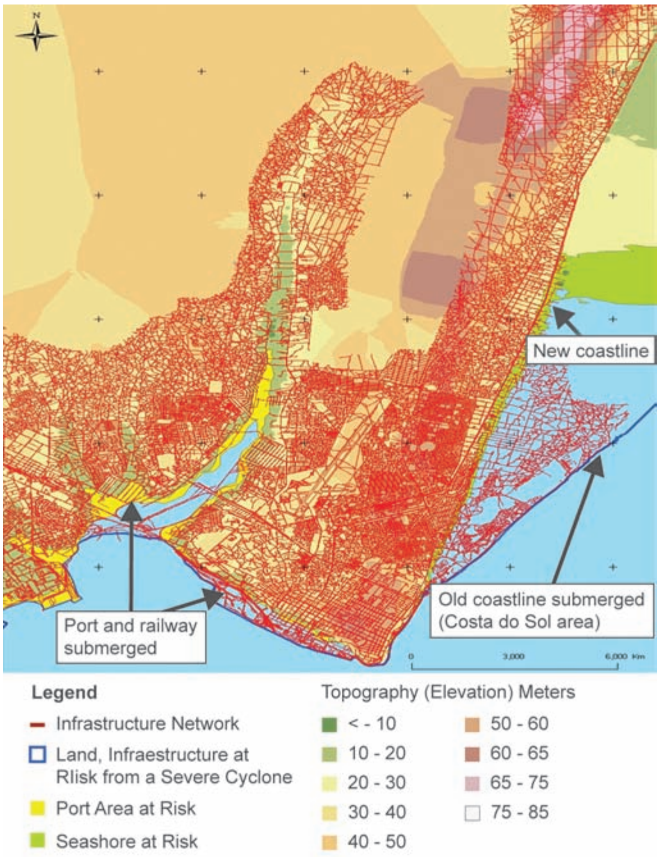
Table 2.17: Extreme sea levels expected at long return periods at various ports and for the representative low and high sea level rise scenarios.

There is a clear difference between the two scenarios. Under all scenarios for Maputo in 2030 the coastal land and the people living and working there are under threat from extreme sea level events, and will need to be appropriately protected.



Map 2.19: 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.

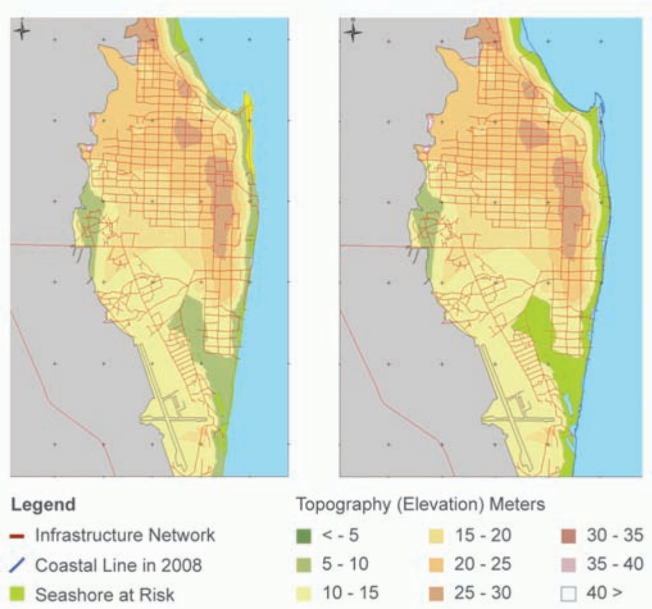
The implications of the High SLR Scenario are much more serious for Maputo, as much more coastal land will be at risk.



Map 2.20: 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.

If not protected by new coastal defenses, a sea level rise of 5m by 2100 will flood the entire area of the Marginal. In addition, the port and its rail links will need to be gradually relocated 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 its high ground.

Vilanculos and Inhambane are two small ports in the northern sector of the South. Vilanculos is a small port 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. This combined with sea level rise and more intense storms will lead to coastal erosion and affect beach facilities, which must be taken into account when considering future (tourism) developments.



Map 2.21: 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.

Inhambane is situated within a river estuary with higher land protecting it from the open sea. The river is prone to flooding and much of the town lies below 2m in elevation and is similarly exposed to sea level rise.

Map 2.22: Google Earth map of Inhambane.

3

Hydrology and river basin analysis

3.1 Hydrologic historical and baseline analysis
Dr. Kwabena Asante, Climatus and Agostinho Vilankos, DNA

3.2 Future impacts of climate change on river flow, floods and saline intrusion
Dr. Kwabena Asante, Climatus and Agostinho Vilankos, DNA

Hydrologic Historical and Baseline Analysis

Dr. Kwabena Asante, Climatus and Agostinho Vilankulos, DNA.

3.1a Introduction

3.1b Past trends in flow in Mozambican rivers

3.1a Introduction

This report presents an assessment of the impacts of climate change on the hydrology of Mozambique. The assessment is based on the integration of seven global climate models downscaled with a regional climate model into two geospatial hydrologic models. The results of the modeling are analyzed to estimate changes in the magnitude and frequency of floods and droughts as well as water availability in the river basins that drain through the country. Coastal hazards which impact the major river systems of Mozambique are also assessed.

3.1b Past trends in flow in Mozambican rivers

An analysis of past flows at river gauges in Mozambique indicates that there are extended wet and dry phases which can last for 20 years or more. While there are slight variations in the period of the record, each of the stations selected has approximately 50 years of annual records covering the period 1950 to 2008. The stations used in the analysis include Madubula (E-6) in the Maputo river, Goba (E-10) in the Umbeluzi river, Ressano-Garcia (E-23) in the Incomati river, Combomune (E-33) in the Limpopo river, (E-67) in the Pungue river, and (E-91) in the Licungo river. The Zambezi and other major rivers are excluded from this analysis because of large data gaps exceeding 10 years (20 years in the case of the Zambezi).

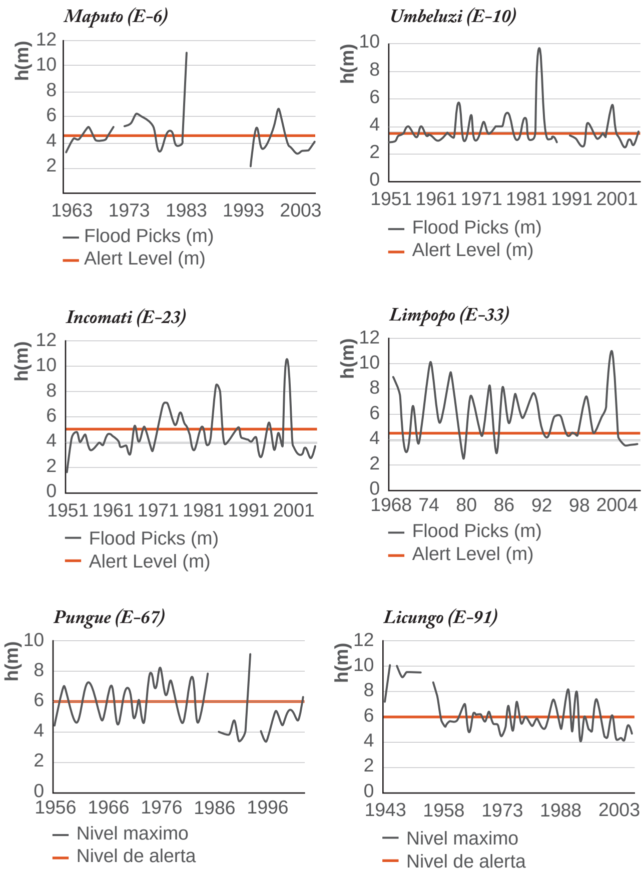


Figure 3.1: Periods of occurrence of the four largest floods in the six gauging stations.

In terms of frequency of occurrence, and based on the flood alert level ("nível de alerta") defined for each gauge station, floods occurred every 2.8 years in the Maputo river, 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 for the Licungo. This implies that on average, Mozambican rivers are currently expected to exceed the flood alert level every 2 to 3 years. However, very large floods exceeding 1.5 times the flood stage occur much less frequently, about once every 15 to 20 years.

To study changes in flooding patterns, the four largest annual flood peaks were selected for each station and graphs produced to reflect ranking by year of occurrence. The graph below shows the ranking of maximum flows observed at various flow stations in some of the countries river basins.

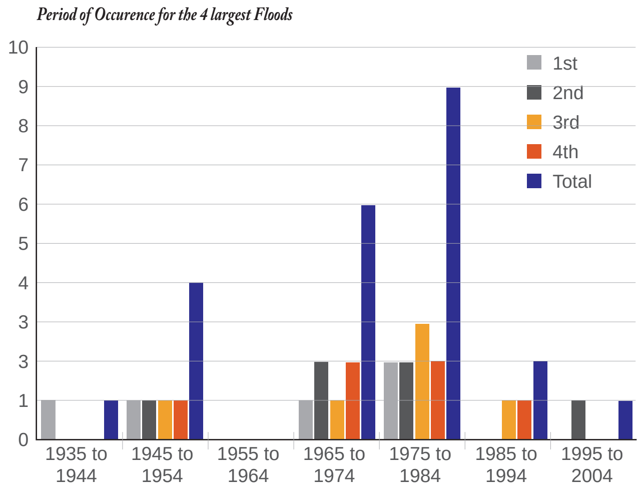


Figure 3.2: Periods of occurrence of the four largest floods in the six gauging stations.

From the graph, it is clear that 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 the 20 major flood events analyzed in this study occurred during the decade from 1970 to 1980. This active period is followed by a subsequent 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.

From the available data no conclusion can be made in terms of trends on flood behavior.

Future impacts of climate change on river flow, floods, saline intrusion

Dr. Kwabena Asante, Climatus and Agostinho Vilankulos, DNA

3.2a Hydrological modelling methodology

3.2b Water Resources Impacts of Climate Change

3.2c Conclusions and recommendations

3.2a Hydrological modelling methodology

Figure 3.3 presents the assessment methodology used in this study schematically.

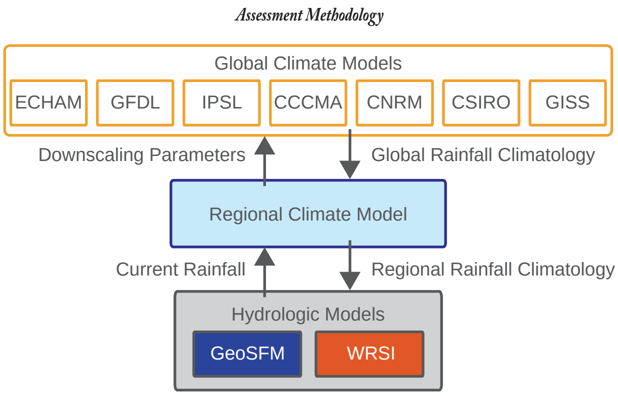


Figure 3.3: Assessment methodology for this study.

The analysis is conducted for a 40-year historical period from 1961 to 2000, and for a 20-year future period going from 2046 to 2065. The analysis covers all drainage areas across southern Africa for basins which flow into Mozambique.

Water resource conditions are determined by ingesting daily rainfall and evaporation data in to the Geospatial Stream Flow Model (GeoSFM). The daily rainfall analysis and evaporation data are either historical data or the predictions coming from the seven global climate models (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO, and GISS) that were downscaled to the region under study.

The water supply is determined from average river flow conditions while 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.

The study covered the following aspects:

- Stream flow analysis to estimate changes in the magnitude and frequency of floods
- Droughts analysis to estimate tendencies in terms impacts on rainfed agriculture
- Water demand analysis to estimate the water availability in the river basins that drain through the country
- River estuary inundation analysis to estimate coastal hazards which impact the major river systems of Mozambique

Stream flow analysis

To study expected climate-induced changes in the main rivers basins of Mozambique, a hydrologic modeling effort was undertaken to generate historical and future hydroclimatologies. The historical hydroclimatology covers the 40-year period from 1961 to 2000 while the future hydroclimatology extends for the 20-year period from 2046 to 2065. The hydrologic modeling approach adopted in this study involves coupling hydrologic models to a regional climate model which is in turn coupled to a series of global climate models.

The hydrologic models used in the study are the Geospatial Stream Flow Model (GeoSFM) and the Water Requirements Satisfaction Index (WRSI). Both of these models were developed by the US Geological Survey Earth Resources Observation and Science Center (USGS EROS), and have been used to support operation monitoring in many data sparse settings.

The coupling was achieved through the exchange of rainfall and temperature fluxes among the models. The global climate models used in the study include ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS.

The model setup began with terrain analysis in GeoSFM to derive modeling units for the eleven main Mozambican river basins namely Maputo, Umbeluzi, Incomati, Limpopo, Save, Buzi, Pungue, Zambezi, Licungo, Motepuez and Rovuma.

The analysis which used 1km digital elevation data from the USGS resulted in 2577 subbasins, each associated with a unique river reach. The typical subbasin covers an area of about $1200km^2$ while the river reaches are typically 45km long. Connectivity among the subbasins is also established during the terrain analysis. Topographical, soils and land cover parameters required for characterizing the subbasins for use in flow simulations were also extracted for existing geospatial databases.

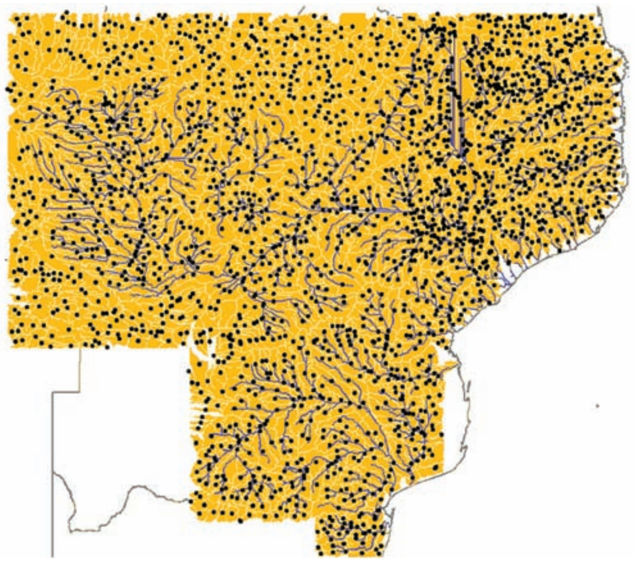


Figure 3.4: Sub-basin and rivers systems delineated with GeoSFM for the Mozambique Climate Change Project.

Drought analysis

For drought analysis, a maize crop water requirements satisfaction index (WRSI) was used as a drought indicator. WRSI measures the adequacy of available soil moisture to satisfy crop water needs during the various stages of its development. WRSI has been shown to be a good indicator of the impacts of drought on crop production since it is linearly related to yield-reduction.

Water Requirement Satisfaction Index (WRSI)	Crop Performance
100 to 95	Very Good – Good
94 to 60	Average – Acceptable
59 to 50	Poor
Less than 50	Failure

Table 3.1: Crop performance assessed based on the water requirement being met as represented by the Water Requirement Satisfaction Index (WRSI).

For this analysis, the WRSI algorithm was implemented at daily time steps in a spreadsheet and integrated with rainfall and evapotranspiration inputs which were extracted from original geospatial formats using GeoSFM. A fixed start of season was adopted to facilitate computation of the impacts of climate effects during two distinct growing seasons.

The WRSI computation was performed for two distinct 90-day seasons beginning on October 1st for the Oct-Nov-Dec season and January 1st for the Jan-Feb-Mar season, respectively. The choice of a 90-day maize crop as an indicator is based on its status as the main food crop in the region.

Water demand analysis

The changes to stream flow computed using the hydrologic model described above do not take into account water use in the respective basins. Water use is typically composed of municipal, industrial and agricultural demands. The magnitude of these uses is a function of the population, socio-economic conditions, type and extent of agricultural and industrial activities as well as local cultural preferences. With the exception of population, these parameters are extremely difficult to predict with any accuracy since they involve human choices and are easily influenced by both local and global socio-political changes. Future population estimates can be predicted more accurately since population growth rates are quite stable in the absence of sudden shocks such as conflicts.

In this study, existing population growth rates are used with current population estimates for 2000 to compute future population estimates. Growth rates obtained from the World Bank (2007) are Angola (2.6%), Botswana (1.6%), DR Congo (2.3%), Lesotho (1.6%), Malawi (2.9%), Mozambique (2%), South Africa (2.5%), Swaziland (2.5%), Zambia (2.2%) and Zimbabwe (1.1%). These growth rates allow both current and future water availability per capita to be computed by dividing simulated median stream flow values by projected total population upstream of any point of interest. Basins experiencing water scarcity are identified using the internationally used threshold of less than 1,000m^3/capita/year. By comparing current and future maps of water availability, river basins likely to become water scarce were identified.

The use of a universal water scarcity definition fails to account for actual water use within the region. Water use data for all the countries in the region is available from the FAO Aquastats database. These datasets include sectoral water usage rates for the municipal, agricultural and industrial sectors in each country. National per capita water usage rates were computed by summing up the individual sectoral rates and dividing by national populations. Large differences were observed in water use rates in the region. Countries like South Africa and Zimbabwe have high usage rates of about 250m^3/capita/year. Medium usage countries such as Botswana and Malawi use around 100m^3/capita/year while low usage of around 25m^3/capita/year is found in Mozambique, Angola and Lesotho.

Four future water use scenarios rates were developed based on these per capita water usage rates. The first involves using current uneven water usage rates while the other three scenarios assume equitable usage with the respective high, medium and low per capita water usage rates mentioned above. The results of this water management analysis are presented under the respective river basin subsections of the southern, central and northern region headings.

River estuary inundation analysis

The inundation extent associated with rising sea levels in the estuaries of the river basins is also presented under the respective river subsections. Most of the Mozambican coast is protected by sand dunes formed through the deposition of sand as a result of wind and wave action. The river estuaries are low points in the band of protection through which sea water can easily propagate inland. These estuaries are vulnerable to the combined effects of chronic sea level rise, tidal wave action and acute events such as tropical storms and cyclones.

To identify the potential risk area, a severe impact scenario involving the simultaneous occurrence of these events was modeled using the values in Table 3.2 . These values correspond to the estimations made relating to cyclones and sea level rise for the period of 2046 to 2065.

Region	Global Sea Level Rise	Tidal Rise (above MSL)	Cyclone-Induced Storm Surge	Combined Event Total
North	0.2 m	2.2 m	0.3 m	2.7 m
Central	0.2 m	3.6 m	0.5 m	4.3 m
South	0.2 m	2.2 m	0.3 m	2.7 m

Table 3.2: Values used to model a severe impact scenario:

Elevation data from the Shuttle Radar Topography Mission (SRTM) was used to characterize the shape of the river estuaries in both their longitudinal and transverse directions. The inundation extent is identified as the difference between the final and initial elevation grids. The results of this analysis are presented in terms of length of intrusion and spatial extent of inundation for each river basin.

3.2b Water Resources Impacts of Climate Change

An analysis of the differences between the historical and future hydroclimatologies computed during this study was conducted. These differences provide an insight into how climate change is impacting water resources in Mozambique. The main changes examined include changes in water availability, the magnitude and frequency of flooding, likely impacts of droughts on crop performance and the frequency of total crop failure.

Figure 3.5 presents the results of the rainfall patterns predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS).

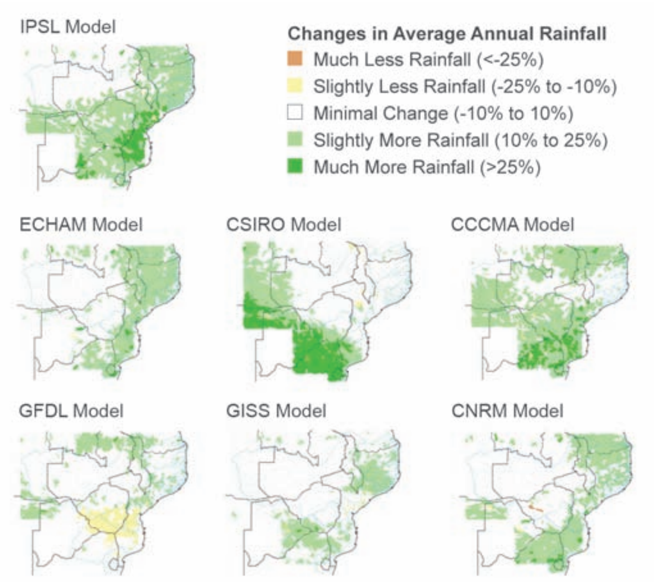


Figure 3.5: Changes in average annual rainfall for the seven GCMs.

It is clear that the models behave differently, which will result in different outcomes. In order to make sense of this, the likelihood of different outcomes were examined. The analysis uses the following classification:

Figure 3.6 presents the results from the seven GCMs based on this classification system

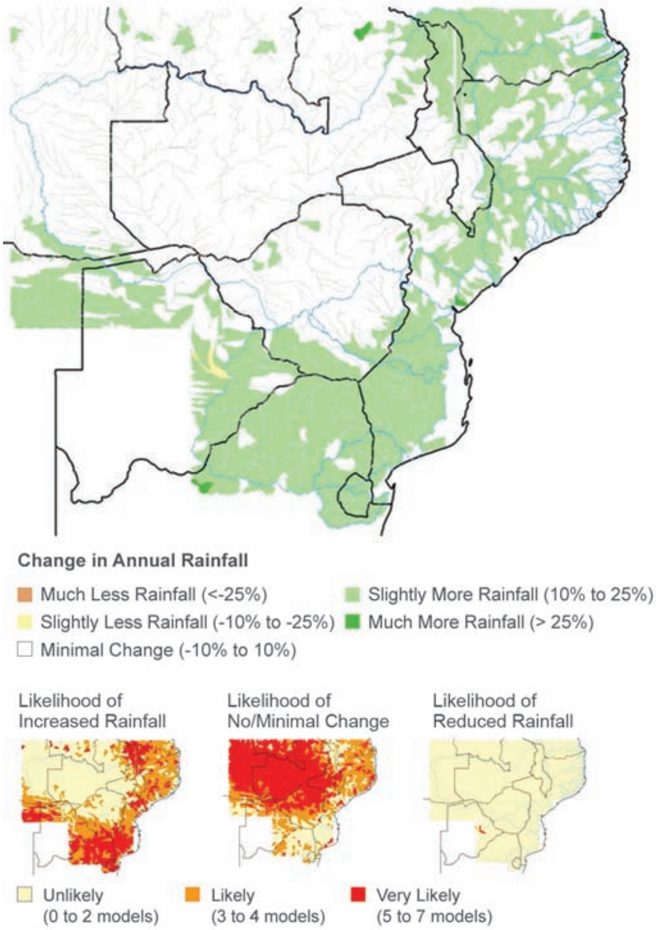


Figure 3.6: Average changes in the rainfall from the seven GCMs and associated likelihoods.

Much of Mozambique is likely to experience slightly increased rainfall. In the Limpopo, the increases extend throughout the basin. In the Save and Zambezi basins, no change in annual rainfall is expected in Tete and in portions of the basins outside of Mozambique's borders. The North is a patchwork of slight increases and unchanged rainfall.

Figure 3.7 presents the results of the water resource supply predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS).

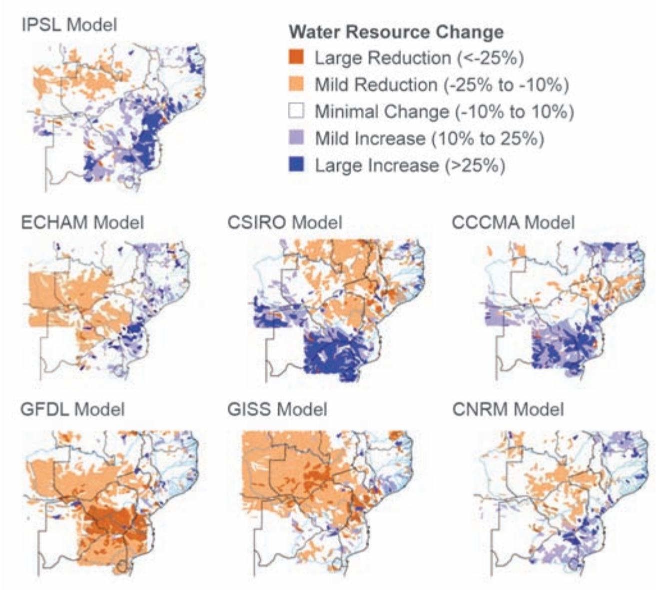


Figure 3.7: Changes in the median river flow for the seven GCMs.

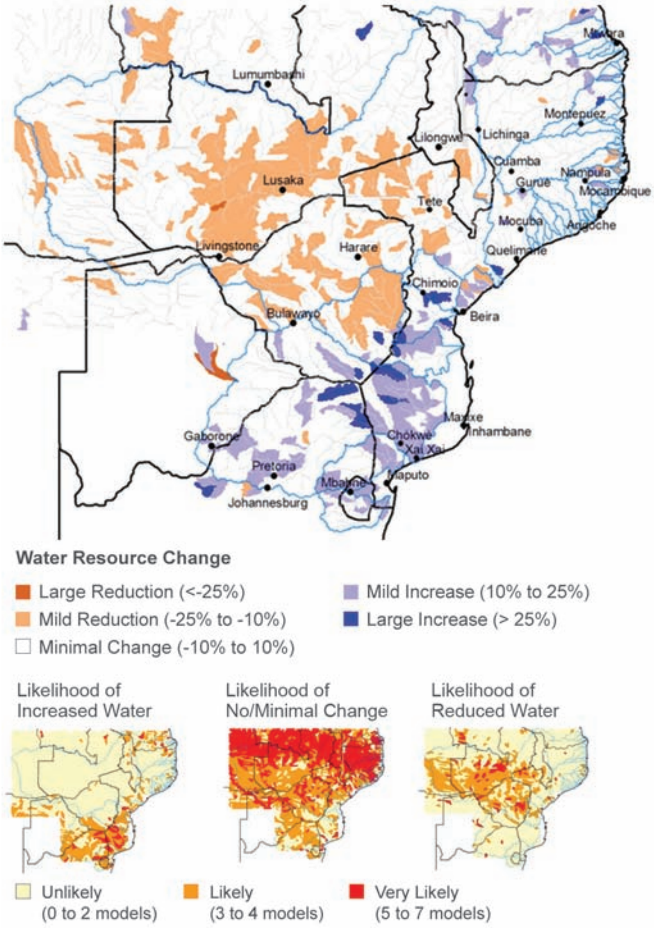


Figure 3.8: Average changes in the average river flow from the seven GCMs and associated likelihoods.

The Limpopo and other southern basins are likely to see increased water supply, whilst reductions are expected in portions of the Zambezi and Save basins. Water supply is unlikely to change for the northern basins. The Buzi and Pungue are within the transition zone with no strong trends in any direction.

Figure 3.10 shows the results of the changes in the magnitude for the flood risk hazard predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS).

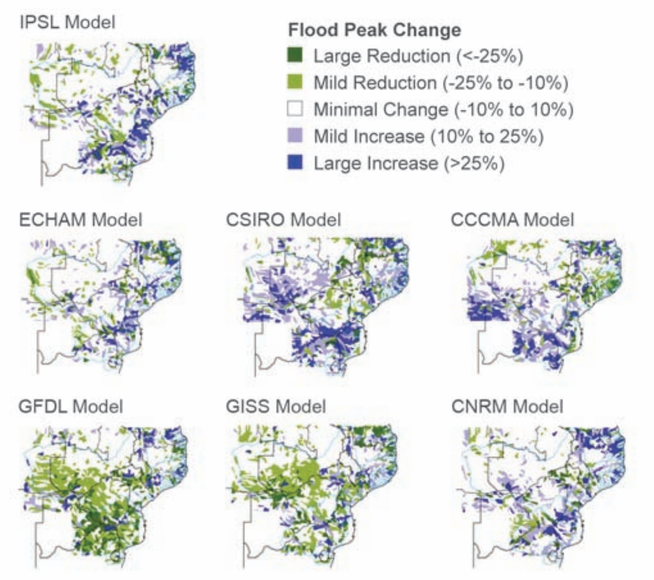


Figure 3.9: Changes in magnitude of flood peaks for the seven GCMs.

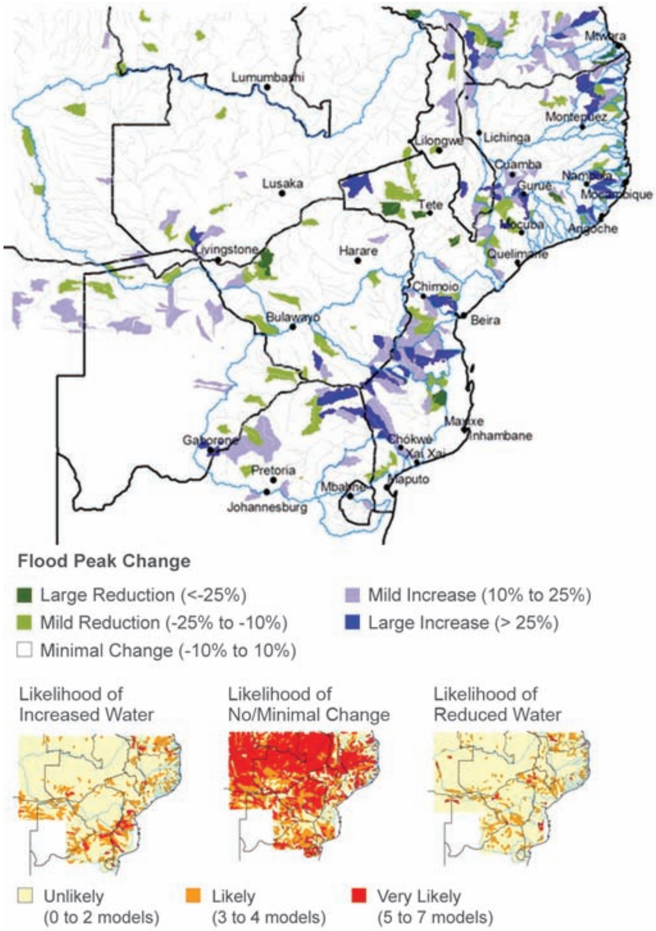


Figure 3.10: Average changes in the magnitude of floods from the seven GCMs and associated likelihoods.

The magnitude of flood peaks will remain unchanged in most of the region except for the lower reaches of the Limpopo, Save and Pungue, where increases are predicted.

Figure 3.12 presents the results of the changes in frequency for the flood risk hazard predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS) and the corresponding likelihoods.

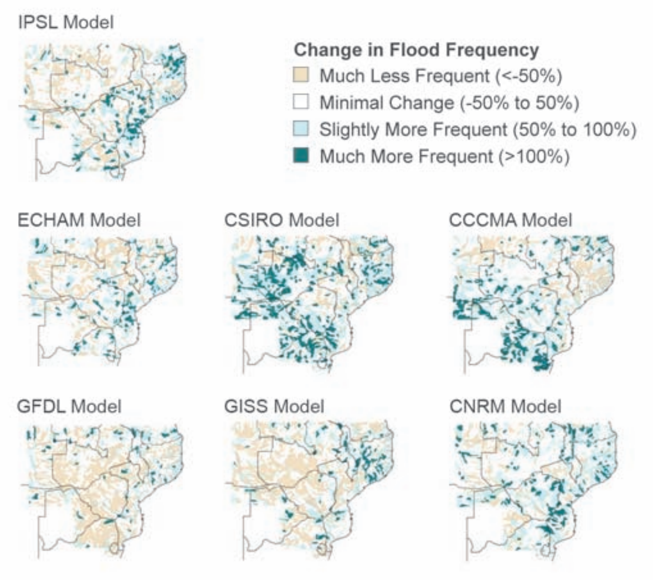


Figure 3.11: Changes in frequency of floods for the seven GCMs.

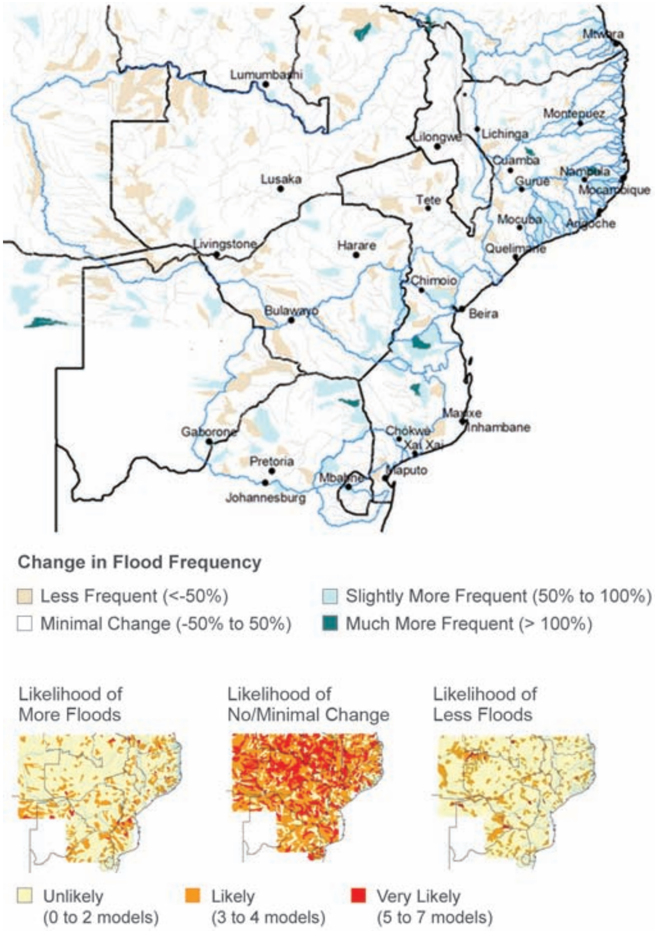


Figure 3.12: Average changes in the flood frequency from the seven GCMs and associated likelihoods.

No clear pattern of change in flood frequency is expected in the region. Small patches of slightly increased flood frequency are expected in coastal catchments especially in the central part of the country. Most other changes are minor and occur in small headwater catchments.

Figure 3.14 shows the results of the OND drought risk predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS), and corresponding likelihoods.

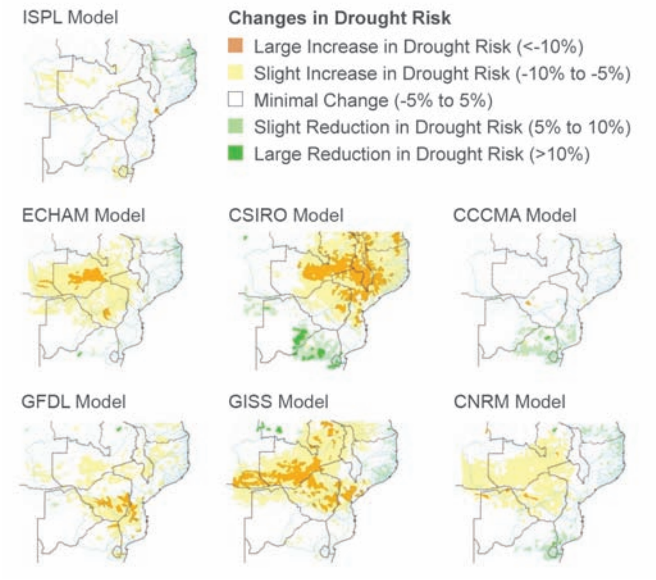


Figure 3.13: Changes in median maize WRSI for the Oct-Dec for the seven GCMs.

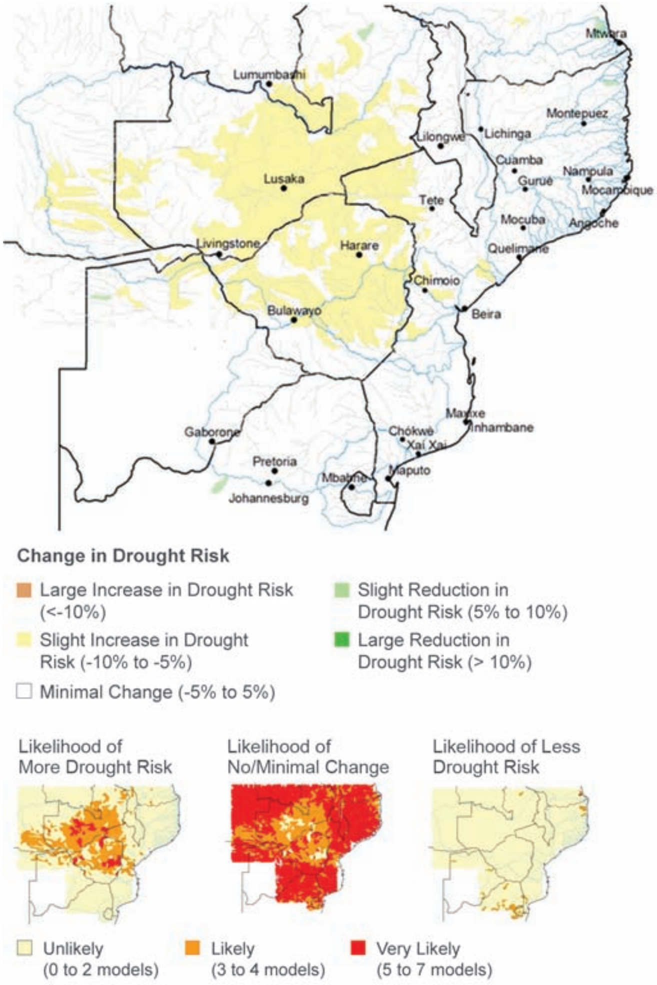


Figure 3.14: Average changes in the OND drought risk from the seven GCMs and associated likelihoods.

For the season OND, a slight increase in the risk of drought is anticipated in the central part of the country extending into Zimbabwe and Zambia. No changes in the risk of drought are expected elsewhere.

Figure 3.16 shows the results of the OND crop failure risk predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS) and corresponding likelihoods.

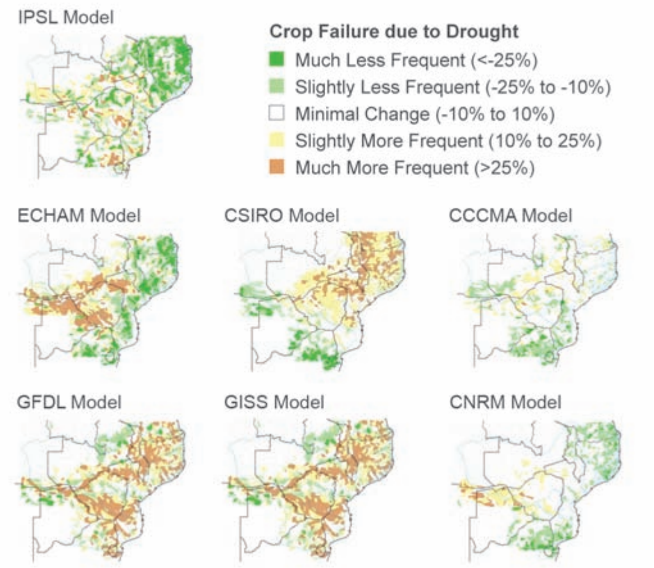


Figure 3.15: Changes in frequency of maize crop loss for Oct-Dec for the seven GCMs.

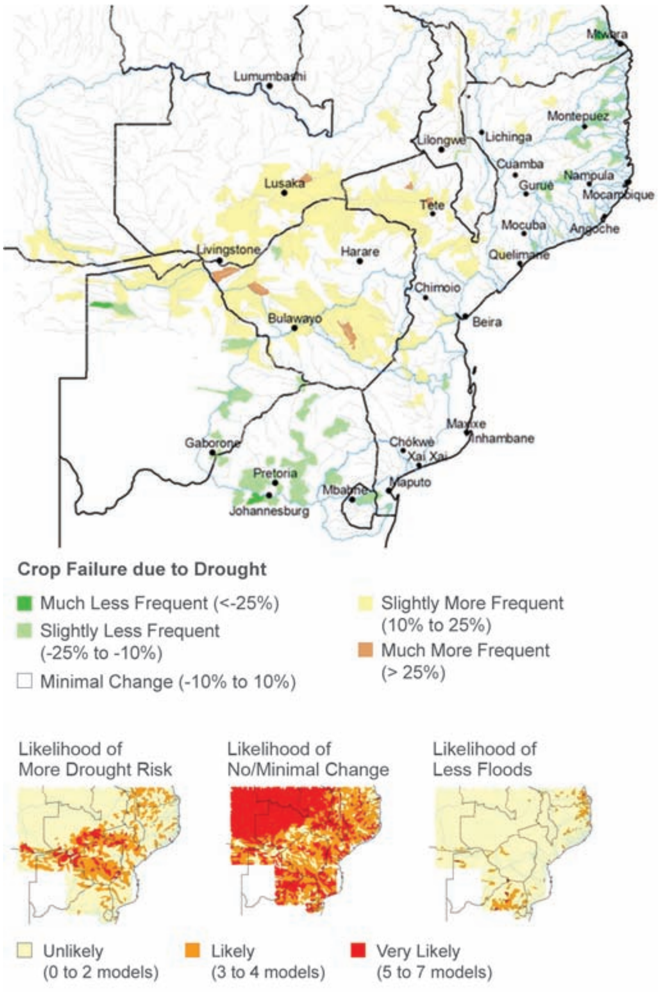


Figure 3.16: Average changes in the Oct-Dec crop failure risk from the seven GCMs and associated likelihoods.

For the season OND, a slight increase in the risk of crop failure is expected in central Zimbabwe, in southern Zambia and in central Mozambique particularly around Tete. A few isolated zones of improvement in the North are anticipated.

Figure 3.18 shows the results of the JFM drought risk predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS.) and corresponding likelihoods.

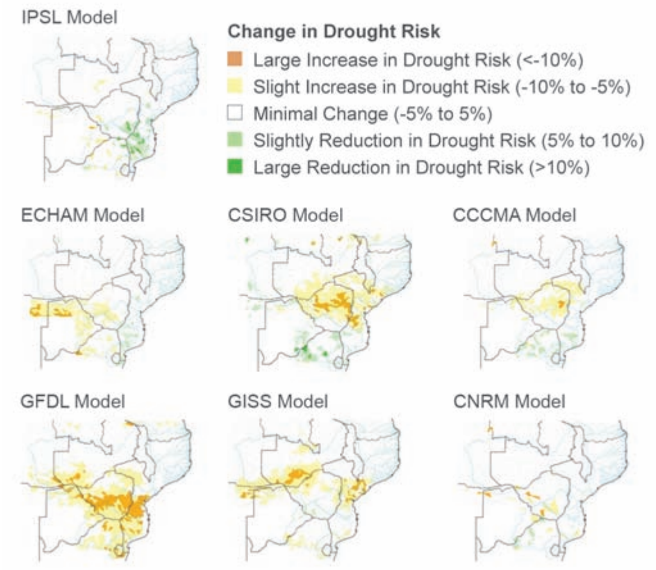


Figure 3.17: Changes in median maize WRSI for Jan-Feb for the seven GCMs.

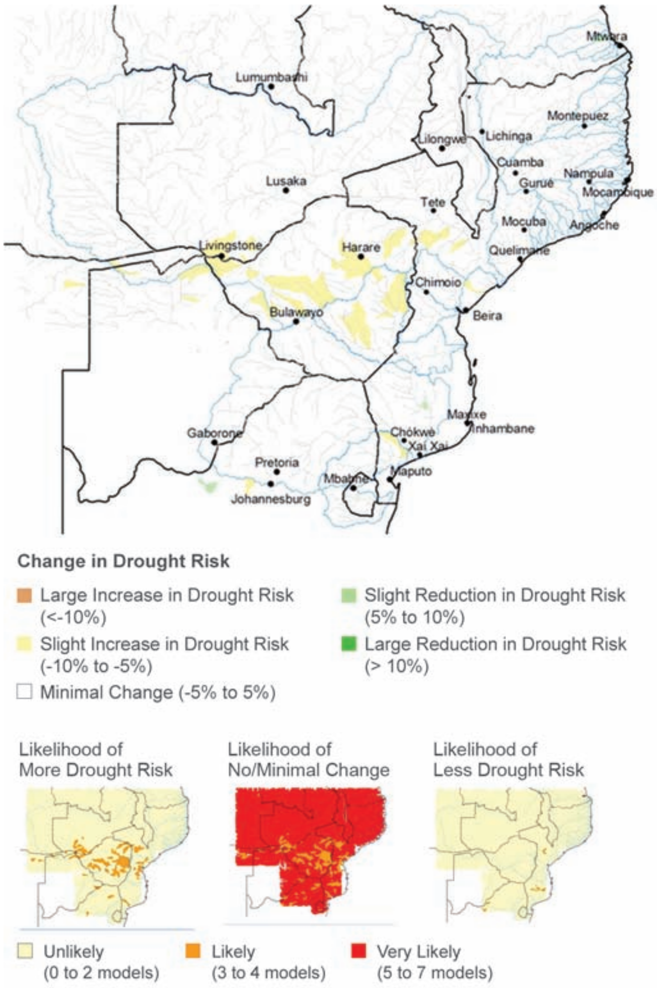


Figure 3.18: Average changes in the Jan-Mar drought risk from the seven GCMs and associated likelihoods.

For the season Jan-Feb-Mar, a slight increase in the risk of drought is expected in central Zimbabwe. No changes in the risk of drought are expected in Mozambique.

Figure 3.20 shows the results of the JFM risk of crop failure predicted by the seven GCMs used in this study (ECHAM, GFDL, IPSL, CCCMA, CNRM, CSIRO and GISS) and corresponding likelihoods.

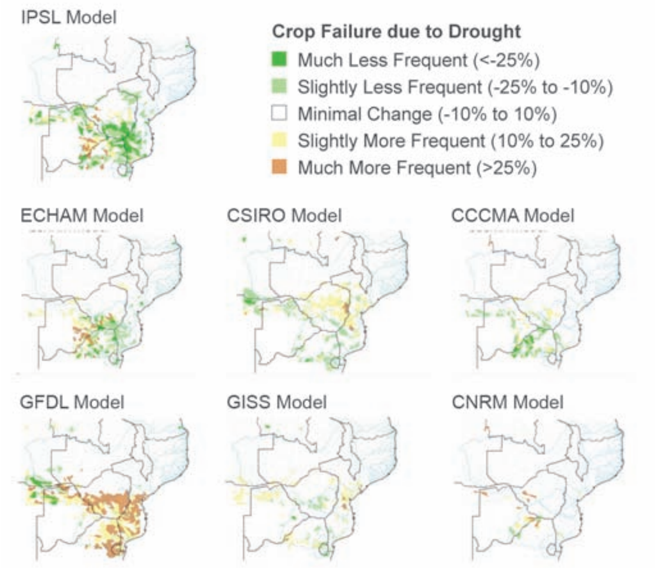


Figure 3.19: Changes in frequency of maize crop loss for Jan-Mar for the seven GCMs.

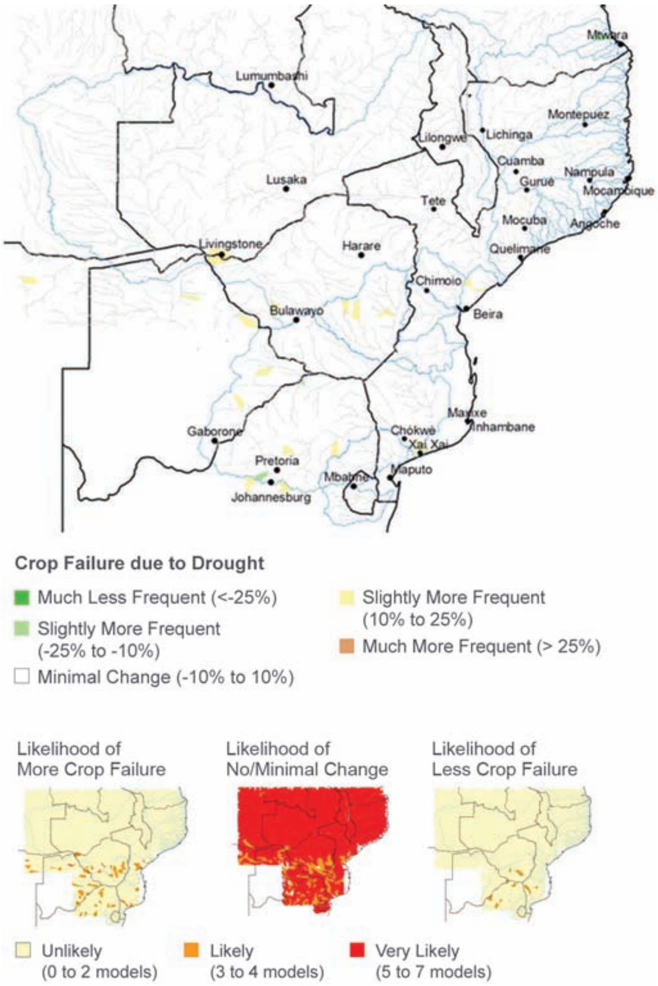


Figure 3.20: Average changes in the Jan-Mar crop failure risk from the seven GCMs and associated likelihoods.

For the season JFM, no change in frequency of crop failure due to drought is expected in Mozambique or the rest of region.

Figures 3.21 and 3.22 show the expected changes in per capita water availability and the associated residual water supply at current per capita usage rates.

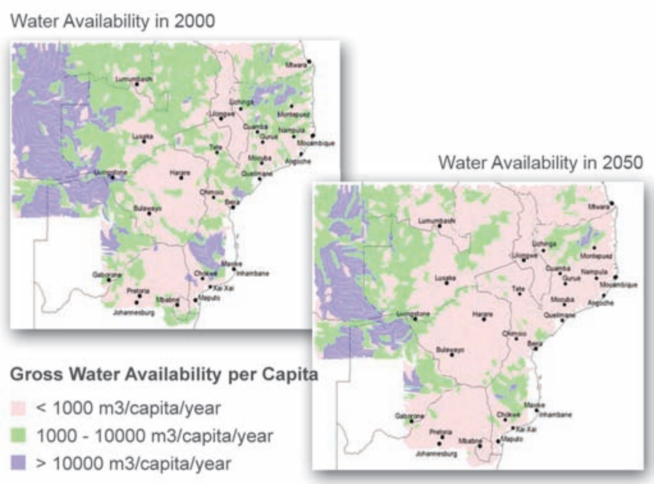


Figure 3.21: Changes in per capita water availability.

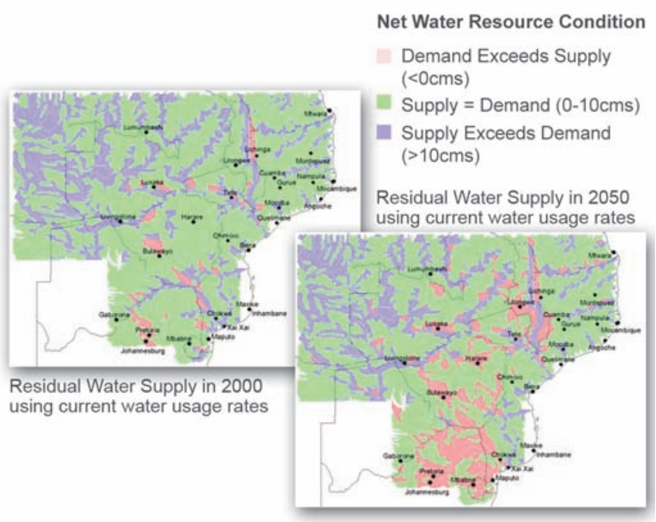


Figure 3.22: Changes in the residual water supply at current per capita usage rates. The unit cms refers to cubic meters per second (m^3/s).

Figure 3.23 presents three different scenarios - the residual water supply at low, medium and high per capita usage rates.

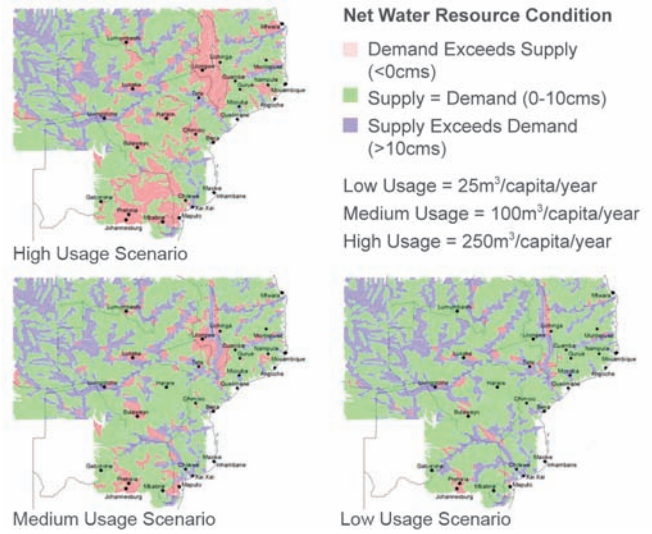


Figure 3.23: Changes in the residual water supply at low, medium and high per capita usage rates. The unit cms refers to cubic meters per second (m^3/s).

From Figures 3.23, it can be concluded that, increasing populations will exert more water demand, and current per capita water usage rates cannot be sustained in most basins in southern Mozambique including the Limpopo, Incomati and Umbeluzi. 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.

If medium water usage of $100m^3$/capita/year is adopted by all countries, most parts of the Limpopo and Incomati basins will be able to meet projected water demands in 2050. Water demands in the Umbeluzi and Maputo can only be met under the low usage scenario of ($25m^3$/capita/year).

Ocean tides are the largest natural forcing affecting sea water intrusion into river systems. Table 3.3 shows the extent to which this intrusion is already occurring. Sea level rise and storm surge appear to be much smaller in magnitude. 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 3.3: Sea water intrusion into river systems.

Distance inland refers to the distance inland that sea level rise associated with storm surge will cause flooding problems. Salt intrusion goes much further inland as exemplified in the case of the Pungue river which is the main source of drinking water for the cities of Beira and Dondo and of irrigation water for the Mafambisse sugar estate in Mozambique. The raw water intake for both water users is located at about 82km from the estuary mouth. In dry years the intrusion of salt water reaches the intake, which causes the intake to be interrupted. This phenomenon may happen in the dry season during spring tide. As a result pumping is interrupted for several hours near high tide. This problem has 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).

In the natural situation a minimum monthly discharge of $12m^3/s$ is required to prevent salt water from reaching the intake during the high water of a spring tide. The actual water discharge upstream of the water intake will have to be higher, since these minimum discharges do not take into account the water abstracted to supply to the irrigation and urban areas or a minimum discharge required to maintain the aquatic ecosystem. Due to these current water abstractions salinity problems near the water intake occur approximately 10% of the time. An additional water abstraction of $5m^3/s$ will lead to an increase in the salinity intrusion and a more frequent closing of the water intake of approximately 10% of the time. During neap tide the sand banks act as a temporary natural salt intrusion barrier reducing the chance of salt water reaching the water intake (S. Graas and H. H. G. Savenije, 2008).

Salt intrusion is also presently a problem in the Incomati river which has a large development in irrigation. A minimum flow of $5m^3/s$ is required in the estuary just to control salt-water intrusion. The same problem happens in the Limpopo which also has large developments and investments in irrigation and in the Zambezi. Vast areas of the interior of South - Central Mozambique (Incomati, Umbeluzi, Limpopo and Pungue) have lost land, through salt-water intrusion, resulting from the low discharges of effluents (F. Tauacale, 2002).

The results of the hydrologic modeling are presented for southern, central and northern regions of the country to facilitate transfer of the results to decision makers.

Southern of Mozambique

Rain

In southern Mozambique, six of the seven climate models run indicate a tendency towards increased average annual rainfall of about 25%. The only major exception to the increased rainfall trend is the GFDL model which indicates a tendency towards slightly reduced rainfall over the region.

The projected increases generally extend inland through the entire drainage area of the Limpopo and basins to its south. Rainfall in the upstream drainage area of the Save in Zimbabwe is projected to remain unchanged or slightly reduced.

However, the increase in temperature also results in a 10% increase in reference evapotranspiration. This results in some of the rainfall gains being lost particularly in the warmer portions of the drainage area in Botswana and parts of South Africa.

Droughts

The projected increases in rainfall result in only slight modifications in crop growing conditions. This is because the warmer temperatures also generate higher evapotranspiration rates and consequently crop water requirements.

For the main growing season in JFM, five of the seven models (ECHAM, CSIRO, CCCMA, GISS, CNRM), indicate that the risk of damage to crops in southern Mozambique remains unchanged. The driest model (GFDL), predicts a zone of significant increase in drought risk centered on the Save basin and extending southward into the Limpopo basin. The wettest model (IPSL), predicts reduced drought risk over the Limpopo basin.

The frequency of complete crop failure during the JFM season is similarly unchanged with the wettest (IPSL) predicting improvements in the Limpopo basin while the driest (GFDL) predicts increased frequency of drought. The remaining five models show most of the southern region remaining unchanged but with isolated patches of reduced crop failure frequency.

Taken together, the models converge on a prediction of unchanged risk of drought and frequency of crop failure during the JFM season.

The median model results for the OND season also indicate unchanged drought risk in southern Mozambique. Four of the seven models indicate unchanged drought risk levels while two models (CCCMA and CNRM) indicate slightly reduced risk levels (about 5%) and one model suggests slight increases in drought risk.

The median frequency of crop failure in the OND season also indicates minimal change but there is greater uncertainty in this result because of greater divergence among model results. While three models including the ECHAM, CCCMA and CNRM, indicate the likelihood for widespread improvements throughout the southern region, the GFDL and GISS models indicate widespread increase in crop failure.

The seventh model contains a mixture of patches with slight increases and slight reduction adjacent to each other. This result indicates that changes in crop failure patterns during the OND season are extremely sensitive to small perturbations. It should be monitored closely as it could provide an indication of the state of the climate.

Floods

With regards to flood hazards in southern Mozambique, a 25% increase in the magnitude of large flood peaks was identified along the main stems of both the Limpopo and Save rivers. These increases were observed in five models including the IPSL, ECHAM, CSIRO, CCMA and CNRM. The GFDL and GISS models both recorded decreasing flood magnitudes extending upstream into South Africa and Zimbabwe.

Much weaker signals of changes in frequency of flooding were observed with four of seven models indicating less frequent or unchanged flood occurrences. Exceptions include the CSIRO, CCCMA and CNRM which indicate increasing flood risk but mostly in smaller sub-basins away from the main stem.

Water Resources

Natural river flows are expected to increase in all basins in southern Mozambique, a conclusion supported by five of the seven models. The exceptions to this trend are the GFDL which consistently predicts reduced river flows and the GISS which predicts a patchwork of slight reductions and slight increases.

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 46 million in 2050. Even with a 15% rise in natural river flows, this would imply a 64% drop in per capita water availability by 2050.

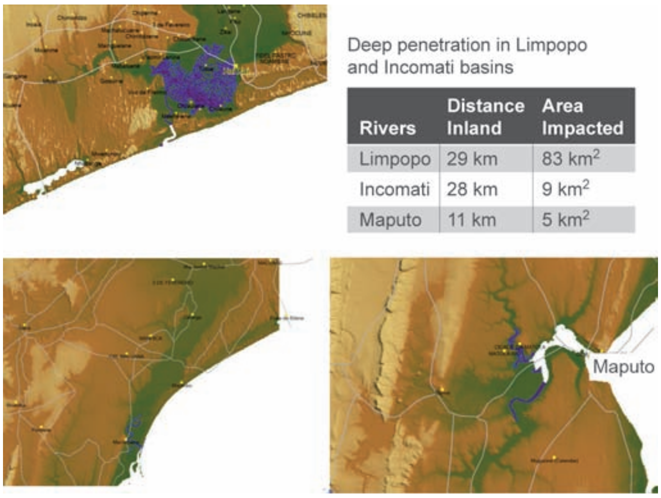
Similar three fold increases in population and 60-70% drops in water availability are also predicted for the Incomati, Umbeluzi and Maputo basins. A smaller drop of about 40% would be experienced in the Save because of lower population growth rates in Zimbabwe.

If the current uneven usage rates are maintained or uniform high usage rates are adopted across the region, 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 under median and low usage scenarios while the Umbeluzi and parts of the Incomati can only be maintained under the low usage scenario.

These results emphasize the need to reduce reliance on these rivers by developing alternate water sources, whilst avoiding the development of new agricultural uses in these basins.

Coastal River Inundation

Map 3.1 shows that the rivers of southern Mozambique are characterized by long, wide floodplains which are highly susceptible to saltwater intrusion. The length of inland penetration is almost identical for the Limpopo (29km) and Incomati (28km) rivers. However, the area inundated by saltwater 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 3.1: Inundated areas and salt water intrusion in the Limpopo, Incomati and Maputo rivers.

Central Mozambique

Rain

In central Mozambique, four of the seven climate models indicate that most areas will experience a tendency towards slightly increased rainfall while three models indicate rainfall will remain unchanged. The exceptions to this trend include Tete and the headwaters of the Save and Zambezi basins in Zimbabwe and Zambia, where most models indicate unchanged or even slightly reduced rainfall.

These upstream rainfall reductions could translate into significant reductions in river flows as higher temperatures increase evapotransipiration loss from open water bodies, soils and vegetation.

Droughts

In terms of drought, central Mozambique is the most likely to experience increased risk of droughts and crop failure. The adverse effects are also more pronounced during the OND season than in the JFM.

For the JFM season, four models (GISS, CSIRO, GFDL and CCCMA) indicate pockets of slightly increased drought risk stretching from the Buzi and Pungue basins into the Zambezi basin near Tete. In three other models (ECHAM and CNRM), the zone of increased drought risk is centered farther inland over Zimbabwe. The IPSL model shows no increase in drought risk.

All seven models indicate minimal or no change in the frequency of crop failure. The main message from the JFM drought analysis is that a zone of increased drought risk centered over Zimbabwe and probably stretching into Mozambique could have important implications for transboundary water usage and agricultural trade in the region during the during the JFM season.

The extent and severity of the drought risk increases during the OND season. At least five models indicate large increases in drought risk (>25%). The zone of increased risk covers most of Zimbabwe, Zambia and the areas of Mozambique around Cahora Bassa. In two of the models (CSIRO and GISS), coastal areas of central Mozambique, extending across the Pungue and Buzi basins are also affected.

The median frequency of crop failure is also enhanced with many areas showing between 10% and 20% increases in frequency of failure. This increased failure is especially enhanced in three models (CSIRO, GFDL and GISS). However, two models (CCCMA and CNRM) show almost no change in frequency of crop failure while two models (IPSL and ECHAM) actually show decreasing frequency of crop failure.

The consensus from these models seems to be that there will be a zone of increased crop loss within the drainage area of the Centre but there is disagreement among the models on the exact location of the zones.

Floods

Increase in flood hazards does not appear to be a concern in most of the Centre. Large portions of the interior of southern Africa are predicted to experience minor decreases (IPSL, ECHAM and CNRM) or even widespread, large decreases (GFDL and GISS) in the magnitude of flood peaks. The main exception to this trend is a zone of increased flood peaks centered near the Caprivi Strip where Angola, Botswana, Namibia, Zambia and Zimbabwe meet. This zone of increased risk is particularly enhanced in model runs with CSIRO and CCCMA inputs.

However, the flood magnitudes downstream of this area fall to normal or slightly below normal. This is because of reductions in the flows from surrounding tributaries originating in other parts of the interior which are experiencing reduced runoff generation.

The frequency of flooding is generally expected to reduce slightly across the region 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.

Water Resources

In terms of water resources, coastal basins in central Mozambique such as the Pungue and Buzi are expected to experience increases in streamflow while the Zambezi which originates in the interior of the continent is expected to see reduced streamflow.

Reductions in the river flow of the Zambezi about 15% are predicted by all models except IPSL. This model predicts that coastal enhancements will be sufficient to overcome reduced flows from the interior. In any case, the coastal enhancements are unlikely to be felt at Cahora Bassa where flows are stored for hydropower production. Actual flow reductions in the Zambezi could be much larger given the increasing risk of droughts and the growing population within its drainage area.

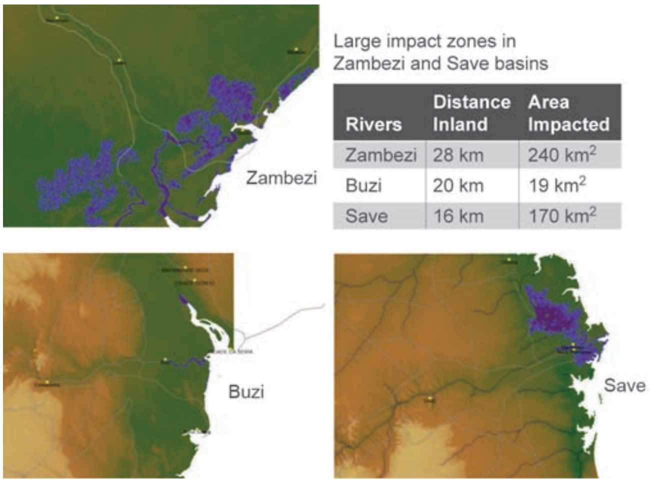
Assuming current population growth rates, per capita water availability is predicted to fall from about 1900m^3/capita/year in 2000 to about 500m^3/capita/year by 2050. Using current national per capita water usage rates, it is estimated that actual discharge entering Mozambique could be reduced by about 25% percent by mid-century. Under the high and medium equitable water usage scenarios, discharge would drop by 44% and 14%, respectively. The exception to this trend is the Shire Valley where many river reaches will be over-allocated under current usage, medium and high usage scenarios by 2050. 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. However, no specific analysis has been conducted to access how the changes in the timing or reliability of flows could impact hydropower production. Given the importance of Cahora Bassa to the Mozambican economy, it is important to devote additional resources to study the timing and economic implications of these flow reductions on power production and to develop strategies to mitigate these impacts.

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 but not the high scenario, whilst the Buzi has adequate water to meet all four water use scenarios.

Coastal River Inundation

Central Mozambique 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 penetration of about 28km. The marshland vegetation in the delta could provide some natural resistance to this intrusion. High flows associated with annual flooding of the Zambezi could also help to wash back some of the saltwater.

However, conservation of marshland vegetation and ecohydraulic 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 170 km^2 stretching 16km inland inundated. The northern bank of the Save River, extending from Machanga to Divinhe could be the most impacted by the inundation. In the Buzi, the inundation covers a small area (19 km^2) but it extends far inland (20km), as shown in the Map 3.2.



Map 3.2: Inundated areas and salt water intrusion in the Zambezi and Save basins.

Northern Mozambique

Rain

The climate simulations point towards increased rainfall in northern Mozambique. Four of seven models indicate that rainfall increases of about 15% could be experienced throughout the region while three other models indicate the likelihood of only localized or minimal changes in annual rainfall.

Since most of the river basins in this region are internally draining, the region offers the best opportunity for Mozambique to benefit from the positive impacts of climate change independent of the actions of neighboring countries. However, few changes of major consequence are expected in this region.

Droughts

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

For the OND season, median predictions are similarly devoid of changes in drought risk. However, there is less certainty in the results as the CSIRO model indicates increased drought risk, particularly along the Malawian border.

The situation is considerably less certain with regards to the frequency of crop failure. Three models (IPSL, ECHAM and CNRM) indicate much less frequent incidents of crop failure while three other models (CSIRO, GFDL and GISS) indicate much more frequent crop failure. The CCCMA model predicts minimal changes over the region but with isolated patches of reduced crop failure.

When these model results are taken together, the median prediction for the OND season calls for mild reductions in frequency of crop failure in coastal areas and no change elsewhere in the region.

Floods

With regards to changes in flooding, there are mixed signals in the northern region. No changes in magnitude of flood peaks were simulated in the interior part of the region. By contrast, most coastal watersheds recorded large changes in flood peaks in model results. The changes were a patchwork of both increased and reduced flood peaks with a higher number of watersheds showing increases. These results indicate that while the climate models have some difficulty figuring out exactly where rainfall events will occur, there is a general expectation of increased flood peaks in small watersheds wherever storms make landfall. The prediction with regard to the frequency of flooding is a similar patchwork of increasing and decreasing frequencies in isolated watersheds. More watersheds showing increases in frequencies than decreases but the clustering needed to confirm a consistent trend of change is absent.

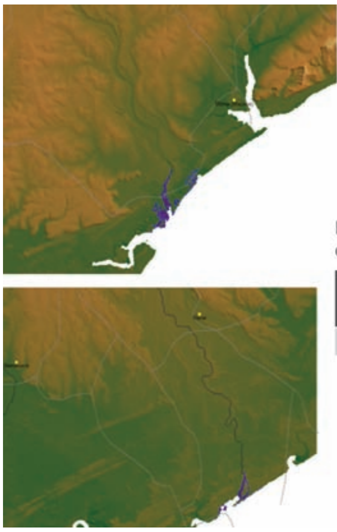
Water Resources

Most models agree on the absence of change in the simulations of streamflow. Two small areas show minor deviations from this trend. The southern portion of the region shows reduced streamflow in CCCMA and CSIRO simulations. The northern tip of the country near the mouth of the Rovuma River shows a region of increased water resources the IPSL, ECHAM and CNRM models.

Uneven water usage rates are really not a consideration in this region since most of the rivers are entirely within Mozambique. At current per capita usage rates, all river reaches have adequate water to meet demands until 2050. However, with an increasing population, about 60% of river reaches could become water scarce by 2050 compared to 25% in 2000.

Coastal River Inundation

Map 3.3 shows that saltwater intrusion does not pose a major problem for the river systems of northern Mozambique. This is because the terrain is generally more rugged with steeper slopes along the river channel. Typical longitude slopes are about 3m per kilometer near the mouth. The distance of inland penetration for the Licungo and Ligonha are 4km and 5km, respectively. The area inundated in the Licungo is 2km² three times as large as that of the Ligonha.



Minimal impact in northern basins due to relatively steep terrain

Rivers	Distance Inland	Area Impacted
Ligonha	5 km	6 km²
Licungo	4 km	2 km²

Map 3.3: Inundated areas and salt water intrusion in the Ligonha and Licungo rivers.

These impacts are relatively mild compared to other parts of the country.

3.2c Conclusions and recommendations

This study has found that considerable uncertainty surrounds the magnitude of the hydrologic impact of climate change in Mozambique. However, some clear spatial patterns of change have emerged which can form the basis of future adaptation planning. These include the region of drought centered in the interior of the continent over Zimbabwe, the increase in coastal rainfall, and reduction in drought risk in northern Mozambique during the OND season.

The main conclusions from this study can be summarized as:

- Increased drought risk and frequency of crop failure is predicted for the OND growing season in an area centered over Zimbabwe and extending into parts of Zambia and central Mozambique.

- During the major growing season in JFM, no change in either drought hazard or frequency of crop failure is expected in Mozambique.

- No change in drought profile is expected in most of northern and southern Mozambique during the OND growing season. A slight decrease in frequency of crop failure may even occur in northern Mozambique.

- The Zambezi, whose drainage area lies in the interior of the continent, is likely to see a reduction in annual flow which could impact hydropower generation.

- River basins in central Mozambique, including the Save and Buzi, could see increases in magnitude and frequency of flooding, particularly in coastal catchments. The Limpopo could also see increases in magnitude of floods.

- Increased precipitation in coastal sub-basins is expected to result in increase in internally-generated runoff which can be managed within the country.

- The Limpopo, Save, Pungue and some rivers in northern Mozambique will experience an increase in natural water resources.

- Increasing populations will exert more water demand, and current per capita water usage rates cannot be sustained in the most basins in southern Mozambique including the Limpopo, Incomati and Umbeluzi. 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.

- If medium water usage of 100m^3/capita/year is adopted by all countries, most parts of the Limpopo and Incomati basins will be able to meet projected water demands in 2050. Water demands in the Umbeluzi and Maputo can only be met under the low usage scenario of (25m^3/capita/year).

- Ocean tides are the largest natural forcing affecting sea water intrusion into river systems. This intrusion is already occurring now. Sea level rise and storm surge appear to be much smaller in magnitude. 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.

General recommendation on possible adaptation measures:

Water Supply Management
- Develop strategies to improve capture and storage of internally-generated runoff in both urban and rural areas
- Develop off-stream storage infrastructure to store excess flood waters for use in drought years

Policy Initiatives
- Pursue a regional policy of equitable per capita water use
- Adopt demand management policies such as limiting new surface and ground water developments in water scarce sub-basins

Protective Works
- Evaluate the construction of river locks to prevent salt water intrusion
- Evaluate injection wells and other hydraulic barriers to saltwater intrusion

Climate adaptation is more effective when it enters existing local and national planning processes as a variable which influences investment choices rather than as a standalone project or program of work.

4

Land use and food security analysis

4.1 Land use and land cover historical and baseline analysis

Jacinto Mafalacusser, IIAM and Dr. Mario Ruy Marques, IIAM

4.2 Impacts of climate change and socio economic developments on land use and land cover – potential effects on crop yields

Dr. Mario Ruy Marques, IIAM, Jacinto Mafalacusser, IIAM, Prof. Rui Brito, UEM, Dr. Marc Metzger, University of Edinburgh and Dr. Mark Tadross, UCT

Land Use and Land Cover historical and baseline analysis

Jacinto Mafalacusser, IIAM and Dr Mario Ruy Marques, IIAM

4.1a Introduction

4.1b Methodology and Procedures

4.1a Introduction

The world's climate is changing rapidly: projections from models for the current century suggest an increase in global average surface temperatures of between 1.4 to 5.8 ºC by 2100 (IPCC, 2007). Yet the impacts of climate change are likely to be highly variable, spatially. Rainfall increases are likely in temperate areas, whereas the tropics and sub-tropical regions are likely to experience decreases in some areas (IPCC, 2007). At the same time, weather variability is likely to increase, with Africa being particularly badly affected by climate change, and the Sub-Saharan and Southern Africa regions liable to experience the most extreme conditions.

The natural effects of climatic variability in fragile ecosystems are exacerbated by the interactions of indirect socio-economic drivers, where human population growth patterns, the flow of the rural population to major urban centers, and high rural poverty indices are just some of the features which exert a strong pressure on the resilience of agro-ecological and social systems. Based on these current and future trends, and in order to cope with indeterminate natural hazards, there is a need to quantify future change using multiple climate models and to understand what the climate scenarios can and cannot say about the future.

This assessment is supposed to make a significant contribution to increasing the adaptive capacity of several rural communities and local institutions to climate variability and the expected effects of future climate change. This involved identifying and testing options to increase the adaptive capacity of the system at different levels, including farmers, communities, institutions, and government, through the use of natural synergies that exists between the expertise of the different partners.

Given the wide diversity of environments, agricultural production systems and economic organization in the country, the approach adopted for this assessment has been to:

- Analyze the nature and distribution of land resources relevant to agriculture
- Determine to what degree and extent land resources are currently used
- Predict their potential agricultural use, yield gap analysis and associated mitigation measures, i.e. how improved land utilization types will contribute to high suitability conditions and to what extent
- Determine what would be the changes in terms of land suitability resulting from climate change

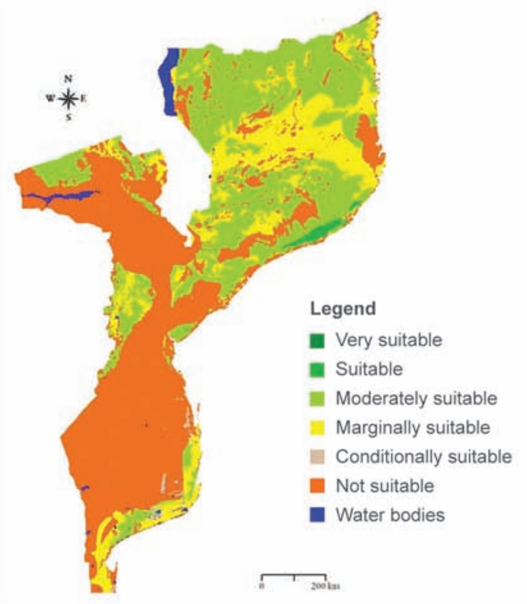
4.1b Methodology and Procedures

A range of innovative integrated methodologies have been followed/used in this assessment. First, to quantify the magnitudes of the effects of climate variability and change on the productivity of agricultural resource bases (rainfed crop production, extensive livestock production, agro-forestry, tree crop plantations, among others), and secondly how these changes affect rural households. To achieve this spatial data layers related to agricultural land utilization types (production systems), land cover, natural resources, and fragile environment systems were collated and documented.

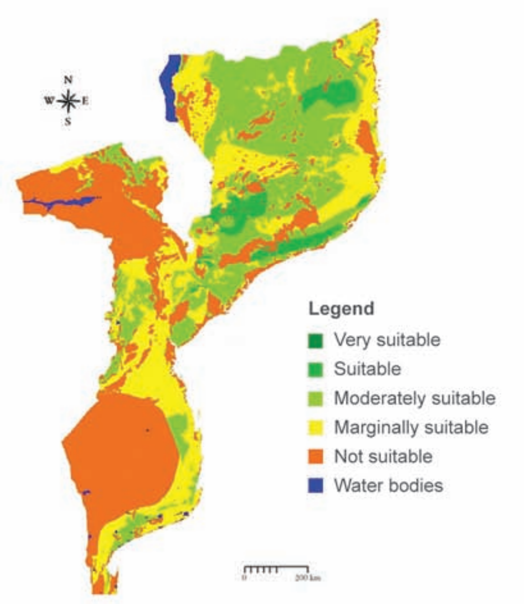
The current and potential scenarios for the classification of the land utilization suitability has been assessed with a dynamic and automated land evaluation system (ALES), which operates on the basis of a decision-tree model for each land utilization type, matching its eco-physiological and socio-economic requirements, with the relevant land/environment attributes, i.e. soil, terrain and climate characteristics/qualities (Rossiter, 1997).

The system results in the simulation of crop yields/performance under different levels of management, where observed yields are associated with prevailing traditional small holder low input farming systems, and potential yields corresponding to limitation free highly managed commercial crop production systems.

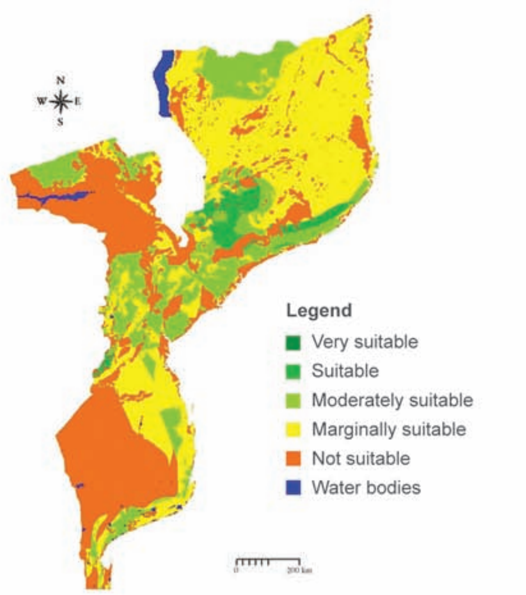
The selected crops for this study include cassava, maize, soya, sorghum, cotton and groundnut. This gives a combination of different crops grown mostly under rainfed conditions, and represents different crop types that react differently to changes in temperature and rainfall patterns. These selected crops were used to produce the land suitability maps under current conditions, and the land suitability maps under climate change for three different models (IPSL, ECHAM, and GPDL).



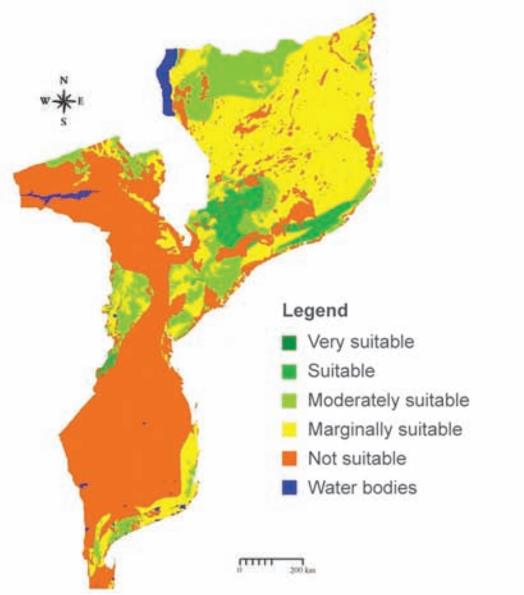
Land suitability map for cassava and current conditions.



Land suitability map for cassava under climate change according to the IPSL model.



Land suitability map for cassava under climate change according to the ECHAM model.



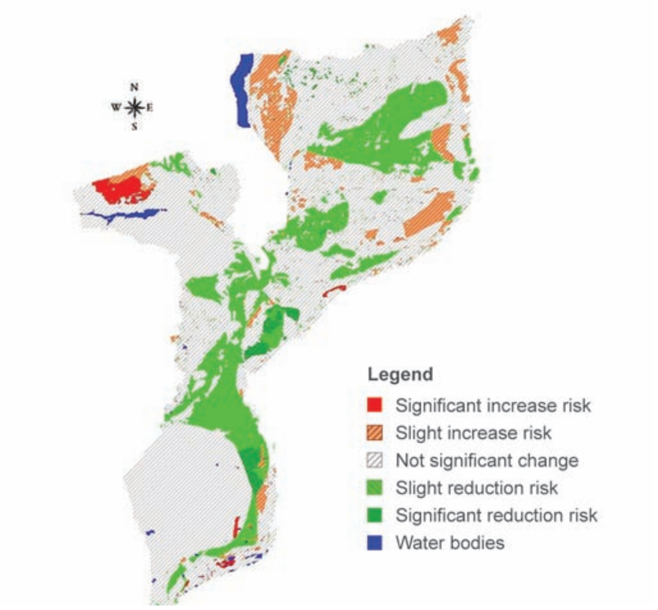
Land suitability map for cassava under climate change according to the GFDL model.

Map 4.1: land suitability maps for cassava, under the current condition and under climate change based on three models (ECHAM, IPSL and GPDL).

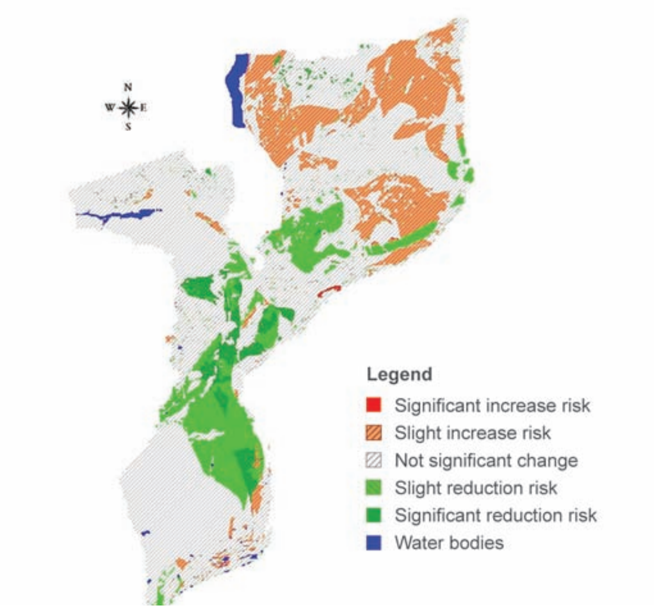
Map 4.1 shows the land suitability maps for cassava, under the current condition and under climate change based on three models (IPSL, ECHAM, and GPDL). These maps have five different suitability classes (very suitable, suitable, moderately suitable, marginally suitable, and not suitable).

Each of the maps resulting from the climate change (ECHAM, IPSL and GFDL) were then compared to the current conditions and classified according to five different classes:

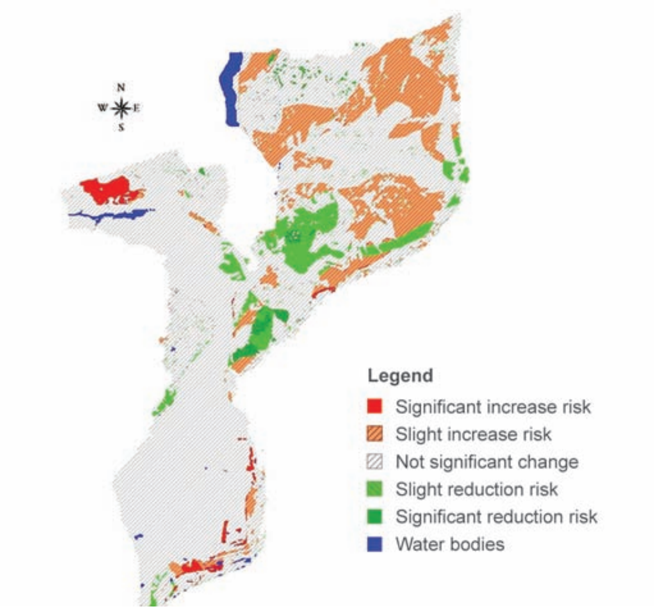
- *Significant Reduction in Risk*, equivalent to a change to a better suitability class in two levels
- *Slight reduction risk*, equivalent to a change to a better suitability class in one level
- *No Significant Change*, equivalent to no change in the suitability class
- *Slight Increase Risk*, equivalent to a change to a worst suitability class in one level
- *Significant Increase in Risk*, which is equivalent to a change to a worst suitability class in two levels



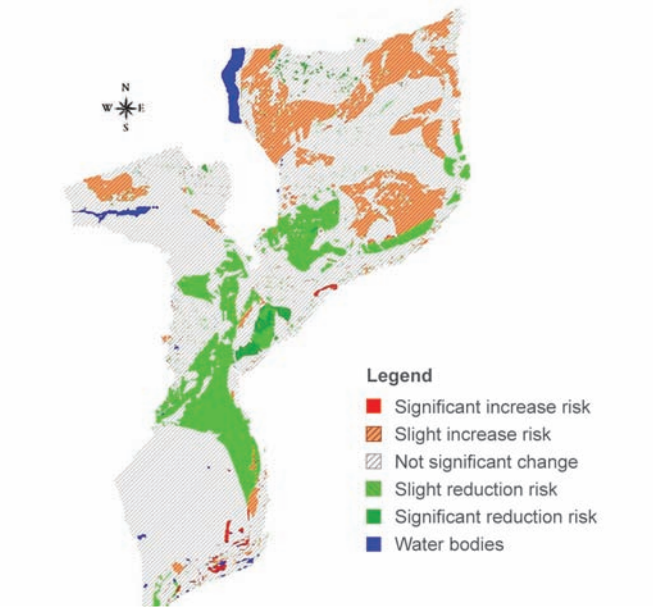
Land suitability changes for cassava under climate change according to the IPSL model.



Land suitability changes for cassava under climate change according to the ECHAM model.



Land suitability changes for cassava under climate change according to the GFDL model.



Average land suitability changes under climate change for all three GMC models.

Figure 4.1: land suitability changes for cassava, under the current condition and under climate change based on three models (ECHAM, IPSL and GPDL).

Figure 4.1 shows the result for the three different models (ECHAM, IPSL and GFDL), and the average change resulting from all three models.

The following discussion and analysis of the climate change impacts is based on these maps.

Climate data

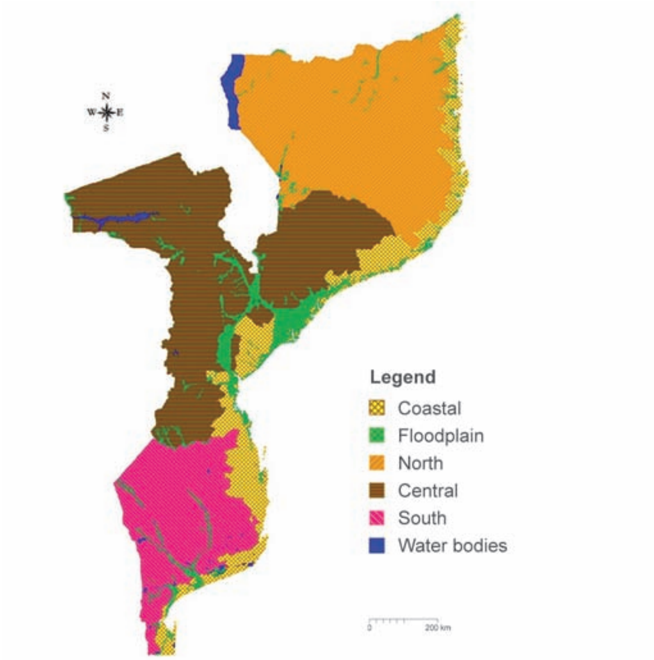
Climate data and figures used in the current analysis are the result of historical (trends) in the climate of Mozambique and those projected for the 2046 and 2065 period, from a set of 7 downscaled GCMs (Tadross, 2008).

The records and projections were derived from daily temperature and rainfall measurements since 1960 from 32 synoptic weather stations around Mozambique which were supplied by the meteorological agency (INAM). Only 27 stations with sufficient data for rainfall and temperature have been used as the basis for interpolation for the remaining 108 climate stations that the current Mozambique Land Evaluation System uses for deriving crop suitability classifications.

Due to time constraints on running different simulations, only three of the seven downscaled GCMs were used. The first one (IPSL) represents the wettest conditions, the second (ECHAM) represents average conditions and the third (GFDL) represents the driest conditions.

Zoning

The zoning of Mozambique was prepared to represent a macro-analysis regional framework for the spatial macro-analysis, discussion and presentation of the assessment outputs. 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. Map 4.2 presents the land zoning for the specific purposes of the current assessment exercise.



Map 4.2: The five different land zoning used in this report (Coastal, Floodplain, North, Central and South).

Table 4.1 gives a general description of most important agro-ecological features for each of the zones.

Zone	Agro-ecologies Name	Rainfall (mm/year)	Soil types	Most important crops
Inland South	Semi-arid to arid Interior South	400-600	Sands to Loamy-clays	Cassava, maize, groundnuts, and sugar cane
Floodplain South	Semi-arid and Coastal	600-1000	Vertisols and fluvisols	
Coastal South	Semi-arid Coastal South	500-600	Deep Sands	
Inland Central	Mid-elevation Central	1000-1400	Sands and Clays	Cassava, maize, rice, sorghum, and sugar cane
Coastal Central	Coastal Central	1000-1400	Vertisols and fluvisols	
Floodplain Central	Dry Semi-arid Zambézia and Tete	500-800	Sands-clays	Cassava, maize, groundnut, sorghum, rice and cotton
Inland Northern	Interior Central and North	1000-1400	Sands-clays	
Coastal North	Coastal North	800-1200	Mostly sands, clays on a small scale	Cassava, maize, rice and groundnuts

Table 4.1: General description of most important agro-ecological features for each of the five zones.
Source: Modified after INIA (1996) and Walker et al. (2006).

Inland Zones (North, Central and South):
The two dominant agro-ecologies are the Inland Central and North, most represented by the high altitude region. Collectively, agro-ecologies that are serviced by the Central zone (inland, coastal and floodplain) contribute more than 30% to the value of production. The more dynamic maize-producing zones with significantly more production per household are the mid-elevation and flood plain zones, of the Central Zone, where mean annual production per household approaches or exceed 800kg. Rice production particularly under rainfed conditions on hilly and mountainous terrain is common.

Inland North and Central:
Agro-ecology corresponding to the Inland North produced most of the sorghum particularly in the period 2002-03. Given sorghum's role as a food security crop for a considerable number of households in Nampula province, it is important for the inland North. High-yielding, short-matured, photo-period insensitive varieties are not well adapted to the growing season conditions of Northern Mozambique. Rainfall at planting is uncertain and the risk of rainfall at harvesting is high.

The agro-ecologies of the interior North and Centre also contributed more than 20% to the value of production of cassava. In 2001-02, households produced on average more than 1.5 metric tons. Economically, groundnuts are the most important grain legume and are produced throughout Mozambique, but agro-ecologies in the inland and coastal North account for over 60% of production.

These agro-ecologies are the only areas where mean production approaches 100kg per household in severe droughty years like the 2002/03 crop season. Average yields under normal rainfall conditions and for small holder farmers approaches 500kg in southern regions and up to 1,000kg in the Centre and North.

The inland Central and North is probably the most dominant zone in that part of the country. The floodplain is mainly characterized by very V-shaped narrow river valleys, where the flood plains is almost limited to river terrace systems or low lying transitional slopes from the drainage lines and the intermediate slopes.

The inland Centre and North corresponds to the extensive middle altitude region of Zambezia, Nampula, Niassa and Cabo Delgado, and it includes land with altitudes ranging from 200 to 800m, corresponding to subplanaltic, low planaltic and mid-planaltic regions in Zambezia, Nampula and southern Niassa and Cabo Delgado Provinces. The area consists of a slightly undulating terrain, with alternation of low hills (interfluves) and valleys.

The altitude of the plain varies from about 200 to 500m, while the characteristic feature of the area, the inselbergs, presents altitudes from 600 to 1,200m, often with steep slopes and bare rocks.

Annual rainfall for most of the areas between 200 and 500m ranges from 1,200-1,400mm, whereas the inland mid-planaltic region annual rainfall is about 1,000-1,200mm. A relatively sub-humid dry region with lower annual rainfall dominates the southern part of Niassa, Cabo Delgado and the northern of Nampula Provinces, where rainfall is between 800 to 1000mm. There is a great soil variation across this region. The largest part of the area, approximately 75%, including Inselbergs and valleys, has soils derived from quartz-rich rocks (granites and gneisses). The soils from the upper parts of the interfluves of the area are deep, reddish to brown, well drained, with sandy topsoil overlying a medium to heavy textured soil.

The soils of the midslopes and lower slopes of the interfluves are sandy, brownish to grey, sometimes with small rock fragments of quartz or iron-manganese, concretions like, in the subsoil. The soils of the valleys and dambos (shallow valley floors) are deep and dominantly sandy textured, but also stratified and clay soils occur. About 25 to 30% of the area consists of rock-outcrops. Major limitations for agricultural development are soil depth, soil erosion, and soil fertility. Quite a substantial part of the region is under cultivation or under conservation status or under forest land concession for logging.

Inland South:
Maize is important for food security in the South. Value of production in the three southern agro-ecologies, i.e. inland, flood plains, and coastal, totals more than $10 million (Walker et al. 2006). The highly visible Chokwe irrigation district in agro ecology corresponding to inland South and partially floodplain South only contributed about 9% to the national value of production of $18 million in 2001-02.

Cultivated land according to the forest inventory (UIF, 2007), accounts for approximately 25,500,000ha (IIAM, 2008), with inland zones (North, Central and South) representing 76% of the total cultivated land. The inland Southern zone experiences quite distinct environments regarding its potential for agricultural development. It is dominated by land subject to moderate to severe drought risks, showing strong seasonal and dry climate which combined with coarse textured and/or gravelly and stony and/or rather shallow soils cause pronounced soil moisture deficiencies. Rainfed food crop production and commercial crop production is of high risk. Irrigation is a major mitigation management issue if any production is likely to be achieved.

The inland flat to very gently undulating sandy plains deposited over old distinct grey and brown mottled plastic clay deposits, consist of Mananga soils. The Mananga soils have been classified according to the thickness of the sandy top layer and its colour is related to drainage and to thickness of the sandy cover. The shallow sandy plains (sand sheets) are composed of coarser or finer sands, depending on the underlying Mananga or post-Mananga mantle: an argillic, a natric or a cambic horizon developed in the Mananga material below the sandy top layer. Very often their sub-soils are saline/or sodic.

The Mananga soils are highly erodible. The sandy clay loam textured subsoil’s compact easily when wet and become capped when dry. Drainage is a problem. Banks of open drains needs protection against erosion. Exceptionally good surface water management and irrigation scheduling are required.

The shallow sandy plains (sand sheet) have low available moisture capacity, low intake rate and poor drainage conditions (compact horizon under the sandy top layer), which again make good irrigation scheduling essential. Installation of drains is essential to avoid soil toxicity and salinity problems. The easily dispersed topsoil is highly erodible. Sheet erosion and eolian reworking are at the origin of this layer.

Coastal Zone:
The three coastal zones (south, central and north) with about 20% of maize production present a daunting challenge. Maize does not enjoy a comparative advantage in these agro-ecologies, but it will be an important commodity there for many years to come. Lowland maize has been difficult to improve; few varieties are well-adapted to lowland conditions. Mean production is only about 250kg per household.

Coastal Central and North are considered dominant agro-ecologies/zones for rice production. Production per household was low in 2001-02. Only agro-ecology of the Coastal North produced significant yields above 80kg.

Coastal North has been reported to be also important in terms of cassava production, a crop showing significant adaptation to dominant agroecologies. Since the late 90s, cassava has been afflicted by several sources of biotic stress mostly brown streak disease and mosaic virus; however, there is still no clear evidence that such stress results from any moisture or soil fertility stress or hazards. Together with the Inland North zone, it accounts for more than 60% of groundnut production, being probably the most important grain legume crop in the region.

Northern Coastal Zone:
The Coastal North zone corresponds to the coastal littoral north of Nampula and Cabo Delgado, and it consists of a narrow coastal strip of land from Moma up to the northern parts of Cabo Delgado, with an average altitude <200m. Rainfall across the region ranges from 800mm, in the northern and southern parts of Nampula and Cabo Delgado Provinces respectively, to 1,200mm in the southern of Nampula Provinces.

The soils follow the dominant toposequence. Parts of the light and coarse textured soils on the slightly higher and top-flat terrain of the sandy dunes, alternate with the alluvial soils of the floodplains of major rivers draining into the sea, and with hydromorphic mineral and organic soils of swales, seasonally flooded. Rice cultivation (paddy rice and surface sub-basin irrigated rice) is common in Moma, Angoche, and Monapo and Mussoril districts. The wet baixas (depressions) crops like rice, sugar cane, banana, vegetables and sweet potato are preferred, whilst in the less wet baixa, maize, sweet potato and vegetables are mainly grown.

The agricultural potential for several food and industrial crops is large because of the prevailing climate conditions, in the southern parts of the country. A major constraint is the population levels in the area. This results in a lot more pressure on the available land resources. Nampula is the province shows the highest population densities in the country.

Central Coastal Zone:
The Central Coastal Zone is again quite an extensive region which comprises two major land systems, i.e. the beach ridge land system, corresponding to the freshwater environment, and the coastal plain which corresponds to the saline environment, under active influence of the tides, associated with the estuarine plains.

As with the results described earlier, and particularly for Zambezia and Nampula provinces, the Central and Northern Coastal Zones are dominated by commercial coconut plantations, which dominate the wider sandy ridges, while the narrow parallel sandy beach ridges are occupied by small holder farmers, where the main crops are coconut, mango, cashew, banana, as well as food crops like cassava, sweet potato and maize.

The sandy ridges are alternated with depressions/swales running parallel to the coast in most cases, where the small holder farmers normally grow rice during the wet/rainy season, while sweet potato, maize, cowpea are grown on manmade ridges as a major soil and water conservation practice to improve drainage conditions for crop growth.

The coastal plain is an extensive flat terrain system showing a complex network of small creeks communicating with sea tides. It is practically flooded during the wet season. It shows severe constraints for agricultural development because of the high salinity hazard, poor to swampy conditions, very heavy soils, and access difficulties. Under such soil and water prevailing conditions, it allows for rice cultivation but on a very marginal condition. These areas are further limited during the dry season owing to poor water quality for irrigation because major rivers and tributaries suffer from severe salt intrusion thus limiting its potential for crop production. The area is mainly covered with mangrove forests. Livestock on extensive communal pastures may be an option to consider to crop production.

South Coastal Zone:
The South Coastal zone accounts for 50% of the total cultivated land for the respective zone. Both Coastal South and North together account for more than 80% of the total cultivated Coastal land mostly due to the dominant fruit tree cropping systems, where fruit tree crops such as cashew and coconut play an important role in the traditional socio-economic, culturally and environmentally traditional agricultural systems. As distinct from land, which is a common resource, trees planted are normally seen as the personal property of the individual who planted them.

The value of any harvest therefore can, and does, accrue to the individual, whether male or female, to use for whatever purpose. This also further contributes to land security rights. The Southern Coastal zone offers a greater potential for fruit tree crop development, once the area is more vulnerable to drought events and tree crops are able to develop eco-physiological mechanisms to cope with extended moisture stress conditions.

The planting and tending of trees carries only a small risk of failure and does not impose itself on the grower in order to remain reasonably productive. It also plays an environmental role by acting as a wind break barrier mitigating potential soil erosion hazards along the coastal line.

Another important feature, which may represent a significant contribution for crop production in terms of the Coastal South Zone, because of its strategic natural conditions, are wetlands. Wetlands are ecosystems, which have recently commanded quite a lot of attention. The need for their sustainable development warrants further attention. The importance of wetlands is related to their potential to retain large volumes of water, which can be used for system maintenance and for dry season agriculture.

According to Gomes et al. (1997), the Southern Coastal zone of Mozambique is characterized by arid and semi-arid climates together with light/coarse textured soil having low available water content (AWC). Here, according to Reddy (1986), 50% of the area has soils with an AWC less than 100mm/m and 25% less than 50mm/m. This exacerbates the risk of drought and most of the area has a chance of dryland crop failure over 50%.

The mean annual rainfall decreases from 800-1,000mm near the coast, to less than 400mm in the interior, mainly concentrated during the rainy period between October and April (Reddy, 1986). Associated with this pattern of rainfall distribution, are the heavily populated coastal zones and high land use intensity (Snidjers, 1986). This is despite the low fertility of these soils and resulting low yields.

To address these adverse conditions, farmers usually cultivate the lowland areas where the residual soil water content can be used for crop growth. The main limitations are: a) high investments to promote drainage and prevent floods, b) bad soil structure associated with low infiltration rates and, c) risks of salt intrusion due to tidal fluctuation and lowering of the water table. Yield losses are mainly due to flooding and excessive soil water during the rainy season, while in the upland areas, it is mainly the result of large soil water deficits which can occur throughout the year.

According to the wetland classification (Gomes et al. 1997), most of these lowland areas belong to the Palustrine system. They play a very important role for food security and household income of thousands of families. Five wetland ecosystems occur in Mozambique, marine, estuarine, riverine, lacustrine and palustrine system. The most important systems for agricultural development are the riverine and palustrine systems. The riverine associated with the southern Floodplain zone, being the largest one, and the palustrine with the Coastal South Zone. The palustrine system includes the coastal lakes, lagoons, swamps, and peat lands. Peat lands are of enormous importance for small-scale agriculture. Peat soils and hydromorphic sandy soils are common in the South, where semi-arid conditions predominate, and its importance is associated with water availability all year round.

Floodplains Zone:
Production is beset by both droughts and floods in lowland-rainfed rice, the dominant agro-ecology, floods particularly in the central floodplain, and droughts in the South. Such fluctuations in production were evident in the two years of the agricultural surveys. Production rebounded in 2002-03 with five agro-ecologies producing more than 100kg/household.

Nevertheless, regional differences exist, with Zambezia (Central Coast/Floodplain) exhibiting negative yield growth in the most recent past, and Nampula (North Coastal) and Gaza (South Inland and Floodplain) showing a considerable increase in yields. Agro-ecology corresponding to Central Floodplain registered good sorghum harvest particularly in 2002-03.

The central and southern Floodplain zones are quite important environments for most of the rural households, dependent on agriculture as the main source of food. Normally the households have two farms, the main one by the river banks (low zone) and the other, away from the river banks (high zone). This is an important and strategic mechanism to mitigate flood and drought impacts. During excessive wet seasons they concentrate on the up-land farms, during moisture stress conditions they prefer the lower zones to secure food crop production and to increase the success of crop harvest.

Because of major impacts of floods hazards the natural characteristics of the Southern Floodplain Zone shows very little change in the area of cultivated land. Figures have remained quite consistent over the last thirty years. Another potential reason may be associated with the fact that a considerable amount of land is for irrigated agriculture, i.e. estimates from the last national irrigation survey (Marques et al. 2004) show that 62% from the total equipped irrigated land or 75,747ha is located in the Southern Floodplain Zone, although only 31% of the area was operational at the time of the survey. Irrigated land is dominated by the largest irrigation scheme existing in the country which is the Chokwe scheme located in the Limpopo River floodplain, and those located in Incomati River floodplain belonging to the large commercial sugar cane estates. However, irrigation development in all of the major river basins in the Southern zone is limited by water access and availability.

The South and Central Floodplain zones are dominated by extensive alluvial plains, inland from the coastal dune belt or zone. Alluvial soils associated with the river floodplains cover large areas in the Limpopo, Inkomati, Umbeluzi, Maputo, Buzi, Pungue, and Zambeze and its tributaries valleys.

Generally, the major river floodplains are covered with fertile soils. These have the potential for agricultural development. Suitable lands for agriculture include flat to gently undulating areas, well to imperfectly drained pluritextured soils. In the medium upstream courses of Limpopo, Incomati, Umbeluzi, Buzi, Pungue and Zambeze, the more dissected and coarse-textured areas are classified as not suitable. Intermediate areas, less suitable for agriculture consist of flat and periodically inundated areas which are poorly drained and, areas exposed to moisture stress for much of the year. The land assessed as unsuitable for agriculture or with limitations for such land utilization types, like dryland crop production and irrigated crop production, has a pastoral value. It is also suitable for livestock production, or for fast growing exotic tree species, where average annual rainfall exceeds 1,000 mm, or for conservation purposes, as in the Inland South and Central Zones, where a substantial portion of area of land is under conservation status.

A great part of the cultivated area located in low-lying soils, which during floods are largely inundated by major river waters. The major consequences of flooding are: saturation of the soils with water; fertilization of the soils with silt; flushing of salts out of the soils; and inaccessibility for cultivation during the period of high water. The three first conditions may be considered as positive impacts of regular flooding, while the last one would benefit from flood control. Saturation of soils with flood waters or a high water table allows rainfed crop production in most parts of the river valley, particularly on those soils with limited water holding capacity in the root zone.

Flooding in the rainy season matches rainfall water deficits during the growing period (occurrence of more than one droughty period) allowing for a good crop season. The flood recession cropping, mainly vegetables, maize and sweet potatoes, indicates that water provided by flooding is of some importance. It is probable that flooding is beneficial primarily in the drier parts of the valleys, where sowing can be extended at least one month into the crop calendar based on residual soil moisture availability.

Fertilization from floodwaters is important for the maintenance of soil fertility. Floodwaters contain more organic and inorganic deposits, which settle on the inundated land and fertilize the soils, especially with organic matter and phosphorus.

Flushing out of salts is also a positive impact of floods. When flooding is reduced, salt accumulation is a serious problem for agricultural soils as well as for the productivity of the plains. Under the prevailing arid conditions of the Limpopo, Incomati, Buzi, Pungue and Zabeze Basins, salts tend to accumulate in soils not washed out by rain or floodwaters. Moreover, the underground fresh water aquifer is shallow, and it overlies saline water. The most fertile soils are located in low-lying areas. Therefore they are exposed to greater risk of salinization than other soils occurring in the Basin for different reasons: surface runoff containing dissolved salts from higher areas (i.e. from Mananga platforms); poorly drained soils parallel to the river, containing mildly saline to non-saline groundwater, depending on the degree of flooding. If not flooded, salinization will increase since even heavy rainfalls will not suffice to flush out the salts. In cases where the groundwater table is high, upward capillary movement of even very mildly saline groundwater will cause salinization of the surface water. In the areas close to the coast, salts of marine origin cause additional salinization. The saline groundwater table is high in places, and marine deposits are present.

The soils are poorly drained to swampy and are covered by swamp grassland or herbaceous swamp vegetation and mangrove. Strongly gleyed alluvial soils and peat soils are dominant and offer little or no agricultural potential without major improvements. These normally correspond to estuarine plains which are dominated by mangrove vegetation woodland or forests. Table 4.1 summarizes major attributes for each zone.

Land Evaluation and Land Suitability Classification

To execute a land evaluation, information on land is needed in terms of climate, topography and soils. Information for the whole country is available from the National Soil Data Base and METEO (climate) Data Base, held at the Crop and Natural Resource Management Department (DARN), the Mozambique Agricultural Research Institute (IIAM). The databases are part of the Mozambique Land Evaluation System – MOZLES (Beernaert, 1995), which uses land qualities and land characteristics to describe the land in terms of its natural resources. These are called land mapping units.

The land mapping units are defined very generally in terms of climate, soils and landforms, with some information having been assessed by extrapolation from other secondary sources, i.e. satellite imagery, geological maps, etc. Additional land use/cover maps (UIF, 2007; CENACARTA, 1998; INIA, 1986) and associated databases (UIF, 2007; CENACARTA, 1998) were made available for the analysis. The system is based country-wide and mapped at a scale of 1:1.000.000.

Such a system and its associated map base are compiled on a provincial basis, and provide an appraisal on the land resources, population distribution at village level (INE, 1997), and current land use (UIF, 2007; CENACARTA, 1998; INIA, 1986).

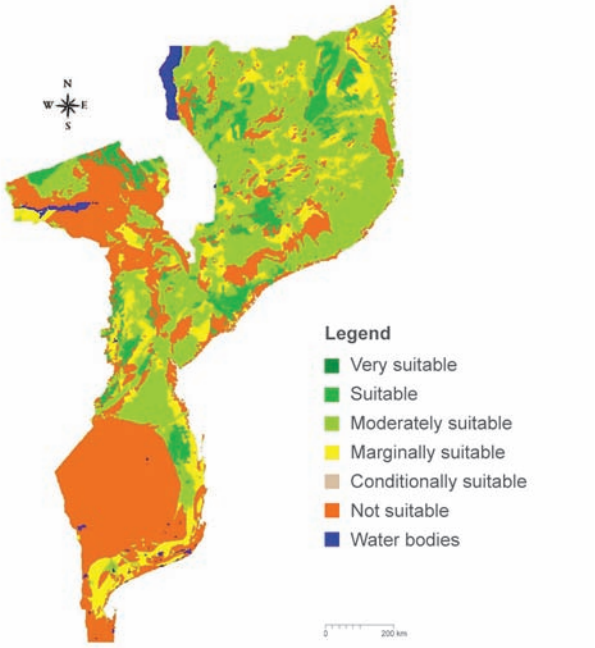
Ecophysiological requirements of the main food and cash crops have been compiled from relevant literature and from previous agronomic experimentation within and outside the country. This work has resulted in the final preparation of a series of tabular descriptions of crops. This information has been used to define the probable limitations to production for each crop in each land mapping unit in the MOZLES.

The information in the database (land resource data) is linked to the ecophysiological data to provide the inputs for the initial assessment of the potentialities and limitations of the land resources of the country for agricultural development and population growth. The final assessment takes into account factors such as land capability, land suitability, sustainable production and potential population supporting capacity.

From this information maps were produced on a country bases indicating the suitability for each of the crops according to six classes, namely:

- Very suitable
- Suitable
- Moderately suitable
- Marginally suitable
- Conditionally suitable
- Not suitable

Map 4.4 categorises these classes by color. Except for the first class of land, i.e very suitable for crop production, and the last, i.e. not suitable for crop production, all other classes refer to the most serious terrain, soil and climate limitations, either in terms of slope, occasional flooding, imperfect drainage, rockiness or stoniness, drought risk, fertility level, soil depths, and soil toxicities.



Map 4.3: Present land suitability map for rainfed soya under current conditions.

Crop Production and Yield Data

Literature describing smallholder farming systems throughout the country has been used, including information from the agro-ecological zoning classification (INIA, 1996). Additional crop production and crop yield data, at a national and sub-national level has been sourced from reports representing time series for the 80s, 90s and 2000 (DNSA,1992- 2008), and experimental and research yield data (INIA,1997-1999).

Subsistence food production in Mozambique is based on a diversity of staples, all of which are root and tuber (cassava and sweet potato), grain legumes (cowpea, pigeon pea, groundnuts), cereals (maize, rice, sorghum), and cash crops (cotton, sunflower, soya bean, wheat).

The environmental conditions under which many of these are grown vary widely, and adaptation is achieved through both the development of complex management practices, the use of different varieties/cultivars, and strategies to cope with adverse and inadequate crop production conditions.

Reported yields of selected representative crops at household level show wide variation. This is due in part to the uncertainty over the measures of total yields, as the crop can be harvested over long periods, i.e. cassava roots and maize fresh cobs, cassava and other crops leaves, and in part due to the reliability of estimates obtained from necessarily few samples (Early Warning System). In addition, it owes to the complex systems found under multi-crop, mixed crop and intercrop production. Further components contributing to yield variation are the diverse crop management practices.

Maize is produced throughout Mozambique. Four of the eight agro-ecologies produce more than $6 million worth of maize (Walker et al. 2006). Among cereals, rice is the most important crop after maize in terms of the value of production. Table 4.2 shows that most rice production takes places in the Central region of the country (62%), followed by the North (31%). The South holds only 7% of total production. The Centre and the North are also the most populous parts of the country. Most of the production growth is primarily the result of increases in the area cultivated, rather than increases in total yield. In the period 1997/98 to 2003/04, the nation experienced hardly any yield growth. Average yield is quite low at 1.02 ton/ha.

Sorghum is the other cereal that is considered an important commodity, particularly in the inland areas. Like rice, mean sorghum production fluctuated sharply between the two survey years. Cassava production is more concentrated than maize with the three coastal agro-ecologies (South, Central and North) accounting for over 60% of the value of production.

The remaining crops correspond mainly to cash crops either produced by the small holder farmers or by the new emergent commercial farmers, or a combination of both. Under such initiatives commercial groups back the production and marketing of the commodities, for example, soya beans (recently introduced), sunflowers, and cotton. Sugar cane is a commercial crop that has been produced by the large scale commercial companies. More recently such companies have backed and supported the establishment of out growers schemes. These have proven successful, both in terms of production, and the quality of the produce.

Wheat production is very limited in terms of its area and location, with many of the initiatives again falling under the responsibility of small holder farmers or small commercial farmers, who operate in areas normally under 5 ha. These are largely concentrated in the plateau areas like Manica/ Chimoio/Barue in Manica Province, and Angonia and Tsangano in Tete Province. Estimates are presented for these crops without differentiating the production and yields according to the zoning classification.

Crop	Average Yield (Ton/ha)		
	1950s	1990s	2006/07
Sunflower	0.5-1.5	0.5-1.1	0.5-1.5
Soya bean	1.3	-	0.2-0.45 [2]
Wheat	0.72	-	0.6-1.7
Sugar Cane	60-90	90-110	110-130 [3]
Cotton	1.45	1.31	0.3-0.6 [4]

Table 4.2: Evolution of Agricultural Production and Yields of Crops in Mozambique.

[1] Adaptado das Estatisticas Agrárias. 1996. Estatisticas Agrarias 1994. Departamento de Estatistica, Ministerio de Agricultura e Pescas. Maputo, Mocambique;

[2] Dias (2008) reported for small holder farmers and small commercial farmers in Sofala, Manica and Tete, yields up to 3.0 t/ha, with an average of 2.0 t/ha under rainfed conditions;

[3] Sugar cane production under high level of inputs yields > 130 t/ha 2007/08 crop season (SSIP/DNSA, 2008);

[4] Average figures for the country although regional differences in production/yield would be expected; top farmers without fertilizers, under rainfed conditions, following just weeding and other plant protection recommendations managed to get 1.5 t/ha;

Agricultural production systems are horticulturally based and have evolved across a large range of sophisticated but low input cropping practices and farming systems. These exploit the highly complex distribution of natural environments found in Mozambique and its vulnerability to the most common natural disasters, mainly droughts and floods. Agriculture in Mozambique personifies risky production. The floods of 2000 were possibly the most famous weather-related rainfall event.

Widespread, regional drought in 1992 was equally infamous. Every year various sources of risk exact a toll on production. Table 30 illustrates the point that 44 to 87% of producers in the TIA 2002 (MINAG-DE, Trabalho de Inquérito Agrícola), lost a percentage of their crops to one natural hazard.

Crop	Total No. Of Observations	Affected Commodities (%)	Source of Risk (%)							
			Drought	Excess Rain	Floods	Diseases	Insects	Animals/ Rats/Birds	Rots	Others
Maize	3128	74.7	72.6	5.2	1.7	2.8	1.8	11.1	1.1	3.8
Rice	1001	76.2	65.2	4.6	3.3	1.4	1.2	19.3	0.6	4.4
Sorghum	1263	70.8	64.2	1.5	0.4	1.3	1.9	25.9	0.9	3.9
Groundnuts	2340	78.4	67.3	3.0	0.9	4.1	2.9	16.1	2.8	2.9
Cowpea	2294	83.5	66.0	2.4	0.7	6.3	9.5	10.9	2.5	1.7
Bambara nut	1140	79.9	70.9	3.9	0.4	2.5	2.5	10.0	6.8	3.1
Pigeonpea	544	59.8	48.3	2.2	1.1	3.5	11.4	21.9	3.9	7.7

Table 4.3: Sources of Risk by Crop in Mozambique. ***Source: Walker et al. 2006***

Table 4.4 provides some preliminary information on yield reducers and its relation to regional vulnerability and major source of risks. Unfortunately such analysis is only valid for four crops (maize, rice, sorghum and groundnuts) out of the ten crops selected forthe overall assessment. Those omitted include cassava, sunflower, soya bean, wheat, sugar cane and cotton. Sorghum is sensitive to bird damage and too much rain, while pigeon pea yield depends on the insect pests, principally pod borer. Rice requires water control, whereas groundnuts do not like too much rain or moisture.

According to Walker et al (2006), the most important source of risk is drought. The incidence of precipitation in the rainy season is almost never ideal for crop growth and harvesting. More than 50% of the producers of each commodity said that drought had caused production losses in 2002. In response to the same question, the majority of respondents cited drought as a significant cause of productivity loss in 2003 for all commodities except for pigeon pea (41%). Pigeon pea and cowpea are drought tolerant crops but nevertheless severe water stress affects yields.

Drought was again prevalent in 2004-2005 and 2007 (Queface, 2008). About 800,000 households were declared food insecure. Localized areas in all provinces were declared as targets for relief efforts, but the households were concentrated in drought-prone areas of Tete and Gaza districts. 37 of the 80 TIA districts contained people declared to be food insecure (FEWS NET, 2005). Tables 4.4 and 4.5 present actual crop yields standing for each of the selected zones under current and prevailing agricultural rainfed farming systems.

Nevertheless, despite the causes, the actual yields in Mozambique are very low, as shown in Tables 4.4 and 4.5, giving average yields for different years. If we look at Maize, the yields go from the lowest around 0.1 ton/ha in the inland dry South with poor soils to the highest of 2.0 ton/ha in the inland North with better climate and better soils.

Zone	Maize			Sorghum			Rice		
	98/99	02/03	06/07	98/99	02/03	06/07	98/99	02/03	06/07
Inland South	0.1–1.0	0.2–0.3	0.28	0.6–0.7	0.02–0.25	0.4	–	–	1.0
Floodplain South	0.3–0.7	0.25–0.4	0.34	0.6–0.7	0.02–0.25	0.42	2.4	0.8–0.9	2.4
Coastal South	0.4–1.0	0.1–0.4	0.4	0.6–0.7	-	0.5	1.6–2.4	0.04–0.18	0.38
Inland Central	0.8–.6	0.45–0.9	0.88	0.87	0.15–0.25	0.5	–	0.03–0.1	0.37–0.55
Coastal Central	0.4–1.6	0.3–0.5	0.9–1.1	0.68–0.8	0.06–0.19	0.5	0.87–1.17	0.07–0.18	0.23–1.2
Floodplain Central	0.4–1.5	0.5–0.85	1.1–1.2	0.63–0.8	0.13–0.27	0.7	0.87–1.17	0.03–0.2	0.2–1.0
Inland Northern	0.5–2.0	0.46–0.65	1.2	0.5–0.7	0.15–0.19	0.75	0.6–1.2	0.07–0.18	0.8–1.0
Coastal North	0.25–1.0	0.2–0.3	0.9–1.0	0.5–0.6	0.09–0.13	0.75	0.6–1.2	0.11–0.14	0.7–1.2

Table 4.4: Mean actual household Maize, Sorghum and Rice production in Tons (ton/ha) by zones in 98/99, 02/03 and 06/07.
Source: Estatisticas Agrarias. 1999/00. Estatisticas Agrarias 2002/03. Estatisitcas Agrarias 06/07. Departamento de Estatistica, Ministerio de Agricultura e Pescas. Maputo, Mocambique.

Zone	Cassava[1]			Groundnut			Beans		
	98/99	02/03	06/07	98/99	02/03	06/07	98/99	02/03	06/07
Inland South	4.9	0.3–0.7	6.1	0.44–0.51	0.01–0.03	0.23	0.5–0.6	0.01–0.03	0.24
(R1 e R3)	4.9	0.3–1.1	5.8	0.44–0.51	0.01–0.04	0.22	0.4–0.6	0.016–0.04	0.24
Floodplain South (R1, R2 e R3)	4.9	0.35–1.1	6.5	0.44	0.02–0.04	0.30	0.38	0.016–0.04	0.26
Coastal South (R2)	5.2–5.7	0.1–0.5	7.0	0.4–0.62	0.02–0.04	0.5	0.3–0.6	0.02–0.05	0.54
Inland Central (R4 e R7)	5.2–5.9	0.6–1.8	7.0	0.65–0.9	0.08–0.1	0.58	0.6–0.7	0.05–0.18	0.58
Coastal Central (R5)	5.2	1.4–2.0	6.0	0.5–0.6	0.02–0.03	0.36	0.4	0.01–0.05	0.37
Floodplain Central (R6)	5.9	1.1–1.7	7.0	0.4–0.5	0.02–0.06	0.57	0.3–0.6	0.03–0.7	0.56
Inland Northern (R7)	5.9	0.6–1.8	7.0	0.65–0.9	0.08–0.1	0.57	0.3–0.6	0.05–0.18	0.55
Coastal North (R8)		1.5–1.6		0.44–0.65	0.06–0.09			0.03–0.04	

Table 4.5: Mean actual household Cassava, Groundnuts and Beans production in Tons (Ton/ha) by zones in 98/99, 02/03 and 06/07.
Source: Estatisticas Agrarias. 1999/00. Estatisticas Agrarias 2002/03. Estatisitcas Agrarias 06/07. Departamento de Estatistica, Ministerio de Agricultura e Pescas. Maputo, Mocambique.

Crop	Input level	Very suitable	Suitable	Moderately suitable	Marginally suitable	Not suitable
Maize (lowland)	High Low	7.1–5.7 1.8–1.4	5.7–4.3 1.4–1.1	4.3–2.8 1.1–0.7	2.8–1.4 0.7–0.4	1.4–0.0 0.4–0.0
Maize (highland)	High Low	10.9–8.7 2.7–2.2	8.7–6.5 2.2–1.6	6.5–4.3 1.6–1.1	4.3–2.2 1.1–0.6	2.2–0.0 0.6–0.0
Sorghum (lowland)	High Low	5.1–4.1 1.3–1.0	4.1–3.1 1.0–0.8	3.1–2.0 0.8–0.5	2.0–1.0 0.5–0.2	1.0–0.0 0.2–0.0
Sorghum (highland)	High Low	8.8–6.2 2.2–1.6	6.2–4.7 1.6–1.2	4.7–3.1 1.2–0.8	3.1–1.6 0.8–0.4	1.6–0.0 0.4–0.0
Cassava	High Low	13.6–10.9 3.4–2.7	10.9–8.2 2.7–2.0	8.2–5.4 2.0–1.4	5.4–2.7 1.4–0.7	2.7–0.0 0.7–0.0
Groundnut	High Low	3.3–2.6 0.8–0.6	2.6–2.0 0.6–0.5	2.0–1.3 0.5–0.3	1.3–0.7 0.3–0.2	0.7–0.0 0.2–0.0

Table 4.6: Potential yields for some crops in rainfed agriculture in Mozambique, expressed in ton/ha, according to the suitability class and according to different inputs. *Source: Adapted from "Generalized Agro-Climatic Suitability for Rainfed Crop Production".*

Table 4.6 gives the potential yields for some crops in rainfed agriculture in Mozambique for five different suitability classes (very suitable, suitable, moderately suitable, marginally suitable, and not suitable), and two different input levels (high and low).

Table 4.7 summarizes the observed extreme values of yields (highest and lowest) for the relevant crops for this study, and for the comparison of potential yields under rainfed crop production for the same crops.

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

Table 4.7: Lowest and highest observed yields, and potential yields in ton/ha. [(1)] Adapted from "Generalized Agro-Climatic Suitability for Rainfed Crop Production".

Most of the production growth has primarily been the result of increases in cultivated area, rather than increases in yield. In the most recent period of 1997/98 to 2003/04, there was hardly any yield growth for the country as a whole. Average yield is quite low at 1.02 ton/ha.

Sorghum is the other cereal that is considered an important commodity particularly in the inland areas. Like rice, mean sorghum production fluctuated sharply between the two survey years.

Cassava production is more concentrated than maize with the three coastal agro-ecologies (South, Central and North) accounting for over 60% of the value of production.

Notes

[1] In the case of 98/99 crop season Cassava yields have been predicted, while for the other crops figures represent observed data.

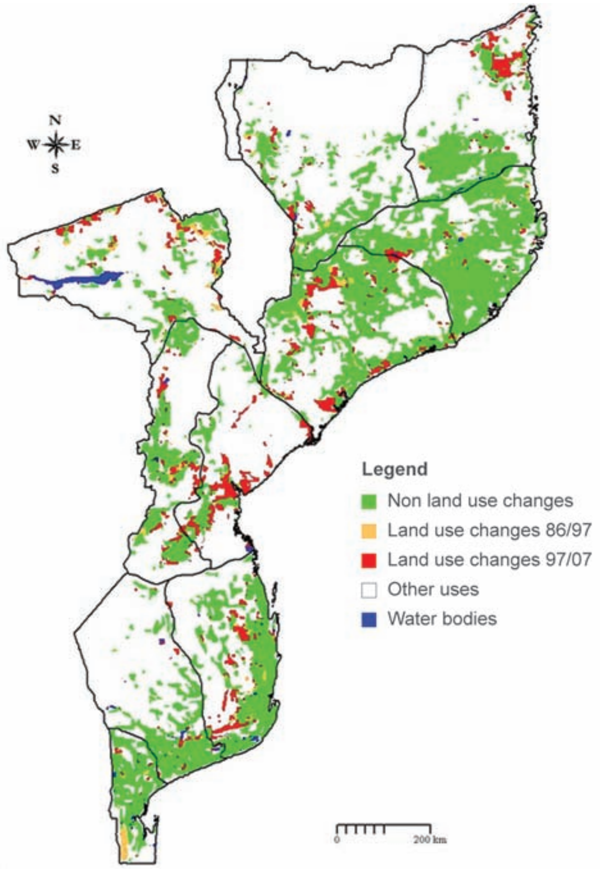
Actual Land Use/Cultivated Areas

In terms of cultivated land, looking at each of the different zones, the Central floodplain contributes 60% of the total cultivated land estimated for the floodplains. Map 4.5 and Table 4.8 present major temporal land use changes for the last three decades and associated areas, as well as the present potential available land for different land uses. In Table 35 the present available land for crop production does not include productive forest, and conservation areas.

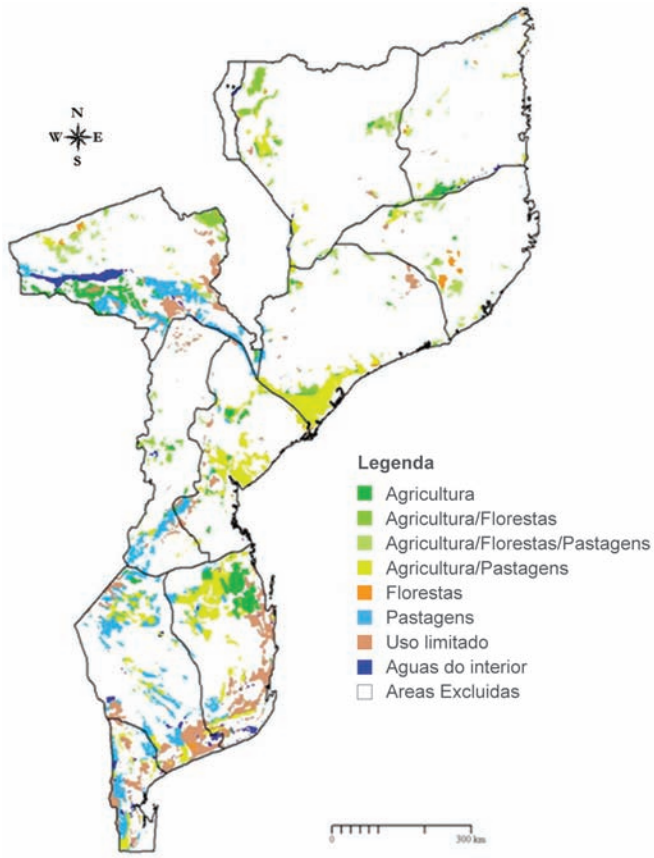
The question of available land is becoming critical if the present situation takes into consideration future population growth. Table 35 shows that only 26.6% of land is currently available for the expansion of agriculture without interfering with other land uses. If the present technologies are kept, Mozambique will run into conflicting situations that become similar to those already occurring in Brazil, i.e. with the formation of the landless workers movement. Taking the year of 2005 as a reference point, the population of Mozambique was approximately 19,420,000 million and the area under agricultural cultivation was around 25,537,200 ha, equal to 1.31 ha/capita. Considering that there are 6,796,400ha available, corresponding to an increase in the population of 5,188,000 million. With a population growth rate of approximately1.75%, by 2015 the population will be approximately 24,517,600. Under this scenario, all the available land will be used if the present situation persists. The increment in agricultural land from 1986 to 2007 includes productive forest land, protected ecological zones, as well as natural parks and conservation areas.

It should be noted that that if Mozambique opts for agriculture intensification, around 30 to 50% of the present land used will be reduced once almost half of the land in the rural environment is under fallow cultivation. In addition, if increases in yields are included, a lot of land will be saved. So crucial aspects are:

- Agriculture intensification
- Technological development
- Irrigation development
- Increase in yields



Land use changes from 1986 to 2007



Potential available land for different land uses

Figure 4.2: Land Use Changes from the year 1986 to 2007 and potential available land for different land uses.

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 4.8: Summary of Land Use Changes (ha) from the year 1986, 1997 and 2007, according the different zones.

Impacts of Climate Change and socio economic developments on Land Use and Land Cover - Potential effects on crop yields

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4.1a Impacts and implications of climate change on agricultural land use and crop production of selected zones

4.1b Adaptation Measures and Recommendations

4.1c Conclusions

4.2a Impacts and implications of climate change on agricultural land use and crop production of selected zones.

Climate change influences on land use and land cover are an important factor in determining the vulnerability of ecosystems and local agro ecologies. Climate change exerts a strong influence over dryland vegetation type, biomass and biodiversity, as well as on other major natural and manmade environments. Rainfall and temperature determine the potential distribution of terrestrial vegetation and plant crops, and constitute the principal factors in the genesis and evolution of soil. The high temperatures and low rainfall resulting from climate change in the semi arid environment lead to poor organic matter production and rapid oxidation. These result in high rates of soil fertility decline, loss of crop productivity, decreases in fallow periods required to restore natural soil fertility, water and wind erosion, and other related stresses. These serve to highlight the importance of these factors and the direct impacts on soil and indirect impacts on land degradation.

Climatic stresses also include high soil temperatures, seasonal excess of water, short duration low temperatures, seasonal moisture stress and extended moisture stress. These stresses are likely to impact directly on crop yields and agricultural productivity on a local and regional level, thus affecting overall crop suitability and its geographic or spatial distribution.

Where crops are grown near to their maximum temperature tolerance and where dryland, non-irrigated agriculture predominates, the challenge of climate change could be overwhelming, especially impacting the livelihoods of subsistence farmers.

The scenarios for this analysis were created by changing the observed data on current climate according to temperature and rainfall simulations of three out of seven different general models (GCMs), representing extreme drought and wetness and a third as an intermediate condition, i.e. the ECHAM model simulating intermediate, GFDL and IPSLI simulating drought and wetness respectively. The IIAM crop suitability models were used to estimate how climate change, i.e. simulated climatic factor values resulting from running the climate change models mentioned previously, may alter the crop suitability either in terms of suitability ratings or geographic distribution. Models were used were for cassava, maize, soya, sorghum, and groundnut. For the purpose of the discussion, crops considered only include cassava, maize and soybean.

The present exercise aims to demonstrate how climate change impacts on crop adaptability and suitability. It identifies reference food crops which better demonstrate such changes. For example, it identifies cassava as the major root crop due to its peculiar tolerance to seasonal and extended moisture stress and poor soil fertility conditions. This contrasts sharply with maize and soybean which suitability have been severely affected by climate change at the zonal level.

A range of statistics are then calculated to examine local changes in suitability for each crop, the changes in areas suitable for each crop, and zoning patterns in these changes. Maps are also produced demonstrating the changes in suitability for the selected crops under each GCM model. All the relevant maps are presented at the end of this chapter. The section includes the suitability map for the current conditions, the average suitability map under climate change based on the results from the three different models (ECHAM, GFDL and IPSL), and the resulting changes in the associated risks, for all six crops under study.

Zoning	Changes in Risk	Cassava (% area)				Maize (% area)				Soya (% area)			
		(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.
North	Significant Reduction Risk	0.9	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Slight Reduction Risk	1.9	1.9	1.9	1.9	28.3	28.3	26.8	27.8	1.9	1.9	0.0	1.2
	No Significant Change	56.6	53.5	57.8	56.6	71.7	71.3	72.9	71.9	85.1	73.4	74.7	77.7
	Slight Increase Risk	38.3	43.2	38.8	40.1	0.0	0.3	0.0	0.1	12.8	23.7	22.8	19.8
	Significant Increase Risk	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.6	0.9	2.5	1.4
Central	Significant Reduction Risk	1.2	5.6	1.5	2.8	1.8	0.6	2.1	1.5	2.1	1.8	2.4	2.1
	Slight Reduction Risk	21.6	17.5	9.8	16.3	25.1	19.4	22.2	22.3	5.6	5.9	5.3	5.6
	No Significant Change	70.1	72.6	79.6	74.1	71.6	69.0	70.4	70.3	70.1	62.7	67.2	66.6
	Slight Increase Risk	6.5	3.6	5.3	5.1	1.5	10.9	5.0	5.8	10.1	13.6	11.5	11.7
	Significant Increase Risk	0.6	0.6	3.6	1.6	0.0	0.0	0.0	0.0	12.5	16.0	13.6	14.0
South	Significant Reduction Risk	0.0	0.0	0.0	0.0	15.0	0.0	16.2	10.4	20.6	1.3	45.0	22.3
	Slight Reduction Risk	3.8	13.7	1.9	6.4	9.4	0.6	47.4	19.1	51.1	35.2	28.8	38.4
	No Significant Change	93.1	83.0	92.9	89.7	75.0	95.5	36.1	68.9	26.2	60.3	21.9	36.1
	Slight Increase Risk	1.9	3.1	3.1	2.7	0.6	3.7	0.0	1.5	2.5	3.1	3.8	3.1
	Significant Increase Risk	1.3	0.0	1.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2
Coastal	Significant Reduction Risk	4.3	11.2	4.3	6.6	6.0	0.0	5.2	3.7	2.5	0.0	3.4	2.0
	Slight Reduction Risk	30.8	26.7	10.4	22.7	20.5	9.5	21.5	17.2	5.0	8.6	4.3	6.0
	No Significant Change	53.8	48.2	66.8	56.2	73.5	80.1	73.1	75.5	72.0	68.0	55.6	65.2
	Slight Increase Risk	10.3	13.8	16.5	13.5	0.0	10.3	0.0	3.4	10.9	15.5	27.4	17.9
	Significant Increase Risk	0.9	0.0	1.7	0.9	0.0	0.0	0.0	0.0	10.0	7.8	9.4	9.1
Floodplain	Significant Reduction Risk	3.1	12.5	3.2	6.3	10.9	6.3	10.9	9.4	3.1	1.5	6.2	3.6
	Slight Reduction Risk	17.2	9.4	6.3	11.0	23.4	15.9	24.9	21.4	6.3	6.1	1.5	4.6
	No Significant Change	70.3	68.6	77.5	72.1	65.6	65.0	62.3	64.3	67.5	64.6	61.5	64.5
	Slight Increase Risk	6.3	7.8	7.9	7.3	0.0	12.7	1.6	4.7	12.6	9.2	10.8	10.8
	Significant Increase Risk	3.1	1.6	4.7	3.1	0.0	0.0	0.0	0.0	11.0	18.4	20.0	16.5

Table 4.9: Changes in risk for cassava, maize and soya, resulting from the climate change for three different scenarios (ECHAM, GFDL and IPSL). Changes are expressed as a % of the area.

Zoning	Changes in Risk	Sorghum (% area)				Cotton (% area)				Groundnut (% area)			
		(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.
North	Significant Reduction Risk	1.6	1.6	0.0	1.0	13.7	13.7	11.8	13.1	4.4	4.4	4.1	4.3
	Slight Reduction Risk	6.2	7.5	4.4	6.0	24.5	24.8	26.5	25.3	44.2	42.0	30.3	38.8
	No Significant Change	82.4	70.4	46.7	66.5	54.3	55.0	54.8	54.7	48.2	51.0	62.4	53.9
	Slight Increase Risk	8.1	7.5	34.9	16.8	7.5	6.5	6.9	6.9	2.5	2.2	2.8	2.5
	Significant Increase Risk	1.6	13.1	14.0	9.5	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
Central	Significant Reduction Risk	0.0	0.0	0.0	0.0	5.6	6.2	3.0	4.9	1.8	3.0	3.2	2.7
	Slight Reduction Risk	13.3	14.2	8.3	11.9	14.8	13.3	18.1	15.4	17.8	40.0	20.1	26.0
	No Significant Change	65.3	74.0	67.3	68.8	63.0	58.6	62.9	61.5	76.2	51.0	72.6	66.6
	Slight Increase Risk	17.7	6.8	14.8	13.1	16.6	21.6	16.0	18.1	3.6	5.0	3.5	4.0
	Significant Increase Risk	3.5	5.0	9.5	6.0	0.0	0.3	0.0	0.1	0.3	0.9	0.3	0.5
South	Significant Reduction Risk	0.0	0.0	0.6	0.2	3.8	0.0	3.1	2.3	0.0	0.0	0.0	0.0
	Slight Reduction Risk	61.8	5.6	60.2	42.5	30.2	1.3	51.3	27.6	21.2	33.1	22.5	25.6
	No Significant Change	35.6	64.0	36.0	45.2	66.0	97.5	45.6	69.7	69.7	24.4	70.5	54.9
	Slight Increase Risk	1.9	26.1	2.5	10.2	0.0	1.3	0.0	0.4	8.1	36.8	6.2	17.0
	Significant Increase Risk	0.6	4.3	0.6	1.9	0.0	0.0	0.0	0.0	0.6	5.6	0.6	2.3
Coastal	Significant Reduction Risk	0.0	0.0	0.0	0.0	4.3	2.6	2.6	3.2	0.0	1.7	0.0	0.0
	Slight Reduction Risk	35.6	33.0	31.0	33.2	17.2	9.5	18.8	15.2	23.0	69.2	20.5	37.5
	No Significant Change	54.7	61.7	56.0	57.5	75.0	75.9	69.2	73.4	73.2	24.8	71.7	56.6
	Slight Increase Risk	9.5	5.2	7.8	7.5	3.4	12.1	9.4	8.3	1.7	2.6	6.0	3.4
	Significant Increase Risk	0.0	0.0	5.2	1.7	0.0	0.0	0.0	0.0	1.7	1.7	1.7	1.7
Floodplain	Significant Reduction Risk	0.0	0.0	0.0	0.0	13.8	12.5	9.2	11.9	1.6	1.6	0.0	1.1
	Slight Reduction Risk	17.2	13.8	10.9	14.0	23.1	18.8	29.2	23.7	33.2	46.8	38.0	39.4
	No Significant Change	70.2	69.2	57.8	65.7	52.3	50.0	53.8	52.1	61.7	45.3	58.6	55.1
	Slight Increase Risk	9.4	12.3	28.1	16.6	9.2	17.2	7.7	11.3	3.2	4.7	3.2	3.7
	Significant Increase Risk	3.1	4.6	3.1	3.6	1.5	1.6	0.0	1.0	0.0	1.6	0.0	0.5

Table 4.10: Changes in risk for sorghum, cotton and groundnut, resulting from the climate change for three different scenarios (ECHAM, GFDL and IPSL). Changes are expressed as a % of the area.

Table 4.11 summarizes the results for changes in risk for sorghum, cotton and groundnut for Mozambique:

Zoning	Changes in Risk	Cassava (% area)				Maize (% area)				Soya (% area)			
		(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.
North	Significant Reduction Risk	1.40	4.30	1.50	2.40	4.40	0.60	4.60	3.20	4.50	0.90	8.80	4.73
	Slight Reduction Risk	13.20	12.40	5.80	10.47	23.00	17.90	27.80	22.90	11.70	9.60	7.00	9.43
	No Significant Change	68.20	65.00	73.10	68.77	72.00	75.00	65.50	70.83	67.90	66.50	60.60	65.00
	Slight Increase Risk	16.40	17.70	17.20	17.10	0.60	6.40	1.80	2.93	10.00	15.10	15.70	13.60
	Significant Increase Risk	0.80	0.40	2.10	1.10	0.00	0.00	0.00	0.00	6.30	7.80	7.90	7.33

Zoning	Changes in Risk	Sorghum (% area)				Cotton (% area)				Groundnut (% area)			
		(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.	(mean) ECHAM	(dry) GFDL	(wet) IPSL	aver.
Central	Significant Reduction Risk	0.50	0.50	0.10	0.37	8.30	7.60	6.20	7.37	2.10	2.70	2.40	2.40
	Slight Reduction Risk	21.60	12.80	18.20	17.53	21.20	15.00	26.90	21.03	28.40	43.40	24.90	32.23
	No Significant Change	65.10	69.50	53.70	62.77	61.40	65.10	57.70	61.40	64.90	43.30	68.00	58.73
	Slight Increase Risk	10.60	10.30	19.30	13.40	9.00	12.10	9.20	10.10	3.70	8.90	4.00	5.53
	Significant Increase Risk	2.00	6.90	8.60	5.83	0.10	0.20	0.00	0.10	0.50	1.60	0.50	0.87

Table 4.11: Changes in risk for sorghum, cotton and groundnut, resulting from the climate change for three different scenarios (ECHAM, GFDL and IPSL). Changes are expressed as a % of the area.

For cassava, most of the land (68.8%) remains unchanged and 17.1% has a slightly increased risk, and 10.5% has a slightly reduced risk. For maize most of the land (70.8%) remains unchanged and 22.9% has a slightly reduced risk. For soya, most of the land (65.0%) also remains unchanged, 13.6% has a slightly increased risk, and 9.4 % has a slightly reduced risk. For sorghum most of the land (62.8%) also remains unchanged, 17.5% has a slightly reduced risk, and 13.4% has a slight increased risk. For cotton most of the land (61.4%) remains unchanged, and 21.0% has a slightly reduced risk. For groundnut, most of the land (58.7%) remains unchanged, and 32.20% has a slightly reduced risk.

Note: These conclusions are based on the average behavior of all three different models. There is no reason to believe that one model is better than the other, it only reflects the limitations in our present understanding of climate change. The factors involved are too many to have a clear picture of what is happening. The results are affected by the type of crop, soil type, temperature, and rainfall.

Inland North:
The results show that the land suitability of the inland Northern zone for Cassava 53 is likely to remain unchanged at 59%, with almost the same % of the area under the effect of different climate models. The results show 38 to 43% with a slight decrease in suitability of area for cassava production.

Regarding the land suitability for maize, 71 to 73% of the region is likely to remain unchanged, and between 27 and 28% is likely to experience a slight improvement on the overall suitability of the present land area.

For Soya 75 to 85% of the region is likely to remain unchanged, and between 13 and 24% is likely to experience a slight decrease on the overall suitability of the present land area.

The situation for sorghum, the other cereal, is that 47 to 82% of the region is likely to remain unchanged, showing a larger variance between different models, as a result of a larger sensitivity of the crop to climate change. Between 7 and 35% is likely to experience a slight decrease on the overall suitability of the present land area, with the largest in the wet IPSL model, denoting that sorghum is very sensitive to climate change under extreme wetness, particularly in high altitude areas.

In relation to cotton, 54 to 55% of the region is likely to remain unchanged, and between 24 and 26% is likely to experience a slight improvement on the overall suitability of the present land area.

For groundnut, 48 to 62% of the region is likely to remain unchanged, and between 24 and 26% is likely to experience a slight improvement on the overall suitability of the present land area.

Inland Central:
The results show that for the land suitability of the inland Central zone for Cassava 70 is likely to remain unchanged at 80%. It also shows that 10 to 22% with a slightly increase in land suitability area for cassava production.

Regarding Maize suitability, 69 to 72% of the region is likely to remain unchanged, and between 19 and 25% is likely to experience a slight improvement on the overall suitability of the present land area.

For Soya 63 to 70% of the region is likely to remain unchanged, and between 12 and 16% is likely to experience a significant decrease on the overall suitability, and between 10 and 14%, a slightly decrease on the overall suitability of the present land area.

The situation for sorghum is that 65 to 74 % of the region is likely to remain unchanged, and between 7 and 18% is likely to experience a slight decrease on the overall suitability of the present land area.

In relation to cotton, 59 to 63% of the region is likely to remain unchanged, between 16 and 22% is likely to experience a slight decrease on the overall suitability, and between 13 and 18% is likely to experience a slight improvement on the overall suitability of the present land area.

For groundnut, 51 to 76% of the region is likely to remain unchanged, and between 18 and 40% is likely to experience a slight improvement on the overall suitability of the present land area.

Inland South:
The results show that the land suitability of the inland South zone for Cassava 83 is likely to remain unchanged at 93%, and about 2 to 14% with a slightly increase in suitability for cassava production.

Regarding the land suitability for maize, 36 to 95% of the region is likely to remain unchanged, and between 1 and 47% is likely to experience a slight improvement on the overall suitability of the present land area. From the results, it becomes clear that in the inland south, the different models behave very different because it is a semi-arid region where temperature and rain are crucial to rainfed agriculture.

For soya, 22 to 60% of the region is likely to remain unchanged, and between 29 and 51% is likely to experience a slightly increase on the overall suitability of the present land area, showing a similar sensitivity towards climate change under semi-arid conditions.

The situation for sorghum is that 36 to 64% of the region is likely to remain unchanged, and between 6 and 62% is likely to experience a slight increase on the overall suitability of the present land area, denoting once more the sensitivity under semi-arid conditions.

In relation to cotton, 46 to 97% of the region is likely to remain unchanged, and between 1 and 51% is likely to experience a slight increase on the overall suitability, with a similar pattern as the previous crops.

For groundnut, 25 to 70% of the region is likely to remain unchanged, and between 21 and 33% is likely to experience a slight improvement on the overall suitability of the present land area.

Coastal Zone:
The results show that the land suitability of the Coastal zone for Cassava 48 is likely to remain unchanged at 66%. It also shows that a10 to 30% slight increase in suitability area for cassava production.

Regarding land suitability for maize, 73 to 80% of the region is likely to remain unchanged, and between 9 and 21% is likely to experience a slight improvement on the overall suitability of the present land area.

For soya 56 to 72% of the region is likely to remain unchanged, and between 11 and 27% is likely to experiences a slight decrease on the overall suitability, and between 9 and 10%, a significant decrease on the overall suitability of the present land area.

The situation for sorghum is that 55 to 62% of the region is likely to remain unchanged, and between 31 and 36% is likely to experiences a slight increase on the overall suitability of the present land area.

In relation to cotton, 69 to 76% of the region is likely to remain unchanged, between 9 and 19% is likely to experience a slight increase on the overall suitability, and between 3 and 12% is likely to experience a slight decrease on the overall suitability of the present land area.

For groundnut, 25 to 73% of the region is likely to remain unchanged, and between 20 and 69% is likely to experiences a slight improvement on the overall suitability of the present land area.

Floodplain:
The results show that land suitability for the Floodplain zone for cassava 69 is likely to remain unchanged at 775. It also shows that about 6 to 17% with a slightly increase in suitability area for cassava production, and 6 to 8% with a slight decrease.

Regarding land suitability for maize suitability, 62 to 66% of the region is likely to remain unchanged, and between 16 and 25% is likely to experience a slight improvement on the overall suitability of the present land area.

For soya 61 to 67% of the region is likely to remain unchanged, between 11 and 20% is likely to experience a significant decrease on the overall suitability, and between 9 and 13%, a slightly decrease on the overall suitability of the present land area.

The situation for sorghum is that 58 to 70% of the region is likely to remain unchanged, between 9 and 28% is likely to experience a slight decrease on the overall suitability of the present land area, and between 11 and 12% is likely to experience a slight increase.

In relation to cotton, 50 to 54% of the region is likely to remain unchanged, between 19 and 29 % likely to experience a slight increase on the overall suitability of the present land area.

For groundnut, 45 to 62% of the region is likely to remain unchanged, and between 33 and 47% is likely to experience a slight improvement on the overall suitability of the present land area.

Table 39 and 40 summarize the findings for the different regions in terms of average results, as well as maximum and minimum values observed, giving some incite in terms of crop behavior and response to climate change in the different regions of Mozambique.

Zoning	Changes in Risk	Cassava (% 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	10.26	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	10.98

Table 4.12: Average, maximum and minimum changes observed for cassava, maize and soya, resulting from the climate change. Changes are expressed as a % of the area.

Table 4.12 shows that for cassava, the "*no significant change*" is the dominant category in all five zones, ranging from an average value of 90% in the south to 56% in the coastal region. In most of the regions, with the exception of inland North, the second most highly observed class is towards a slight increase in suitability. In the inland North, there is a slight decrease in suitability.

Maize follows a similar pattern with "*no significant change*" as the dominant class in all five zones. It ranges from an average value of 76% in the Coastal zone to 64% in Central region. The second most observed class is towards a slight increase in suitability in all regions.

For soya, the dominant class is "*no significant change*" in all regions with the exception of the inland South, where the dominant is the "*slight reduction in risk*". The second most dominant is either "*no significant change*" as shown in the inland South, or a "*slight increase in risk*" as in the inland North and Coastal regions, or a significant decrease in risk as seen in the Central region and in the Floodplains.

Zoning	Changes in Risk	Sorghum (% area) Average	Sorghum Maximum	Sorghum Minimum	Cotton (% area) Average	Cotton Maximum	Cotton Minimum	Groundnut (% Area) Average	Groundnut Maximum	Groundnut Minimum
North	Significant Reduction Risk	1.04	1.56	0.00	13.06	13.66	11.84	4.26	4.36	4.05
	Slight Reduction Risk	6.02	7.48	4.36	25.28	26.48	24.53	38.83	44.20	30.25
	No Significant Change	66.50	82.39	46.68	54.72	54.97	54.35	53.88	62.38	48.24
	Slight Increase Risk	16.81	34.86	7.48	6.94	7.45	6.52	2.49	2.81	2.18
	Significant Increase Risk	9.54	14.00	1.55	0.00	0.00	0.00	0.31	0.31	0.31
Zoning	**Changes in Risk**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
Central	Significant Reduction Risk	0.00	0.00	0.00	4.94	6.21	2.97	2.66	3.25	1.78
	Slight Reduction Risk	11.93	14.20	8.30	15.40	18.10	13.31	25.95	40.02	17.79
	No Significant Change	68.84	73.96	65.25	61.50	63.02	58.58	66.61	76.18	50.99
	Slight Increase Risk	13.12	17.72	6.80	18.07	21.60	16.02	4.05	5.04	3.54
	Significant Increase Risk	6.02	9.49	3.54	0.10	0.30	0.00	0.49	0.89	0.30
Zoning	**Changes in Risk**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
South	Significant Reduction Risk	0.21	0.62	0.00	2.30	3.77	0.00	0.00	0.00	0.00
	Slight Reduction Risk	42.49	61.75	5.59	27.56	51.25	1.25	25.57	33.09	21.17
	No Significant Change	45.18	63.98	35.55	69.73	97.50	45.63	54.87	70.48	24.35
	Slight Increase Risk	10.16	26.09	1.87	0.42	1.25	0.00	17.04	36.84	6.24
	Significant Increase Risk	1.87	4.35	0.62	0.00	0.00	0.00	2.29	5.62	0.62
Zoning	**Changes in Risk**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
Coastal	Significant Reduction Risk	0.00	0.00	0.00	3.15	4.31	2.56	0.57	1.71	0.00
	Slight Reduction Risk	33.20	35.58	31.00	15.19	18.80	9.48	37.52	69.16	20.47
	No Significant Change	57.46	61.74	54.67	73.35	75.86	69.23	56.56	73.21	24.76
	Slight Increase Risk	7.51	9.55	5.22	8.31	12.07	3.45	3.41	5.97	1.70
	Significant Increase Risk	1.73	5.17	0.00	0.00	0.00	0.00	1.71	1.71	1.70
Zoning	**Changes in Risk**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
Floodplain	Significant Reduction Risk	0.00	0.00	0.00	11.86	13.85	9.23	1.05	1.58	0.00
	Slight Reduction Risk	13.98	17.15	10.93	23.71	29.23	18.75	39.38	46.83	33.20
	No Significant Change	65.74	70.17	57.75	52.06	53.85	50.00	55.13	61.66	45.27
	Slight Increase Risk	16.56	28.10	9.36	11.34	17.19	7.69	3.68	4.68	3.16
	Significant Increase Risk	3.62	4.62	3.12	1.03	1.56	0.00	0.53	1.56	0.00

Table 4.13: Average, maximum and minimum changes observed for sorghum, cotton and groundnut, resulting from the climate change. Changes are expressed as a % of the area.

Table 4.13 shows that for sorghum, "*no significant change*" is the dominant category in all five zones, ranging from an average value of 69% in the South to 45% in the Coastal region. In most of the regions, with the exception of inland South and the Coastal regions, the second most observed class is towards a slight decrease in suitability. In the inland South and the Coastal regions, there is a slight increase in suitability.

Cotton shows also a similar behavior with "*no significant change*" as the dominant class in all five zones, ranging from an average value of 67% in the inland Central zone to a 54% in the inland North regions. The second most observed class is towards a slight increase in suitability in all regions with the exception of the Central region that shows a slight decrease in suitability.

For groundnut, the dominant class is also "*no significant change*" in all regions, ranging from an average value of 73% in the Coastal zone to 52% in the Floodplain. The second most dominant is the "*slight reduction in risk*" in all regions, showing a similar behavior to maize.

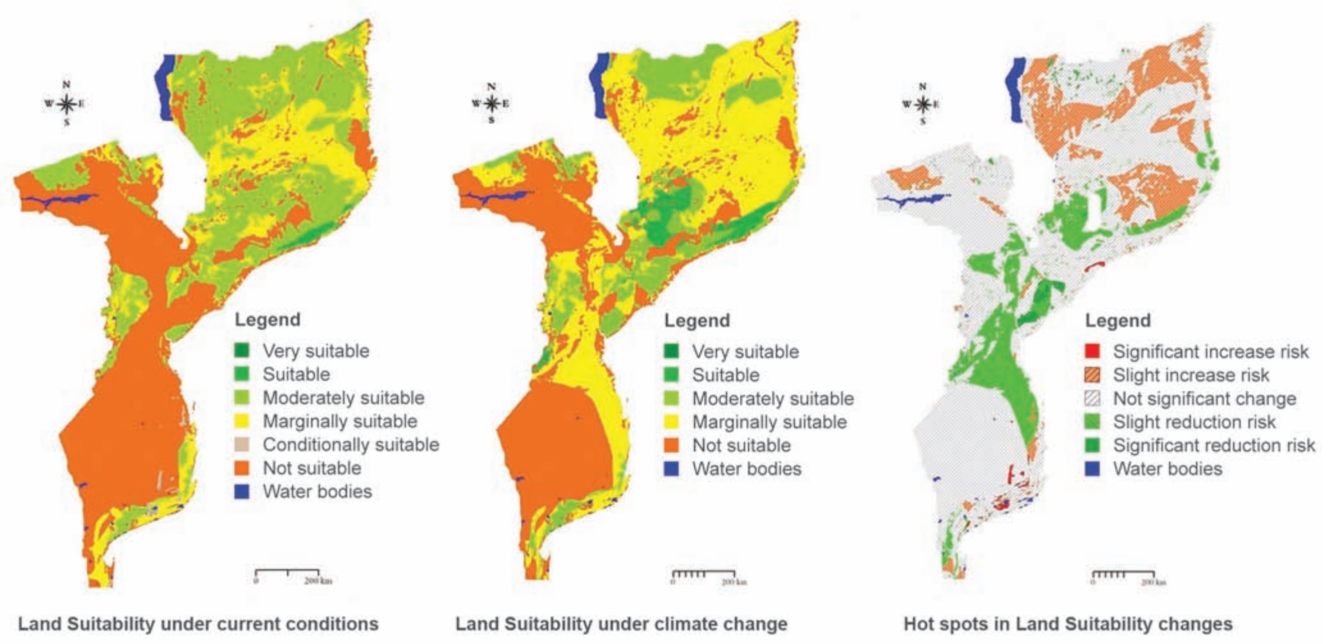

Figure 4.3: Maps of suitability and hotspots for cassava.

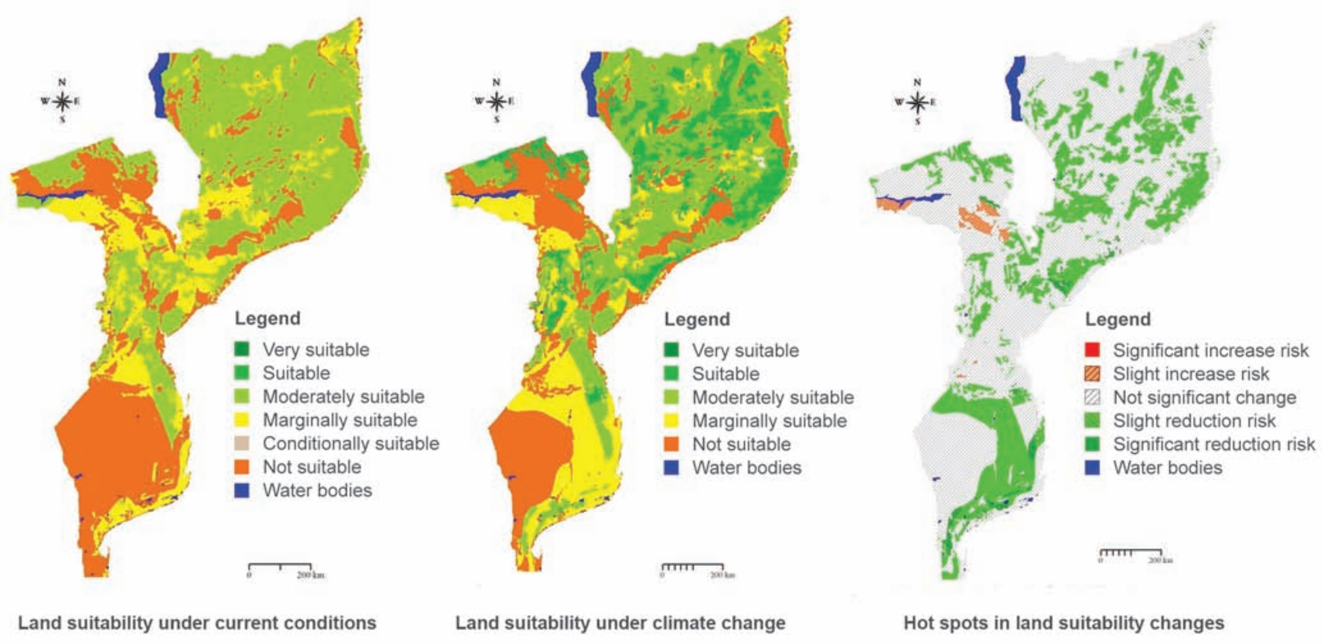

Figure 4.4: Maps of suitability and hotspots for maize.

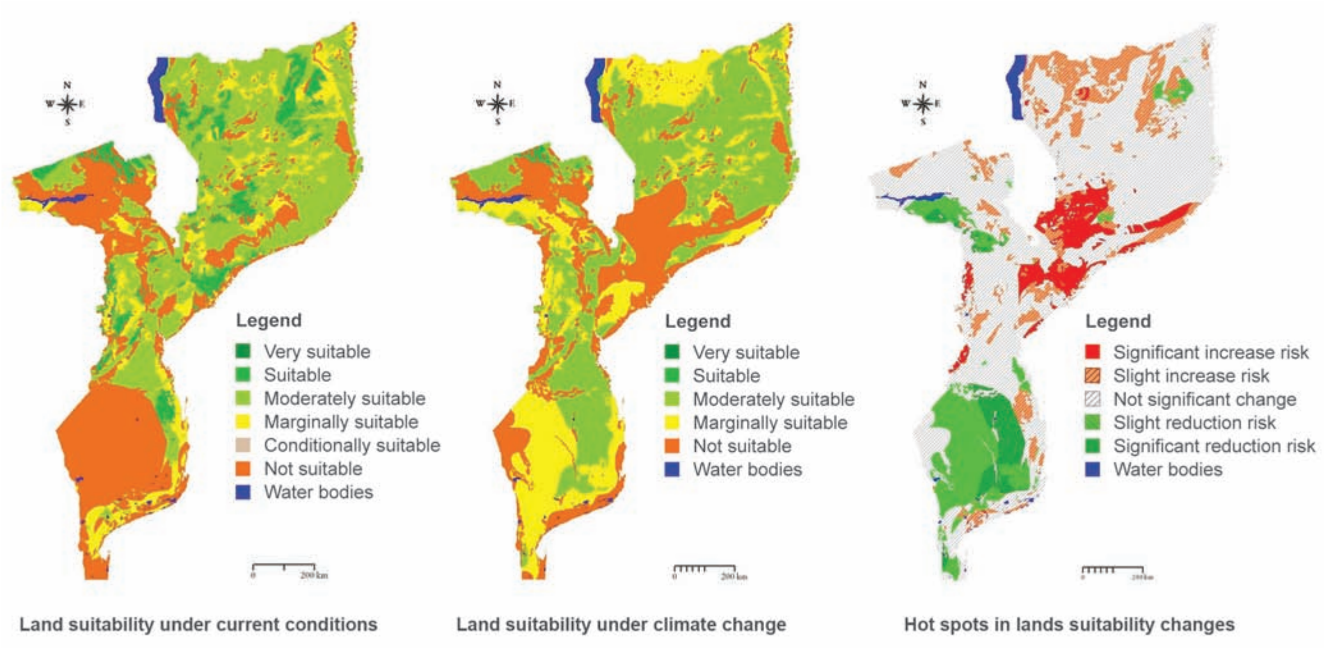

Figure 4.5: Maps of suitability and hotspots for soya.

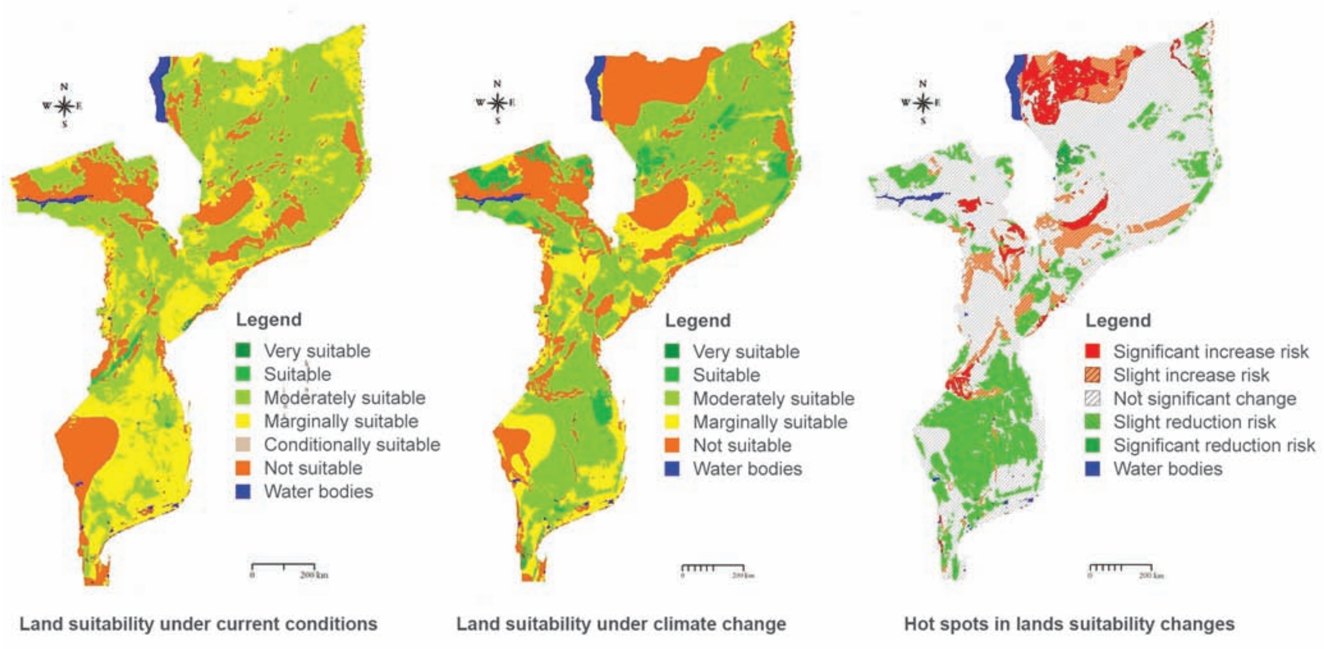

Figure 4.6: Maps of suitability and hotspots for sorghum.

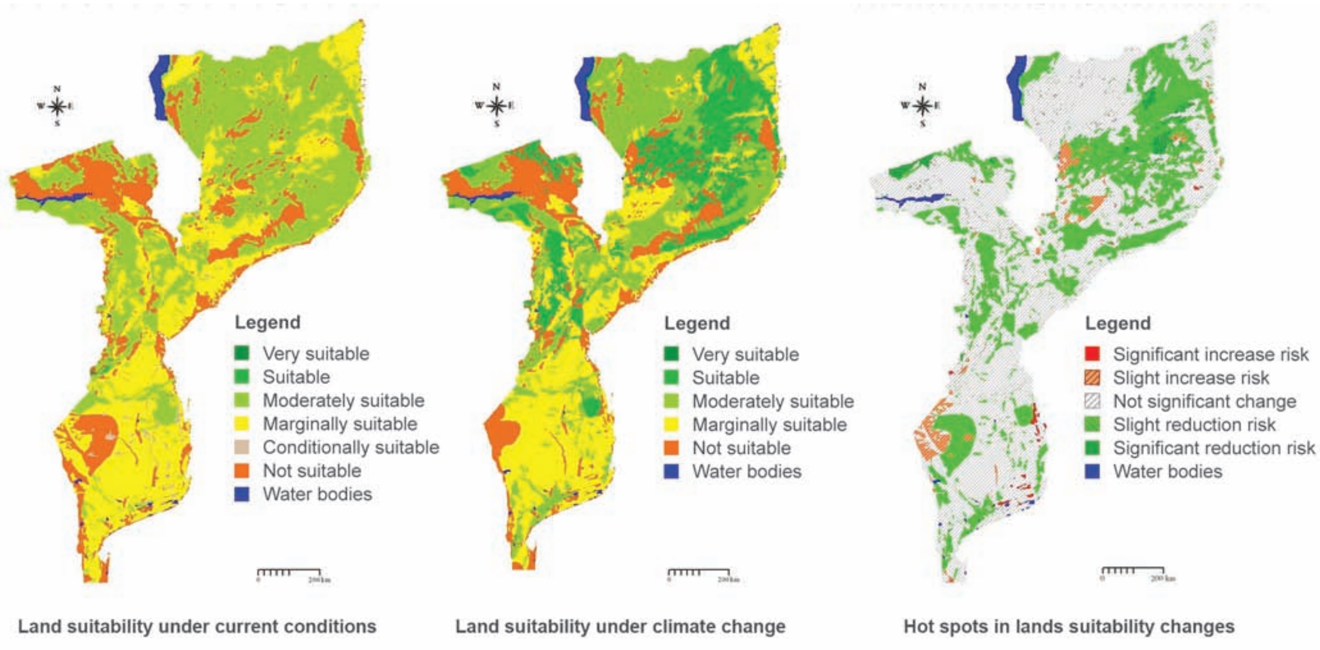

Figure 4.7: Maps of suitability and hotspots for groundnut.

4.2b Adaptation Measures and Recommendations

Water management is a critical issue for life-supported services, assured by rivers, wetlands and freshwater systems. It is not simply a commodity like oil or coal. Each one of the water ecosystems performs valuable services to human societies, such as moderating floods and droughts. Jeopardizing food production, water shortages (droughts) and excesses (floods/inundations) increase the threat of social instability, as food and income security of rural dwellers deteriorates. In Mozambique, declining agricultural output, resulting from land degradation and water scarcity related to climatic uncertainty, have already forced large-scale migration from rural areas to urban centers.

A major challenge of any future policy and strategies regarding the impact of natural hazards on the rural population is, taking into consideration regional challenges, to offer social stability and security for rural dwellers and to achieve greater ecosystem service benefits. These include:

- The protection of watersheds, floodplains, wetlands and other natural capital assets, such as riverine and mountain forests.
- The establishment of environmental flow requirements for rivers, as most countries are doing, i.e. South Africa.
- Introducing ecosystem service protection as a core mandate of river basin administrations/authorities.
- Adopting or amending water laws which encompass management issues by requiring the management of dams and reservoirs, and other critical water conservation structures in ways that protect natural river flows and flood regimes.
- Introducing more intensive agricultural production systems to decrease prevailing slash and burn and shifting cultivation systems.

The first four items are addressed by other disciplines currently studied, i.e. hydrology, environment, and policy and institutional capacity. Consequently the section below focuses predominantly on agricultural production.

In Mozambique over 95% of food is produced under rainfed conditions, where climatic variability already limits agricultural production. Changes in precipitation, river flow patterns and groundwater availability are highly uncertain, and yet of paramount importance for food security. Climate change induced modifications in river flows and groundwater will affect water availability for irrigation. The expected effects of climate change on rainfed agriculture vary by area, also affecting the suitability of land for the growth of crops.

The North is projected to experience the largest gain in suitable areas for cultivation of most of the crops which are adapted to wetter conditions, although crops like sorghum and soybean show some limitations and marginality in the presence of moisture excess. Crops such as cassava, maize, and groundnut, which are rated high as the most cultivated crops in those areas where the amount of rainfall is projected to increase or remain unchanged (cassava first and maize second), represent a great opportunity to realize the high potential available through the introduction of adequate high yielding crop varieties adapted to such moisture conditions. Inundation may increase locally which also represents a good environment for other crops adapted to water logging conditions, for example paddy rice. Such conditions may also support the introduction of other crops normally requiring intermediate and long growing seasons – to cope with excess moisture, such as rubber and coffee in the mid-high altitude areas.

The North is not likely to experience any major reduction in river flows so the irrigation potential remains high for irrigated crop production.

The inland Central zone experiences some reduction in area in terms of its land use suitability potential, with crops like cassava, maize and groundnut showing slight vulnerability to the effects of climate change. Consequently, this area needs to demonstrate improvement in soil and water management practices, in addition to major adaptation measures. For example, shifting planting dates that do not imply major changes in crop calendars, the additional application of irrigation water to crops already under irrigation, changes in crop variety to accommodate varieties better suited to the projected climate.

Results show that those areas, in the South, that are currently most food-insecure will be those most affected by climate change. These areas have arguably the greatest need for new crop varieties that are tolerant to extreme climate conditions, especially drought. Such areas are already experiencing river water flow shortages, which also limit application of irrigation water. Where absolute water quantities decrease famers may have to give up part of their farms or reduce the number of crops in the season.

4.2c Conclusions

The length of the growing period (LGP) is a useful proxy to identify geographic areas where climate change and the subsequent impacts on crop agriculture may be relatively large. The LGP is crop-independent, and it is an effective integrator of changes in rainfall amounts and patterns and temperatures.

Many areas may see some expansion in growing seasons, for example the North, while other areas, particularly in the dry semi-arid Southern and Central zones, may see contractions. These patterns arise as a result of the integration of increasing temperatures throughout the region and shifting rainfall patterns and amounts.

The results show that many already-vulnerable regions in Mozambique are likely to be adversely affected by climate change. These include the mixed arid-semiarid systems in the Gaza and semiarid systems in parts of Northern Inhambane and south of Tete, the coastal and central regions of Southern zones, and many of the drier areas of major river systems like the Limpopo, Save and Zambeze rivers.

Areas suitable for cultivation of a wide range of the Mozambique's most important food and cash crops will shift as a result of climate change. Overall, suitable areas will increase in the centre of the North, but most affected by loss of area will generally be the zones that are already struggling from the impacts of irregular and extreme climate events, such as the South and middle Central.

Further analysis is needed to identify priority species and areas to target for climate adaptation strategies, particularly for improved climate change-tolerant varieties. Adapting crops to climate conditions will allow cultivation to continue in current areas as well as taking advantage of new suitable areas.

Differing trajectories of population growth and economic development will affect the level of future climate change and, simultaneously, the responses of agriculture to changing climate conditions at regional and global scales.

Under conditions of drought, it has long been considered that increased root depth would contribute to better drought tolerance. Increasing episodes of drought, lack of sufficient nutrients, exposure to toxic minerals, and soil compaction are just a few examples of the environmental constraints that the roots are exposed to during plant growth.

Understanding how roots respond to these stresses is crucial for improving crop production under such conditions. It is assumed that while the root depth and abundance would contribute to drought tolerance, profuse rooting would enhance nutrient capture.

Less common crops, for example, chickpea, pigeon pea, cowpea, groundnut, sorghum and pearl millet, are alternatives to increase diversity to cope with climate change and adverse conditions for crop growth and food security.

5

Preliminary wild fire analysis

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5.1 *Introduction*

5.2 *The fire situation in Mozambique*

5.3 *Models and their variables*

5.4 *Validation of forest fire risk zoning (zrif)*

5.5 *Carbon dioxide*

5.6 *Conclusions and recommendations*

5.1 Introduction

Forest fires represent a great concern, because fire plays an important role in the maintenance of a variety of natural and artificial ecosystems. Its occurrence in an uncontrolled way can represent a source of permanent disturbance, bringing biodiversity losses and material damage (NUNES, 2005).

Forest fires stand out for the changes they impose on the landscape structure and, more deeply, on the balance of different ecosystems. From an ecological point of view – the different species and communities of animals and plants, as well as the soil, although the latter in small proportions – all suffer interference in case of a fire.

In Mozambique, the term “uncontrolled burning” has the same meaning as fire, because the latter behaves in the same way, i.e. has tragic effects on the ecosystem.

According to the DNFFB (2002), in Mozambique, 6 to 10 million hectares of forest, corresponding to 11 to 18% of forests and 9 to 15 million hectares of other lands are burned yearly.

In this context, the present work aims to examine the uncontrolled burnings within the context of the impact of climate changes to the risk of and adaptation to natural disasters in Mozambique.

The objectives are defined as follows:

- To establish a broad perspective of the main recent projects of uncontrolled burnings in Mozambique and in the region, including a brief policy analysis.
- To establish a trend analysis of the frequency, location, intensity and impact of uncontrolled burnings in Mozambique over the time span in which precise data exists. Define the present location.
- Identify the focus (high risk and high impact) per region. Overlap the populated areas, land usage/coverage and climate.

5.2 The fire situation in Mozambique

Uncontrolled burning represents the largest potential threat to forest damage in the world. Mozambique is not an exception to that scenario. Vast forest areas are devastated yearly, causing severe damage to society, in addition to reducing the area under forest.

Devastation of forests due to uncontrolled burning in almost all national territory is connected to several factors, including population clusters and wood fuel needs, socio-cultural practices, nomad agriculture, hunting, combined with the lack of resources and the need to meet basic needs.

The frequency of fire occurrences in the country, from a general perspective, tends to increase in a gradual fashion (Figure 5.1), this phenomenon is more acute from a localised point of view. For example, in the Manica and Sofala provinces, there is almost an equal average number of occurrences of fires in absolute terms. However, spatial repetition (burnings in the same areas) are categorised in some areas. Beyond the social and environmental effects, this increases the irreversibility of the natural ecosystem recovery and loss of biodiversity.

The Niassa province is one example of a region with higher than average values of burning occurrences, followed by Tete and Zambezia provinces. Efforts to prevent uncontrolled burnings should focus more attention on such locations, with the aim of reducing the present situation about the incidence of burning occurrences.

The distribution of fire occurrences in terms of the type of coverage varies from province to province (Annex VI), depending on climate conditions, moisture levels of combustible material and topography. From a general perspective, the fires in Mozambique are not distributed according to the vegetation coverage, since almost all this kind of forest is affected by this phenomenon.

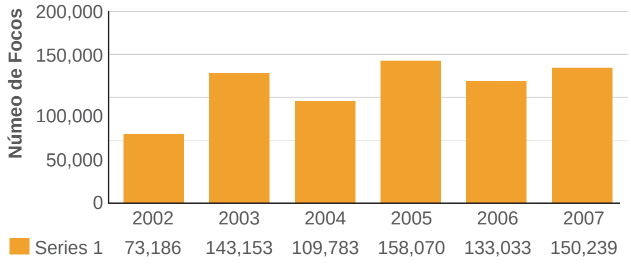

Figure 5.1: Number of fire occurences distribution per year in Mozambique.

5.3 Models and their variables

The use of models to prepare forest fire risk maps is justified by the multiple practical uses that those models can have, both in the prevention and in the forest fire combat fields. As such, in the prevention activities field, by using scenarios based on simulated data entries with historical or forecasting nature, these models can be used, for example to:

- Train fire fighters
- Regulate forestation and territorial ordinance, in order to reduce the harmful or difficult to fight forest fires occurrence risk
- Plan controlled burnings, during the off season and to reduce the amount of fine combustibles on the forest ground, in an economic and ecologically sustainable fashion

The preparation of these models followed a methodology using variables which influence the burnings behaviour. The variables used are: climate conditions; combustible material moisture; slopes orientation and altitude; demographic density; distribution of various vegetal coverage systems and, heat spots.

Climate

Figure 5.2 maps the Fire Danger Index for each region of Mozambique.

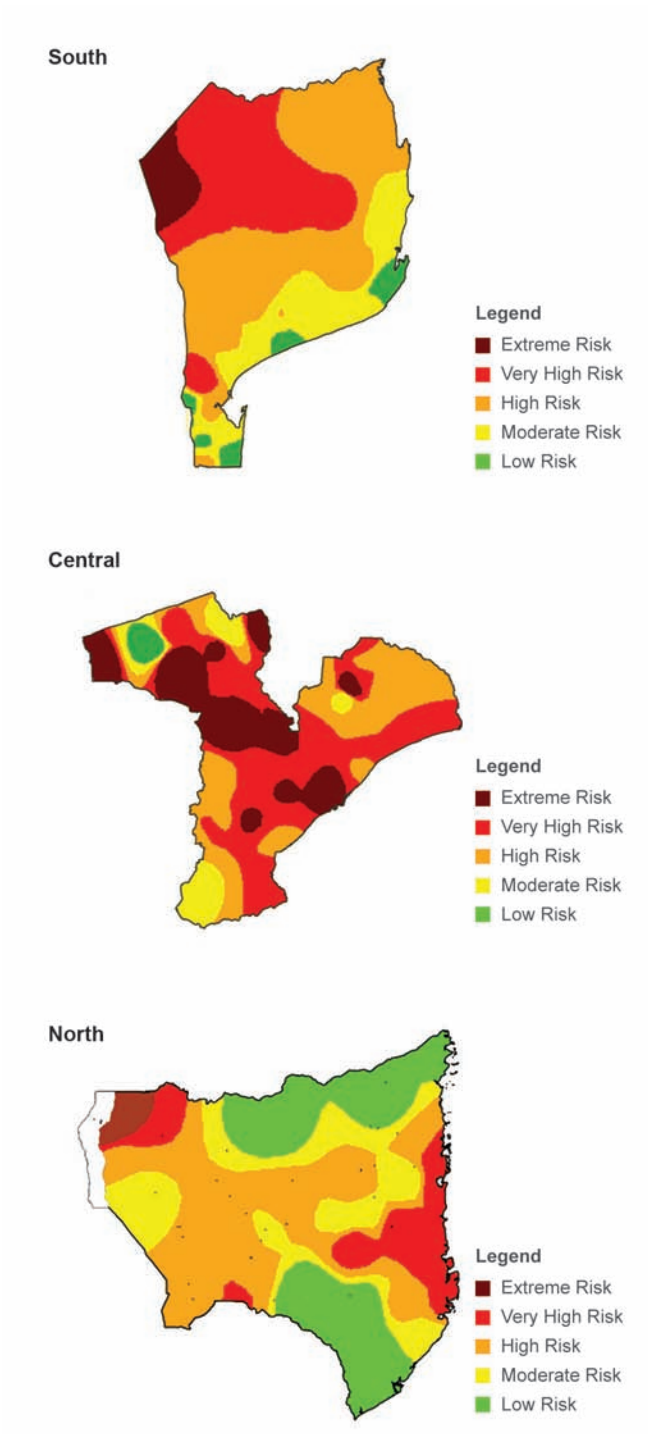

Figure 5.2: Risk Map According to Climate Conditions: Southern, Central and Northern Regions.

According to the weather conditions used in the SAMPAIO (1991) model, adapted for this research, 5.07% of the Southern Region area was classified as “extreme risk”, 29.7% as “very high risk”, 42.7% as “high risk”, 18.0% as moderate risk and 3.9% as low risk.

Risk	Area (km²)	%	Cumulative %
Low	6 566	3.91	3.91
Moderate	30 149	17.99	21.90
High	71 653	42.75	64.65
Very High	30 149	29.68	94.33
Extreme	9 494	5.67	100.00

Table 5.1: Total area per fire risk level, according to weather conditions (Southern region).

23.7% of the Central region’s area was classified as “extreme risk”, 37.4% as “very high risk”, 28.2% as “high risk”, 8.5% as moderate risk and 2.2% as low risk.

Risk	Area (km²)	%	Cumulative %
Low	7 305	2,18	2,18
Moderate	28 399	8,49	10,67
High	94 364	28,22	38,89
Very High	125 117	37,42	76,31
Extreme	79 211	23,69	100,00

Table 5.2: Total area per fire risk level, according to weather conditions (Central region).

For the Northern Region, 3.5% of the region’s area was classified as “extreme risk”, 12.7% as “very high risk”, 36.2% as “high risk”, 21.4% as moderate risk and 26.1% as low risk.

Risk	Area (km²)	%	Cumulative %
Low	75 063	26,12	26,12
Moderate	61 611	21,44	47,56
High	104 015	36,19	83,75
Very High	36 554	12,72	96,47
Extreme	10 159	3,53	100,00

Table 5.3: Total area per fire risk level, according to weather conditions (Northern region).

Humidity of Combustible Material

Figure 5.3 maps the variation in humidity of the combustible material for the three regions in Mozambique.

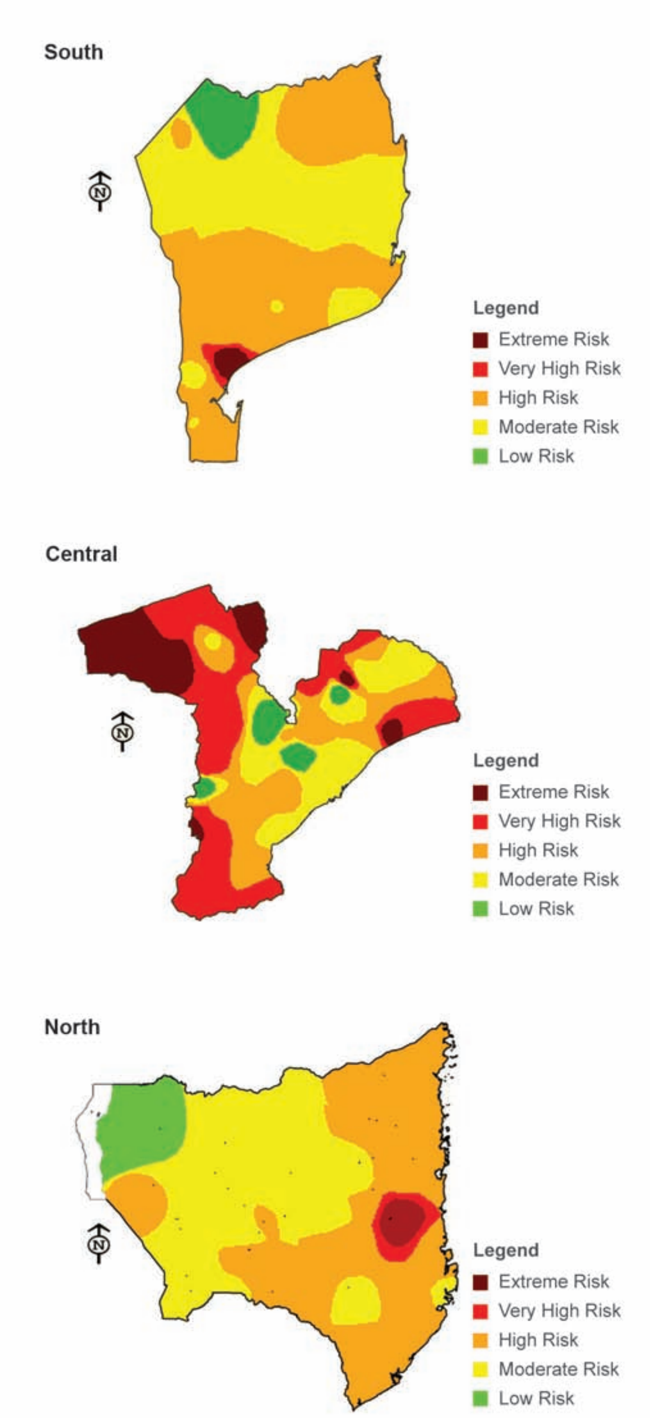

Figure 5.3: Risk Map According to the Combustible Material’s Humidity: Southern, Central and Northern Regions.

Tables 5.4, 5.5 and 5.6, show that approximately 50% of the Central Region's area was classified as "very high risk" (33.07%) and "extreme risk (15.65%). For the Southern and Northern regions, approximately 50% of the area was classified as "low" and "moderate" risk.

Risk	Area (km²)	%	Cumulative %
Low	10 016	5.98	5.98
Moderate	68 185	40.68	46.66
High	85 887	51.24	97.9
Very High	1 587	0.95	98.85
Extreme	1 938	1.15	100.00

Table 5.4: Fire risk level, per area, according to the combustible material humidity (Southern Region).

Risk	Area (km²)	%	Cumulative %
Low	16 358	4.89	4.89
Moderate	69 094	20.66	25.55
High	86 033	25.73	51.28
Very High	110 593	33.07	84.35
Extreme	52 305	15.65	100.00

Table 5.5: Fire risk level, per area, according to the combustible material humidity (Central Region).

Risk	Area (km²)	%	Cumulative %
Low	29 173	10,15	10,15
Moderate	116 023	40,37	50,37
High	131 041	45,60	90,97
Very High	5 639	7,96	98,93
Extreme	5 524	1,07	100,00

Table 5.6: Fire risk level, per area, according to the combustible material humidity (Northern Region).

Topographical Features

Slope

Figure 5.4 illustrates the variation in land slope in the three regions of Mozambique. This is a factor of great importance in fire propagation, as it contributes to the pre-heating of combustible materials.

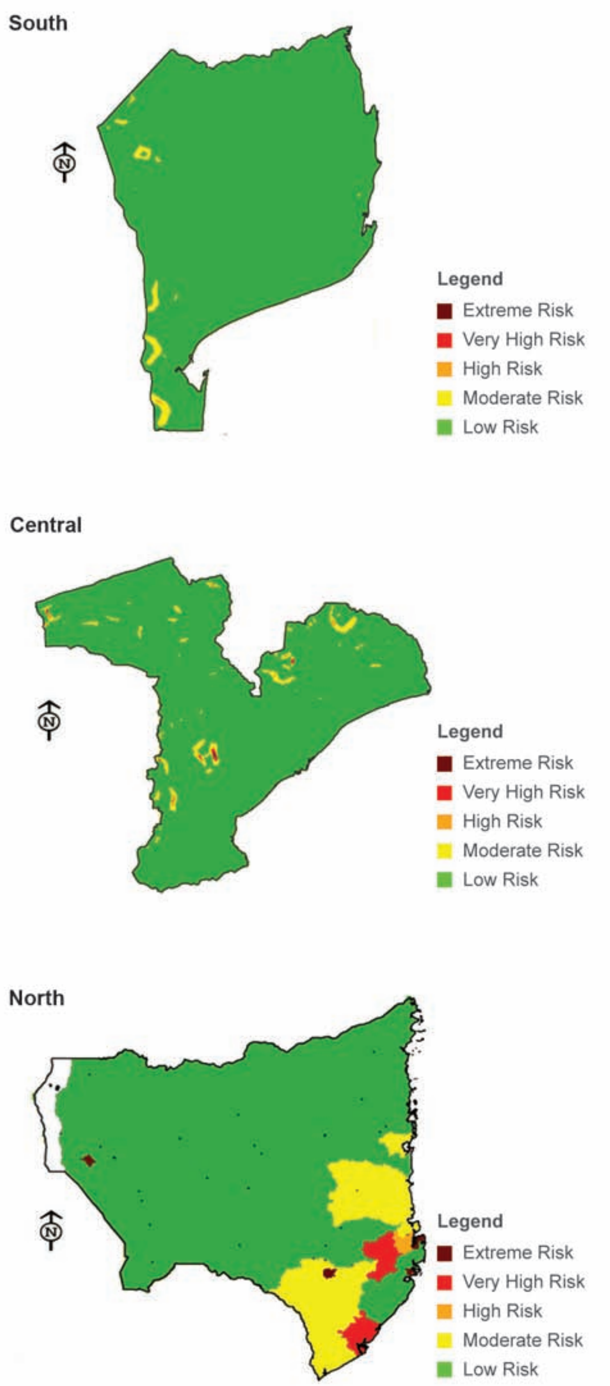

Figure 5.4: Risk Map According to the Land's Slope: Southern, Central and Northern Regions.

Tables 5.7, 5.8 and 5.9 show that approximately 98% of the area has a slope of 0% to 16% and only 2% of each region's area has slopes above 16%, therefore contributing to a low risk regarding this fire propagation factor.

Risk	Area (km^2)	%	Cumulative %
Low	165 287	98.58	98.58
Moderate	2 325	1.39	99.97
High	42	0.03	100.00
Very High	0	0.00	100.00
Extreme	0	0.00	100.00

Table 5.7: Fire risk level, per area, as a function of land slope (Southern Region).

Risk	Area (km^2)	%	Cumulative %
Low	325 453	97.31	97.31
Moderate	7 493	2.24	99.55
High	1 140	0.34	99.89
Very High	295	0.09	99.98
Extreme	67	0.02	100.00

Table 5.8: Fire risk level, per area, as a function of land slope (Central Region).

Risk	Area (km^2)	%	Cumulative %
Low	281 320	97.89	97.89
Moderate	5 056	1.76	99.65
High	776	0.27	99.92
Very High	151	0.05	99.97
Extreme	72	0.03	100.00

Table 5.9: Fire risk level, per area, as a function of land slope (Northern Region).

Slopes direction

Figure 5.5 shows the Slopes direction in the three regions of Mozambique.

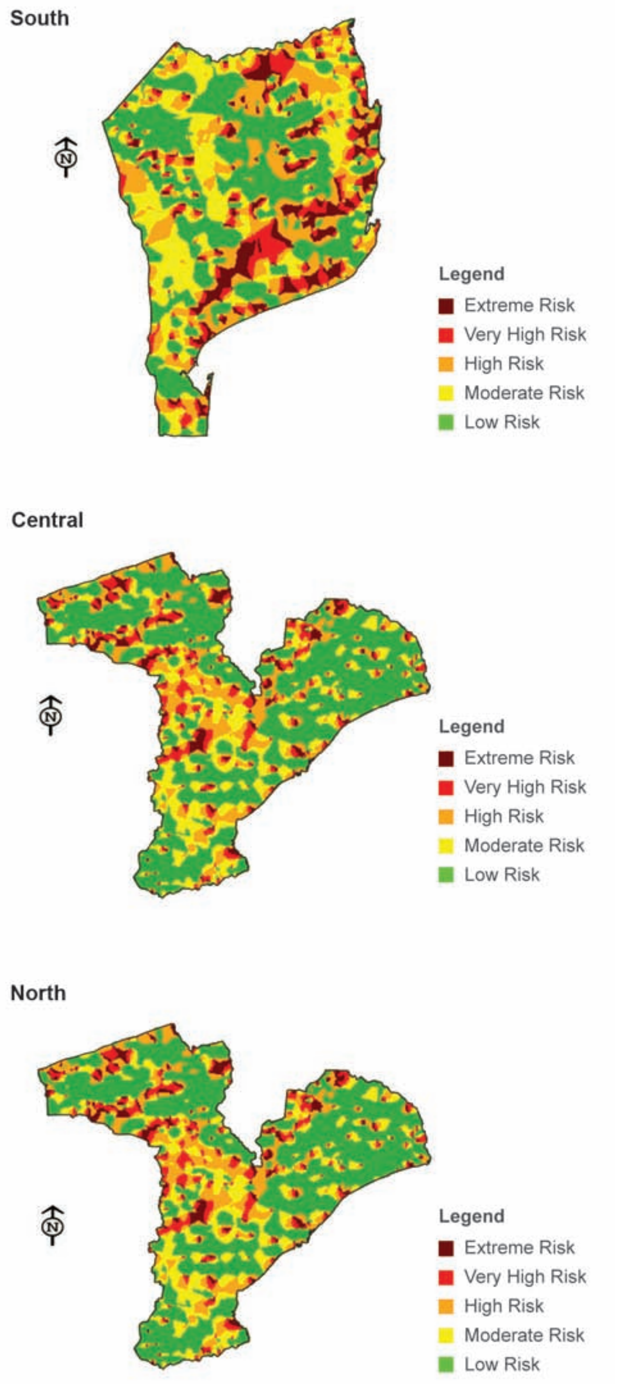

Figure 5.5: Risk Map According to the Slopes' Orientation: Southern, Central and Northern Regions.

According to the data presented in Tables 5.10, 5.11 and 5.12 it can be seen that:

- 35.9%, 51.0% and 34.8% of the slopes in the Southern, Central and Northern regions respectively, have a southeast, south, southwest orientation or are plain and were classified as low risk, which means that the solar radiation effects on combustible material drying are very small
- 21.7%, 17.6% and 19.0% of the slopes in the Southern, Central and Northern regions respectively, have an east orientation, which corresponds to moderate risk, since these are illuminated in the mornings and the solar radiation is consumed through the evapotranspiration process
- 24.8%, 19.3% and 25.6% of the slopes in the Southern, Central and Northern regions respectively, have a northeast and west orientation, which corresponds to a high risk
- 8.3%, 6.8% and 11.3% of the slopes in the Southern, Central and Northern regions respectively, have a north orientation, which corresponds to a very high risk, since they are illuminated during the afternoon period and that energy is used to dry the combustible material
- 9.4%, 5.3% and 10.3% of the slopes in the Southern, Central and Northern regions respectively, have a northwest orientation, which corresponds to an extreme risk, since they are illuminated during the hottest period of the day and the combustible materials dry faster.

In summary, about 20% of the area of each region is turned north and northwest and therefore are considered to be of a higher risk.

Risk	Area (km²)	%	Cumulative %
Low	60 106	35.87	35.87
Moderate	36 332	21.68	57.55
High	41 498	24.76	82.31
Very High	13 954	8.33	90.64
Extreme	15 678	9.36	100.00

Table 5.10: Fire risk level, per area, as a function of slopes' orientation (Southern Region).

Risk	Area (km²)	%	Cumulative %
Low	170 388	51.00	51.00
Moderate	58 712	17.57	68.57
High	64 475	19.29	87.86
Very High	22 838	6.83	94.69
Extreme	17 727	5.31	100.00

Table 5.11: Fire risk level, per area, as a function of slopes orientation (Central Region).

Risk	Area (km²)	%	Cumulative %
Low	99 652	34.79	34.79
Moderate	51 711	18.96	53.75
High	73 172	25.55	79.30
Very High	32 416	11.32	90.62
Extreme	29 456	10.28	100.00

Table 5.12: Fire risk level, per area, as a function of slopes orientation (Northern Region).

Altimetry

Figure 5.6 represents the altitude variation of the land in the three regions of Mozambique.

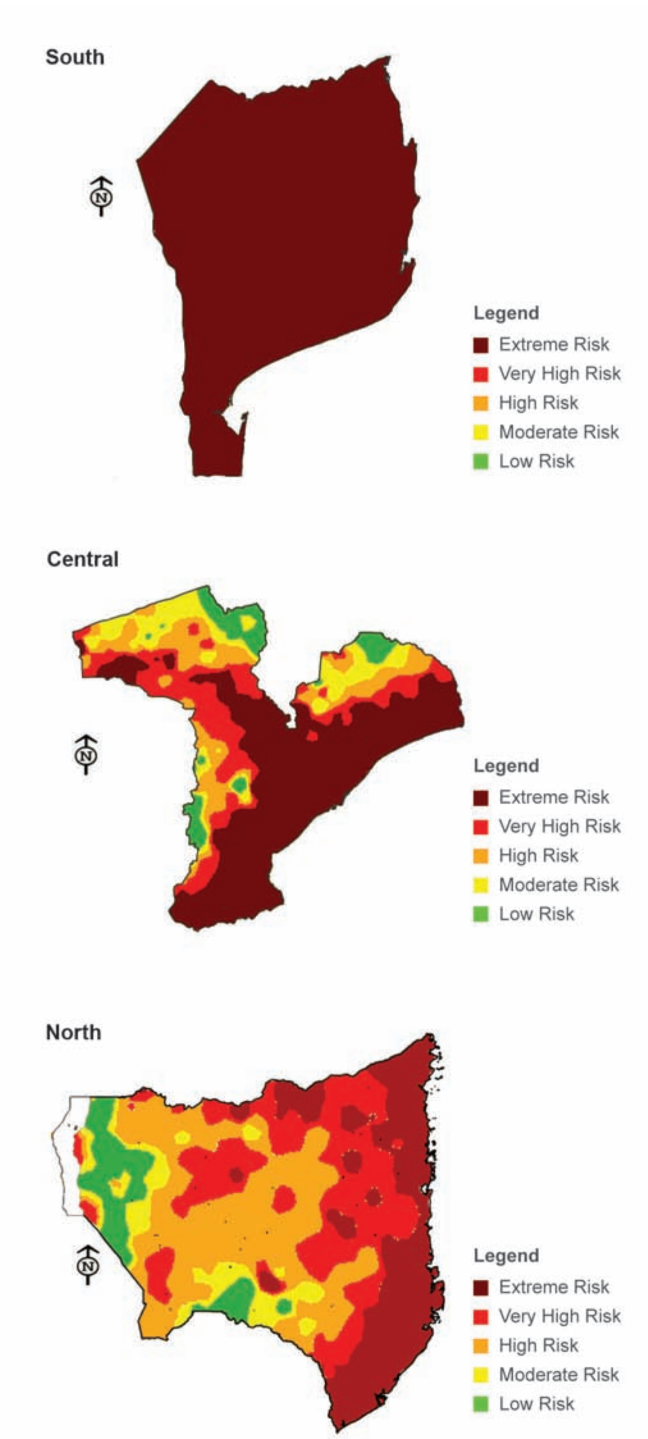

Figure 5.6: Risk Map According to the Altitude Variation: Southern, Central and Northern Regions.

According to the data presented in Tables 5.13, 5.14 and 5.15, it can be observed that approximately 100% of the Southern Region area was classified as "extreme risk" (100%) and for the Central and Northern areas, about 80% of the area was classified as being "high risk" and "extreme risk".

With an increase in altitude a decrease in temperature can be observed followed by an increase in relative humidity. Therefore the land elevation, in relation to the sea level, is relevant for the risk study since it has an effect on each locations' climate conditions, and over the humidity characteristics of the combustible material.

Risk	Area (km^2)	%	Cumulative %
Low	0	0.00	0.00
Moderate	0	0.00	0.00
High	0	0.00	0.00
Very High	0	0.00	0.00
Extreme	167 560	100.00	100.00

Table 5.13: Fire risk level, per area, as a function of land elevation (Southern Region).

Risk	Area (km^2)	%	Cumulative %
Low	23 165	6.93	6.93
Moderate	37 833	11.31	18.24
High	51 122	15.29	33.53
Very High	60 325	18.04	51.57
Extreme	161 959	48.43	100.00

Table 5.14: Fire risk level, per area, as a function of land elevation (Central Region).

Risk	Area (km^2)	%	Cumulative %
Low	23 049	8.02	8.02
Moderate	23 912	8.32	16.34
High	91 796	31.94	48.28
Very High	7 699	26.79	75.07
Extreme	7 165	24.93	100.00

Table 5.15: Fire risk level, per area, as a function of land elevation (Northern Region).

Vegetal Coverage

Figure 5.7represents the risk according to the land use in the three regions of the Mozambique (Annex VII).

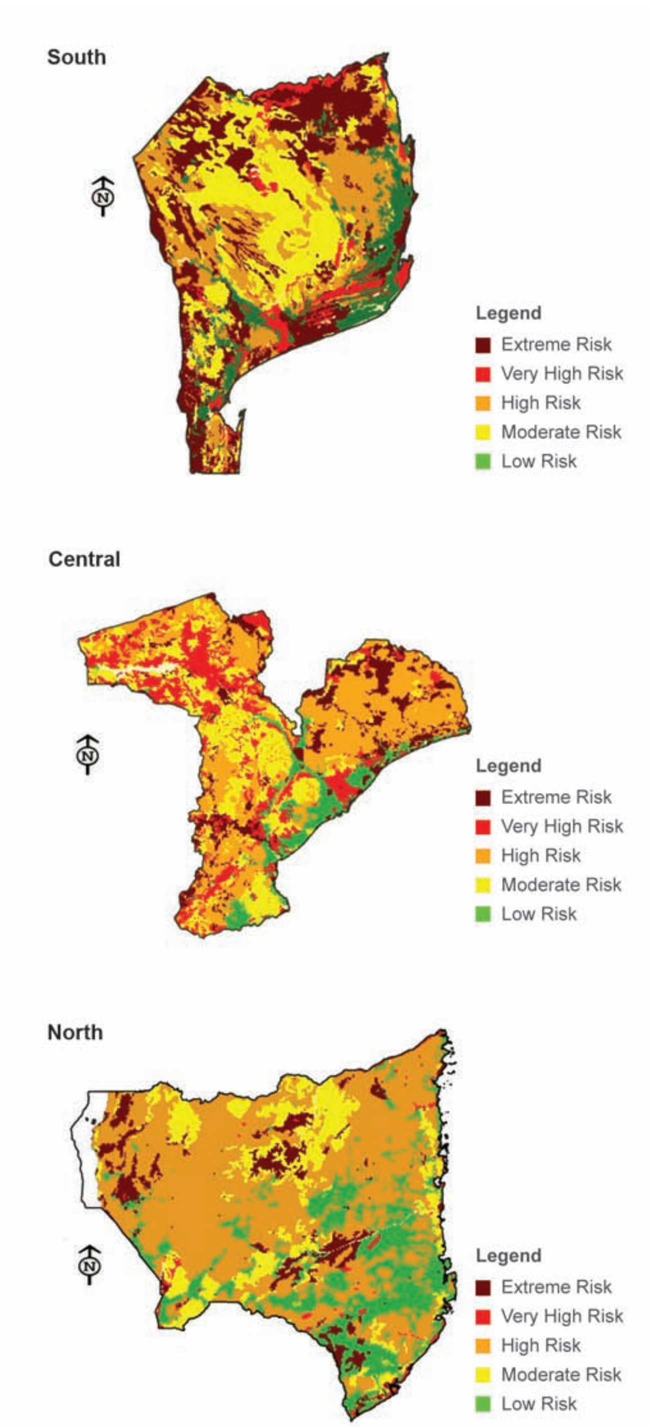

Figure 5.7: Risk Map According to Land Use: Southern, Central and Northern Regions.

According to the data presented in Tables 5.16, 5.17 and 5.18, approximately 35% of the Southern Region area was classified as very high risk" (6.40%) and "extreme risk" (29.46%); for the Central Region, about 30% of the area was classified as "very high risk" (11.55%) and "extreme risk" (19,06%); and finally for the Northern Region, approximately 27% of the area was classified as "very high risk" (19.92%) and "extreme risk" (7.61%).

Risk	Area (km^2)	%	Cumulative %
Low	18 879	11.40	11.40
Moderate	45 269	27.33	38.73
High	42 076	25.41	64.14
Very High	10 606	6.40	70.54
Extreme	48 787	29.46	100.00

Table 5.16: Fire risk level, per area, as a function of vegetal coverage (Southern Region).

Risk	Area (km^2)	%	Cumulative %
Low	28 112	8.51	8.51
Moderate	70 527	21.34	29.85
High	130 681	39.54	69.39
Very High	62 995	19.06	88.45
Extreme	38 207	11.55	100.00

Table 5.17: Fire risk level, per area, as a function of vegetal coverage (Central Region).

Risk	Area (km^2)	%	Cumulative %
Low	4 138	1.48	1.48
Moderate	41 035	14.71	16.19
High	157 035	56.28	72.47
Very High	21 236	7.61	80.88
Extreme	55 557	19.92	100.00

Table 5.18: Fire risk level, per area, as a function of vegetal coverage (Northern Region).

Influence of Human Activities

Demographic Density

The National Institute of Statistics (INE) offers statistics that allow an understanding of the geographic distribution of the population among districts.

The majority of districts, for all three regions considered in this research, are in the lowest density category (40 inhabitants /km²) (Figures 5.8, 5.9, 5.10).

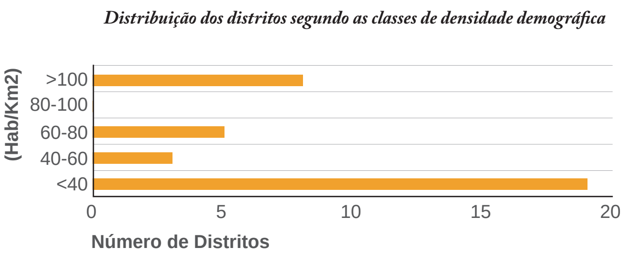

Figure 5.8: Distribution of districts according to demographic density categories (Southern Region).

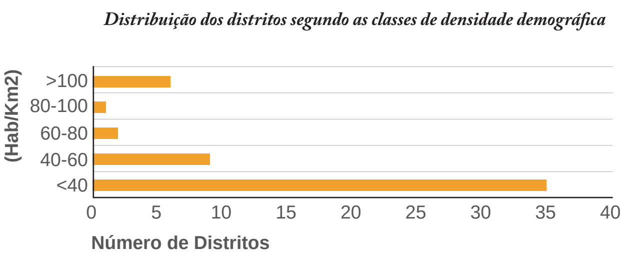

Figure 5.9: Distribution of districts according to demographic density categories (Central Region).

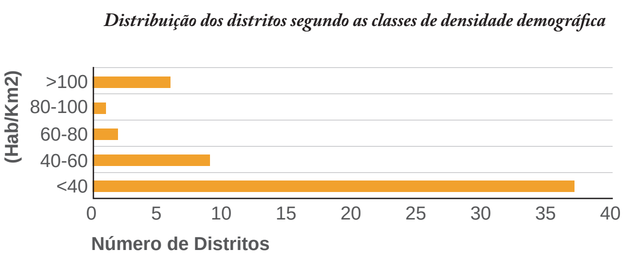

Figure 5.10: Distribution of districts according to demographic density categories (Northern Region).

Figure 5.11 illustrates the spatial distribution of the population in each region of Mozambique.

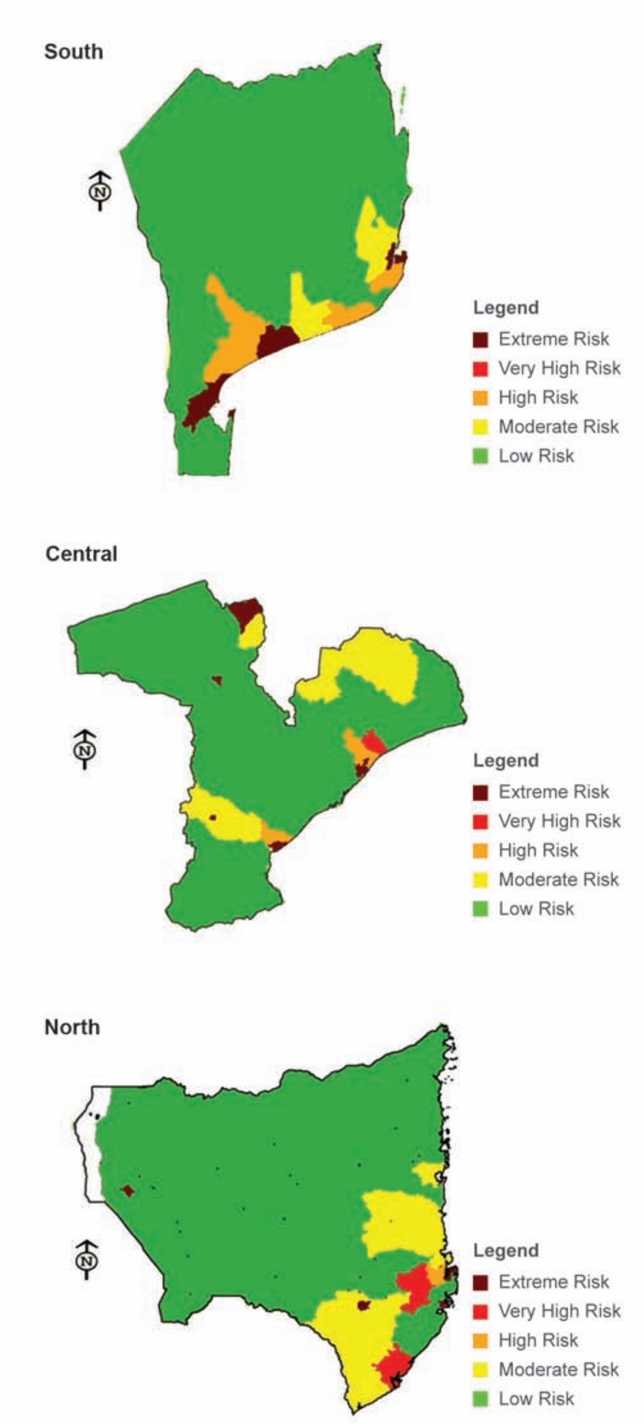

Figure 5.11: Risk Map According to Demographic Density: Southern, Central and Northern Regions.

According to the data presented in Tables 5.19, 5.20 and 5.21, approximately 80% of the area in each region was classified as “low risk”.

Risk	Area (km²)	%	Cumulative %
Low	144 167	86.07	86.07
Moderate	8 206	4.9	90.97
High	10 419	6.22	97.19
Very High	0	0	97.19
Extreme	4 706	2.81	100.00

Table 5.19: Fire risk level, per area, as a function of demographic density (Southern Region).

Risk	Area (km²)	%	Cumulative %
Low	273 038	81.65	81.65
Moderate	48 320	14.45	96.1
High	5 852	1.75	97.87
Very High	2 040	0.61	98.46
Extreme	51 450	1.54	100.00

Table 5.20: Fire risk level, per area, as a function of demographic density (Central Region).

Risk	Area (km²)	%	Cumulative %
Low	239 778	83.43	83.43
Moderate	38 655	13.45	96.88
High	1 150	0.40	97.28
Very High	6 552	2.28	99.56
Extreme	1 265	0.44	100.00

Table 5.21: Fire risk level, per area, as a function of demographic density (Northern Region).

Road System Distribution
Figure 5.12 shows the area of influence map due to human circulation in the three regions (Annex VI).

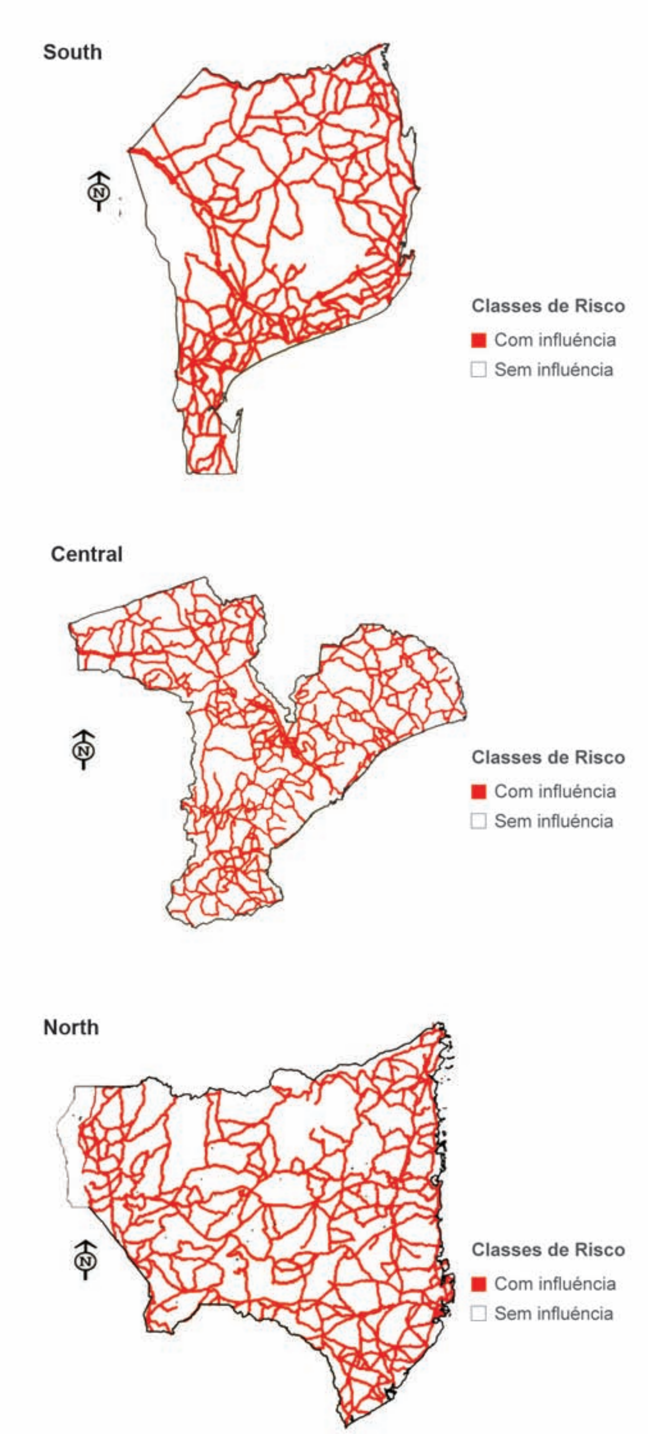

Figure 5.12: Risk Map According to Road Distribution: Southern, Central and Northern Regions.

According to the data presented in Tables 5.22, 5.23 and 5.24, approximately 80% of the area in each region has no human circulation influence, expressed by the marginal areas in the primary and secondary roads.

Risk	Area (km^2)	%	Cumulative %
Without Influence	128 171	76.52	76.52
With Influence	39 329	23.48	100.00

Table 5.22: Fire risk level, per area, as a function of the road system distribution (Southern Region).

Risk	Area (km^2)	%	Cumulative %
Without Influence	259 595	77.63	77.63
With Influence	74 805	21.37	100.00

Table 5.23: Fire risk level, per area, as a function of the road system distribution (Central Region).

Risk	Area (km^2)	%	Cumulative %
Without Influence	224 431	78.09	78.09
With Influence	62 969	21.91	100.00

Table 5.24: Fire risk level, per area, as a function of the road system distribution (Northern Region).

Integration of Preliminary Risk Maps

Three models were used in this study as presented in the following table:

Model	Equation Used	Source
I	[0,655*DD+0,655*SV]+[(0,29*D%+0,11*OE-0,1*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)

Table 5.25: Data Integration Models.

Legend:

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.

The results of the combination of preliminary risk maps based on the three models used are presented in Figures 5.5 to 5.22 and in Tables 5.26, 5.27 and 5.28.

Risk	Model I Area (km^2)	%	Model II Area (km^2)	%	Model III Area (km^2)	%
Low	14 696	8.93	35 851	21.77	24 762	15.03
Moderate	42 792	26.00	40 542	24.61	36 483	22.15
High	41 424	25.17	43 477	26.40	55 382	33.63
Very High	45 405	27.59	29 655	18.00	32 903	19.98
Extreme	20 269	12.32	15 186	9.22	15 174	9.21

Table 5.26: Fire risk level per integration model (Southern Region).

Risk	Model I Area (km^2)	%	Model II Area (km^2)	%	Model III Area (km^2)	%
Low	47 170	14.50	17 692	5.44	97 409	30.02
Moderate	102 503	31.50	13 961	42.95	151 473	46.68
High	92 734	28.50	102 949	31.67	65 677	20.24
Very High	55 461	17.04	60 133	18.50	9 710	2.99
Extreme	27 542	8.46	4 704	1.45	238	0.007

Table 5.27: Fire risk level per integration model (Central Region).

Risk	Model I Area (km^2)	%	Model II Area (km^2)	%	Model III Area (km^2)	%
Low	43 295	15.85	84 788	30.71	27 738	10.08
Moderate	98 213	35.95	87 305	31.62	147 187	53.46
High	78 460	28.72	66 466	24.07	87 291	31.71
Very High	39 203	14.35	31 911	11.56	12 619	4.58
Extreme	14 006	5.13	5 614	2.03	478	0.17

Table 5.28: Fire risk level per integration model (Northern Region).

The integration Models II and III did not use the climate conditions and combustible material humidity variables. The variation in altitude was also not included in Model III.

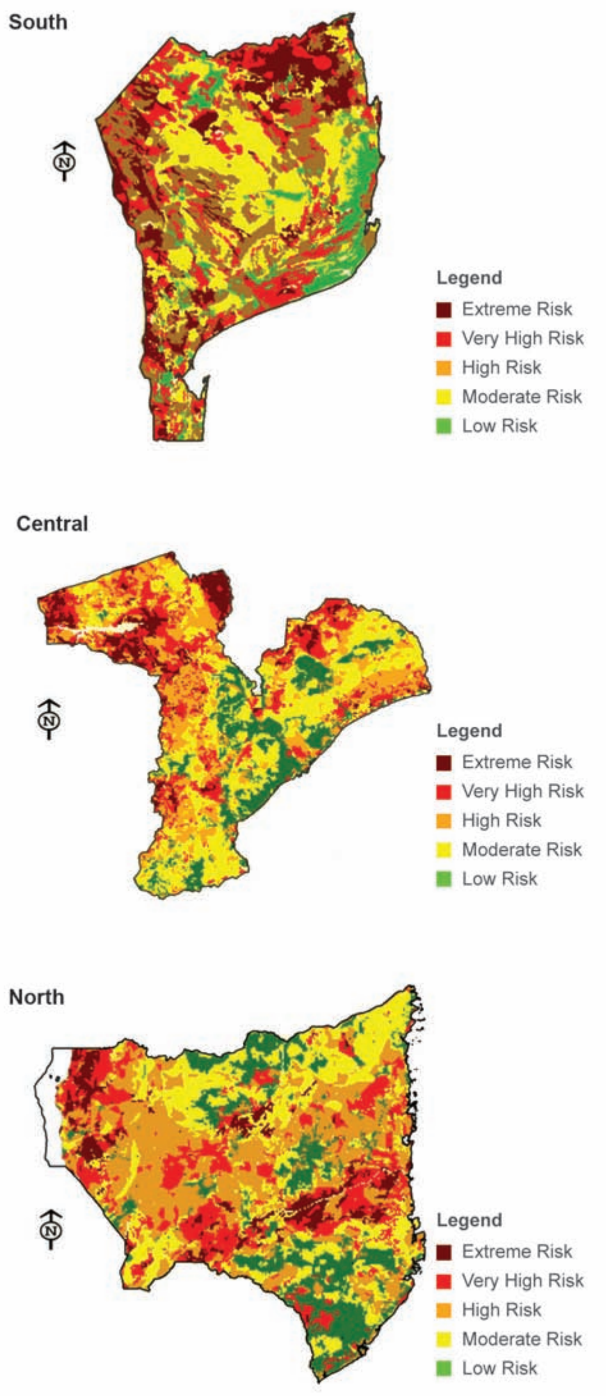

Figure 5.13: Risk Map According to the model proposed by Oliveira et al (2002): Southern, Central and Northern Regions.

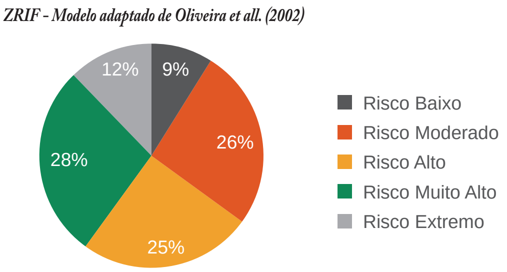

Figure 5.14: Southern region area distribution (%) per forest fire risk level, according to the model suggested by Oliveira (2002).

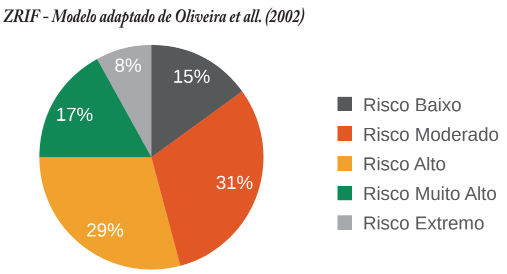

Figure 5.15: Central region area distribution (%) per forest fire risk level, according to the model suggested by Oliveira (2002).

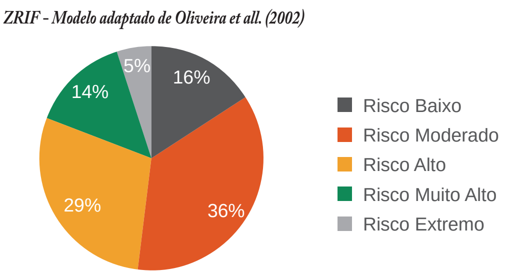

Figure 5.16: Northern region area distribution (%) per forest fire risk level, according to the model suggested by Oliveira (2002).

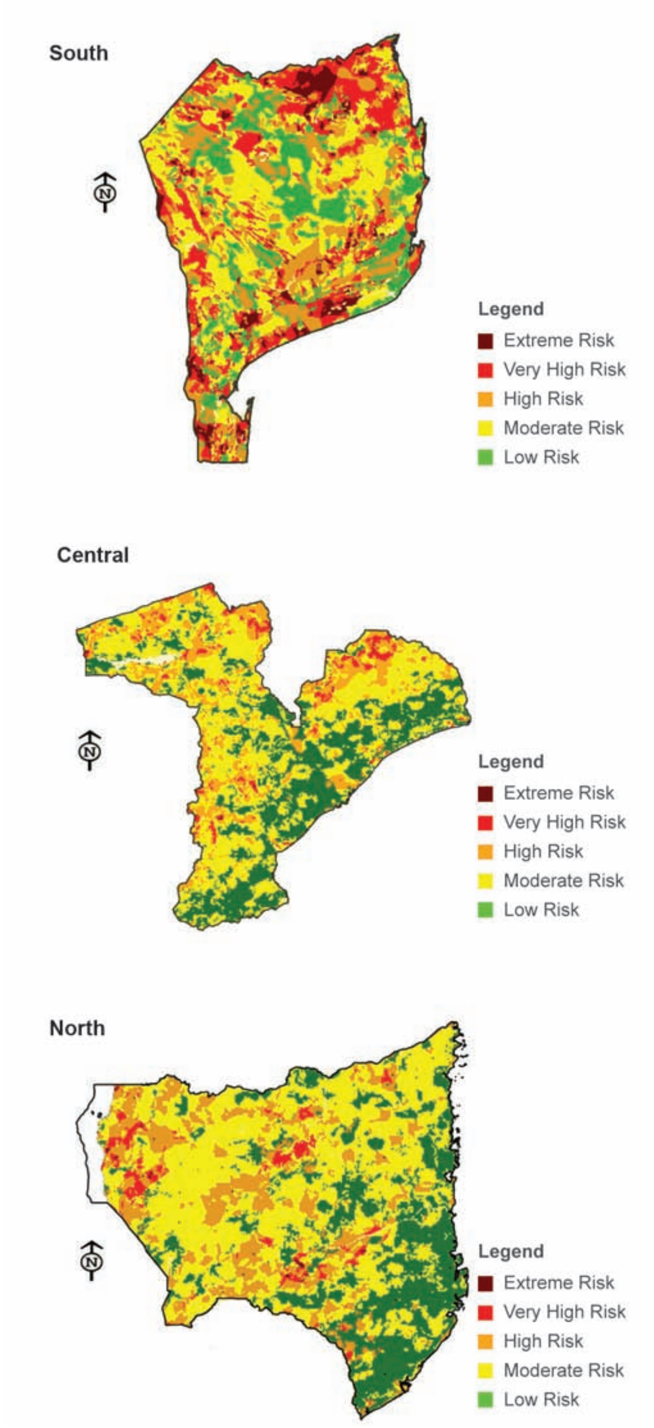

Figure 5.17: Risk Map According to the model proposed by Salas and Chuvieco (1994): Southern, Central and Northern Regions.

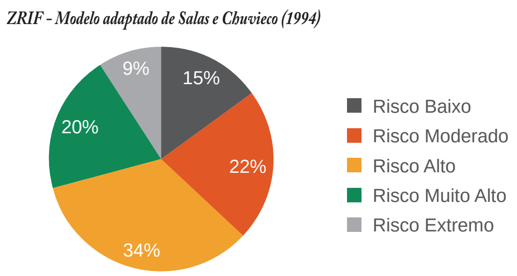

Figure 5.18: Southern region area distribution (%) per forest fire risk level, according to the model suggested by Salas and Chuvieco (1994).

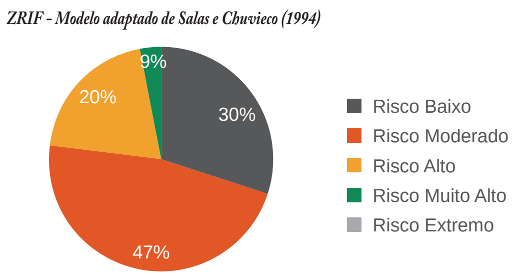

Figure 5.19: Central region area distribution (%) per forest fire risk level, according to the model suggested by Salas and Chuvieco (1994).

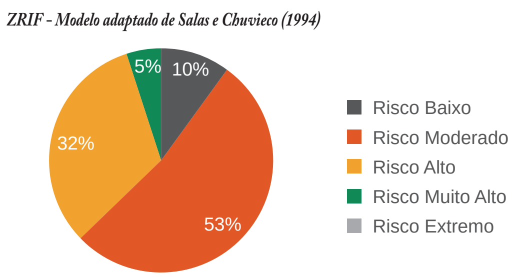

Figure 5.20: Northern region area distribution (%) per forest fire risk level, according to the model suggested by Salas and Chuvieco (1994).

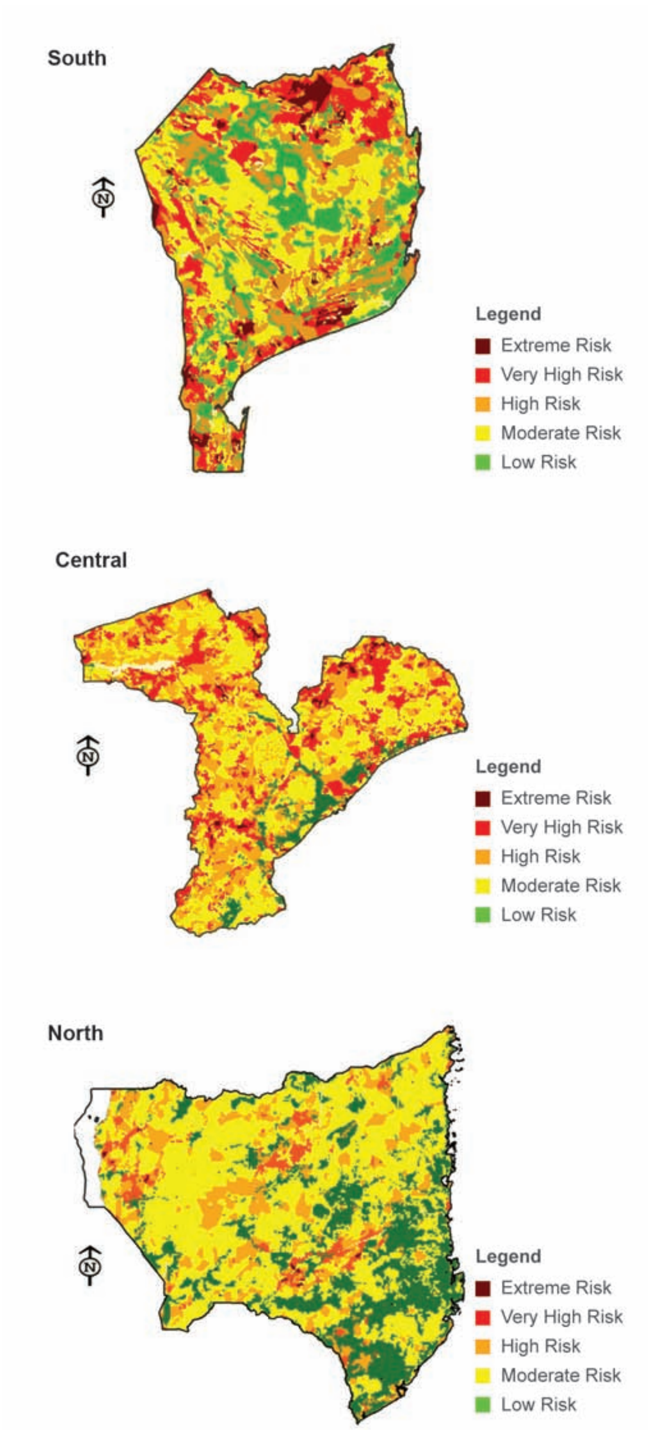

Figure 5.21: Risk Map According to the model proposed by Ferraz and Vettorazzi (1998): Southern, Central and Northern Regions.

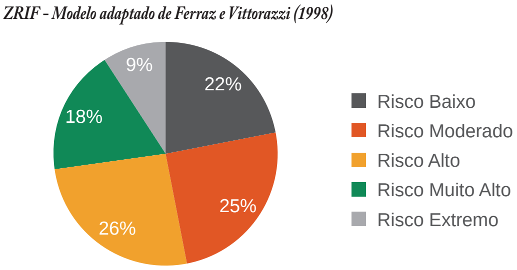

Figure 5.22: Southern region area distribution (%) per forest fire risk level, according to the model suggested by Ferraz and Vettorazzi (1998).

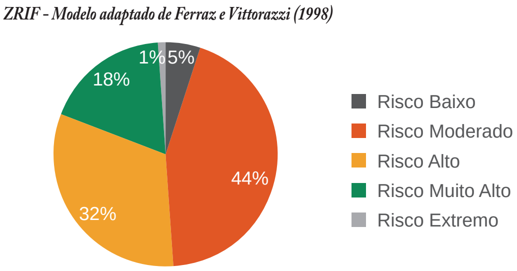

Figure 5.23: Central region area distribution (%) per forest fire risk level, according to the model suggested by Ferraz and Vettorazzi (1998).

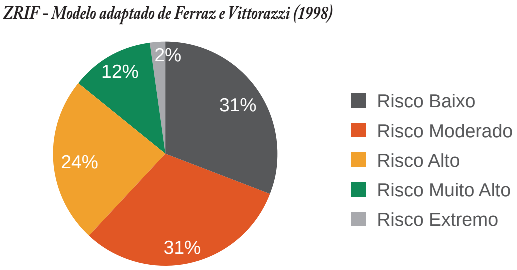

Figure 5.24: Northern region area distribution (%) per forest fire risk level, according to the model suggested by Ferraz and Vettorazzi (1998).

5.4 Validation of forest fire risk zoning (zrif)

Figure 5.25 shows the fire risk zoning validation map for the three regions in the Country. The data is derived from spatial representation of the heat occurrence density per km². This was obtained through the MODIS sensor during the 2002 to 2007 period.

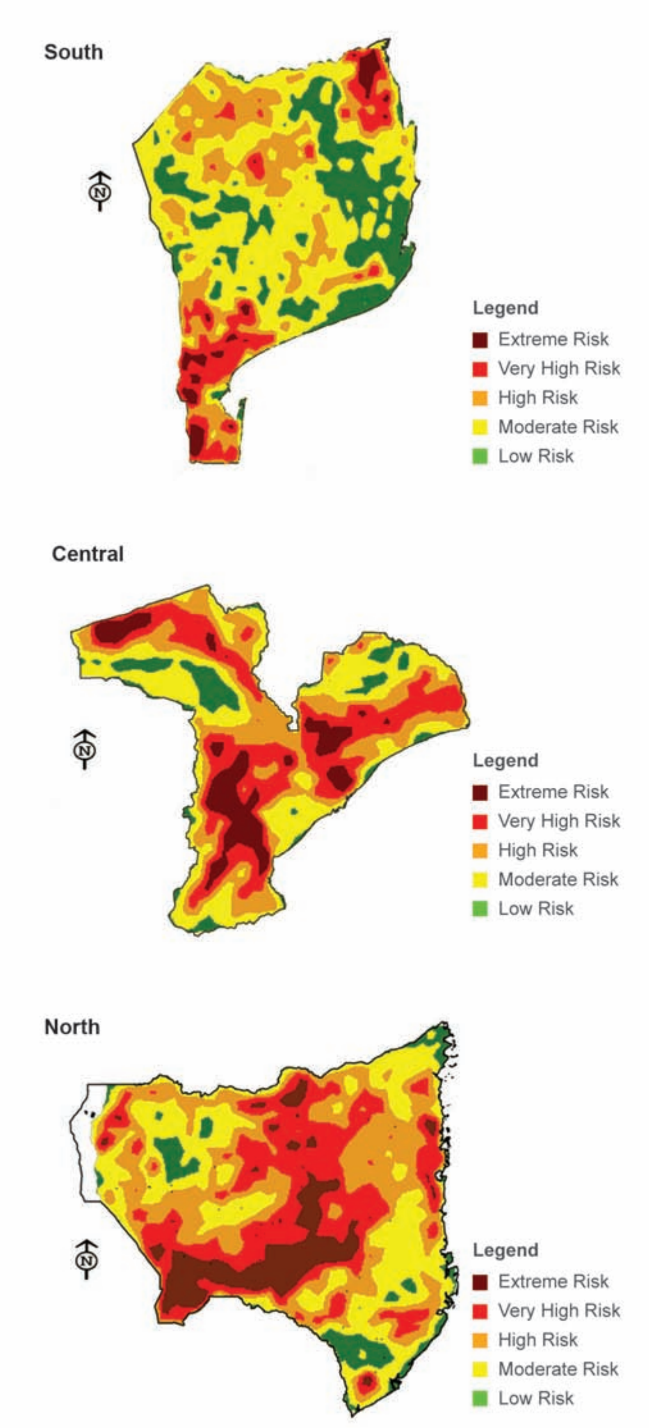

Figure 5.25: Risk Map According to Heat Occurrences registered between 2002 and 2007: Southern, Central and Northern Regions.

According to the data presented in Tables 5.29, 5.30 and 5.31, it can be observed that for the Southern Region, approximately 63% of the area was classified as "low risk" (21.2%) and "moderate risk" (42.2%); for the Central Region about 36% of the area was classified as "low risk" (7.8%) and "moderate risk" (28.5%) and, approximately 34% of the Northern Region area was classified as "low risk" (6.5%) and "moderate risk" (27.3%).

Risk	Area (km²)	%	Cumulative %
Low	35 477	21.18	21.18
Moderate	70 752	42.24	63.42
High	38 977	23.27	86.69
Very High	17 437	10.41	97.1
Extreme	48 557	2.90	100.00

Table 5.29: Area per risk category according to the risk map as a function of heat occurrences detected by MODIS sensor (Southern Region).

Risk	Area (km²)	%	Cumulative %
Low	26 083	7.80	7.80
Moderate	95 438	28.54	36.34
High	91 224	27.28	63.62
Very High	82 965	24.81	88.43
Extreme	38 690	11.57	100.00

Table 5.30: Area per risk category according to the risk map as a function of heat occurrences detected by MODIS sensor (Central Region).

Risk	Area (km²)	%	Cumulative %
Low	18 624	6.48	6.48
Moderate	78 546	27.33	33.81
High	86 996	30.27	64.08
Very High	71 333	24.82	88.9
Extreme	31 901	11.10	100.00

Table 5.31: Area per risk category according to the risk map as a function of heat occurrences detected by MODIS sensor (Northern Region).

The maps obtained through the integration models were compared with the map obtain through the heat occurrences sensor MODIS. The results are presented in Tables 5.32, 5.33 and 5.34. The values vary on a scale of zero to four. The "0" value (difference between the occurrence map and the maps derived from the models) indicated the coincidence between the risk values given in the respective models. The larger the concentration of areas in the values "0" and "1", the more reliable the proposed risk model is.

For the Southern Region, Models II and III present a similar performance in the estimation of fire risk (approximately 62% of the differences between the risk values "0" and "1"), however, model I presented the worst performance (59%).

For the Central region, Model III presented the best performance in estimating fire risk (65% of the differences between risk values "0" and "1").

For the Northern region Model II presented the best performance in estimating fire risk (67% of the differences between risk values "0" and "1"), while Model III presented the worst performance (56%).

Differences between the validation map and models	Model I Area		Model II Area		Model III Area	
	%	Cum.%	%	Cum.%	%	Cum.%
0	21.56	21.56	21.46	21.46	22.54	22.54
1	37.51	59.07	40.84	62.30	39.89	62.43
2	25.08	84.15	23.56	85.86	23.03	85.46
3	13.01	97.16	9.92	95.78	10.17	95.63
4	2.84	100.00	4.22	100.00	4.38	100.00

Table 5.32: Comparison between the risk map obtained from heat occurrences and the ones obtained by the integration models (Southern Region).

Differences between the validation map and models	Model I Area		Model II Area		Model III Area	
	%	Cum.%	%	Cum.%	%	Cum.%
0	19.61	19.61	19.09	19.09	22.17	22.17
1	36.08	55.17	35.34	54.43	42.44	64.61
2	26.77	81.94	26.64	81.07	26.73	91.34
3	15.15	97.09	15.96	97.03	8.05	99.39
4	2.91	100.00	2.97	100.00	0.61	100.00

Table 5.33: Comparison between the risk map obtained from heat occurrences and the ones obtained by the integration models (Central Region).

Differences between the validation map and models	Model I Area		Model II Area		Model III Area	
	%	Cum.%	%	Cum.%	%	Cum.%
0	21.55	21.55	25.33	25.33	19.64	19.64
1	40.85	62.4	41.86	67.19	37.20	56.84
2	24.18	86.58	23.53	90.72	26.58	83.42
3	11.89	98.47	8.35	99.07	13.05	96.47
4	1.53	100	0.93	100	3.53	100

Table 5.34: Comparison between the risk map obtained from heat occurrences and the ones obtained by the integration models (Northern Region).

5.5 Carbon dioxide

According to the Intergovernmental Panel for Climate Changes (IPCC), the present increase in the concentration of greenhouse gas (GG) in the atmosphere potentially has serious consequences, including sea level rise, the intensification of extreme weather phenomena, desertification of some areas, reduction in agricultural production, polar ice melting, and others.

Human activities lead to the emission of several GGs i.e. carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These three gases are chemically stable and persist in the atmosphere for time horizons which can vary from decades to centuries or more, and consequently have a long term influence on climate.

The gas emissions, although a global problem, vary spatially according to different country development levels, and its causes, in the most developed countries, are connected to industrialization, and in developing countries are connected to agri-forest resource management and soil usage (MICOA, 2005).

In this context, Mozambique is not an exception regarding GG emissions. In terms of CO_2 produced by the forests as a result of burnings, it can be noted that within an interval of 4 years the emissions level per forest increased by more than 335% since 1990 until 1994 (Table 5.35).

SECTOR	CO2EMISSÃO (10 Ton) Year 1990	Year 1994	Increase (%) (1994-1990)
Energy	1043	1531	46.7
Processing Industry	40	51	27.5
Agriculture			
Florests	1769	7680	335.0
Incineration			
TOTAL	**2852**	**9262**	**225.0**

Table 5.35: Greenhouse gas emissions per sector in Mozambique. ***Source: MICOA (2005).***

One of the most relevant aspects in the studies of carbon fixation in forests is the biomass variable, which needs to be determined and estimated in a reliable way, otherwise there will not be consistency in the quantification of carbon fixed in forest ecosystems (Sanquetta, 2002).

An accurate estimation of forest biomass and its changing pattern over time is a pre-requisite to helping understand the great controversy about the role of forests in the carbon cycle (Sedjo, 1992 and Fan et al., 1998).

To Guedes et al. (2001) the biomass (kg/m^2) is a productivity indicator (kg/m^2/year) of a place, varying with rainfall, temperature, latitude and altitude. Productivity and biomass may not be related and vary with the succession state of the vegetation in. For example, an adult forest which has a lot of biomass may have low productivity.

According to Carvalho (2001), by burning areas above 10 hectares, approximately 50% of the biomass, i.e. wood is turned into CO_2. According to the same author, in vast areas, the biomass combustion is usually more effective, being a function of the head produced in the process.

More precise data is needed to estimate the amount of carbon dioxide freed into the atmosphere as a result of burning, per unit of fire per year, and, to be able to interpret data to estimate the contribution of burning in Mozambique to global warming.

5.6 Conclusions and recommendations

Studies on the subject uncontrolled burnings in Mozambique, as well as in Africa, include MICOA's "Mudanças climáticas e estratégias de adaptação" ("climate changes and adaptation strategies" in English) presented in 2005 by the Ministry for Environmental Action Coordination; "Avaliação de incidencia, causas, intensidade e extenção das queimadas descontroladas na reserva do niassa" ("Evaluation of the incidence, causes, intensity and extension of uncontrolled burnings in niassa reserve" in English), Marufo (2007); "Regime de fogos em areas protegidas de africa sub-sariana" ("fire regime in protected areas of sub-saharian africa", in English), Palumbo & Grégoire (2000). All the authors are unanimous in stating that fires are responsible for the devastation of large forest areas every year, both across Mozambique and in the regions. The main causes of such burnings are connected to human action.

In the period 2002-2007 Niassa province registered more burnings occurrences, followed by Tete and Zambezia provinces. In general, fires in Mozambique do not follow a specific forest type, conversely they depend more on the climate conditions, topography and population clusters, since all forest types are fire prone.

Based on the comparison between the risk maps, it can be concluded that:

The three integration models used for zoning present similar outcomes:

- The methodology used in describing and valuing the variables related to the forest fire risks has proven efficient for risk definition
- Due to the resemblance between the results obtained and the risk maps generated by models II and III for the Southern Region, it can be concluded that Model II is the most appropriate to represent the forest fire risk distribution in this region, because it makes use of a larger number of variables
- For the Central and Northern regions, Models III and II respectively have shown a better performance, being the most appropriate to represent the distribution of forest fire risk in the specified regions

The zones which are classified as being high, very high and extreme risk must be the priority for:

- Forest fire control and prevention actions, close to the populations and other economic agents which use fire as an integral part of their activities
- The adoption of new technologies in the agricultural and livestock sectors which induce productivity increases without compromising the environment
- Mozambique to take advantage of the industrialized countries' credits to perform activities related with the carbon capturing

6

Preliminary health analysis

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Preliminary Health Analysis

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6.1 Introduction

6.2 Vulnerability to climate change

6.3 Health impacts

6.4 Impact scenarios

6.5 Recommendations for adaption

6.6 Conclusions

6.1 Introduction

While poor nations and poor populations are experiencing the most severe impacts from the changing climate, the diverse dimensions of climate change itself – rising temperatures, sea level rise, altered weather patterns, greater extremes, and diminished return times between extreme weather events – present new exposures and risks for all nations (IFRC & RCS, 2006).

For Africa, the climate prognosis is especially dire. A United Nations report (UNFCCC, 2006) projects continued drying of the continent, with increasing consequences for health, crop yields, livelihoods, refugees, and conflict. Rainfall across the Sahel has already fallen 25% in the past three decades. The wider epidemics of meningococcal meningitis can be expected.

By 2025, 480 million Africans are projected to face water scarcity or stress. Meanwhile, the same report projects that 30% of Africa's coastal infrastructure may be inundated and 80–90% of species' suitable habitats will shrink. Mountain biodiversity, where glaciers, plants, and mosquitoes are already migrating upward (Epstein et al., 1998), could be further degraded on peaks lacking room for species to shift. Wetlands are likely to decrease as disappearing montane glaciers decrease runoff, and subsistence crops, such as sorghum, millet, maize, cassava and groundnuts, are projected to suffer. These losses will increase pressure on bushmeat hunting, which will further threaten biodiversity, accelerate environmental change, and expose wider population to rodent- and bat-borne viral hemorrhagic fevers.

The IPCC states with "very high" confidence that climate change is contributing to the global burden of disease and premature deaths (IPCC, 2007). Warming affects the potential range and seasonality of infectious diseases, while weather affects the timing, intensity and location of outbreaks. Given that risk is a function of the hazard, exposure and vulnerability, low-income countries are expected to suffer the most from climate change. On the other hand, changes occurring in the North Atlantic (salinity and temperature) and projected variability over this century (Stott et al. in press), suggest that Europe and the U.S. (especially the northeast) will continue to experience more variable and severe weather. Adapting to the changing climate is thus a central issue for all nations, and the preparations for the reducing health consequences involve:

1. Disease-specific monitoring and responses.
2. Event-driven preparation, responses and recovery.
3. Enhancing development.

The IPCC scenarios, contained in the Special Report on Emissions Scenarios (SRES 2000), make projections by the middle and end of this century and beyond, and assume that climate change will be linear and involve gradual warming. But events of the last five years have overtaken the initial SRES scenarios. Climate has changed faster and more unpredictably than the scenarios outlined. Many of the phenomena assumed to lie decades in the future are already well underway. This faster pace of change on many fronts indicates that more sector-specific, short-term impact scenarios are needed to complement the longer-term projections based on emissions scenarios, in order to adequately plan for short-term structural and systemic changes needed to cope with the coming climate.

6.2 Vulnerability to climate change

Mozambique may be the most flood-prone nation in Africa (Cairncross & Alvarinho, 2006). The floods in early 2000 in Mozambique (brought on by six weeks of rain and two tropical cyclones) were the worst the nation had experienced in many decades; an estimated 700 people drowned, and more than two million people were impacted by the floods (Cairncross & Alvarinho 2006). The health impacts and the impacts on agriculture, animals, livelihoods, and physical, communication and energy infrastructure were extensive.

Persistent and recurrent drought, on the other hand, may hold the longest term threat for Mozambique (Aragon et al., 1997), and the other nations in Southern Africa (IPPC, 2007), in terms of health, nutrition, resources and power. Factors shown to compound the severity of the impact of climatic variability and extreme weather events include preexisting conditions of poor infrastructure, poverty, poor healthcare services and delivery, and political unrest. The IPCC (2001) states that Africa is “highly vulnerable” to the impacts of climate change due to widespread poverty, recurrent droughts, inequitable land distribution, and over-dependence on rain-fed agriculture. The IPCC predicts that “climate change will exacerbate existing physical, ecological/ biological, and socio-economic stresses on the African coastal zone”.

Certain agricultural and land use practices, such as tillage and flat cultivation, can cause erosion during heavy rains and reduce crop yields (Paavola, 2004). Soil erosion can then degrade water supply and quality once reaching rivers and reservoirs (Paavola, 2004). Deforestation increases vulnerability: degradation of natural forests, through replacement of natural vegetation with cash crops, deforestation for timber, and forest fires, led to landslides in 1998 in Chinzongue and Tamanada villages in Mozambique (UNDG, 2000). As the population grows and people, particularly nomadic tribes in search for food and water for themselves and their livestock, push into onto less productive or peripheral lands, they become more susceptible to the impacts of drought, and border conflicts (Simms & Reid, 2005; Christian Aid, 2006).

6.3 Health impacts

Warming is projected to increase the incidence of insect-borne diseases, as insect vectors and microorganisms are highly sensitive to temperature. Precipitation also affects:

- The breeding sites of mosquito vectors (e.g. for malaria)
- Water-borne disease outbreaks (such as cholera and other diarrheal diseases
- Rodent-borne diseases.

Warming and severe weather can also influence the growth of crops, and the pests (e.g., rodents, locust), pathogens and weeds that affect productivity. Note that adequate nutrition provides the most important defense against morbidity and mortality from infectious diseases.

Some diseases of animals (e.g. Rift Valley fever, transmitted by Aedes aegypti) are also responsive to changing meteorological conditions. Extreme weather events, such as tropical cyclones, heavy rains and drought, can directly affect health (via accidents, drowning, snake bites, starvation) and in their aftermath (with 'clusters' of mosquito-, water- and rodent-borne diseases).

Malaria

Mozambique is among the ten nations in the world most affected by malaria. Stable and endemic transmission make malaria Mozambique's number one cause of illness and mortality, accounting for 44 to 67,000 deaths annually in all age groups. In addition approximately 682,000 pregnant woman and 2.8 million children under age five are at risk from malaria (Bradbury & Edward, 2005).

Malaria transmission has been correlated with temperature changes in the highlands of Africa (Githeko & Ndegwa, 2001; Koenraadt et al., 2006; Pascual et al., 2006), and in Asia and Latin America. While the increase in high elevation malaria is also affected by population mobility, deforestation, drug and pesticide resistance, the change in temperature alters the conditions conducive to malaria transmission at high altitudes. The changes in elevation, exposing previously naive populations, are occurring in tandem with retreat of mountain glaciers and the upward migration of plant communities (Epstein et al., 1998). The seasonality favoring malaria transmission may also be increasing in Southern Africa (see Tanser et al., 2003, below).

A study by Zhou et al. (2004) in seven highland sites in Ethiopia, Kenya, and Uganda, using data from 1978-1998, found an association between monthly rainfall and monthly malaria incidence, with a time lag of 1-2 months, and maximum and minimum temperature with malaria cases with a time lag of 2-5 months. The authors concluded that climate variability explains more than 40% of the variance of malaria cases, and that the synergistic effects of increased temperature and rainfall have brought about the resurgence of malaria in the highlands. Craig et al. (2004) also found seasonal changes in malaria case numbers to be significantly associated with climate variables of mean maximum daily temperature from the preceding season and total rainfall of the current summer wet months.

Projections of Malaria Distribution

A variety of models of malaria transmission have indicated that changes in temperature and precipitation could alter the transmission of malaria, with previously unsuitable areas of dense human population becoming suitable for transmission (Lindsay and Martens, 1998; Martens et al., 1999; Rogers & Randolph, 2000).

Martens et al. (1999) projected that by 2100, ongoing warming will enlarge the zone of potential malaria transmission from an area containing 45% of the world's population to an area containing about 60%. The temperature cut-off point for epidemics versus non-malarious zones is 18°C; 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). A rise from 20°C to 25°C, for example, reduces the extrinsic incubation period (EIP) for Plasmodium falciparum parasites from 26 to 13 days (Macdonald 1957), in time for transmission to occur within the life-time of the anopheline mosquitoes.

Today roughly 45% of the population of Zimbabwe is currently at risk for malaria (Freeman, 1995). With warming predicted to rise ~ 0.2°C per decade (IPCC, 2007), the warming of the African highlands could cause an increase in the suitability for malaria transmission in these areas (Hartman et al., 2002; Ebi & Gamble, 2005).

Despite differing methods and varying results (see Hay et al. 2002), the models reach similar conclusions: The future spread of malaria is likely to occur at the edges of its current geographical distribution.

Notably most of the analyses are based upon projected changes in average temperatures, rather than the more rapid increase in minimum temperatures observed; and thus may underestimate the on-going and future biological responses (Epstein & Mills, 2005).

Changes in Seasonality

In Africa, there is projected to be a 16-28% increase in person-months of exposure by 2100, with mainly altitudinal expansion of 5-7% (Tanser et al., 2003). South Africa showed a substantial latitudinal expansion for malaria transmission, and in all three scenarios used in the model of Tanser and colleagues (2003), there were increases of more than 100% in person-months of exposure by the end of the 21st century.

Extreme Weather Events

While long-term data sets are often incomplete, a focus on extreme weather events (EWEs), when relief efforts are mounted can reveal spikes in disease incidence associated with the extremes. And as EWEs are projected to be more frequent and intense, these data and the projections based upon them provide useful information for planning adaptive measures to reduce the health consequences of climate change.

The increase in frequency and intensity of extreme weather events associated with climate change (Karl & Trenberth, 2003; IPCC, 2007) could lead to higher numbers of malaria epidemics from increased rainfall alone. In the highland areas of Kenya, Tanzania and Ethiopia, rainfall has been shown to increase the breeding sites of the anopheline mosquitoes (Bodker, 2003; Abeku et al., 2004), though, in some circumstances very heavy rainfall, can wash away larvae (Lindsay et al. 2000). The 1997/1998 El Niño event was significantly associated with increased malaria epidemics in many areas of East Africa (Abeku et al., 2004; Yanda et al., 2005; Wandiga et al., 2006).

Malaria incidence often rises acutely following floods, as new breeding sites in standing water are created. Following the 2000 floods a Japanese relief team working in Gaza reported an increase in malaria of 4-5 times the magnitude of non-disaster periods (Kondo et al., 2002; Epstein & Mills, 2005). But efforts by the Mozambican Ministry of Health, UNICEF, and NGOs to provide mosquito nets, sprays, and effective drug treatment to populations limited the impact in many areas (Bradbury & Edward, 2005).

Other diseases

African sleeping sickness (African trypanosomiasis), transmitted by the tsetse fly, is found in Tete Province in central Mozambique, and afflicts humans and cattle: 25 million people are at risk in East and West Africa. Studies of habitat changes conducive to the spread of this disease, using modeling and remote sensing, allow for projections of this disease with climate forecasting (Rogers & Randolph 1991; Terblanche et al. 2007). Filariasis (elephantiasis) has not been studied with respect to climate change, but as a mosquito-borne disease, warrants attention.

Chikungunya Fever

The first reported cases of chikungunya fever occurred in 1952 in southern Tanzania and northern Mozambique (Epstein, 2007). Chikungunya draws its name from the Makonde people and connotes the contortions of those who contract this dengue-like disease. Serological surveys reveal that CHIK fever occurs throughout Mozambique, with the highest prevalence in the north (J. Cliff, pers. comm., 2008).

From 2004-2006 CHIK fever emerged from its sylvatic (forest-dwelling animals) reservoir, afflicting nearly 500,000 people in Kenyan coastal towns of Lamu and Mombasa, and the Indian Island nations of Reunion, Comorros and the Seychelles Africa. In the same time frame nearly 200 tourists from Europe and the Caribbean returned home with CHIK fever. (It later appeared in Asian nations bordering the warm Indian Ocean; then the Philippines; and, in the summer of 2007, in Italy (spread there by Aedes albopictus, the Asian tiger mosquito).)

While previous outbreaks of CHIK fever have most often followed heavy rains (Jupp & Mcintosh 1998) leaving floodplains, 'unusually dry, warm conditions preceded the [East African and Indian Ocean] outbreaks … the driest since 1998 for some of the coastal regions (Chretien et al., 2007).' Peri-domestic water storage in containers infrequently replenished and elevated temperatures provided favorable breeding sites for Ae. aegypti, facilitating the transmission of chikungunya virus.

“These results suggest that drought-affected populations may be at heightened risk for chikungunya fever, and underscore the need for safe water storage during drought relief operations (Chretien et al., 2007).” A Health Early Warming System for conditions conducive to CHIK fever can help mobilize clean water supplies and provide timely educational messages to communities (e.g., to cover outdoor water storage containers).

Meningococcal Meningitis

Bacterial meningitis is transmitted person-to-person, with epidemics of meningococcal meningitis in the African meningitis belt (the Sahel) associated with drought. El Niño events may lengthen the dry season in the Sahel, and droughts may aerosolize pathogens in dust particles and allow bacteria to invade dried mucus membranes (Gross 2002). The IPCC (2007) projections for an increase of 5-8% in the arid and semi-arid land in Africa could increase transmission and favor the expansion of the meningitis belt. There were several epidemics of meningococcal meningitis in Mozambique in the late 1990s (J. Cliff, pers. comm., 2008).

The association of meningococcal meningitis epidemics with drought can be useful for Health Early Warning Systems, allowing timely vaccination against this vaccine-preventable disease.

Cholera and other diarrheas: event driven

Cholera in this pandemic first appeared in Mozambique in the Province of Sofala in 1973 (Aragon et al. 1997) and re-emerged in 1978. The source of entry is not known, but the finding that Vibrio cholerae bacteria are harbored in ocean plankton (Epstein et al., 1993; Colwell, 2008), suggests that plankton blooms (affected by temperatures and sometimes triggered by coastal flooding), may have been the "vector," via fish and shell-fish consumption. Alternatively, it was introduced by a traveler from another endemic region. Regardless, it became part of the flora of sanitation and clean water supplies in Mozambique, and (most likely from its reservoir in plankton in inland water bodies) periodically reappears, especially following flooding (sanitation contaminating clean water supplies) and with warm temperatures.

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.

Heavy rains and flooding can disrupt water systems and contaminate drinking water with waste water and solid waste, leading to water-borne diseases including cholera and other diarrheal diseases (Bateman, 2002; Yanda et al., 2005; Anyamba et al., 2006; Griffith et al., 2006; Nangoma 2007). 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). According to the WHO, there were close to 9,000 cases of cholera and 300 deaths in Mozambique alone during this El Niño event[1].

In 2000, the extensive flooding is estimated to have caused 8,000 cases of diarrheal disease in the months following the flooding (IPCC, 2007). A Japanese relief team sent to the state of Gaza after the March 2000 floods detected infectious disease in 85% of the patients they saw; the incidence of diarrhea increased 2-4 times over non-flood periods (Kondo et al., 2002). Pre-existing inadequate sanitation and safe drinking water serves to exacerbate the impacts of heavy rains and flooding.

Mortality from cholera can be dramatically reduced by provision of safe drinking water, sugar and salt solutions. Reducing mortality thus depends on better forecasting, storage of sugar and salt packets (oral rehydration therapy or ORT), training and deployment of personnel, community outreach and education, and ensuring safe water supplies. Boiling water is often not possible due to inadequate sources of energy.

Rodent-borne diseases

Unstable weather conditions can lead to explosions of rodent populations (Levins et al.,1993). Heavy rainfall and flooding can lead to outbreaks of rodent-borne plague. On the other hand, in Tete Province along the Malawian border, drought conditions have sometimes led to the movement of humans and rodents in search of food (Barreto et al., 1995), driving domestic and wild rodents into close contact with humans; leading to outbreaks of bubonic plague.

Disturbances, such as deforestation and excessive use of pesticides, can also reduce predators of rodents (shakes, birds of prey), unleashing rodent pests from these natural controls. Heavy rains following droughts are also associated with population explosions; droughts reduce predators and the rains provide new food sources for the rodents. Flooding can also drive rodents from their underground burrows.

The emergence of a new arenavirus in Zambia in 2008 (ProMED, 2008), may be carried by rodents. The index case was a Zambian resident who was evacuated to South Africa, where the health personnel attending her also developed the disease. The means of transmission and concurrent meteorological conditions need to be assessed.

Crop pests

Rodent population explosions may have been responsible for the maize losses in Zimbabwe during the 1982/83 El Niño event (Epstein & Chikwenhere, 1994a&b). In addition to the loss of farmlands in the 2000 floods, rodents and other pests invaded food granaries (ACT 2005), increasing the agricultural losses. Other crop pests, such as locust, may follow periods of drought punctuated by minimal rains.

Rising atmospheric carbon dioxide and climate change pose threats to cassava production.

Notes

[14] Note: El Niño events are most often associated with drought conditions in Southern Africa. But both large El Niño events in recent decades (1982/83 and 1997/98), as remote sending images depict, were associated with heavy rains in the coastal regions of southern Mozambique. Climate forecasting for Mozambique must therefore take into account the degree of El Niño/Southern Oscillation anomalies, the location of the Inter-tropical Convergence Zone (ITCZ) and the SSTs in the Indian Ocean.

Konzo

During droughts, there is an increase in cyanogenic glycoside concentrations in the cassava root. Malnourishment also reduces the body's ability to detoxify the cyanide (CN).

In 1981, during intense drought, the first outbreak of spastic paraparesis in Mozambique was reported. Over a thousand cases occurred in the northern provinces of Nampula and Cabo Delgado (MOH 1984). Initially the disease was given a local Mozambican name, but was subsequently called konzo, after the first description in the then Belgian Congo.

Since that first report, konzo has persisted in Nampula province with periodic upsurges associated with drought (Ernesto et al., 2002). In the most recent episode, in 2005, epidemics were reported from Zambezia, as well as in Nampula province (J. Cliff, pers. com., 2008).

Outbreaks of Acute Cyanide Poisoning

Outbreaks of acute cyanide poisoning have been reported from the towns of Xai-Xai and Chimoio during drought (Cliff & Coutinho, 1995). People in these towns turned to bitter cassava, and did not have the knowledge about how to safely remove the cyanide.

Brown Streak (root rot).

- This fungal disease harms the tubers of cassava, making it inedible
- Heavy rains and flooding foster fungal growth
- Floods foster fungal growth

Impacts of increased carbon dioxide.

- The leaves of cassava grown under the disturbance of increased CO_2 show an increase in the CN content (R. Gleadow, unpub. data, 2008).
- Cassava leaves are key constituent of matapa (plus peanuts (protein) and coconut oil), but preparation of matapa includes pounding, which destroys the cyanide-containing glycosides.
- Preliminary data finds that the biomass of cassava tubers declines when grown under elevated CO_2 (R. Gleadow, unpub. data, 2008).

As all emission scenarios project an increase of atmospheric CO_2 over the coming decades, these findings are particularly alarming, given that cassava is an essential part of the African diet.

Mental health

There are few studies of the impacts of climate change on emotional/mental health. In Arctic nations, the impacts on social cohesion, family life and mental health due to loss of coastal communities and livelihoods, are already evident (ACIA 2004). As weather patterns shift and agriculture and livestock become less predictable, the issues of mental health and associated family conflicts and violence need to be monitored. Significant sea level rise in coastal Sofala Province and elsewhere, could lead to the abandonment of settlements and concomitant social stress.

Diseases of wildlife and livestock

In Kenya outbreaks of Rift Valley Fever (RVF) have been associated with increased rainfall accompanying El Niño events (Linthicum et al., 1999; Anyamba et al., 2001; Patz et al., 2005). Linthicum and colleagues (1999), using data from 1950-1998, showed that outbreaks of RVF in Kenya followed periods of heavy rainfall, and Anyamba et al. (2001) found that RVF outbreaks are strongly correlated to both rainfall and high SSTs, with over 75% of the RVF outbreaks occurring during warm ENSO (El Niño) events.

Marine impacts

Warming sea temperatures and extreme weather events can have detrimental impacts on the ecosystem and biodiversity. Studies examining the effects of the 1997/1998 El Niño on coral reefs off Mozambique show significant amounts of bleaching and coral mortality, with rates as high as 99% (Motta et al. 2001). Coral communities in the Xai-Xai lagoon reef and Inhaca Island reefs showed an average mortality of 64.6% and 36.5% (Pereira, 2000; Perry, 2003) and increase of certain types of algae and invertebrates (Pereira et al., 2000; Obura et al., 2003).

Coral bleaching and storm damage in addition to fishing pressure are responsible for declining fish diversity and stocks (Schleyer et al., 1999; Pereira et al., 2000; Christian Aid, 2006). There are also implications for the travel and tourism industry.

6.4 Impact scenarios

Two impact scenarios envision gradual warming with growing variability, and more frequent and more intense weather extremes. The impact scenarios differ in the way biological and physical systems respond to the warming and increasingly severe weather.

Scenario I: gradual change

The first impact scenario depicts an increase in disease outbreaks and infestations that harm humans, wildlife, forests, crops and coastal marine systems. The events and their aftermaths would strain coping capacities in Mozambique and threaten resources, farming and industries, such as timber, tourism, travel. Changes in water availability and floods and droughts pose threats to the nation's energy sector, and the impacts could be felt throughout the economy.

Under this scenario diseases would continue to spread and cause greater morbidity and mortality. Malaria could spread further in highland areas in provinces north of the Zambezi River, and expand the seasonality of transmission. More flooding could precipitate large upsurges of this endemic disease.

Flooding and droughts under the first scenario would cause severe crop and livestock losses with tens of thousands of cultivated land and livestock affected. More extreme droughts would cause more below-average yield years. Livestock may contract diseases due to droughts or flooding, exacerbating malnutrition, protein loss and the fertilizer they provide for agriculture. Food insecurity could further be aggravated by agricultural pests, while food aid could be hampered by infrastructure damages. Roads, buildings, and water systems in coastal plains could be damaged by rising sea levels and increased moisture.

Even with gradual climate change, species would be lost as habitats shift. Loss of certain species and invasions of other species could severely compromise the integrity of ecosystems, their biodiversity and functions. Bleaching and mortality of coral reefs, one of the most biologically diverse ecosystems, could rise.

Scenario II: surprises and non-linear changes

The second impact scenario projects that warming and enhanced variability produce surprises, with sudden, wide-scale health and environmental impacts, as climate change pushes managed and natural ecosystems past tipping points. The consequences for agriculture, for example, could be driven by wide-spread drought and the concurrent rise in crop pests (e.g., locust, rodents). As such, the second scenario envisions a future inherently more chaotic and unpredictable than the first scenario. Some of the impacts envisioned by the second scenario are very severe and would involve catastrophic, widespread damages, with severe impacts on the economy of Mozambique.

Under the second scenario, greater and more severe impacts are predicted. In this scenario, widespread famine due to massive declines and losses in crop yield from droughts or flooding, could affect a greater proportion of the Mozambican population. The melting of the ice caps on Kilimanjaro and decreased flows on some major rivers will threaten electricity generation, water for crop irrigation, and livelihood of people who depend on those rivers. Downed bridges, railways, water and electrical systems, and health posts would make recovery an extremely difficult task.

Under the second scenario, insect-, water- and rodent-borne disease can be projected to rise substantially. The habitat range of disease vectors would expand dramatically, affecting more vulnerable and non-immune populations, increasing the case fatality rates. Heavy rains and storms would disrupt water and sanitation systems, forcing people to turn to unsafe sources, increasing water-borne diseases.

The impacts of deforestation, which already endangers local species and contributes to warming, would escalate, pumping more CO_2 into the atmosphere through forest fires and lack of carbon sinks.

With the second scenario[2], coral reefs, which already reached mortality rates of 60% due to the 1997/1998 El Niño event, would be at serious threat of collapsing. Coral reefs — already multiply stressed — could collapse from the effects of warming, ocean acidification and opportunistic diseases. The fishing industry in Mozambique could also collapse due to loss of coral reef nurseries and decreasing fish stocks from multiple stresses.

Other examples include:
- Repeated heat waves on the order of the 2003 European summer, which severely harms populations, kills livestock, wilts crops, leads to wildfires and spreads disease[3].
- Chronic water shortages would become more prevalent, especially in semi-arid regions.
- Current water usage levels and greater hydrological extremes can be projected to result in many more environmentally-displaced persons, with concentrated populations having an increased susceptibility to disease spread.
- Widespread diebacks of forests from drought and pests.

On the other hand, a more positive scenario is that climate reaches a new equilibrium, allowing a measure of adaptation and the opportunity to rapidly reduce the global environmental influence of human activities, namely fossil fuel combustion and deforestation.

Notes

[2] Note that this second scenario is not a worst-case scenario. A worst-case scenario would include large-scale, nonlinear disruptions in the climate system itself — slippage of ice sheets from Antarctica or Greenland, raising sea levels many meters; accelerated thawing of permafrost, with release of large quantities of methane; and shifts in ocean thermohaline circulation (the stabilizing ocean "conveyor belt").

[3] Note: The probability of such an extreme heatwave (six standard deviations from the norm) has increased between two and four times over the past century due to global warming (Allen & Lord, 2004; Stott et al., 2004).

6.5 Recommendations for adaption

Using Forecasting and Remote Sensing to Prepare for Early Warning Systems (EWEs) and Disease Outbreaks

Modeling can be a useful tool for predicting future events and playing out potential scenarios. With enough warning, model predictions can help in disaster preparedness and early mobilization of personnel and response units. Models can be used to help provide probabilities of where and which impacts may arise. With advanced warning of increased potential from flooding, for example, communities with inadequate hygiene and water facilities can be targeted before the onset of heavy rains for promotion of education and proper waste disposal, and provision of oral rehydration capacity (including clean water), to minimize the risks of cholera, dysentery, and other diarrheal diseases.

Remote sensing can be a powerful predictor of disease transmission in Africa. Remotely sensed images in seasonal climate can predict mosquito vector distribution patterns (Rogers et al., 2002) and RVF outbreaks (Anyamba et al., 2001). Normalized difference vegetation index (NDVI) – a “greening” index, indicative of recent rain, are helpful in predicting tsetse fly habitats in Southern Africa (Rogers & Randolph, 1991; Robinson et al., 1997). A positive NDVI in the preceding month is strongly and consistently correlated with malaria cases (Hay et al., 1998), and duration of the malarial transmission season can be predicted by counting the number of months in which NDVI exceeds a threshold of 0.35-0.4 (Rogers et al., 2002).

Health Early Warning Systems (HEWS)

Flood-related Ills	Measures
Cholera	1. Safe water supply. 2. Oral rehydration packets. 3. Oral and IV rehydration services. 4. Transport capacity. 5. Tertiary care as back-up for severe cases. 6. Training.
Malaria	1. Stock medications. 2. Stock insecticide-impregnated bednets. 3. Indoor residual and household spraying and other vector control measures. 4. Transport capacity.
Crop pests • Fungal diseases (eg., cassava root rot)	Food aid.
Other: • Snake bites	1. Precautions while farming. 2. Precautions for children. 3. Stocking anti-venom, antihistamines and corticosteroids.

Drought-related diseases	Measures
CHIK fever	1. Assure clean water supplies 2. Provide timely educational messages to communities (e.g., to cover outdoor water storage containers).
Bacterial Meningitis	Timely vaccination against this vaccine-preventable disease.
Cholera and other diarrheas	As above
• Cassava • cyanide neuropathy	1. Warnings regarding the preparation and consumption of cassava 2. Provision of alternative diversified nutritional sources.

Heavy rains following drought	Measures
Rodent population explosions • Plague • Arenaviruses (viral hemorrhagic fevers) • Crop losses	Stock antibiotics. Insecticides; followed by rodenticides. Household cats (rodent-predators).
Locust	Consume locust as protein source

Table 6.1: Health Early Warning Systems

Sea surface temperatures can also be used to predict RVF outbreaks (Anyamba et al., 2001), flood/drought events (Anyamba et al., 2001; Jury & Mwafulirwa, 2002; World Bank, 2003), and agricultural yields (Cane et al., 1994). These tools can be used to provide health and other government officials, health, hydrological and agricultural extension services, with adequate time for a coordinated response that minimizes the impacts on health and well-being.

Disseminating knowledge

Community-level knowledge and networks are crucial for reducing vulnerability and mitigating the impacts of flooding and drought. Another pilot project was started after the 2000/2001 floods to inform communities of flood mitigation activities (Lumbroso et al., 2008). Posters, flyers, and card games about living with floods were distributed to the communities of Carre, Languene, and Matidze to promote the practice of drinking safe water after floods and storage of seeds to plant new crops with minimal delay after floods. Water tanks that catch rainwater, a processing facility, and a seed storage facility were built in these communities.

Some community-level programs have been established to mitigate the effects of flood and drought years for the citizens and small farm owners. In Nwadjahane in Gaza Province, social networks including a service payment system and farming associations to trade agricultural knowledge and drought-resistant crops have provided a cushion for low yield drought years (Simms & Reid, 2005). Use of drought-tolerant crops and maintaining natural landscape diversity has spread (Tyndall, 2003; MICOA, 2003; Simms 2005). A pilot project in N'hambita community in Sofala Province was started in 2006 to pay farmers for producing carbon on their land and provide incentives for planting and maintaining trees and local crops (PlanVivo, 2006). Nurseries for local tree species and plants as well as livestock were provided to the community. These practices are estimated to reduce carbon emissions by 90 tons per hectare and up to 50,000 tons/year while promoting sustainable land use, slowing deforestation, preserving biodiversity, and building capacity for regional organizations.

Reducing vulnerability

The 2001 World Disasters Report identified four themes central to recovery from natural disasters. These include:

1. Investing in sustainable livelihoods to increase the speed of recovery and reduce vulnerability of the poor to disasters.

2. Plugging the spending leaks by maximizing local procurement to ensure that post-disaster resources re-circulate within the local economy rather than leak out.

3. Diversification of local economies to maximize employment to render the economy more disaster resilient.

4. Mitigation of the effects of globalization and of climate change, which are draining necessary resources to cope with and recover from disasters (IFRC & RCS, 2001).

Meeting the Millennium Development Goals – essential for adaptation – will require new sources of energy (Haines et al. 2007). Africa as a continent has huge potential for use of alternative energy sources. It is estimated that almost half of African countries can profitably produce hydropower, but only 7% of this potential is realized due to poor infrastructure and high initial costs (Kabbaj & Katseli, 2003). Over three-quarters of sub-Saharan Africans do not have access to electricity, and most rely on biomass such as firewood for lighting, cooking, and heating (Kabbaj & Katseli, 2003). 91% of the energy in Mozambique comes from fuelwood and charcoal (Simms & Reid, 2005), making deforestation and emissions a substantial problem. It is projected that an extra 76 million tonnes of carbon will be added to the atmosphere each year by 2015 if sub-Saharan Africa is to grow at the rate which is required to meet its Millennium Development Goals (growth of 7.1% per year) (Christian Aid 2006).

The potential exists though, for development of alternative energy sources to meet rising demand in Africa. Africa only contributes 1.3% to the world's installed solar energy facilities, and only 4 out of 53 countries have started exploring underground heat sources (Kabbaj & Katseli, 2003). Africa has an estimated 9,000 megawatts of geothermal power, with only 123 megawatts used today (Christian Aid 2006). Mozambique itself is rich with renewable energy sources – mountains in northern and eastern provinces for hydropower, and plentiful sunshine for photovoltaic cells, solar thermal stations with "power towers" for storage, and solar stoves (Simms & Reid, 2005). International donors and financial organizations can help Africa develop cleanly by investing in renewable energy instead of fossil fields, promoting access to these energy sources, remove obstacles to technology transfer, and adopt targets and timetables to achieve these objectives (WGCCD, 2005). Foreign investments would serve to increase development levels, contribute technological knowledge, and promote self-sufficiency.

Other adaptation measures in Mozambique include the rebuilding of port infrastructure on the coast and creation of corridors and railways to facilitate transport of goods and people (OECD, 2002; 2006). Projects underway in neighboring countries including Ethiopia, Kenya, and Zimbabwe include reforestation and reconstruction with local materials and labor (Simms & Reid, 2005).

Finally, micro-insurance schemes can be helpful in diminishing the risks from the EWEs associated with climate change. Both Swiss Re (with Oxfam America) and Munich Re, the two largest reinsurers in the world (insurers of insurers) are developing schemes to compensate populations for losses. The most sophisticated risk transfer instruments use weather parameters (i.e. precipitation values under or over certain location-specific norms) to trigger payment to those affected by droughts or heavy, crop-damaging rains. In the future such programs can be used more widely and added to development projects, programs and practices.

Table 6.2 summarizes the most prevalent health problems and adaptive measures in Mozambique by region.

Region	Weather extremes	Drought-prone	Most prevalent diseases	Diseases	Adaptive Measures
Coastal	Most cyclone-prone		Malaria	Cholera	Wetland, barrier island and coral reef preservation
Tete		Drought-prone	Malaria	Plague Trypanosomiasis	Population screening Tsetse fly control Stocking Medicines
North		Drought-prone pockets Zambezia (2009)	Malaria	Meningitis Konzo: Nampula, Zambezia & Cabo Delgado Acute poisoning in drought in other areas. Zambezia Plague	Community education Processing measures Food storage, supplies and supplements
Highlands			Malaria: prolonged season & increased. altitude possible		Increased awareness in naïve areas Insecticide – impregnated bednet and medicine distribution Vector control
Center	Flood-prone		Malaria	Cholera	Insecticide – impregnated bednet and medicine distribution Vector control
South	Floods	Drought	Malaria: prolonged season & increased. altitude possible	Cholera	Water chlorinization Clean water supplies Decentralized treatment centers Trained personnel

Table 6.2: Most Prevalent Health Problems and Adaptive Measures in Mozambique by Region.

6.6 Conclusions

The evolving climate is projected to take an enormous toll on African nations. The 2000 Mozambique floods, for example, were the worst in decades and resulted in loss of lives, crops, livestock, infrastructure and millions of livelihoods. Extreme weather events, such as drought, storms and floods, along with changing seasonality of vector-borne disease transmission will continue to expose the Mozambican people to new and potentially widespread risks. Climate change directly threatens the health, livelihoods and food security of the Mozambican people and the impacts of climate change on infrastructure and ecosystems may well have the most profound long-term impacts for the health and well-being of the Mozambican population.

In order to decrease the vulnerability to climate change efforts must be made towards building capacity and improving the resilience of communities.

Thus preparation for climate change to reduce the damages and vulnerabilities must include (expanded from Sasin 2008):

1. New water reservoirs.
2. Prevention of deforestation and reforestation.
3. Note: Importance of the proposed program for Reductions in Greenhouse Gas Emissions from Deforestation and Forest Degradation (REDD), will serve adaptation and climate stabilization.
4. Preservation of coastal marine habitat.
5. Clean distributed and centrally-generated energy systems[4].
6. Expansion of irrigation.
7. Drought and disease-resistant crops and diverse cropping systems.
8. Promotion of agricultural and non-agricultural employment.
9. Microcredit schemes.
10. Micro-insurance for agricultural and meteorological parameters.
11. Fine-scale mapping of areas at greatest risks of disasters.
12. Promotion of community land-use planning; increased weather–tracking and river monitoring stations.
13. Enhancement of Health and Agricultural Early Warning Systems and Disaster Management Information Systems.

Because of Mozambique's geographical location and recurrence of weather extremes in the Mozambique Channel, measures to adapt to a changing climate are needed to reduce the vulnerability of the population. As health and well-being is the final common pathway of social and environmental conditions, the adaptive measures must be comprehensive, including preparation for specific ills; anticipation of clusters of diseases following disasters; and provision of adequate infrastructure to reduce vulnerabilities. As energy infrastructure and availability of distributed energy systems are fundamental to development and adaptation (and climate mitigation), clean, reliable, resilient energy systems are necessary for reducing vulnerability and enhancing the capacity for preparedness, recovery and rebuilding (Epstein et al. 2008). Such a comprehensive approach to climate change adaptation will provide a more long-term, large-scale response to climate change in Mozambique, as compared to coping (Tyndall 2003).

Investments in energy, poverty reduction and improved standards of living can lessen the damages from a changing climate.

Notes

[4] Note: A resilient, robust energy systems serve adaptation and climate stabilization.

7

Socio economic and vulnerability analysis

7.1 Socio economic scenarios

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7.2 Vulnerability analysis

Dr. Anthony Patt, IIASA and Patrick Nussbaumer, IIASA

Climate change historical and baseline analysis

Dr. Marc Metzger, University of Edinburgh

	Executive Summary
7.1a	*Introduction to the INGC scenarios for Mozambique*
7.1b	*Drivers affecting vulnerability*
7.1c	*Extracting available scenario data*
7.1d	*Two narrative storylines for Mozambique to 2060*
7.1e	*Potential impacts and adaptation strategies*
7.1f	*Final conclusions*

INGC Scenarios – Executive Summary

Scenarios as a tool to address uncertainty
The main socio-economic drivers of environmental change are global in scope and are inherently unpredictable. Given such uncertainties, future social and environmental conditions can only be roughly approximated at regional and local scales. Scenarios, providing alternative images of how the future might unfold, can act as an integration tool in the assessment of future environmental and social changes in Mozambique. Scenarios are not predictions, but form a tool for imagining alternative worlds that could result given differences in a few key factors, e.g. the integration and stability of the global economy. Scenarios are designed to challenge our assumptions, focus on key uncertainties, understand cause-and-effect linkages, and test our strategies and plans.

INGC scenarios for Mozambique
For Mozambique, two explorative scenarios were developed, describing contrasting, hypothetical futures, spanning a range of plausible uncertainty in future development. The scenarios are consistent with the IPCC SRES scenarios for climate change, and the timescale has been set to 2060 to be consistent with the climate change modelling in the project. Given the constraints of the present project, existing regional and national scenarios were interpreted for two IPCC SRES storylines to provide mostly qualitative scenarios. Box 1 provides a summary of the two scenarios.

Box 1 Summary of the INGC scenarios

B1 – Global opportunities

Mozambique benefits greatly from the regional stability and the open global economy, attracting substantial foreign investment in agriculture, bio-energy crops, hydro power, tourism, and extraction and processing of natural resources. Stable government and effective governance help ensure that these investments result in growing employment opportunities, improved infrastructure and technological advance. The rapidly growing economy allows the government to make significant improvements in education and health and to invest in adaptation measures (e.g. coastal defences) to reduce vulnerability to hazards. The Mozambique economy moves from global position 157 in 2000 to 140 in 2060 with a GDP of 143 billion US$90. Nevertheless, its GDP per capita, even at US$90 4897, is still one of the lowest in the world.

A2 – Regional constraints

Mozambique is greatly constrained by the global economic developments and regional political instability. Foreign investment is limited due to reduced global trade, and remaining investment mainly tries to exploit and extract cheap natural resources. Regional and national political instability weaken Mozambique's business climate to foreign investors, enabling a limited number of countries to broker hard deals to exploit the country's rich resource base with few benefits for society. Nevertheless, the country is able to become self sufficient in energy supply, through collaboration with foreign investors. GDP rises slowly, there is little poverty reduction, and the government has insufficient funds to make significant investment to raise development standards or reduce vulnerability to natural hazards. The Mozambique economy drops from global position 157 in 2000 to 162 in 2060 with a GDP of 9.3 billion US$90. Its GDP per capita, at US$90 222, remains one of the lowest in the world.

Adaptation under the two scenarios

The vulnerability of Mozambique is determined by the impacts that could potentially affect the population, and the capabilities of the country to adapt to the impacts. The ability to adapt to climate change impacts differs considerably between the tow scenarios. Strong economic growth, rapid global transfer of new technologies and increased human capital causes a rapid rise in adaptive capacity in the B1 – Global opportunity scenario. Conversely, under the A2-Regional constraints scenario adaptive capacity rises slowly in the, due to limited economic power, slow technology transfer and political lower human capital.

Detailed discussion on specific adaptation measures are outside the scope of the scenarios. It is nevertheless relevant to explore differences in adaptation strategies between the two scenarios, based on the four priorities identified by the National Action Plan for Adaptation to Climate Change (NAPA), as summarised in Table 7.1. Under the B1 scenario, with greater adaptive capacity and stronger government more adaptation measures will be implemented. However, adaptation measures to reduce coastal impacts and water management are very costly and may not be completely successful.

NAPA actions		B1 Global Opportunities	A2 Regional Constraints
Early warning systems	• relatively cheap • top-down implementation	√ √ √	√ √
Strengthen agriculture	• costly • bottom-up implementation	√ √ √	√
Reduce coastal impacts	• very costly • top-down implementation	√ √	-
Improve water management	• very costly • top-down and bottom-up implementation	√ √	-

Table 7.1 √ √ √ successful implementation; √ √ largely successful implementation; √ partly successful implementation; – not implemented at all.

Conclusions for the scenarios

The two scenarios provide extremes for the socio-economic development of Mozambique in the coming 50 years. The storylines show how Mozambique can benefit in a globalised world, attracting sustainable investment in its natural resources while at the same time working on developing its own development levels and human capital. However, there is a serious risk that foreign investors merely exploit Mozambique's resources, without providing any benefits for society.

Despite great differences between the two socio-economic futures, it is also apparent that there are a number of consistent trends between both scenarios. These include the decline of agriculture in the South, negative externalities of agricultural expansion and intensification, the vulnerable coastal zone and rapid urbanisation and population growth. Coping with these issues will require government commitment and long term strategies.

The main differences between the two storylines are in exogenous global developments in the economy and in global and regional stability. Mozambique has little influence on these matters, and these factors will, in part, determine whether the country will experience rapid development or relative stagnation. It is however important to realise that there are also many endogenous drivers that can be influenced by government policy including:

- ensuring stable governance
- working towards regional stability, e.g. through trade agreements
- developing and sticking to long term development strategies
- ensuring a competitive business climate
- ensuring foreign investment are sustainable and benefit society
- ensuring public investments are climate proof

By acting on these issues now, Mozambique can set itself on a development trajectory that can raise development levels dramatically over the next 50 years.

7.1a Introduction to the INGC scenarios for Mozambique

The vulnerability of the people of Mozambique to environmental change in the coming decades is the result of complex, dynamic processes which are determined by a range of driving forces, including demographic, socio-economic, technological and environmental change. As a result, future evolution of vulnerability in Mozambique is highly uncertain. There is nevertheless an urgent need to know: what are the major trends and driving forces affecting Mozambique? Which of these processes are amenable to change through national policies and governance? How might INGC strategies be adapted in the future to take account of these processes? The INGC scenarios will help to answer these questions through explorations using different foresight analysis techniques.

The main socio-economic drivers of environmental change are global in scope and are inherently unpredictable. Given such uncertainties, future social and environmental conditions can only be roughly approximated at regional and local scales. Scenarios, providing alternative images of how the future might unfold, can act as an integration tool in the assessment of future environmental and social changes in Mozambique. Scenarios are not predictions, but form a tool for imagining alternative worlds that could result given differences in a few key factors, e.g. the integration and stability of the global economy. Scenarios are designed to challenge our assumptions, focus on key uncertainties, understand cause-and-effect linkages, and test our strategies and plans. Normative scenarios describe desired futures and discuss the required policy actions to reach this goal, while explorative scenarios describe contrasting, hypothetical futures, spanning a range of plausible uncertainty in future development.

Over the last decade a large number of studies have developed scenarios to explore potential future changes at global and regional level. For Mozambique, the Agenda 2025 study (Committee of Councilors, 2003) forms an important scenario exercise, identifying the most desired future for 2025. Annex VIII gives an overview of existing scenarios studies and objectives and characteristics. The present study will build on the scenario framework developed by the Intergovernmental Panel on Climate Change (IPCC) in the Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000). The Millennium Ecosystem Assessment scenarios (Reid et al., 2005), which focus specifically on human well-being, will provide the background for more detailed interpretations. While some important drivers are available at the national level, or even at a spatial grid, other relevant drivers will be interpreted for Mozambique, following both qualitative and quantitative approaches developed in previous studies (e.g. Rounsevell et al., 2006).

The present study will focus on Mozambique as a country, with specific attention to sub-regions with similar social and biophysical characteristics (Annex IX). The timescale has been set at 2060, and two IPCC SRES scenarios (A2 and B1) were selected to represent possible variation in future changes.

The construction of the scenarios consists of the following steps:

1) Identifying the most relevant drivers affecting the vulnerability of the people in Mozambique and obtaining data for the current state past trends of the drivers

2) Extracting available scenario data, trends and storylines from previous studies

3) Developing semi-quantitative narrative storylines for Mozambique

4) Interpreting modelled impacts and adaptation strategies within the scenario context

7.1b Drivers affecting vulnerability

Identifying drivers

Understanding the factors that cause changes in vulnerability is essential to increase adaptive capacity and to develop strategies to cope with future disasters. The Millennium Ecosystem Assessment (MA) typology for drivers (MA, 2003) forms a suitable framework for structuring drivers (Box 2). Most of the drivers affecting the inherent vulnerability of Mozambique can be considered indirect drivers.

Box 2 Millennium Ecosystem Assessment definitions of typology of drivers (MA, 2003)

Driver: Any natural or human-induced factor that directly or indirectly causes a change in [vulnerability].

Indirect driver: A driver that operates more diffusely, often by altering one or more direct drivers, and its influence is established by understanding its effect on direct drivers.

Direct driver: A driver that unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy.

Endogenous driver: A driver whose magnitude can be influenced by decision-makers.

Exogenous driver: A driver that cannot be altered by decision-makers

The endogenous or exogenous characteristic of a driver depends on the organizational scale. Drivers can be exogenous at one level (a farmer) but endogenous at other levels (the nation-state).

Although the literature identifies a range of generally applicable indicators (e.g. Brooks et al., 2005; Vincent (2004); UNDP (2004)), it is important to identify the most relevant drivers affecting the vulnerability of the people of Mozambique. Local experts in the fields of agronomy, hydrology, sustainable development and hazard relief were therefore consulted to identify drivers, which were then structured following the terminology developed of the MA (Box 2). Altogether, five sets of drivers were distinguished: demographic and societal drivers, economic drivers, socio-political drivers, scientific and technology drivers and environmental drivers, presented in Table 7.2.

The present study focuses on Mozambique as a country. Endogenous drivers are therefore the drivers that can be influenced by intervention of the Mozambique government. A separate column in Table 7.2 indicate which drivers are largely endogenous, as well as providing a qualitative measure on the level of potential influence by the government. While many drivers are potentially endogenous, the level of influence may be limited due to constraint, e.g. in resources.

Drivers	Policy influence	Government action that can influence these drivers
Demographic and societal drivers		
life expectancy	M	Investment in healthcare, vaccination, education and economic development
population growth	L	Difficult to regulate, depends largely on economy and culture. Improve education especially for women
urbanisation	M	Improve infrastructure and services in rural areas
household size and structure	L	Difficult to regulate, depends largely on economy and culture
poverty	M	Attract foreign investment, create jobs, improve education
income inequality	M	Difficult to regulate, although higher income tax and minimum wage could be raised
self sufficiency	H	Support improvements in agricultural technology, create food reserves to buffer impacts of disasters, develop trade strategies
access to education	H	Improve access and promote participation
advancement of women	H	Dependant on economy and employment possibilities and gender policies
access to health and medical services	H	Invest in healthcare and infrastructure and vaccination
HIV/Aids	M	Improve education, improve healthcare
water borne disease (malaria, cholera, diarrhoea)	H	Invest in sanitation and infrastructure
Economic drivers		
economic growth	H	Create stable investment climate and appropriate financial structures; however also dependant on global markets
investment in road infrastructure	H	Stimulate private investments where possible, otherwise public investment
internet access and mobile phone coverage (ICT)	H	Stimulate private investments where possible, otherwise public investment
scientific and technology development	M	Stimulate private investments where possible, otherwise public investment in education, universities and research institutes and promote international technological cooperation
agriculture innovation and productivity	H	Public investment, but dependant on uptake and costs of inputs, availability of insurance, etc.
energy imports	H	Promote sustainable energy production (hydro and bio), create investment market for gas and coal resources
access to electricity	H	Stimulate private investments where possible, otherwise public investment
trade balance	M	Reduce dependency on fuel imports; stimulate export through foreign investments

Drivers	Policy influence	Government action that can influence these drivers
Sociopolitical drivers		
strength of national government	M	Transparent and effective policies reading to reduction of poverty.
political stability	H	Promote a peace culture and regional cooperation and integration
public safety	M	Reduce poverty and promote effective law enforcement, fighting corruption and organized crime.
control of corruption	M	Transparent use of the public funds and governance and promote ethical values and culture.
Physical, biological and chemical drivers		
damage by droughts	H	Effective early warning systems, preventive, mitigations and adaptation measures
damage by cyclones	H	Effective early warning systems, preventive, mitigations and adaptation measures
damage by river flooding	M	Effective early warning systems, preventive, mitigations and adaptation measures
damage by coastal erosion	M	Effective early warning systems, preventive, mitigations and adaptation measures.
damage by wild fires	M	Education and promotion of sustainable and less risky practices.

Table 7.2: List of important drivers affecting the vulnerability, and an indication how policy could influence these drivers.

Low (L) Nearly impossible to influence, dependant on wider trends of robust systems

Medium (M) Can be influence in the long term, but requires patience and very high levels of investment

High (H) Could be influenced in the intermediate term when efforts are well targeted.

Extracting baseline and trend data for the drivers

Data about the current state and recent trends of the drivers listed in Table 7.2 have been extracted from a range of data sources. In some cases, only national data was available. Where regional data could be obtained, indictors were summarised for different zones, as explained in Annex VIII.

Some examples of these analyses are given below. The full analysis of historic trends and the baseline is presented in a separate project report, while national values are reported in Table 7.6.

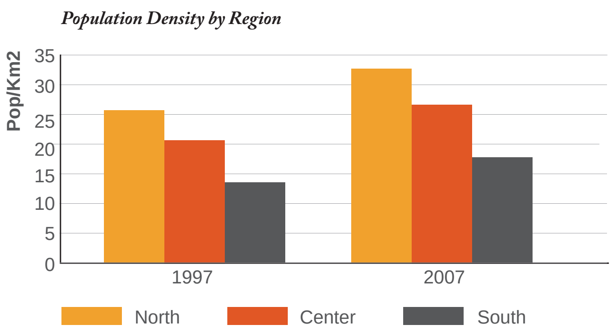


Figure 7.1: Population density by region
Source: INE – Dados Prliminares do Censo 2007.

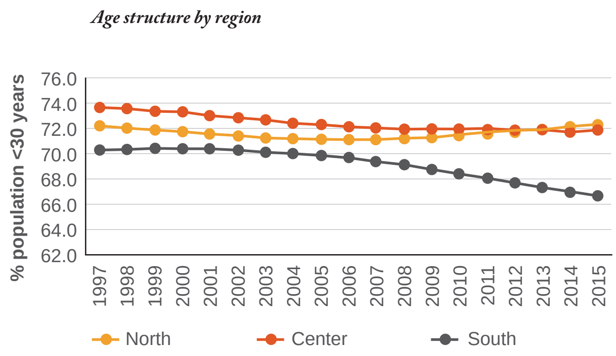


Figure 7.2: Age structure by region *Source: INE, 2004 – Projecções Demográficas 1997-2015. Projections based on the 1997 census.*

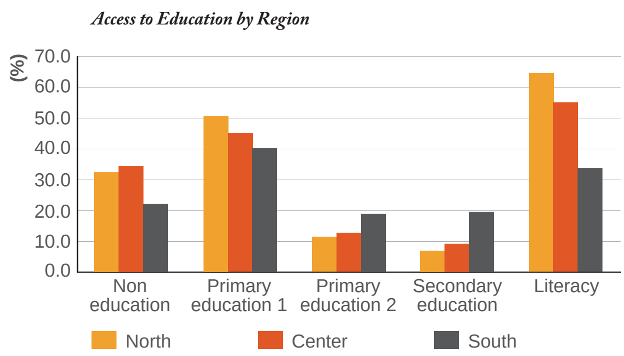
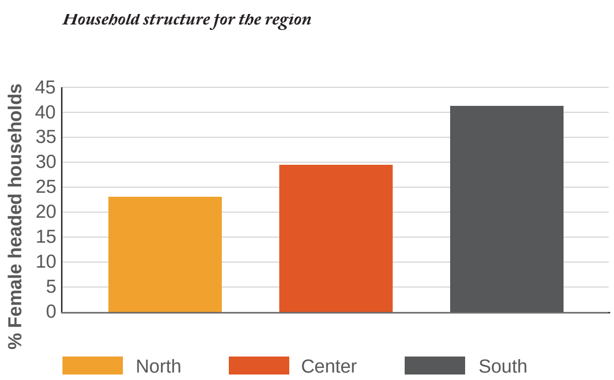


Figure 7.3: Access to Education by region *Source:INE, 2003 – Questionário de Indicadores Básicos de Bem-Estar (QUIBB).*



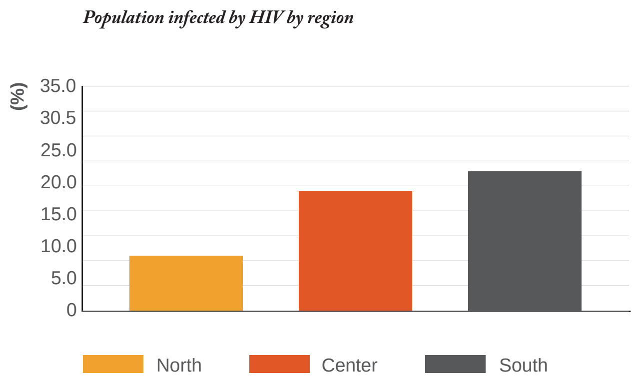


Figure 7.4: Household structure for the region. ***Source:INE, 2001 – Questionário de Indicadores Básicos de Bem-Estar (QUIBB).***

Figure 7.5: Population affected by HIV by region. ***Source: AIM-DISPLAY, 2007 – Impacto Demográfico do HIV/SIDA em Moçambique.***

Agro ecologies Zone	Name	Rainfall (mm/year)	Temperature (ºC)	Soil types and Fertility		Hazards/Stress factors	Irrigation	Most important crops
Inland South	Semi-arid to arid Interior South	400-600	> 24	Sands to Loamy-clays	Inland sandy plain leached and low fertility; Mananga soils moderately fertile;	Land subject to moderate to high drought risk; moderate erosion; land with alkaline soils (saline and sodic deposits);		
Floodplain South	Semi-arid and Coastal	600-1000	26 – 28	Vertisols and fluvisols	Moderately to high fertile soils;	Land subject to moderate to high drought risk; land subject to irregular flooding, and occasional deep devastating flooding; potential saline hazard;	74.861,9 ha equipped; only 22.968 ha operational;	Cassava, maize, groundnuts, rice and sugar cane
Coastal South	Semi-arid Coastal South	500-600	17.5 – 25	Deep Sands	Low fertility	Floods, droughts, cyclones, and wind erosion.	885 ha equipped; only 177 ha operational	
Inland Central	Mid-elevation Central	1000-1400	22 – 24	Sands and Clays	Low to moderately fertile soils;	Slightly stony/or rocky land; slight drought risks; moderate erosion;	3.460,5 ha equipped; 1.039,2 ha operational;	
Coastal Central	Coastal Central	1000-1400	> 24	Vertisols and fluvisols	Moderately to high fertile soils;	Land subject to occasional seasonal flooding/inundation; land with poorly drained soils; minor to moderate wind erosion; cyclones; potential salinization of soils;		Cassava, maize, rice, sorghum, and sugar cane
Floodplain Central	Dry Semi-arid Zambézia and Tete	500-800	> 25	Sands-clays	High fertility;	Land subject to moderate drought risk; land with poorly drained soils; subject to frequent irregular flooding, with occasional deep devastating flooding; cyclones prone.	35.160 ha equipped; 14.646 ha operational;	
Inland Northern	Interior Central and North	1000-1400	20 – 25	Sands-clays	Low to moderately fertile soils;	Moderate to strong erosion; stony/or rocky land;	2.451,5 ha equipped; 261,5 ha operational;	Cassava, maize, groundnut, sorghum, rice and cotton
Coastal North	Coastal North	800-1200	> 25	Mostly sands, clays on a small scale	Low to moderately fertile soils;	Minor to moderate wind erosion; moderate drought risk; cyclones prone;	900 ha equipped; 365 ha operational;	Cassava, maize, rice and groundnuts

Table 7.3: Agro-ecological characteristics of the different zones. ***Source: Modified after INIA (1996) and Walker et al. (2006)***

7.1c Extracting available scenario data

Quantitative data from existing modelling studies

As mentioned in the introduction, the present study is based on the IPCC SRES scenario framework (Nakicenovic et al., 2000), which is one of the most widely used frameworks used in regional environmental impact assessments (e.g. Schröter et al., 2005). SRES consists of a comprehensive set of narratives that define the local, regional and global socioeconomic driving forces of environmental change (e.g. demography, economy, technology, energy and agriculture). The SRES storylines were structured in four major 'families' labelled A1, A2, B1 and B2, each emphasising a largely different set of social and economic development pathways, organised along two axes. The vertical axis represents a distinction between (A) more economically and (B) more environmentally and equity orientated futures. The horizontal axis represents the range between (1) more globalisation and (2) more regionally oriented developments.

Two contrasting scenarios, A2 (regional-economic) and B1 (global-sustainable), were selected for the present study. Box 2 gives an overview of these scenarios, based on the global descriptions in SRES. While climate change exposure will be similar for up to 2060 for both scenarios, the global socio-economic developments are very different. As such, they form two opposite plausible development trajectories for Mozambique in coming decades.

The descriptions in Box 3 provides the summary of the global picture, which formed the basis for the model runs providing regional figures for the original SRES. At present, the most comprehensive regional interpretations of the SRES storylines are provided by International Institute for Applied Systems Analysis (IIASA) Greenhouse Gas Initiative (GGI)[1] (Grubler et al., 2007). A suite of disciplinary models operating at different spatial resolutions were interlinked and integrated into an overall assessment framework, providing indicators for Sub-Saharan Africa, individual countries as well as coarse spatial information for GDP and population.

A second available source of scenario data is the integrated assessment model IMAGE (IMAGE team, 2001). IMAGE was developed over the last 15 years and has been used extensively to explore potential impacts of global change at the global level, i.e. for the IPCC and the MA. IMAGE provides indicators for 17 world regions, including Sub-Saharan Africa. Relevant indicators for the present study include those on agricultural production and demand, caloric intake and diet, and bio-energy crop area.

A summary of the data extracted from GGI and IMAGE are presented in Table 7.3, and Figures 7.1-7.9. Until approximately 2030 there is great similarity between the scenarios in demographic development, showing a rapid growth in the total population and very rapid urbanisation. Economically, Mozambique benefits far more from the B1 scenario, with access to global markets and sustainable foreign investment, resulting in food self-sufficiency by 2030. Both the total Gross Domestic Product (GDP) and GDP per capita rise fast, and by 2030 begin to affect demographic development, dampening both population growth and urbanisation. Conversely, in the A2 scenario, economic development remains low and the population, completely concentrated in urban centres, continues to grow rapidly until the end of the century.

These data, along with the climate projections, form the boundary condition for interpreting future trends in the indicators listed in Table 7.2, and developing qualitative narrative storylines, described in the next section.

Note

[1] Available at: http://www.iiasa.ac.at/Research/GGI/DB/

Box 3: Short description of the global SRES A2 and B1 scenarios, based on (Nakicenovic et al., 2000).

A2 – Regional Economic	B1 – Global Sustainable
Principles The A2 future represents a differentiated world, characterized low trade flows, relatively slow capital stock turnover, and slow technological change. The world "consolidates" into a series of economic regions. There is strong emphasis on self-reliance in terms of resources and less emphasis on economic, social, and cultural interactions.	**Principles** The B1 future represents a world with a high level of environmental and social consciousness combined with a globally coherent approach to a more sustainable development. Governments, businesses, the media, and the public pay increased attention to the environmental and social aspects of development.
Economy Economic development is uneven and the income gap between now-industrialized and developing parts of the world does not narrow. Global average per capita income in is low, reaching about US$7200 by 2050. By 2100 the global GDP reaches about US$250 trillion.	**Economy** Economic development is balanced, and efforts to achieve equitable global income distribution are effective. Global average per capita income in is high, reaching about US$13,000 by 2050. By 2100 the global GDP reaches about US$350 trillion.
Population Fertility rates decline relatively slowly, due to the emphasis on family and community life, resulting in a global population of 15 billion by 2100.	**Population** A demographic transition to low mortality and fertility occurs, motivated partly by social and environmental concerns. Global population reaches 9 billion by 2050 and the declines to about 7 billion by 2100.
International The A2 world has little international cooperation. People, ideas, and capital are less mobile so that technology diffuses slowly.	**International** The B1 world has strong international cooperation. People, ideas, and capital are mobile so that technology diffuses rapidly.
Governance Social and political structures diversify; some regions move toward stronger welfare systems and reduced income inequality, while others move toward “leaner” government and more heterogeneous income distributions.	**Governance** A strong welfare net prevents social exclusion on the basis of poverty. However, counter-currents may develop and in some places people may not conform to the main social and environmental intentions of the mainstream in this scenario family.
Technology Technological change is heterogeneous, as industry adjusts to local resource endowments, culture, and education levels. With substantial food requirements, agricultural productivity is one of the main focus areas for research and development. Initial high levels of soil erosion and water pollution are eventually eased through the local development of more sustainable high-yield agriculture.	**Technology** Technological change plays an important role. Research and development is enhanced and devoted to increase resource efficiency. A combination of technical and organizational change yields high levels of material and energy saving, as well as reductions in pollution. Labour productivity also improves as a by-product of these efforts.
Energy Regions with abundant energy and mineral resources evolve more resource-intensive economies, while those poor in resources place a very high priority on minimizing import dependence through technological innovation to improve resource efficiency and make use of substitute inputs. The fuel mix in different regions is determined primarily by resource availability. High-income but resource-poor regions shift toward advanced post-fossil technologies (renewables or nuclear), while low-income resource-rich regions generally rely on older fossil technologies.	**Energy** The B1 storyline sees a relatively smooth transition to alternative energy systems as conventional oil and gas resources decline. There is extensive use of conventional and unconventional gas as the cleanest fossil resource during the transition, but the major push is toward post-fossil technologies, driven in large part by environmental concerns.
Environment Although attention is given to potential local and regional environmental damage, it is not uniform across regions. Global environmental concerns are relatively weak, although attempts are made to bring regional and local pollution under control and to maintain environmental amenities.	**Environment** Environmental quality is high, as most potentially negative environmental aspects of rapid development are anticipated and effectively dealt with locally, nationally, and internationally. Land use is managed carefully to counteract the impacts of activities potentially damaging to the environment. Strong incentives for low-input, low-impact agriculture, along with maintenance of large areas of wilderness, contribute to high food prices and relatively low level of meat consumption. These proactive local and regional environmental measures and policies also lead to relatively low GHG emissions, even in the absence of explicit interventions to mitigate climate change.

	Sub Sahara Africa		Mozambique	
Demographic and social drivers	**A2 Regional Economic**	**B1 Global Sustainable**	**A2 Regional Economic**	**B1 Global Sustainable**
Population growth Fig. 6 Source: GGI	Rapid and steady rise 2000: 100% 2030: 205% 2060: 335% throughout the 21st century.	Rapid rise until 2030, then levelling off from 2050. 2000: 100% 2030: 200% 2060: 245%	Steady rise throughout the 21st century. 2000: 100%, 17.6 million 2030: 170%, 29.6 million 2060: 240%, 35.3 million	Slow rise until 2030, then levelling off and even slightly decreasing after 2060 2000: 100%, 17.6 million 2030: 160%, 28.3 million 2060: 165%, 29.3 million
Urbanisation Fig. 7 Source: GGI	Very rapid urbanisation 2000: 34% 2030: 51% 2060: 68%	Rapid urbanisation trend slows and levels off by end of century. 2000: 34% 2030: 49% 2060 :61%	Very rapid urbanisation. 2000: 30%, 5.6 million urban 2030: 60%, 18.0 million urban 2060 : 85%, 41.9 million urban	Rapid urbanisation trend slows by 2030 and inverses from 2050. 2000: 30%, 5.6 million urban 2030: 55%, 16.2 million urban 2060 : 65%, 18.8 million urban
Urban – rural distribution of wealth Fig. 8 Source: GGI	Not available	Not available	There is no economic growth in rural regions and their contribution to the global economy therefore decreases rapidly: 2000: 50%, 0.9 billion US$90 2030: 25%, 0.9 billion US$90 2060: 10%, 1.0 billion US$90	There is strong economic growth, also in rural regions. Nevertheless the contribution of the rural economy to the total economy decreases, to a stable level: 2000: 50%, 0.9 billion US$90 2030: 30%, 3.8 billion US$90 2060: 30%, 41.2 billion US$90
Caloric intake Fig. 9 Source: IMAGE	Slight increase in daily caloric demand, mainly due to a large increase in consumption of animal products. 2000: 100%, 2184 kcal total 2030: 103%, 2254 kcal total 2060: 108%, 2352 kcal total 2000: 100%, 191 kcal animal 2030: 150%, 284 kcal animal 2060: 220%, 424 kcal animal	Small increase in daily caloric demand due to a very large increase in consumption of animal products 2000: 100%, 2184 kcal total 2030: 109%, 2378 kcal total 2060: 122%, 2655 kcal total 2000: 100%, 191 kcal animal 2030: 210%, 400 kcal animal 2060: 375%, 723 kcal animal	Not available	Not available
Food security Fig. 10	The region is just about self-sufficient in most crops, though it cannot meet demand for tropical cereals.	By 2020 the region is self-sufficient, and becomes a strong exporter of all major crops.	Not available	Not available

(Table 7.4 continued)

	Sub Sahara Africa		Mozambique	
Economic drivers	**A2 Regional Economic**	**B1 Global Sustainable**	**A2 Regional Economic**	**B1 Global Sustainable**
Economic growth Fig. 11 Source: GGI	Moderate economic growth, but above global average. Average annual growth 2000-2030: 3.6% 2030-2060: 4.3% Compared to global average: 2000-2030: 2.7%, 2030-2060: 2.2%. GDP at MER: 2000: 330 billion US$90 2030: 950 billion US$90 2060: 3560 billion US$90	GDP rises very fast, much faster than global average. Average annual growth 2000-2030: 5.5% 2030-2060: 7.0% Compared to global average 2000-2030: 3.4% 2030-2060: 2.8%. GDP at MER 2000: 330 billion US$90 2030:1650 billion US$90 2060:14720 billion US$90	GDP rises moderately, below SSA average. Position of economy in the world (185 nations) drops from place 157 in 2000 to 162 in 2030 and 160 in 2060. Average annual growth 2000-2030: 2.3% 2030-2060: 3.3% GDP at MER 2000: 1.7 billion US$90 2030: 3.4 billion US$90 2060: 9.3 billion US$90	GDP rises very fast, much faster than SSA average. Position of economy in the world (185 nations) rises from place 157 in 2000 to 140 in 2030 and 112 in 2060. Average annual growth 2000-2030: 6.8% 2030-2060: 7.8%. GDP at MER 2000: 1.7 billion US$90 2030:12.4 billion US$90 2060:143.3 billion US$90
Wealth per capita Fig. 12 Source: GGI	GDP per capita rises moderately fast. Average annual growth 2000-2030: 1.1% 2030-2060: 2.7% Compared to global average 2000-2030: 1.5% 2030-2060: 1.5%. GDP per capita at MER: 2000: $540 2030: $760 2060: $1730	GDP per capita rises fast. Average annual growth 2000-2030: 3.2% 2030-2060: 6.4% Compared to global average 2000-2030: 2.3% 2030-2060: 2.6%. GDP per capita at MER: 2000: $540 2030: $1370 2060: $9800	GDP per capita rises slowly and Mozambique remains the second lowest of the world until 2060 when it reaches the third lowest position. Average annual growth 2000-2030: 0.6% 2030-2060: 2.1% GDP per capita at MER: 2000: $98 2030: $116 2060: $222	GDP per capita grows extremely fast. In world ranking (185 nations) Mozambique goes from position 184 in 2000, to 183 in 2030 and 180 in 2060. Average annual growth 2000-2030: 5.1% 2030-2060: 7.7%. GDP per capita at MER: 2000: $98 2030: $439 2060: $4897
Bio-energy demand Fig. 13 Source: IMAGE	Bio-energy crops only slowly begin to play a role after 2040. Sugar cane is the least important crop.	Bio-energy crops begin to play a role in 2030, and their importance grows rapidly. Until 2060 all bio-energy crops appear to have equal importance.	Not available	Not available
Agricultural export Fig. 14 Source: IMAGE	Maize is the only major export crop, showing a continual rise.	Export of agricultural products grows considerably. By 2030 all crop groups show a net export.	Not available	Not available

Table 7.4: Summary of exiting modelled outputs for the SRES A2 and B1 scenarios from the GGI (Grubler et al., 2007) and IMAGE (IMAGE team, 2001) models. All economic values are expressed in US$ at 1990 (US$90) value at Market Exchange Rate (MER). ***Source: IMAGE***

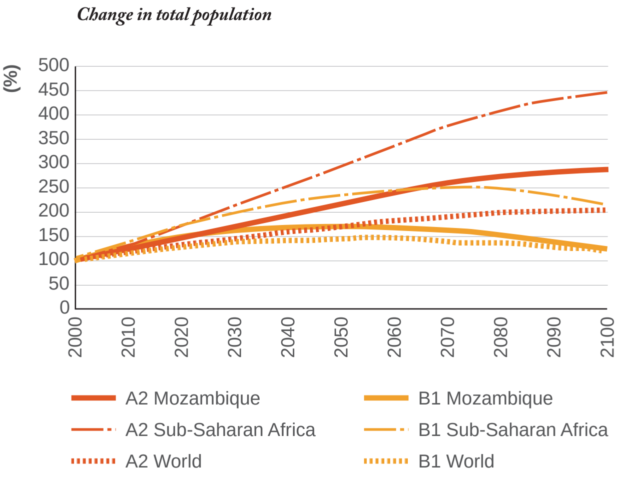


Figure 7.6: Changes in total population.

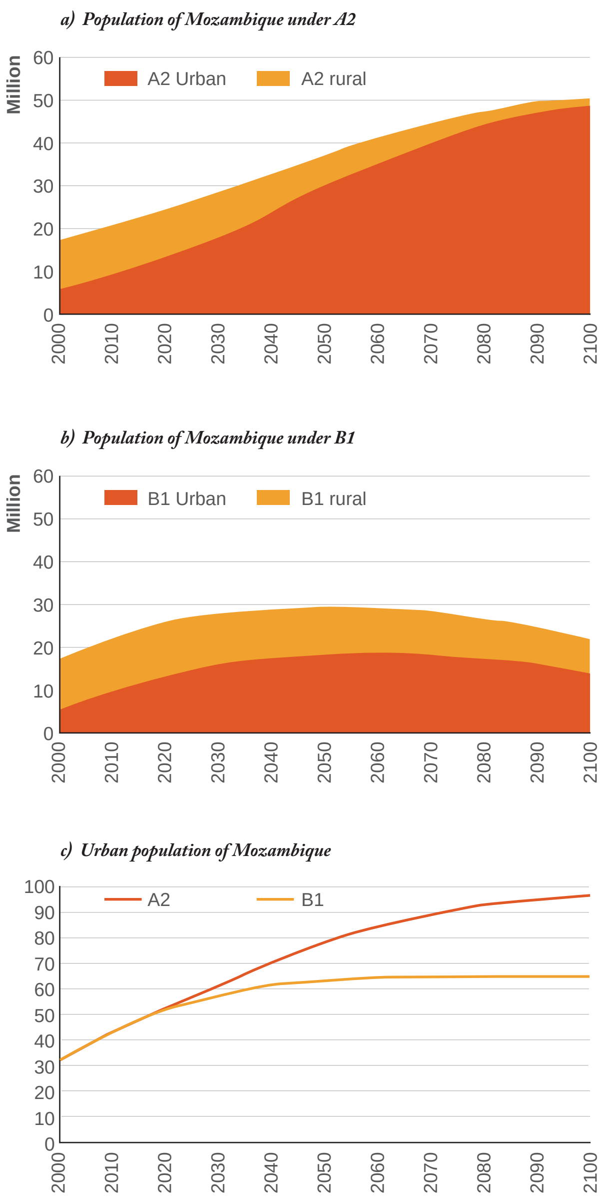


Figure 7.7: Population under a) A2, b) B1 c) urban.

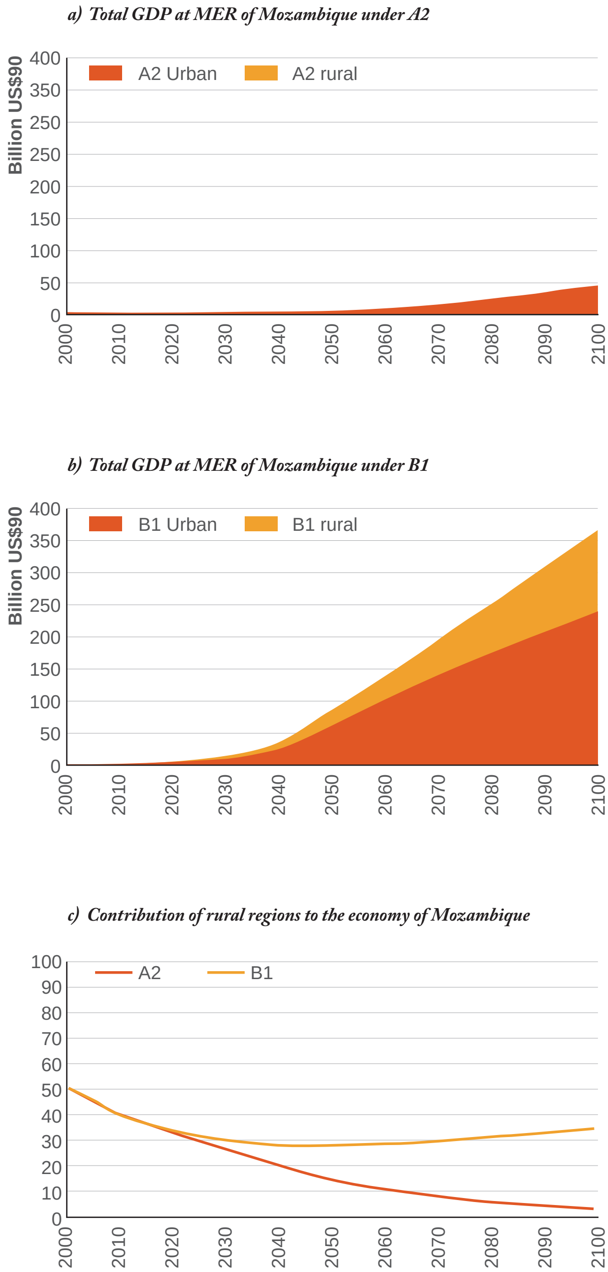
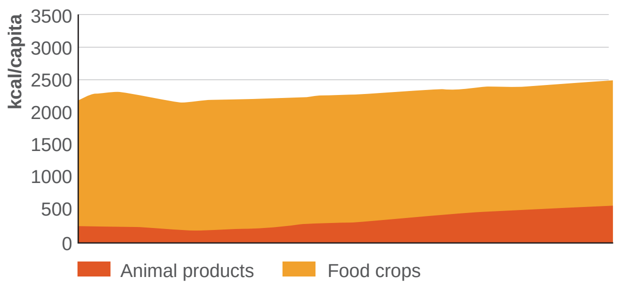
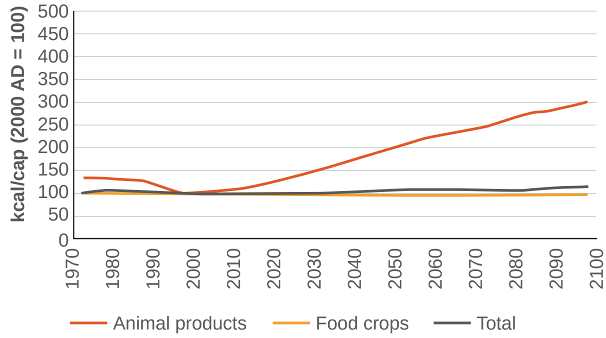


Figure 7.8: Total GDP at MER under a) A2, b) B1, c) rural.

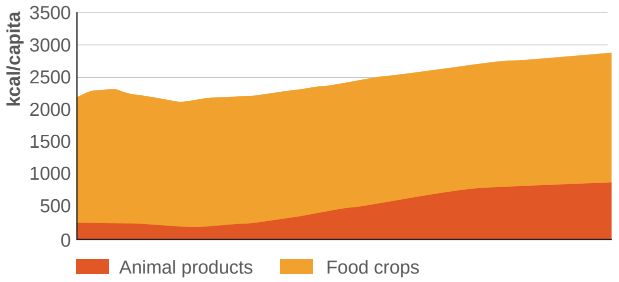
a) Daily calorific demand A2



b) Change in daily calorific demand A2



c) Daily calorific demand B1



d) Change in daily calorific demand B1

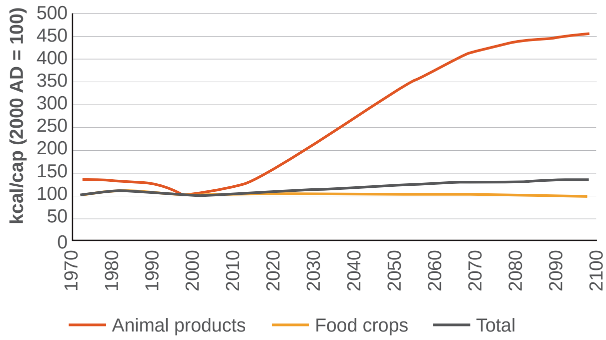
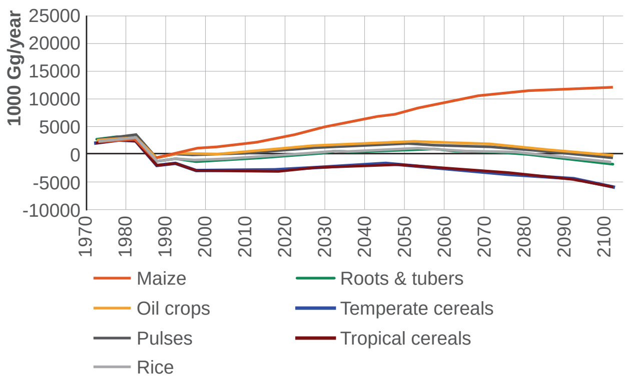


Figure 7.9: Daily calorific demand and change in daily calorific demand under a) A2 and b) B1.

a) Export (+) and import (-) of food crops A2



b) Export (+) and import (-) of food crops B1

Figure 7.10: Export and import of food crops under a) A2 and b) B1.

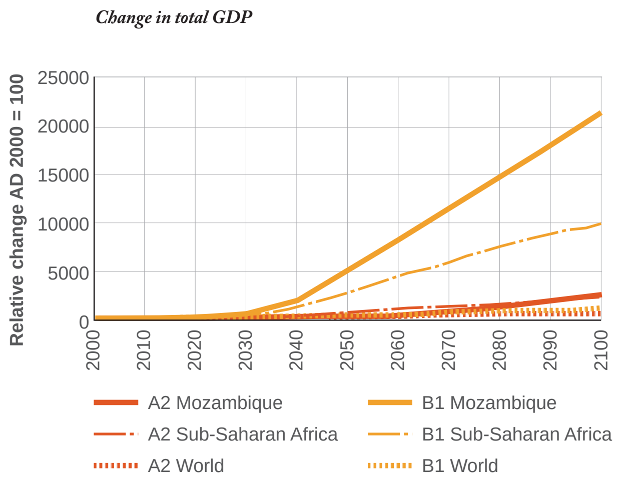


Figure 7.11: Change in total GDP.

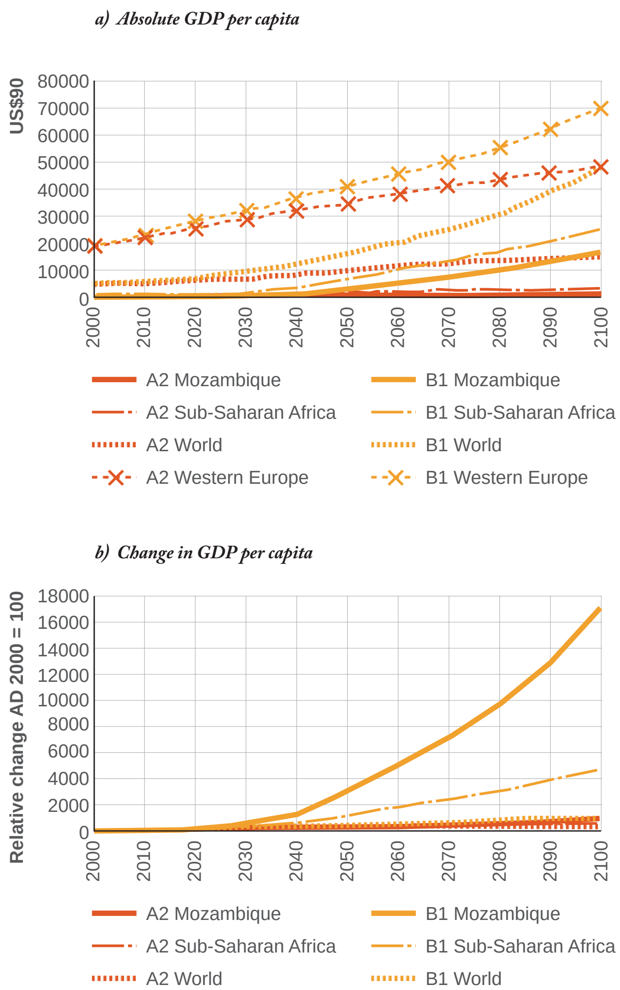


Figure 7.12: a) absolute GDP per capita, b) Change in GDP per capita.

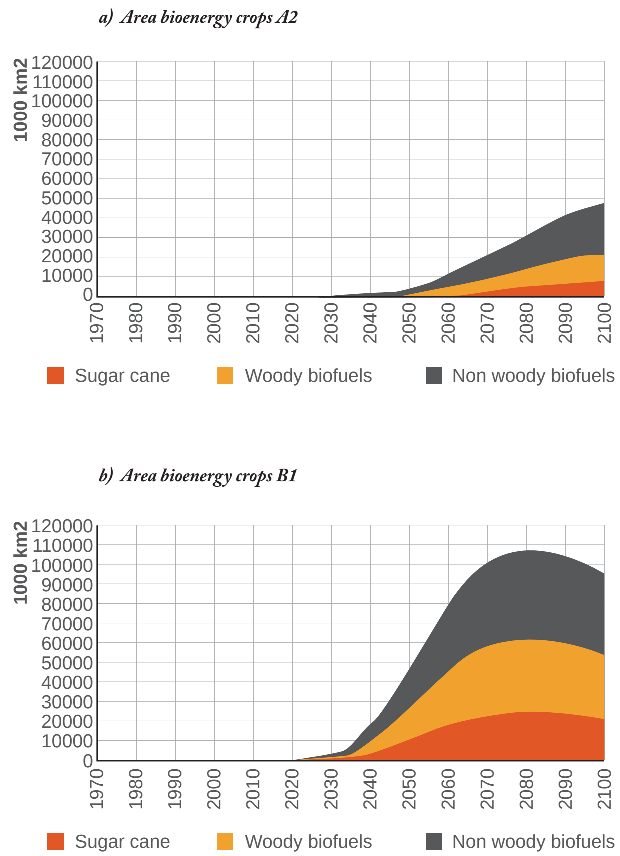


Figure 7.13: Area of bioenergy crops under a) A2, b) B1.

Qualitative global and regional scenario context

B1 – Global opportunities

Global context

Based on the IPCC SRES B1 assumption and the MA Global Orchestration scenario (MA, 2005). Because SRES B1 emphasises the importance of technological change, some aspects of the MA Technogarden scenario are also used.

This scenario describes a world of global cooperation, not only to improve the social and economic well-being of all people, but also to protect and enhance global public goods and services (e.g. public education, health, and infrastructure). There is a focus on the individual rather than the state, the inclusion of all impacts of development in markets (internalization of externalities), and use of regulation only where appropriate. Trade barriers such as tariffs and subsidies are abandoned by developed countries (e.g. the European Union and the US), allowing developing countries full access to global markets. Technological advances in agriculture lead to significant increases in productivity in all regions, through improved management systems and crops varieties. Environmental problems and disasters are prevented or resolved through global mitigation and coordinated intervention.

2000-2015
- There is growing awareness of the global interconnectedness of social, economic and environmental problems
- World leaders realize they must accept responsibility along with the benefits of a globalised world
- Developed countries gradually remove trade, allowing developing countries access to global markets

2015-2030
- Growing global governance is leading to higher standards for health, business practices, distribution and management of food and fuel
- There are rapid advances in technology, especially in agriculture and energy generation, especially in developing countries, who have invested in new technologies and infrastructure
- Most regions outside the western world experience considerable expansion and intensification of agriculture.
- Significant foreign and multinational investment in agriculture, including patents for technologies and crops

2030-2060
- Population growth levels off, mostly due to economic growth in developing countries
- Technological advances lead to low cost energy for all people
- Wealth leads to a strong increase in meat demand, leading to further expansion of agriculture and associated deforestation.

Regional context

Based on the SafMA African Partnership scenario (Scholes and Biggs, 2004).

Within a world of global cooperation, regional collaboration is successful and lead to improvements in governance and security. Stability in the region attracts foreign investment leading to economic growth, development, and higher levels of human well-being. Regional food security improves through intensification and new technologies. Population pressure and industrial and agricultural development initially lead to negative environmental impacts, but these effects stabilise as effective institutions develop to regulate resource use.

Governance
Current political initiatives for African and regional collaboration (e.g. NEPAD1, SADC) are successful. African leaders commit themselves to promoting good governance and regional peace and security to attract foreign investment in the region as well as debt relief.

Economy
The region is able to attract increased foreign investment and experiences high economic growth, accompanied by modernisation of information and communication technologies. A growing proportion of the energy needs of an increasingly wealthy and urbanised population are met by hydropower, but the highly industrialised south still obtains the majority of its power from coal. In rural areas, wood fuel remains an important energy source

Population, health and well-being
Population continues to grow rapidly until 2030, but then population growth levels off due to economic growth and improved human well-being. There are great improvements in infrastructure, health (especially HIV/AIDS programmes) and education

Agriculture and food security
Regional-scale food security is greatly improved by the intensification and diversification of agriculture, using highly selected seeds (including genetically modified organisms), irrigation, pesticides and fertilisers. However, a focus on cash crops, grown commercially, and a strong linkage to the global economy marginalizes small growers and impoverishes agricultural diversity. Consequently, vulnerability to pest outbreaks increases, and together with an increased frequency of droughts and floods resulting from climate change, leads to large swings in cereal production and intermittent food shortages.

Environment
Growing mining, manufacturing and agricultural operations reduce water and air quality. Water purification costs increase due to higher contaminant loads, contributing to the rising price of water. Intense competition for water resources south of the Zambezi hampers economic development and creates conflict situations.

A2 – Regional constraints

Global context

Based on the IPCC SRES A2 assumptions and the MA Order of Strength scenario (MA, 2005).

In this scenario, the world becomes progressively compartmentalized as governments and then businesses and citizens turn their focus inward in response to threats from global terrorism and the breakdown of several processes involving global cooperation. People see looking after their own interests as the best defence against economic insecurity. Citizens reluctantly accept the argument that a militarily and economically strong liberal democratic nation can maintain global order and protect the lifestyles of the wealthy world and provide some benefits for any poorer countries that elect to become allies. In a fundamental departure from the early twenty-first century, even rhetoric about the importance of trade liberalization disappears in a backlash against globalization, which is seen as a source of instability and threats.

2000-2015
- Teetering between globalisation and compartmentalisation
- Continued trade liberalisation, but increased focus on national security
- Decline in international trust
- Dead-lock in international trade agreements

2015-2030
- Wide spread use of trade tariffs to control markets and impose control
- Wide spread use of subsidies by rich countries to protect self sufficiency
- Poorer countries depend on exporting commodities that are not produced by wealthy countries (e.g. minerals, forest products) leading to degradation
- New technologies developed in richer countries are expensive and thus inaccessible to poorer countries
- Foreign aid restricted and available on a very ad hoc basis to tackle specific crises
- Development of new trading blocks, alliances between some African countries and Europe

2030-2060
- Greater polarisation between rich and poor countries
- Environmental degradation in poorest countries
- Downward cycles with escalating poverty

Regional context

Based on the SafMA African Patchwork scenario (Scholes and Biggs, 2004).

While democracy and good governance take hold in some countries in southern Africa, severely limited state effectiveness, economic mismanagement and conflict in most countries prevent the region from improving the well-being of its citizens. Regional food security does not improve, and expansion of agricultural land together with a lack of regulation result in substantial environmental degradation.

Governance
While democracy and good governance take hold in some countries, ineffective governance, corruption and economic mismanagement in most of the region keep it impoverished. Localised military conflicts continue to drain resources, damage infrastructure and impede the provision of services.

Economy
Low economic growth rates and declining foreign investment lead to the increased economic marginalisation of Sub Sahara Africa.

Population, health and well-being
The rural population relies heavily on a declining natural resource base for their subsistence, and many people migrate to cities, where they remain impoverished. In much of the region, wealthier middle-class citizens support their lifestyles through private boreholes, electricity generators, and directly import a range of basic goods. Most governments are unable to ensure the provision of reliable, safe water or modern energy sources, resulting in high mortality from waterborne diseases and indoor air pollution aggravated by the high incidence of HIV/AIDS.

Agriculture and food security
Improvements in agricultural productivity are not sufficient to meet the needs of the growing population, resulting in large-scale conversion of woodlands to crops, and the expansion of agriculture into marginal lands. Climate change brings more frequent droughts and consequently crop failures, especially in marginal areas. Large quantities of food aid are needed to support the urban poor in particular; delivery of food aid in rural areas is impeded by poor infrastructure and conflict.

Environment
Large-scale deforestation occurs, both for agricultural expansion and for charcoal production. Poor enforcement of environmental standards, where they exist, result in deteriorating water and air quality. Water quality is further degraded by increased soil erosion and untreated sewage. A water supply crisis in the shared river basins in the southern part of the region is a major source of regional tension.

7.1d Two narrative storylines for Mozambique to 2060

Recent developments in Mozambique

Before elaborating on the narrative storylines for Mozambique it is important to understand the context of recent changes in the country. Two recent studies by the World Bank (WB, 2005; WB 2008) provide a comprehensive overview of the country's rapid development since the end of the civil war in 1992 (Box 4).

However, recent data show bewildering variation in welfare outcomes. In some areas infant mortality and nutrition are getting worse while consumption is going up. Recently collected perceptions data point to a population less content with what the government is providing. In addition, vulnerability to natural hazards and price fluctuations remains high, threatening to undermine recent gains.

Subsequent sections of this chapter will explore two contrasting narrative storylines on for the future of Mozambique until 2060. In the B1 – Global Opportunities scenario, Mozambique's rapid development is able to continue along present trends, supported by a globalised world with stable governance and support for sustainable development. By contrast, in the A2 – Regional constraints scenario, both Mozambique development declines by global economic development and regional political instability.

Box 4: The context of recent development in Mozambique since the civil war (1992), extracted from WB (2005) and WB (2008).

Life for most Mozambicans has improved dramatically since the end of the civil war in 1992. Mozambique was an extremely poor country at the time of its elections in 1994, with decimated infrastructure, a weak economy, and fragile institutions. Since then, it has been astonishingly successful at restoring growth and improving welfare. Sustained growth-driven primarily by investments in physical capital-reduced monetary poverty from 69% of the population in 1997 to 54% in 2003 and the depth and severity of nonincome poverty even more. Broad-based, labour-intensive private-sector growth has been efficient in reducing poverty because it was equally distributed. At the same time, investments in social and economic infrastructure extended access to public services, reduced welfare inequalities, and supported the livelihoods of the average Mozambican

The social debt at the end of the civil war-a severe lack of social services in rural areas-required massive investments in buildings and physical inputs and in trained staff to run the services. Donors were ready to fund good projects in underserved areas, and the government was determined to get these funds and use them to reduce poverty. The greatest successes were in roads and in education, where high levels of spending (20% of total government expenditures) produced the greatest improvements in both access and outcomes for poor and rural families. In other sectors public programs were not developed or implemented as quickly to reach the underserved, so the gains were limited and some opportunities lost.

The ignition for growth came from new private investment in physical capital and high levels of public spending. Public spending on rehabilitating the infrastructure needed to gain access to markets supported growth in rural incomes. Farmers had access to good quality land to expand and diversify production. Households increased their integration with markets-locally and regionally. Using cash gained from selling agricultural produce or working for cash either during harvest or in the off-season, they invested in new small and microbusiness ventures. They also invested in better housing and in sending their children to school.

The backbone of proper growth in Mozambique was the response of family farmers and family-owned businesses-where more than 90 % of the labour force in Mozambique works-to the progrowth economic policies of the government. These policies held down inflation while reducing the cost of doing business and lowering restrictions on competition, such as price controls and inefficient monopolies.

However, it is unclear whether Mozambique is continuing to beat the odds on shared growth. The latest comprehensive data on living standards are from 2003, when about half the population was classified as poor, and the evidence since then is sketchy. Government data show continuing increases in access to services, and rural income survey data show that average household incomes have increased. Based on extrapolations of a few indicators, the Ministry o f Planning and Finance predicts a continuing fall in poverty. But other indicators point to a slowdown in that fall. Rural income inequality seems to be growing, and already high urban inequality persists, so fast growth may now have less of a poverty-reducing effect.

B1 – Global opportunities

Summary

This scenario depicts a globally connected society in which policy reforms that focus on global trade and economic liberalization are used to reshape economies and governance, emphasizing the creation of markets that allow equitable participation and provide equitable access to goods and services. These policies, in combination with large investments in global pubic health and the improvement of education worldwide, generally succeed in promoting economic expansion and lift many people out of poverty into an expanding global middle class. Supranational institutions in this globalized scenario are well placed to deal with global environmental problems such as climate change.

Mozambique benefits greatly from the regional stability and the open global economy, attracting substantial foreign investment in agriculture, bio-energy crops, hydro power, tourism, and extraction and processing of natural resources. Stable government and effective governance help ensure that these investments result in growing employment opportunities, improved infrastructure and technological advance. The rapidly growing economy allows the government to make significant improvements in education and health and to invest in adaptation measures (e.g. coastal defences) to reduce vulnerability to hazards. The Mozambique economy moves from global position 157 in 2000 to 140 in 2060 with a GDP of 143 billion US$90. Nevertheless, its GDP per capita, even at US$90 4897, is still one of the lowest in the world (Grubler et al., 2007).

Governance

The country continues to experience political stability, allowing the development and implementation of long term strategies, e.g. for creating a favourable business environment to attract foreign investment and create jobs, but also for improving infrastructure, and healthcare and for education to build human capital. Crime and corruption decrease and government is effective in improving public safety. Strong effort is made to abolish poverty and to reduce income inequalities, continuing the implementation of programmes such as PARPA (Programme for support of the reduction of absolute poverty) and the Millennium Development Goals. The government strongly supports regional collaboration and integration through SADC, which gives Mozambique a central role in regional transport to global markets through its harbours.

Economy

Mozambique has a competitive position on the global market with its substantial natural resource base, stable business climate and cheap labour force. The country can therefore attract considerable foreign investment and demand sustainable implementation. The main economic sectors attracting investments are agriculture, fisheries, bio-energy, hydro-energy, tourism, fossil fuel extraction (gas, coal) and mining mineral resources (bauxite, titanium, gold, gem stones). Harbours and railways connections, forming important trade routes for land locked neighbouring countries, are expanded rapidly, with help of private investment. Foreign investment in the energy sector is used to ensure self-sufficiency for energy at a favourable price, which attracting additional investment in processing industries, which are crucial for future economic growth. Continued rapid economic growth of 6-8% per year (Grubler et al., 2007) allows the government to make substantial investments in ICT, infrastructure, education, technology and agricultural productivity. The open markets and growing purchasing power means that foreign products become affordable for large parts of society. The Mozambique economy moves from global position 157 in 2000 to 140 in 2060 with a GDP of 143 billion US$90. Nevertheless, its GDP per capita, even at US$90 4897, is still one of the lowest in the world (Grubler et al., 2007).

Population, health and well-being

The population of Mozambique continues to grow until 2030 and then levels off at 29 million inhabitants (Grubler et al., 2007), mainly because improved socio-economic conditions reduce the need for large families. For the coming decades, rural regions remain deprived and offer few prospects, leading to continued urbanisation. The rapid growth of cities leads to its own problems, especially concerning hygiene and demand for housing, water and public services (transport, education, healthcare). However, the government's substantial public investment in infrastructure, health and education overcome most problems and from around 2030 socio-economic conditions in rural regions have improved sufficiently to halt urbanisation. The growing economy results in greater wealth and rising living standards for most of the population, and reduce the present regional socio-economic differences between North, Central and South. Access to medical services, vaccination and HIV/Aids care and prevention in greatly improved. Sanitation becomes available for most of the population in urban centres. There is general access to primary and secondary education while, tertiary education is available to large parts of society.

Agriculture and food security
Despite increased temperatures and more frequent droughts, Northern and Central Mozambique continue to have favourable agro-ecological conditions, with good rains and access to water for irrigation. Growing regional and global food demand, combined with the stable business climate leads to considerable foreign investment in large scale plantations. Greater wealth and better education lead to better technology and management of local food crops as well. Smallholder farming decreases, shifting towards larger co-operations growing a combination of cash crops and staples. Despite climate change impacts there is a gradual increase in productivity . By 2030 Mozambique is completely self-sufficient, with a buffer to cope in case of natural disasters. Despite increases in productivity, there is considerable regulated expansion of farmland, mainly in the Centre and North of the country, to accommodate the growing population increase and increase in caloric intake due to better diets and larger meat consumption. Bio-energy crops become increasingly important, both as export products and for local energy supply. Intensive production is regulated strongly in more favourable agro-ecological zones to prevent competition with local food supply or ecological degradation.

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 and regulations for mining and agricultural expansion. There is considerable expansion of agricultural land for domestic food provision, export of cash crops and the production of bio-energy crops. The reduction of smallholder farming results in a strong decrease in uncontrolled forest fires, while the general availability of electricity reduces deforestation for firewood. Natural forests receive strong protecting and logging concessions and subsequent processing are managed sustainably. Natural parks and reserves also receive strong protection and along with the natural forests contribute to international carbon trading schemes. Nevertheless, intensification and expansion of agriculture and mining leads to local pollution and environmental and ecological degradation.

Natural hazards
The government tries hard to implement adaptation measures to cope with natural hazards and is well prepared to cope with hazards when they occur. More frequent droughts (Tadross, this project) and flooding (Mavume this project) will cause for continued variability in agricultural productivity, despite improved natural resource management and appropriate government policies (e.g. to control fire hazard). Rising temperatures and more frequent droughts lead to greater water demand for a agriculture and human consumption, which can lead to conflict, despite government regulations, improved technology (e.g. efficient irrigation) and investment in infrastructure (e.g water tanks and pipes). By 2060 Mozambique, with a GDP per capita of US$4897 (Grubler et al., 2007), can afford high category coastal protection from cyclones (Nicholls & Tol, 2006; Hoozemans et al., 1993), protecting most vulnerable coastal areas, despite global sea level rises of about 150mm (compared to 1990 levels) (Nicholls & Tol, 2006; Hoozemans et al., 1993).

A2 – Regional constraints

Summary
This scenario represents a regionalized and fragmented world concerned with security and protection, emphasizing primarily regional markets, and paying little attention to common goods. Nations see looking after their own interests as the best defence against economic insecurity, and the movement of goods, people, and information is strongly regulated and policed. The role of government expands as oil companies, water systems, and other strategic businesses are either nationalized or subjected to more state oversight. Trade is restricted, large amounts of money are invested in security systems, and technological change slows due to restrictions on the flow of goods and information. Regionalization exacerbates global inequality.

Mozambique is greatly constrained by the global economic developments and regional political instability. Foreign investment is limited due to reduced global trade, and remaining investment mainly tries to exploit and extract cheap natural resources. Regional and national political instability weaken Mozambique's business climate to foreign investors, enabling a limited number of countries to broker hard deals to exploit the country's rich resource base with few benefits for society. Nevertheless, the country is able to become self sufficient in energy supply, through collaboration with foreign investors. GDP rises slowly, there is little poverty reduction, and the government has insufficient funds to make significant investment to raise development standards or reduce vulnerability to natural hazards. The Mozambique economy drops from global position 157 in 2000 to 162 in 2060 with a GDP of 9.3 billion US$90. Its GDP per capita, at US$90 222, remains one of the lowest in the world (Grubler et al., 2007).

Governance

The population is dissatisfied with socio-economic developments, leading to political instability and frequent changes of government. As a consequence, there are limited possibilities for consistent long term policies and exiting strategic policies are abandoned, e.g. those for . for creating a favourable business environment to attract foreign investment and create jobs, but also for improving infrastructure, and healthcare and for education to build human capital. The resulting ad hoc policies are mainly reactive, focusing on crises and reducing the negative effects of poverty, not on eliminating the causes. Crime and corruption increase and public safety declines, and there is little national and international commitment to programmes such as PARPA and the Millennium Goals. Regional conflict and instability undermine collaboration, e.g. through the SADC, and limit regional trade and growth of the transport sector.

Economy

It is difficult to secure foreign investment due to regional instability, enabling powerful new economies (e.g. China and India) to broker hard deals that benefit only the influential elite. Exploitive foreign investment, focusing on extracting cheap resources, are concentrated in agriculture, bio-energy, fossil fuel extraction (gas, coal) and mining mineral resources (bauxite, titanium, gold, gem stones). Mozambique has only a limited role as transport corridor for land locked neighbouring countries due to regional instability and economic stagnation. Nevertheless, Mozambique slowly becomes self-sufficient in energy supply in collaboration with the foreign investors. Slow economic growth (2-3% per year) (Grubler et al., 2007) has little effect on employment opportunities. Most of the population does not benefit from advances in ICT, agricultural productivity, technology, infrastructure and education. Regionalised markets make foreign imports expensive and restrict the tourism sector. The Mozambique economy drops from global position 157 in 2000 to 162 in 2060 with a GDP of 9.3 billion US$90. Its GDP per capita, at US$90 222, remains one of the lowest in the world (Grubler et al., 2007).

Population, health and well-being

Population grows steadily to 35 million in 2060 (Grubler et al., 2007). There is very rapid urbanisation, because rural regions offer limited prospects, and by 2060 85% of the population lives in urban centres (Grubler et al., 2007). The rapid growth of cities leads to significant problems, especially concerning hygiene and demand for housing, water and public services (transport, education, healthcare). The government is ineffective in tackling these issues, resulting in increased urban poverty and associated crime and corruption. There is only a slow expansion of the electricity grid, and private electricity generation remains too expensive for many people in rural areas who remain dependant on fuel wood. Private companies restrict investment in ICT to urban centres. Public funds are largely consumed by ad hoc efforts to cope with negative aspects of poverty and minimise 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. Access to education, medical services, vaccination, HIV/Aids care and prevention improves very slowly, while sanitation remains unavailable for most of the population.

Agriculture and food security

Foreign investment in agriculture focuses on large scale plantations producing exportable commodities. Although there are some improvements in agriculture, productivity increases are small and climate change impacts have serious implications for food security, especially in dry years. There is dramatic and relatively uncontrolled expansion of farmland, mainly in the Centre and the North, to meet food demands of the growing population. Small holder farmers remain dominant, although successful plantations and cooperatives are formed in some regions. Bio-energy crops are increasingly important, especially as export products. Large plantations are set up in favourable agro-ecological zones, leading to ecological degradation and competing with water resources and land required for the production of staple foods and livestock production.

Environment

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. Protection of natural forests is weak, leading to wide-spread illegal logging. Natural parks and reserves are threatened by lack of funds for management, wild fires and illegal hunting and logging. 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 which will first occur on overexploited marginal lands.

Natural hazards

The government has limited resources to implement adaptation measures, and is often ill prepared when hazards occur. More frequent droughts (Tadross, this project) and flooding (Mavume, this project) 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. Rising temperatures and more frequent droughts3 lead to greater water demand for agriculture and human consumption which leads to frequent conflict due to lack of government regulations. By 2060 Mozambique, with a GDP per capita of only US$220 (Grubler et al., 2007), cannot afford coastal protection (Nicholls & Tol, 2006; Hoozemans et al., 1993). Global sea level rises of about 150mm (compared to 1990 levels) is likely to lead to a land loss of 750km^2 (0.1% of total land area) (Nicholls & Tol, 2006; Hoozemans et al., 1993) and will seriously impact urban centres along the coast.

Summary of the scenarios

Table 7.5 provides a summary of the two narrative storylines for Mozambique, Table 7.6 provides a summary of the trends of major drivers of vulnerability.

	B1 – Global opportunities	A2 – Regional constraints
Context[1]	• Strong, effective regional governance • Regional cooperation and integration • Political stability and security • Strong formal economic sector • Rapid technological development and modernisation • Significant reduction in poverty • Significant investment in health and education	• Ineffective governance in most countries in the region • Regional fragmentation • Political instability • Informal sector dominates • Slow technological development and modernisation • Little reduction in poverty • Little investment in health & education
Governance	• Political stability • Long-term government strategies, focusing on attracting foreign investment to increase development levels • Strong government effort to abolish poverty and reduce income inequalities	• Political instability • Ad hoc changes in policies, lacking consistent strategies • Government focus on reducing the negative effects of poverty, not on eliminating the causes
Economy	• Large foreign investments in agriculture, bio-energy crops, fossil fuel extraction, and mining, resulting in economic benefits all of society • Mozambique quickly 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 $4897 in 2060[2] • Strong advances ICT, agricultural productivity, technology, infrastructure, education, mainly as a result of positive externalities form economic growth • Affordable foreign products and a growing tourism sector	• Limited foreign investment with restricted number of countries that benefit only the influential elite • Mozambique slowly becomes self-sufficient in energy supply • 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 $222 in 2060[2] • Most of the population does not benefit from advances in ICT, agricultural productivity, technology, infrastructure and education • Foreign imports are expensive and restrict the tourism sector

Population, health and well-being	• Population grows slowly until 2030 and then levels off at 29 million[2].
	• Rapid urbanisation until 2030. From 2030 urbanisation levels off and by 2060 65% 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
	• Investment and advances in ICT greatly improve telephone and internet connectivity
	• Large public investment in health and education is initially concentrated in growing cities, but later extended to rural regions. These include:
	  • Effective vaccination programmes
	  • Reduction in HIV/Aids
	  • Sanitation in most of urban centres
	  • General access to primary education, secondary education available to large parts of society
		• Population grows steadily to 35 million in 2060
		• Very rapid urbanisation, because rural regions offer limited prospects. By 2060 85% of the population lives in urban centres[2]
		• Access to energy remains to expensive for many people in rural areas who remain dependant on fuel wood
		• Private companies restrict investment in ICT to urban centres
		• Public funds are consumed by ad hoc efforts to cope with negative aspects of poverty and minimise 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 • 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 • Despite increases in productivity, there is considerable regulated expansion of farmland, to accommodate the growing population and increase in caloric intake • Smallholder farming decreases, and larger cooperatives emerge growing staple crops • Bio-energy crops are increasingly important. as export product and for local energy supply. Extensive plantations are set up in marginal regions, while more intensive production is regulated strongly in more favourable agro-ecological zones	• Foreign investment in agriculture focuses on large scale plantation producing exportable commodities • Productivity increases are small and climate change impacts have serious implications for food security, especially in dry years • There is dramatic and relatively uncontrolled expansion of farmland to meet food demands of the growing population • Smallholder farmers remain dominant, although successful plantations and cooperatives are formed in some regions • Bio-energy crops are increasingly important, especially as export products. Large plantations are set up in favourable agro-ecological zones, competing with the production of staple foods

	B1 – Global opportunities	A2 – Regional constraints
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-energy 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
Natural hazards	• The government tries hard to implement adaptation measures to cope with natural hazards and well prepared to cope with hazards when they occur • More frequent droughts[3] and flooding[4] will cause for continued variability in agricultural productivity, despite improved natural resource management and appropriate government policies (e.g. to control fire hazard) • Rising temperatures and more frequent droughts[3] lead to greater water demand for agriculture and human consumption, which can lead to conflict, despite government regulations, improved technology and investment in infrastructure • By 2060 Mozambique, with a GDP per capita of US$4897[2], can afford high category coastal protection from tropical cyclones[5,6], protecting most vulnerable coastal areas despite global sea level rises about 150mm (compared to 1990 levels) [5,6]	• The government has limited resources to implement adaptation measures, and is often ill prepared when hazards occur • More frequent droughts[3] and 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 • Rising temperatures and more frequent droughts[3] lead to greater water demand for agriculture and human consumption which 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 rises of about 150mm (compared to 1990 levels) is likely to lead to a land loss of 750km^2 (0.1% of total land area)[5,6] and will seriously impact urban centres along the coast

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[4] Mavume et al. this project

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Table 7.5: A summary of the two narrative storylines for Mozambique.

	Baseline	B1 Global Opportunities		A2 Regional constraints	
Drivers	**2000 or most recent value**	**Trend**	**Value 2060**	**Trend**	**Value 2060**
Demographic and societal drivers					
life expectancy		+++		0	
population growth		++		+++	
urbanisation	17.6 million[1]	++	29.3 million[1]	+++	35.3 million[1]
household size and structure	30%[1]	--	65%[1]	0	85%[1]
poverty		---		--	
income inequality	44%[2]	--	5%[2]	++	26%[2]
self sufficiency		+++		+	
access to education		+++		+	
advancement of women		+++		+	
access to health and medical services		+++		+	
HIV/Aids		--		0	
water borne disease (malaria, cholera, diarrhoea)		---		0	
Economic drivers					
economic growth		+++		+	
(GDP per capita)	98 US$90[1]	+++	4897 US$90[1]	+	222 US$90[1]
investment in road infrastructure		+++		++	
internet access and mobile phone coverage (ICT)		+++		+	
scientific and technology development		+++		+	
agriculture innovation and productivity		---		--	
energy imports		+++		++	
access to electricity		+++		+	
trade balance (export – import)	-0.8 billion US$90[2]		-2.3 billion US$90[2]		-1.2 billion US$90[2]
Sociopolitical drivers					
strength of national government		+		---	
political stability		++		---	
public safety		+++		---	
control of corruption		+++		---	
Physical, biological and chemical drivers					
impacts of droughts		---		+++	
impacts of cyclones		--		++	
impacts of river flooding		--		+++	
impacts of coastal erosion		---		+++	
impacts of wild fires		---		++	

[1] CGI (Grubler et al., 2007); [2] Nussbaumer & Patt, this project; insert other references to data

Table 7.6: Summary of the trends of major drivers of vulnerability for the two scenarios.

+++ very large increase; ++ large increase; + slight increase; 0 no change; - slight decrease; -- large decrease; --- very large decrease

Implications per zone

South

The Southern region is already dry, and climate change is projected to cause reduced precipitation and more frequent drought, which are likely to cause serious water shortages (except in the flood plains, discussed separately). Agricultural water demand, especially for intensive plantations, will compete strongly with growing demands for human consumption. Agricultural expansion is not sustainable, and in the long run not viable. With limited potential for the agricultural sector, the rural population will depend largely on extensive livestock production, forestry, wild life and income from natural parks. There is potential for small-scale hydro-energy generation in some regions.

Most employment is centred around big cities with harbours, and along the transport corridor to South Africa. Depending on the economic development, these urban centres can develop rapidly or succumb under population pressure. Energy intensive industry (e.g. aluminium and cement) will continue to expand as long as energy and labour remain cheap, and transport links are functional. Extraction of natural gas will continue, and heavy mineral sands with titanium oxide will attract substantial investment.

Droughts and wild fires form the main environmental hazards. However, cyclones and sea level rise will affect urban centres along the coast (discussed below) and the flood planes will be affected by flooding.

Central

In general, the Central region has a suitable climate for agriculture. Already foreign investors are setting up substantial plantations in this region, and this is likely to continue, both for the production of cash crops and for staples. These foreign investments could provide an important economic impulse for the region, generating jobs, income, and raising development standards. Although droughts will affect productivity, large rivers (e.g. the Zambesi) can supply water for irrigation. There is potential for both large and small scale hydro-energy generation (e.g. in Tete and Manica provinces).

A second development in the region will be the extraction of mineral resources. Tete province is is rich in coal, and will probably see wide-scale exploitation. Other parts of the region are rich in copper and gold, while the Zambezi valley is claimed to have oil. Environmental impacts of these developments will depend largely on the government's ability to regulate and control negative externalities.

Uncontrolled wild fires, and to some extent drought are the main environmental hazards. Flooding poses a serious risk to plantations in the flood plains (discussed below). Cyclones and sea level rise will affect urban centres along the coast (discussed below).

North

In general, the Northern region has a suitable climate for agriculture, but many parts of the region suffer from poor infrastructure, and it has been difficult to distribute agricultural goods regionally as well as nationally. With growing food demand and foreign investment in agriculture, the infrastructure of the North is likely to be improved significantly over the coming years, eg by expanding railway connections to Malawi and the port of Beira. Combined with a very large labour force, agriculture will face very large expansion. There is potential for small scale hydro power.

The second development in the region will be the extraction of mineral resources. Niassa and Cabo Delgado are rich in coal, while the regions also hold gold reserves (Niassa) and heavy sands (Moma). Here too, the main factor holding back development is the infrastructure.

The main environmental hazards are some local floods and some uncontrolled wild fires. Cyclones are a very serious threat to the Northern coastal region, which is also threatened by sea level rise.

Flood plains

The flood plains have very good soils, and excellent water availability for irrigation. These lands are therefore traditionally the most cultivated, and have also attracted considerable investment in modern agricultural plantations, and associated agro-industry. However, these regions are also extremely vulnerable to flooding, which can destroy plantations, infrastructure and settlements. Climate change is likely to cause more frequent and more severe floods, and without sufficient adaptation measures it will not be possible to develop a sustainable agricultural sector in these regions.

Coastal strip

The coastal strip includes Mozambique's largest cities, important harbours, international airports and the principal road and rail connections. Future urbanisation and population growth will lead to a large expansion of urban settlements. If strong economic growth can continue, there will be large expansion of harbours and infrastructure.

The coastal strip, with its harbours and infrastructure, is a promising region for industrial expansion. Recent findings suggest there is oil along large part of the northern coast, wich would attract additional investment.

It is a great concern that the coastal zone, its infrastructure and urban centres, is also prone to major environmental hazards. Cyclones affect most of the coastal region, with the heaviest impacts in the North. Sea level rise, and associated erosion affects large parts of the low lying coast line, including the important ports of Maputo and Beira. Finally, river flooding in the deltas has great impacts on vital infrastructure connecting the country.

Non-linear and low-probability events

Scenarios explore gradual linear trends into the future. As such they do not incorporate disruptions in these trends caused by low-probability or non-linear events. Such events, e.g. war, long lasting global economic crises, or very rapid climate change, can have major impacts, especially for vulnerable countries with low adaptive capacity. Specific impacts assessment should be carried out to assess the potential impacts of such event, and to evaluate whether it is possible to mitigate or adapt to reduce vulnerability. Nevertheless, the following sections briefly explore some non-linear impacts that could have large consequences for Mozambique.

Rapid sea-level rise

All the linear sea level rise models exclude rapid dynamical changes in ice flow due to continental ice melting in the polar regions. This is an important reservation which led the IPCC to abandon its initial projections for sea level rise through the 21st century. It now believes that there should be recognition of the possibility of an acceleration of sea level rise from polar ice melt, as described in this non-linear scenario. The approximate contributions available to sea level rise on complete ice melting are considerable.

Glaciers and Ice Caps Available for Melting	Contribution to Sea Level Rise on Melting
Temperate and high tropical regions	0.5 metres
Greenland Ice Sheet	7 metres
West Antarctic Ice Sheet	5 metres
East Antarctic Ice Sheet	55 metres

It is important to recognize that no time scales are available from observations, for the melting of these ice sheets and their incorporation into increased global sea level. However, the gradual progression of climate change through the greenhouse gas stabilization levels, global warming and polar ice melt will provide estimates of the timing and extent of the eventual global sea level rise.

In the meantime, it is possible to explore some of the consequences of such a large scale polar ice melt as an extreme climate scenario, even though its full impact may not be felt for many decades. Whilst protection through various forms of fortified sea walls and dune barriers is the preferred adaptation approach for the low sea level rise expected in the near future, the question arises as to whether or not such an approach will continue to be as economically attractive with sea level rise of the order of metres rather than centimetres. The results of studies addressing this question elsewhere in the world can be of some relevance to Mozambique. Of particular interest are the possible societal responses to a five metre rise in sea level within a century, starting in 2030, as reported by Tol et al (2007). They report on the outcomes of a series of workshops of regional experts and stakeholders, convened to consider the cases of three large and well-populated European estuaries. The most likely response in the Rhone estuary would be retreat, with economic losses, perhaps social losses, and ecological gains as wetland areas increased in size. In the Thames estuary, the outcome would be less clear, but would probably be a mix of accommodation and retreat, with parts of the city centre turned into a Venice of London. In the Rhine delta, the Netherlands, the initial response would be protection, followed by retreat from the economically less important parts of the country and probably from the Amsterdam-Rotterdam metropolitan region as well.

These three case studies by Tol et al (2007) make it clear that adaptation would be difficult even in well developed countries. If the Netherlands does not expect to be able to cope, even with its extensive experience in the protection from the sea and in flood management technology, countries with similar river deltas are not expected to be able to use protection as a viable option either. The remaining option of the evacuation of large populations from tropical deltas in developing countries would be a national calamity for those countries. Whilst, this conclusion of the catastrophic potential effects of polar ice melt lends strong support to efforts leading towards the mitigation of climate change, it is also important to investigate the situation in threatened delta environments in developing countries through an approach, similar to that used by Tol et al (2007).

Beira is a city and port built on old beach deposits on the sea side of the large delta at the mouth of the Pungoe River. It is the second city of Mozambique with a large and growing population. The port is of strategic importance to Mozambique and to the countries of the hinterland, such as Malawi, Zambia and Zimbabwe, to which it is connected by road and rail. Much of the town is low lying and its infrastructure and services are already threatened by storm surges and floods, and sea level rise from polar ice melt will be catastrophic. With a sea level rise of 5 metres, the city centre and port will become an island, cut off from the mainland, and new road and rail communications will need to be constructed. The island city of Beira will need to be protected by a sea wall of at least an additional 3 to 4 metres on all sides. At times of flood, the Pungoe River may well carve out a new channel to the east of this island. It is the cost of all this protection and new construction that could well decide the Mozambican authorities to follow the example of the Netherlands and rather abandon Beira, and build a new port further inland. This is the sort of investigation that needs to be carried out well in advance of long term investment into the city and port of Beira.

7.1e Potential impacts and adaptation strategies

Adaptive Capacity

The vulnerability of Mozambique is determined by the impacts that could potentially affect the population, and the capabilities of the country to adapt to the impacts (IPCC, 2007). Adaptation in general is understood as an adjustment in natural or human systems in response to actual or expected environmental change, which moderates harm or exploits beneficial opportunities. Here, adaptive capacity reflects the potential to implement planned adaptation measures and is, therefore, concerned with deliberate human attempts to adapt to or cope with change. "Autonomous adaptation" by contrast, does not constitute a conscious response (e.g. spontaneous ecological changes).

The concept of adaptive capacity was introduced in the IPCC TAR (IPCC, 2001), according to which the factors that determine adaptive capacity to climate change include economic wealth, technology and infrastructure, information, knowledge and skills, institutions, equity and social capital. Klein et al. (manuscript) suggest that adaptive capacity comprises three components: Awareness, Ability and Action. A regions needs to be aware of the potential impacts, have the technological expertise or ability to adapt, but also requires the economic power to implement the actions.

Table 7.7 gives an overview how this concept can be linked to the two scenarios for Mozambique. Adaptive capacity rises rapidly in the B1 – Global opportunity scenario. This is a consequence of strong economic growth, rapid global transfer of new technologies and increased human capital. Conversely, adaptive capacity rises slowly in the A2 – Regional constraints scenario, due to limited economic power, slow technology transfer and political lower human capital.

Adaptive Capacity (cf Klein et al.)			
Components	Awareness	Ability	Action
Determinants	Knowledge Equity	Technology Infrastructure	Economic power Flexibility
B1 – Global Opportunities	↗	↗	↗
A2 – Regional Constraints	↗	↗	↗

Table 7.7: Adaptive capcity under scenario B1 and A2.

Adaptation measures

Detailed discussion on specific adaptation measures are outside the scope of the scenario report. It is nevertheless relevant to explore differences in adaptation strategies between the two scenarios. This will be done in based on the four priorities identified by the National Action Plan for Adaptation to Climate Change in Mozambique (NAPA). These priorities are:

1. Strengthening early warning systems
2. Strengthening the capacity of the agriculture sector to deal with climate change
3. Reduction of the impacts from climate change on the coastal zones
4. Water resources management within the context of climate change

Table 7.8 provides a summary of the differences for the two scenarios to meet these NAPA actions.

NAPA actions		B1 Global Opportunities	A2 Regional Constraints
Early warning systems	• relatively cheap • top-down implementation	√ √ √	√ √
Strengthen agriculture	• costly • bottom-up implementation	√ √ √	√
Reduce coastal impacts	• very costly • top-down implementation	√ √	-
Improve water management	• very costly • top-down and bottom-up implementation	√ √	-

Table 7.8: Opportunities for meeting NAPA actions under scenario B1 and A2.

√ √ √ successful implementation; √ √ largely successful implementation; √ partly succesful implementation; - not implemented at all

Early warning systems

Early warning systems are important for reducing vulnerability to all environmental hazards. Monitoring, modelling and remotely sensed observations can help in disaster preparedness and early mobilization of personnel and response units. While development of early warning systems takes time and resources, they form relatively inexpensive measures and require top-down implementation by a limited number of agencies or government departments. As such, early warning systems will be successfully implemented in a B1 scenario, and in the A2 scenario there would still be a largely successful implementation.

Strengthening agriculture sector

Despite negative climate change impacts on potential productivity (e.g. through drought), agricultural productivity could increase considerably given the current yield gap. This will require adopting new technologies, and improved farm management systems. Both aspects require substantial investment to develop, but they will also need sufficient support to implement in the field. While large scale plantations funded by foreign companies can be set-up quickly, changing agricultural practises of smallholder farmers or local cooperatives is a slow process that will require long term guidance and support. In the B1 scenario, with its sustainable investment and rapid economic growth, adaptation measures to strengthen the agricultural sector will be successfully implemented. In the A2 scenario there will only be partly successful implementation outside foreign plantations.

Reducing impacts in coastal zone

Protecting coastal regions from the impacts of sea level rise and cyclones is very costly, involving combinations of coastal defences and reallocating or rebuilding infrastructure and industrial and urban centres. Nevertheless, the rapid economic growth under the B1 scenario will allow Mozambique to put in place significant coastal defences, while strong government can insure that future investments in infrastructure are largely adapted to hazards and future sea levels. Either way, the B1 scenario is most likely to be largely successful in implementing adaptation measures. In the A2 scenario economic constraints will largely prevent adaptation measures from being implemented.

Improve water resource management

Improving water resource management will require a combination of top-down (hard) measures such as dams and dykes, and bottom-up acceptance of new management techniques (soft measures). The hard measures are very expensive to implement, and in will have to compete with coastal defences protecting urban centres and infrastructure along the coast. The soft measures will require developing new techniques and supporting local acceptance in the field. Under the B1 scenario there may be funds and government support to allow for a largely successful implementation. However, under an A2 scenario adaptation measured will not be successfully implemented due to a combination of lacking funds and insufficient government support.

7.1f Final conclusions

Future developments are inherently uncertain. The two scenarios presented in this report provide extremes for the socio-economic development of Mozambique in the coming 50 years. The storylines show how Mozambique can benefit in a globalised world, attracting sustainable investment in its natural resources while at the same time working on developing its own development levels and human capital. However, there is the risk that foreign investors merely exploit Mozambique's resources, without providing any benefits for society.

Despite great differences between the two socio-economic futures, it is also apparent that there are a number of consistent trends between both scenarios. These include the decline of agriculture in the South, negative externalities of agricultural expansion and intensification, the vulnerable coastal zone and rapid urbanisation and population growth. Coping with these issues will require government commitment and long term strategies.

The main differences between the two storylines are in exogenous global developments in the economy and in global and regional stability. Mozambique has little influence on these matters, and these factors will, in part, determine whether the country will experience rapid development or relative stagnation. It is however important to realise that there are also many endogenous drivers that can be influenced by government policy including:

- ensuring stable governance
- working towards regional stability, e.g. through trade agreements
- developing and sticking to long term development strategies
- ensuring a competitive business climate
- ensuring foreign investment are sustainable and benefit society
- ensuring public investments are climate proof

By acting on these issues now, Mozambique can set itself on a development trajectory that can raise development levels dramatically over the next 50 years.

Vulnerability analysis

Dr. Anthony Patt, IIASA and Patrick Nussbaumer, IIASA

	Executive Summary
7.2a	*Introduction*
7.2b	*Background: measuring vulnerability*
7.2c	*Insights on Mozambique from previous vulnerability assessments*
7.2d	*Assessing Mozambique's present and future climate vulnerability*
7.2e	*Conclusion*

Executive Summary

This document reports the results from an analysis of Mozambique's vulnerability to climatic risks in 2030 and 2060. It is part of a larger project, led by the National Institute for Disaster Management (INGC) and funded by several sources, that examines changes in future climate conditions Mozambique is facing, the impacts of those risks on food security and coastal flooding, and the numerous drivers of vulnerability. In this report, we pull together several results from our project team members to support our own analysis.

We report begins with a literature review on vulnerability in general, and vulnerability in Mozambique in particular. It reaches four main findings:

- Vulnerability results not just from climate-related hazards and risks, but also the socioeconomic and demographic conditions in a country, which make its population susceptible to harm. To estimate and describe vulnerability, one has to consider both of these sets of factors: exposure to climate risks, and other exogenous factors such as globalization, on the one hand, and the sensitivity of population, and its adaptive capacity, on the other.
- There is no single indicator of vulnerability. How one best described vulnerability needs to be contingent on the uses for which the assessment is intended. Some assessments are used to build theory, while others are meant to inform policy-makers directly. Some assessments examine current vulnerability, while others examine the vulnerability of a particular region in the future. There are many indexes that one can use to describe vulnerability, and these are most useful when it is readily apparent what they represent.

- There have been a number of theory-building vulnerability assessments conducted in Mozambique, and these have mainly occurred at the local level. They have described the factors that have led to people's increased ability to cope with climate related hazards, most importantly flooding. There have also been several vulnerability assessments conducted in Mozambique that have been meant to inform policy-makers. These have catalogued conditions nationally, and suggested those hazards that are most important, and those areas that are most vulnerable. Not surprisingly, it is the river plains that are used for agriculture that are hotspots of vulnerability to flooding, the agricultural areas of the southern part of the country that are hotspots of vulnerability to drought, and the coastal regions of the central and northern parts of the country that are most vulnerable to tropical cyclones. These are areas for immediate policy attention, in order to make them more resilient to the threats currently present.

- There have been several studies, including ongoing work by the World Bank, to make qualitative statements about future vulnerability, but no studies combining the quantitative analysis of climate models with socio-economic development patterns in order to suggest overall trends into the future. This is an area where this report strikes new ground. The report then presents results from a new quantitative analysis of Mozambique's future vulnerability. First, we report on a bottom-up analysis, one that considers several indicators that theory suggest lead to increased or decreased vulnerability. Next, we report on a top-down analysis, that considers the relationship between aggregate social indicators and levels of risk.

From these analyses, we reach several important findings:

- The bottom-up analysis of vulnerability relies on a methodology first developed at the United Kingdom's Tyndall Centre for Climate Research, to develop a numerical index of social vulnerability. Using projections gleaned from a number of sources, we find that Mozambique's indicator improves over the coming 50 years, primarily as a result of falling levels of poverty, and a demographic shift towards a greater proportion of the society being of working age.

- The bottom-up analysis considers two socio-economic development scenarios (the SRES A2 and B1 scenarios), and finds that the improvement in social vulnerability is greater in the latter, primarily as a result of a greater fall in the poverty rate.

- The bottom-up analysis suggests that trends in urbanization expected in the coming decades, present in both scenarios, will lead to reduced social vulnerability.

- The top-down analysis of vulnerability rests on an original statistical analysis of national level disaster data maintained at the Centre for Research on the Epidemiology of Disasters (CRED) in Belgium, as well as socio-economic data from the United Nations database. It examines indicators that correlate with the risk of people being killed by climate-related hazards, or being affected (i.e., in need of assistance) but not killed. It finds that for the former, the Human Development Index (HDI) and the female fertility rate are important correlates. For the latter, it is HDI and the level of urbanization. For both types of outcomes, the size of the country and the number of disaster affecting it are also important correlates of national level of risk levels.

- The empirical analysis confirms the results of previous studies that suggest a non-linear relationship between disaster risks and the level of development. At low levels of development— where Mozambique is now—there is a positive correlation between risk and HDI, suggesting that as people become wealthier, they place themselves in greater risk. At higher levels of development—where South Africa is now and where Mozambique can expect to be by mid-century—there is a negative correlation between risk and HDI, suggesting that as countries pass a certain wealth threshold, they devote more attention to reducing risk. This in turn suggests a point of policy leverage, as Mozambique could mimic the risk reduction measures currently in place in wealthy countries.

- As input to the top-down scenarios, we develop four scenarios of climate risks in Mozambique, using input from our project team members for the first two of these, which represent the lower model estimates of climate risks for Mozambique, and the average of those models predicting increases in climate risks. The latter two scenarios are based on a projected continuation of trends in hazard frequency observed over the past 37 years. For all hazards, the continuation of observed trends suggests much higher frequency in natural hazards than do the model-based scenarios.

- Based on these climate impact scenarios, and socio-economic indicators projections gleaned from a number of sources, we construct a matrix of 12 future scenarios, each of which suggests the risks in the future of being killed or affected by climate hazards.

- In the two climate impact scenarios that rely on our team members' models, overall risk levels either fall, or remain stable, as a result of the combination of improving socio-economic factors and climate change.

- In the two climate impact scenarios based on the continuation of observed trends, overall risk levels rise, especially for the A2 socio-economic scenario, to a point where they are up to an order of magnitude higher than they are today. This suggests that it may be appropriate to address climate risks with targeted policy measures, rather than simply policy measures promoting development.

7.2a Introduction

Mozambique is located in South-Eastern Africa. Its neighboring countries are South Africa, Swaziland, Zimbabwe, Zambia, Malawi, Tanzania, and Madagascar out to sea. The territory covers 799'380 km² of which 13'000 km² consist of water. Mozambique's population was estimated at just over 20 million inhabitants in 2007. There are 10 provinces: Cabo Delgado, Niassa, Nampula, Tete, Zambezia, Manica, Sofala, Inhambane, Gaza, and Maputo. Its multi-party government is independent since 1975. However, the fight for independence and civil war for 16 years only finished in 1992 (Ferguson, 2005). After several years of unrest, the government embarked in restructuring the political environment and stabilizing the economy by implementing macroeconomic reforms.

Those actions have led to significant progress in terms of economic growth, with a real growth rate estimated at 7 %, and GDP per capita reaching 800 USD (PPP) in 2007. In 2006, the primary sector represented about a quarter of the country's GDP. Inflation, although reduced during the late 90s, is still relatively high. Mozambique's economy is very dependent on foreign assistance (Comité de Conselheiros, 2003). Population has doubled in 30 years, going from 10.6 million in 1975 to 20.5 million in 2005.

Mozambique's topography mainly consists of coastal lowlands, with mountains in the West and uplands and plateaus in the central and northwest regions. Its coastline to the Mozambique Chanel and Indian Ocean is 2'515 km long. The climate ranges from subtropical in the South to tropical in the North. The four major transboundary river basins are the Limpopo (South Africa, Botswana, Zimbabwe, and Mozambique), the Komati (South Africa, Swaziland, and Mozambique), and the Maputu/Usuthu (South Africa, Swaziland and Mozambique).

There are strong socio-economic disparities between the capital and the provinces. Important migration flows of the population to urban areas, caused by a combination of civil unrest and hardship in rural areas, exacerbate disfavored living conditions in cities and suburbs where infrastructures do not guarantee access to basic services such as water and sanitation. Albeit significant progress in terms of poverty reduction, increased school enrollment and improved rates of child and maternal mortality, poverty in Mozambique remain endemic, particularly in rural communities. Ranked 172th out of 177 States in terms of Human Development Index (HDI), Mozambique has more than one-third of its population living on less than US$1 a day (UNDP, 2007).

It is for all of these reasons that one ought to be concerned about climate change in Mozambique. Future impacts of climate change and climate variability will depend on the exposure on the one hand, as well as on sensitivity on the other, which in turn evolves as a function of socio-economic parameters and adaptation measures. Climate change will affect both mean temperature and precipitation, as well as the climate variability; Mozambique may be particularly vulnerable to these changes.

Understanding future vulnerability means taking both socio-economic and climate factors into account. With respect to the climate, there is a lot of uncertainty. The Intergovernmental Panel on Climate Change (IPCC) relies on a suite of Global Climate Models (GCMs), each of which is run by a different set of researchers, and each of which has different sets of assumptions, including about the response of the climate to increases in greenhouse gas concentrations.

Globally, it is clear that there will be several degrees warming by the end of the century, even if efforts to limit future emissions are successful. At the local level, the results are far more ambiguous. For example, Cline (2007) estimates, by combining general circulation models, an increase in the annual average temperature of almost 4 ºC between the periods 1961-1990 and 2070-2090 based on a business as usual scenario. Under the same assumptions, the annual average precipitation is expected to remain of the similar magnitude. For Mozambique, the estimated warming ranges from 1.5 ºC in mean annual temperature by 2080, up to 6 ºC.

In this report, we attempt to provide the most comprehensive study to date of the various factors that will contribute to vulnerability in Mozambique over the next 50 years. We review the literature, both as to vulnerability assessment in general, and then with respect to the study of Mozambique's vulnerability in particular. One result of this literature review is the finding that there have been no comprehensive evaluations of the future that incorporate both climate change and social change. Our analysis then proceeds in this direction. First, we build scenarios of future social vulnerability, based on a theoretically-driven consideration of the main socio-economic drivers of vulnerability. Our results suggest that Mozambique in the future will be better prepared to cope with climate related risk than it is today.

Our longer piece of analysis is a topdown study of vulnerability. This rests on an empirical foundation. We have gathered the relevant data on losses from natural disasters found in the EM-DAT database at the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvaine, Belgium, the premier global database on national losses from natural disasters since 1970. We have combined these data with others from the United Nations to conduct a statistical analysis of vulnerability, identifying socio-economic indicators that are correlated with the risk of death on the one hand, and the risk of being negatively affected on the other hand, from the three climatic hazards affecting Mozambique: droughts, flood, and storms. From this statistical analysis, after due validation, we construct a model that we can use to estimate future losses. For this, we need projections on the changes in the frequency of each of the three hazards, and we rely on input from project team members based at other institutions, and involved primarily in the preparation of other deliverables. Our results suggest a wide-spectrum of possible future risk levels, contingent partly on the range of socioeconomic development found in the scenarios we have considered, but even more importantly in the range of possible climatic futures.

7.2b Background: measuring vulnerability

What is vulnerability? The dictionary definition of vulnerable is "capable or susceptible of being wounded or hurt," and of vulnerability is the state of being vulnerable (www.dictionary.com). A pumpkin that is thrown from the top of the Eiffel Tower is obviously in a highly vulnerable state, as are the people walking underneath: it is fairly easy to predict that the pumpkin will crash against the ground, rather hard, harming itself and potentially a lot of people. Most human environment systems, however, are far more complex, and reasonable minds can differ as to whether they are headed for a crash, or will discover an appropriate parachute to ensure a soft landing. For example, consider the interaction of climate change and deforestation in the Amazon, factors that may lead to irreversible transformation (Laurance and Williamson, 2001). Not only did it take decades to recognize that such an outcome was possible, but how the future will unfold is still subject to a great amount of uncertainty. Whether a system is vulnerable today to a future event can only be known for sure once that future event has come and gone, but by then any assessment of today's system vulnerability is too late to be useful.

Vulnerability theory

Researchers have developed theory and guidelines to aid in the assessment of vulnerability, by breaking it apart into different constituent elements that can be analyzed separately. In all cases, the goal is to identify features of the system that contribute to vulnerability, and which can be changed: control variables. The various theories have come out of three distinct efforts. The first body of theory comes out of efforts to identify the potential effects of acute pressure—typically a single natural hazard—on a system, combined with how other features of the system could exacerbate or mitigate that harm (Cutter, 2001). For example, an earthquake might damage a human settlement. The extent and form of the damage can depend on physical features of the system, such as the construction of buildings. How quickly the system can recover from the damage, in turn, depends on institutions: emergency teams take care of the injured and the dead, and insurance and financing mechanisms facilitate rapid rebuilding (Freeman and Kunreuther, 2002). The second body of theory grew out of efforts to understand how a single effect, namely hunger and famine (Ribot et al., 1996), could develop. While it was initially attractive to lay the blame for hunger on a particular cause, such as a drought, the theory of economic entitlements, propounded by Amartya Sen, convincingly demonstrated that people's physical or latent resources play at least as great a role (Sen, 1981). In researching the vulnerability to a single outcome (rather than a source of harm), these researchers attempt to examine the interactions of multiple stresses, often building over time. The third body of theory grew out of efforts to understand the aggregate impacts of a single policy decision, namely the damages associated with the human choice to place additional greenhouse gasses into the atmosphere. As Figure 7.14 shows, climate change vulnerability assessment combines the challenge of considering the effects of multiple physical impacts on the environment with the challenge of considering multiple consequences.

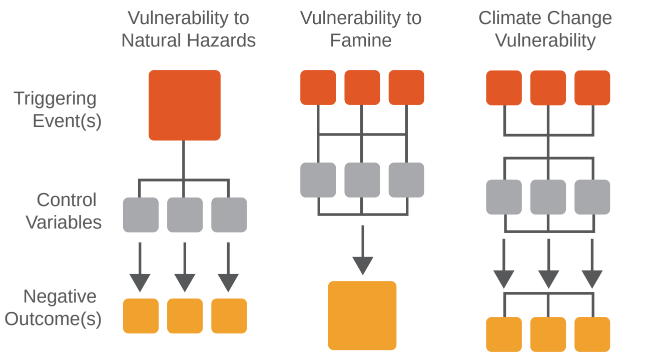


Figure 7.14: Three models of vulnerability and vulnerability assessment. Natural hazards vulnerability is concerned with understanding how control variables can mediate the impacts of a single acute pressure. Famine vulnerability is concerned with understanding how control variables can mediate the effects of a number of separate triggering events, such as war or drought. Climate change vulnerability assessment is concerned with understanding how control variables can mediate the effects of multiple drivers on multiple negative outcomes.
Source: (Patt et al., 2005).

One of the important features of climate change vulnerability is that impacts will often develop over long time scales. To assess vulnerability, then, it has been necessary to take into account how a given society is likely to respond to ongoing developments. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) resolved this by describing vulnerability as a function of three factors: exposure, sensitivity, and adaptive capacity (McCarthy et al., 2001). Exposure describes how the system in question (such as a country, or population) will intersect a climate-induced hazard, such as heat stress, droughts, or tropical cyclones. It could be expressed in terms such as number of people facing an average risk factor. Sensitivity describes the degree to which the people in the system will feel, or be affected by, that exposure. A classic example is the differential sensitivity of the Netherlands and Bangladesh to storm surges: both countries have large populations that are exposed, but in the Netherlands people are protected by flood barriers, and so suffer very little harm, either economically or in terms of loss of life. Adaptive capacity describes the degree to which the system can be expected to transform itself over some relevant time scale to reduce its sensitivity or its exposure. This can be anticipatory adaptation, in response to an assessed risk. It can also be a contemporaneous adaptation, such as when fruit sellers are able to sell building material instead, as a city needs to rebuild from a natural disaster and demand for products changes.

The model of vulnerability that the IPCC developed in the Third Assessment Report, and continued in the Fourth Assessment Report, is helpful on a conceptual but not necessarily quantitative level. It is conceptually helpful because it suggests that we always need to look at both the level of stress (exposure), and the degree to which the system can buffer that stress both at a snapshot in time (sensitivity) and dynamically (adaptive capacity). It is problematic at a quantitative level because it suggests that one can simply describe each causal element with indicators, and then aggregate those indicators to derive a single, unambiguous, picture of vulnerability. This is most certainly not the case.

Vulnerability assessment

As Patt et al. (2008) document, there are a large number of separate indicators for vulnerability, and a wide variety of methodologies for conducting vulnerability assessment. There are three axes along which vulnerability assessments differ: their basic purpose; whether they are top-down or bottom-up; and, whether they are focused in the past, present, or future.

Patt et al. (2008) identify three basic purposes for vulnerability assessment. The first reason to assess vulnerability, closely tied to climate impact assessment, is to draw attention to the problem of climate change, and the need to control greenhouse gas emissions. At a global scale, these are concerned with estimating total losses from climate change, which can then be compared to the costs of avoiding those losses through emissions reductions (Stern, 2007). At a local or national scale, they can be used to draw attention to the injustices associated with climate change. For example, numerous studies have shown that the poor will bear a disproportionate burden of climate impacts, due to a number of reasons (O'Brien and Leichenko, 2000; O'Brien et al., 2004). The second reason to assess vulnerability is to gain a better understanding of causal mechanisms that are involved in turning a stress on the system into an outcome of human loss or suffering, in other words to build theory. Such assessments, or research studies, are typically grounded in empirically-based analysis of historical events. These include the archeological studies described by Diamond (2004) examining the collapse of past societies on Greenland and Easter Island, those based in documented history such as Fraser's (2003) explanation for the Irish Potato Famine, and those used to explain recent events. In Mozambique, for example, there have been several studies of the flooding events of February 2000, identifying the factors that led to loss of life and property (Brouwer and Nhassengo, 2006; Christie and Hanlon, 2001; Lucio et al., 2007). The third reason to assess vulnerability is to assist policy-makers to develop targeted interventions that lessen it. This is where most national-level assessments of vulnerability fall, as they are aimed at mapping out the places where vulnerability is highest (in order to prioritize action spatially), and identifying the primary factors contributing to it (in order to prioritize action sectorally). Often these take the approach of simply documenting current conditions, relying on a pre-existing understanding of how the current conditions can lead to future harm. An example of this would be the monitoring activities that organizations such as FEWS-NET engage in. In other cases, these assessments combine the documenting of current conditions with the building of theory, usually by asking stakeholders how they expect those current conditions can be expected to lead to a risk of harm. Efforts such as the Vulnerability Assessment Committee (VAC), which we describe in more detail below, are an example of this.

The second axis along which vulnerability assessments differ is in terms of whether they take a top-down or bottom-up approach. Broadly speaking, a top-down approach is to examine data at a high level of spatial aggregation, often using indicators that are statistically but not necessarily causally related to the likelihood of harm. Top down approaches can be used to build theory, as in the case of Brooks et al. (2005), which analyzed historical correlations between socio-economic and development indicators and losses from climate-related disaster, in order to identify the most significant leading indicators of loss. Top-down approaches can also be used to identify the need for interventions, such as the United Nations Development Programme (UNDP) Disaster Risk Index (DRI), which identifies those countries where the risks to individuals are greatest, based on analysis of hazard frequency and socio-economic variables (UNDP, 2004). A bottom-up approach, by contrast, focuses on the level at which harm will be felt—typically the household or village—and seeks to identify and describe the state of those factors observable at this level that will directly lead to harm. As with the top-down approach, the bottom-up approach can be used both to build theory—as described in Eriksen et al. (2008)—and to catalog current conditions to assist policy-making. An example of the latter is Vincent (reference), which built a Social Vulnerability Index (SVI) based on existing qualitative theory about causal pathways, and used that as a way to map out relative levels of vulnerability at the national level across Africa.

The third axis along which vulnerability assessments differ is in terms of time, and here there is a strict correlation with the purpose of assessment. Those assessments concerned with building theory necessarily examine past events, since the only way to test hypotheses about whether a system is susceptible to harm is to observe whether, at some later point, harm actually occurred (e.g., Diamond, 2004). Those assessments concerned with drawing attention to the need for international efforts to reduce greenhouse gas emissions are almost always concerned with assessing future vulnerability (e.g., Stern, 2007). Those assessments concerned with helping policy-makers to design effective adaptation strategies need to vulnerability either in the present (to assist short-term decision-making) or the future (to address longer-term decisions). Most of the studies that have been conducted at the national level, by or with funding from government agencies, have considered present day vulnerability (e.g., the monitoring efforts of FEWS-NET). The studies examining future vulnerability have usually been grounded in detailed simulation modeling, around particular scenarios, and it is difficult to tell whether they have actually been useful to actual decision-makers. One of the best examples of this type was the ATEAM research project in Europe, which brought together a number of models in order to project vulnerability until 2080 to changes in ecosystem services brought about by climate change, land use change, and other drivers (Schröter et al., 2005).

Figure 7.15 illustrates these different axes of differentiation of vulnerability assessment. In the following section, we will review a number of assessments of vulnerability for Mozambique that have taken place so far; most of these have had the purpose of building theory or informing adaptation planning, have focused on the present, and have covered the range of top-down to bottom-up. After this review of past assessments, we will develop our own analysis, which relies on existing theory to inform adaptation planning, begins with the present and extends until 2060 in the future, and has both top-down and bottom-up elements.

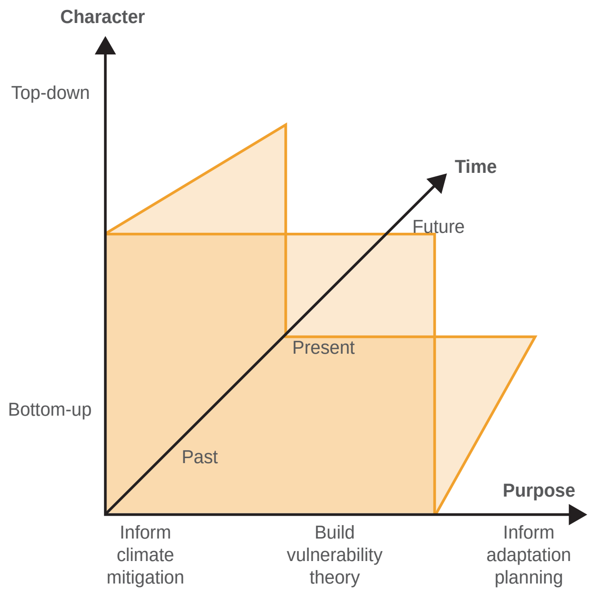


Figure 7.15: Three axes of differentiating vulnerability assessment. Assessments can vary according to purpose, with those that inform adaptation planning being the most relevant for local decision-makers, and those informing climate mitigation being least. They can differ according to whether they are bottom-up or top-down, with both being valuable for different reasons. And they can differ in their time-dimension, examining the past, the present, or the future. Most of the vulnerability assessments that we will review in this report examine present vulnerability either to build theory or inform adaptation planning, and cover the range of top-down to bottom-up. Our own analysis, later in this report, will be to inform adaptation planning, and will have both top-down and bottom-up components covering present to future vulnerability.

7.2c Insights on Mozambique from previous vulnerability assessments

In this section re review past studies that have examined Mozambique's vulnerability to climate hazards, and to climate change. We divide this literature into two broad classes, consistent with our earlier discussion of vulnerability assessment. First, we examine those studies the primary purpose of which has been to develop theory, i.e. to improve our understanding of what sets of factors put people at risk of suffering as a result of climatic disturbances. Some of these studies have fed directly into the actions of the national government, donors, or non-governmental organizations (NGOs), but primarily they have served to illuminate the key areas for concern. In general these studies have been bottom up, with the exception of several empirical top-down analyses that have identified correlations between national level socio-economic and risk data. Second, we examine studies that have sought to assess the current state of vulnerability across the country of Mozambique, the African continent, or the world. These studies have benefited from the former sets of studies, in terms of identifying which variables to gather data for and to analyze, as part of an effort to identify what people, places, or communities are most at risk, and to suggest ways to address this problem.

Theory building studies

There is not space here to summarize the entire literature on vulnerability, much of which is applicable to Mozambique. However, what we can do is to summarize some of those studies that have either taken place in Mozambique and which illustrate dimensions of vulnerability within the country, or else which inform our own analysis later in this report. Some of these have explicitly tried to measure the vulnerability of particular communities, while others have been more concerned with understanding relationships between drivers and outcomes, without an explicit goal of describing levels of risk. We begin with the bottom-up studies, and then move on to consider some top-down ones.

Bottom-up studies

Reporting on work conducted by the German Agency for Technical Cooperation (GTZ), Ferguson (2005) analysed the natural disaster risk in the Búzi District of the Sofala Province. In collaboration with Catholic University of Mozambique, a participatory methodology was used to identify the population at risk from different disaster types. The analysis suggested that different types of natural hazards threatened the safety and livelihoods of approximately one-third of the population. The study found that human activities—agriculture and deforestation—had degraded the study area's natural resources (forest and savannah). Ferguson (2005) argued that the population is particularly vulnerable due to a combination of factors, some related to the location of the area and its topography, and others related to the culture and socio-economic conditions, and that it is this vulnerability that turns a hazard into a disaster. Table 7.9 summarizes the factors leading to an increased hazard on the one hand, and the vulnerability of the population on the other. The study chronicled adaptation measures that had reduced vulnerability: the construction of new settlements on higher ground and away from the river; the rebuilding of damaged infrastructure with due account of the need for being more resistant to cyclones; and the improvement of disaster preparedness through simulation exercises that practiced the implementation of early warning systems.

	Hazard	Vulnerability
Flood	• High precipitations (either in district orupstream) • High tide can temporarily obstruct flow of the Rio Búzi to the sea	• Low level of education • Proximity of towns to the river • Absence of high elevation point for escape • Most people cannot swim and have notenough boats • Non-availability of warning system
Cyclones and tropical storms	• Cyclones develop over the Indian Ocean or the Mozambique Channel when the water temperature is warm. Wind speed can reach up to 300km/h, and are usually accompanied by heavy rain (which could simultaneously cause flooding). • Threat especially for settlements close to coast	• (Same as above) • Traditional houses are not designed and built for resisting to cyclones
Drought	• Climatic variation in Mozambique can lead to one or more year of precipitation below average • Influence of El Niño-Southern Oscillations, which cause high temperature and low precipitation in Eastern Africa, while La Niña causes heavy rains and floods. • Intrusion of saline seawater into the groundwater and the soils during high tide when the water level of the Búzi river is low	• Population living on agriculture of subsistence. Therefore changes in climatic conditions exert significant impacts on socioeconomic systems. • Incapacity of storing supplies as seed for the following year in case of insufficient yields • Alternative sources of food, such as fishing, small livestock, honey, do not allow for substitution. • Almost no irrigation system is in place (Comité de Conselheiros, 2003), neither traditional nor modern.

Table 7.9: Risk and vulnerability factors according to natural disasters in the Búzi District. *Source: Ferguson (2005).*

As more frequent extreme climate events can be expected in the future, and considering the fact that relatively little can be done to reduce the hazard, vulnerability reduction is of utmost importance to minimise casualties and material losses. In this regard, Ferguson (2005) saw an important role for the government to play at different levels, and argued that disaster risk management should be an integrated part of rural development strategies.

Linked to the PRODER project, Kienberger (2007) made use of a participatory Geographic Information System (GIS) for assessing the vulnerability to hazards in nine communities in the district of Búzi and eight communities in the district of Chibabava in collaboration with the Catholic University of Mozambique in Beira. He aggregated a list of vulnerability indicators specific to Mozambique, including physical, socio-cultural, economical, and institutional elements, into an overall vulnerability index. Based on this, the researchers were able to classify individual communities as being of low-to-medium vulnerability, high vulnerability, or very high vulnerability. In 2005, three years after the initial mapping exercise, the researchers returned to the communities to evaluate the effect of the mapping on local decisions. They found that local Disaster Risk Committees had made use of the information in order to improve their planning, although the report was not specific about the details or benefits of that application.

Carmo Vaz (2000) reviewed the major flood episodes that occurred in Mozambique since the independence in 1975 in the Maputo, Umbeluzi, Incomati, Limpopo, Save, Buzi, Pungoé, and Zambezi river basins, and analyses the measures taken to mitigate floods in Mozambique. The author classified mitigation strategies into two categories, namely structural and non-structural. Structural flood mitigation measures included dams, levees, flooding areas, river training, whereas non-structural measures comprise flood zoning, flood management, flood warning systems, emergency plans, raising awareness, and insurance. In regard to dams, the review noted that dams with sufficient storage capacity can play a significant role in attenuating floods. While all major reservoirs in Mozambique incorporate a flood reserve in their operating, Carmo Vaz (2000) underlined the potential perverse effect of dams as a means of mitigating floods. Indeed, for small floods that are being absorbed by the dams, the preparedness of socio-economic systems might decrease and thus be hit even harder in the case of a major flood, since large floods can exceed by far the storage capacity of the reservoirs. Nevertheless, Carmo Vaz (2000) argued for including flood control in the planning, design and construction stages of all new dams in order to take into consideration their multi-purpose.

As part of a more general inquiry into adaptation to climate extreme events, Mirza (2003) reviewed the causes of high vulnerability in Mozambique and characterises extreme weather events in two categories: primary climatic events such as floods, droughts, tropical cyclones, heat waves or cold waves, and coastal storms and storm generated surges; and secondary events such as malnutrition or under nutrition and hunger, outbreaks of diseases or epidemics, rural and urban water shortages, crop plantation failure or harvest failure, and landslides, mudflows and saline water intrusion. The author highlighted nine dimensions and areas for potential improvement. First, socio-economic conditions were judged important factors to vulnerability. Forty percent of the population live under the abject poverty line (less than 1 USD per day), and another 40% live with less than 2 USD per day. Second, Mozambique's debt repayment is drawing substantial financial resources from the national budget that could otherwise be allocated towards promoting development. Third, most of the water causing devastating floods actually originates from abroad. Fourth, the primary objective of water dams is electricity generation, while a multipurpose management would allow to also considering flood prevention. Fifth, design criteria for embankment construction typically consider 5-10 year flood return period, rather than floods of higher magnitude but greater return periods. Sixth, rural areas are generally more affected than urban areas for being more dependent on agriculture. Seventh, communication happened to be poor during past natural disasters, thereby preventing quick and effective humanitarian interventions. Eight, albeit a rapid growing economy, the majority of the population's living conditions do not significantly improve due to marked equity issues with regard to distribution of resources. Ninth, during the major flood in 2000, the human and material resources proved to be inadequate.

Patt and Schröter (2008) conducted a study funded by the World Bank on perceptions of changing vulnerability and risk levels. They analyzed three separate sets of data. First, they held workshops with farmers and local leaders in villages that had suffered from the Limpopo River flood of 2000, and with national level policy-makers in Maputo. What they observed in the two sets of discussions was an apparent mismatch in concern over the primary risks: farmers seemed less worried about the risks from future flooding events than with the shortcomings in how the previous recovery efforts continued to become apparent, while policy-makers seemed unconcerned with the potential unintended consequences of their adaptation strategies. For example, in the policy-makers' workshop, the researchers divided up participants into a number of working groups, and asked each to identify several adaptation strategies, the barriers to successful implementation of those strategies, and the potential negative consequences of those strategies, were they to be fully implemented. All of the groups were able to come up with the first and second lists, but it was only the working group that contained the least expertise on climate adaptation that was actually able to envision negative consequences of climate adaptation: the other groups simply listed additional barriers to implementation. Second, the researchers conducted a survey among policy-makers and farmers, in which they asked respondents to indicate the risk levels from climate-related and non-climate-related events. In general, policy-makers saw the climate-related events as most risky, while the farmers saw the non-climate-related events as riskier. For example, Figure 7.16 shows the different perceptions between farmers and policy-makers as to which risks are presently becoming more severe. This in turn could explain why some adaptations, such as resettlement into villages outside of the floodplain, could thus be viewed as unattractive because they made the non-climate risks (like crime) worse. Finally, the researchers conducted a household survey, again in two villages in the Limpopo floodplain, in which they explored people's perception of climate change, and the causes for the changes they observed. They found that while most people had observed changes, they did not attribute this to issues of pollution coming from outside their community or country. Rather, they believed that they had caused some of the changes by ignoring traditional practices. The researchers suggested that this could further lead to an unwilling to engage in adaptive behavior, since adaptive behavior would represent yet another departure from tradition, and hence result in even more unwanted changes.

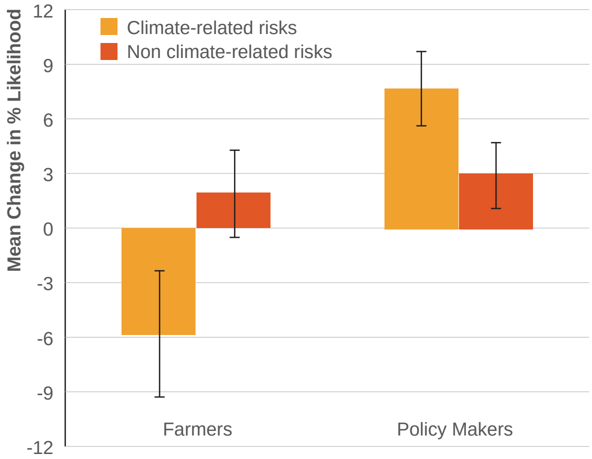


Figure 7.16: Differing perceptions of changing risk levels. In a survey administered to farmers (n = 75) and policy-makers (n = 69), farmers indicated that climate-related risks (e.g. flooding, drought, tropical cyclones) were becoming a less serious threat for them, while non-climate-related risks (e.g. crime, unemployment, falling remittances) were becoming more serious for them. Policy-makers saw the climate-related risks as posing an increasing threat to farmers. The error bars represent one standard error. ***Source: Patt and Schröter (2008).***

Methods	Findings	Policy implications
	Vulnerability Assessment Committee	
• Monitored food crop production and supply data. • Collected data on livelihoods through household surveys.	• Identified the number of people at risk of food insecurity, and amount of food aid needed. • Initially identified drought as the trigger causing to food insecurity. • Later found food insecurity to be the result of multiple stressors.	• Helped to target food and non-food aid. • Demonstrated that a response linked to development is required in addition to a food-relief programme.
	Economic Impact of Climate Change	
• Examined effects of exposure to risks of drought and flood through case study examination of two villages. • Chose case studies based on differing levels of market integration, in order to identify interaction of climate change and trade liberalization.	• Climate change will lead to the marginalization of rainfed farming. • There are unequal benefits from market integration. • There is a lack of integration of local coping and production in formal market structures. • The poorest have no access to new formal opportunities. • The prospects for health and regional employment are poor.	• The most vulnerable are unlikely to be assisted by technology-intensive interventions. • There is a need for investments that enhance the market strength of rainfed farmers. • Details matter: exploiting niche products, local knowledge, and market information can reduce vulnerability
	Disaster risk management	
• Examined flood risks in the Búzi River basin. • Mapped flood risk zones and infrastructure. • Conducted surveys and interviews in order to identify household and community level coping capacity and infrastructure.	• Poverty impedes the establishing of community and household level disaster management structures. • Individual stressors that occur frequently, most importantly HIVAIDS and malaria, make people more vulnerable to disasters.	• Vulnerability can to large extent be targeted by poverty alleviation. • Vulnerability reduction requires long-term investments and engagements in education and economic diversification.

Table 7.10: Comparative analysis of vulnerability assessments. ***Source: Eriksen et al. (2008).***

Eriksen et al. (2008) conducted a comparative analysis of three bottom-up vulnerability assessments in Mozambique and South Africa, and the results are interesting both for the findings of the underlying assessments, and for the added analysis comparing them. The authors were concerned with how a variety of assessment techniques were required, even within a limited geographic area, in order to answer specific questions. They examined three different bottom-up assessments covering Mozambique, the results of which are shown in Table 7.10.

First, a number of agencies throughout southern Africa, including the Southern African Development Community (SADC), the UK Department for International Development (DFID), and the Famine Early Warning System Network (FEWS-NET), formed a Vulnerability Assessment Committee (VAC) for Mozambique, Malawi, and several other SADC countries. The objective was to develop a coordinated system to monitor ongoing food insecurity, allowing for cross national comparisons and the prioritization of relief aid. The assessments started in 2002 with the proposition that droughts were the primary trigger for food insecurity, which implied that rainfall and crop monitoring were the most important activities to engage in as part of a food insecurity monitoring effort. Later, the VACs came to the conclusion that indeed there were multiple triggering factors for food insecurity, and hence it was essential to monitor a wider variety of indicators, and take response measures that consider not just immediate hunger, but also the patterns of development that were the precursors to food insecurity.

The second assessment considered was the Economic Impacts of Climate Change vulnerability assessment, led by the World Bank in cooperation with the Norwegian climate research institute CICERO, the University of Oslo, Rutgers University, and the University Eduardo Mondlane. A key focus of this assessment was on the potential interaction between climate change and economic development. What they found was that climate change tended to have the greatest negative effects precisely on those communities and households that lacked the integration into markets, and hence were failing to participate in economic growth. One explanation for this could be that market integration allows households to be more flexible in their livelihood strategies, and hence more adaptive to climate change impacts. The policy implication from this study was that greater attention to economic integration could be an important means of reducing the vulnerability to climate change.

The third assessment, on disaster risk management, was led by the German Agency for Technical Cooperation (GTZ), in cooperation with the Mozambique Red Cross (CVM) and the Catholic University of Mozambique (Ferguson, 2005). This assessment focused on the Búzi River basin in central Mozambique, and looked closely at conditions on the ground. They engaged in two activities: first, they engaged in mapping to identify the need for specific infrastructure that would mitigate the effects of droughts and floods; second, they identified household- and community-level coping mechanisms and infrastructure. A major implication of their study is that policy interventions need to build upon local knowledge and local practice, rather than interfere with it.

In comparing the results of these three assessments, Eriksen et al. (2008) reached two main conclusions. First, it is essential to consider the multiple stressors that give rise to vulnerability: not just the drought or flood that is the triggering event for food insecurity or a loss of life, but the more fundamental patterns of development that exacerbate or mediate the effects of these risk factors on human suffering. Put into IPCC language, this is saying that assessments need to consider not just exposure, but also sensitivity. The specific factors that make people more sensitive are isolation from markets, a lack of information and education, and a lack of basic infrastructure. Second, it is essential to consider vulnerability as it operates on the household and community levels, taking into account household and community level knowledge and infrastructure. This is another way of focusing on the need to assess adaptive capacity, viewing the household and community as the initial repositories of this capacity. Policy interventions need to build on, rather than act against or interfere with, this capacity.

Several studies have examined vulnerability in the context of the 2000 floods that plagued much of the country. Brouwer and Nhassengo (2006), for example, looked at how gender, knowledge, and social capital played a role in defining who suffered and who recovered most easily from the flood events; they found significant inequalities in impacts, depending on these three factors. Christie and Hanlon (2001) provided one of the most comprehensive documentations of the flood losses, and demonstrated how many of the warnings of the floods that were to come went unheeded by local residents, simply because they misunderstood the magnitude of what was to happen. Lucio et al. (2007), by contrast, suggested that planning at the governmental level was clearly enhanced by advance warnings of high rainfall. Patt et al. (2007) demonstrated how the existence of communication networks to link these two levels of decision-making could lead to poor responses, and greater vulnerability. In the aftermath of the floods, the government initiated an adaptation effort that involved resettling people to higher ground, a policy that local residents to a large extent resisted. Patt and Schröter (2008) describe this, and explain how differing perceptions of risk could have led to this outcome, and hence greater vulnerability. Other studies, such as Bowen (2000) and Galli (2003) have looked at the history of land-use planning in the country, and seen a pattern of lack of local control over settlement decisions, which has indeed exacerbated people's feelings of insecurity and vulnerability.

Top-down studies

Three important studies have conducted top-down empirical analyses of vulnerability and risk, in order to understand how socio-economic indicators, combined with estimates of climate factors, can be used to identify hotspots of vulnerability.

To start off, Yohe and Tol (2002) conducted one of the first empirically-grounded studies of sensitivity and adaptive capacity. They based their analysis on data from the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, which provides national level estimates of the numbers of people killed and otherwise affected, and of economic losses due to natural disasters. First, the analyzed whether low-income countries suffered from a disproportionate number of disasters, and found that they did not. Given this, they then examined whether there was a correlation between income and the effects of disasters. Here they found that there was. The results of their regressions appear in Table 8.3. To explain the numbers killed from natural disasters, they settled on a statistical model that treated Venezuela as a special outlier (since a particular flood there had killed an unusually high number of people), and relied exclusively on per capita Gross Domestic Product (GDP). The latter variable was significant at the 90% confidence level, and the model explained 5% of the variance in the numbers of people killed. To explain the numbers affected, their model relied on per capita GDP, the Gini coefficient (a measure of income inequality), and population density within the country. This model explained 35% of the variance in numbers affected, and all three independent variables were significant at the 95% confidence level or greater. To explain the cost of damage, their model relied only on per capita GDP, which was significant at the 90% confidence level, but explained only 1% of the variance. With respect to this model, they noted that the data quality for damage costs was highly suspect. Altogether, their model results suggest that indicators of development do play a role in determining sensitivity, at least in terms of the human impact of natural disasters, but not necessarily with respect to damage costs. Higher income countries suffer less, while countries with greater income inequality (which are typically less developed and lower income) suffer more. Higher population densities also lead to more suffering. The Yohe and Tol (2002) study did not make any findings specific to Mozambique.

	Killed	Affected	Damage
Venezuela	9.63*		
ln(per capita income)	–0.79*	–1.02***	0.20*
ln(Gini coefficient)		2.21**	
ln(population density		0.24**	
Constant	4.58*	–4.66*	–3.83**
Number of observations	130	108	99
R^2	0.05	0.35	0.01

Table 7.11: Regression results from Yohe and Tol (2002). Dependent variables are the natural logarithms of people killed and otherwise affected (normalized with population size in 1995) and damage done (normalized with GDP in 1995) by natural disasters in the period 1990–2000. ln refers to the natural logarithm. 90%, 95%, and 99% confidence levels are indicated by *, **, and *, respectively.**

Next, a study conducted by the Tyndall Centre for Climate Research, reported by Brooks and Adger (2004) and Brooks et al. (2005), engaged in a similar type of analysis but dug deeper than Yohe and Tol (2002) with respect to the independent variables they analyzed as potential drivers of vulnerability. Again using CRED data at the national level aggregated at decadal timescales, they focused on the relationship between reported mortality and a list of potential proxies for vulnerability to identify key vulnerability indicators. They started by selecting a list of 46 potential variables, and through repeated regression analysis identified 11 with a strong correlation to numbers killed. These were population with access to sanitation, literacy rate (15-24 years old), maternal mortality, literacy rate (over 15 years), calorific intake, voice and accountability, civil liberties, political rights, governmental effectiveness, literacy ratio (female to male), and life expectancy at birth. What is interesting about these results is that once many of the variables associated with development and correlated with income and income inequality are included, income and income inequality itself fail to be significant predictors of vulnerability. This means that it is not the level of consumption that determines vulnerability, but rather those things that greater wealth is used to buy, either by governments or by individuals: better health care, greater literacy, improved sanitation, and better nutrition.

The researchers then used these findings to make statements about relative levels of vulnerability. For each key indicator, they divided the range of data for each variable into quintiles, to which they assigned each country, deriving a score (from 1 to 5). The average score was then calculated for each country across the indicators to produce a composite vulnerability index. The most vulnerable countries were identified by assessing the country rankings across a number of composite indicators using different weighting sets, and were those that occurred in the top quintile for most or all the alternative composite indices. The authors found that most vulnerable countries are situated in sub-Saharan Africa, with Mozambique scoring in the most vulnerable quintile in all 13 indices.

Finally, the United Nations Development Programme (UNDP) sponsored an effort to understand and map out the levels of risk to natural hazards, primary climatic hazards, at a national scale, reported in UNDP (2004). In particular, they wanted to identify those socio-economic variables that correlated with increased levels of disaster risk, magnifying the effects of physical exposure. They considered four different risks separately—earthquake, tropical cyclone, flood, and drought—identifying separate socio-economic correlated with each. A critical part their analysis was to assemble detailed reconstructions of the number of people in harm's way over a twenty-year historical record (1980 – 2000), in each of the countries that had suffered major losses to each of the hazards over the time period. For each hazard, the statistical model that they arrived at contained three key variables:

- Climate impact: the number of events occurring over the period that exceeded a particular threshold intensity. For storms, with was a tropical cyclone categorization; for droughts it was 3 months with less than 50% of average rainfall; for flooding it was inundation of any part of the river basin.
- Population exposed: For each hazard, they considered the population that had been exposed to the hazard. This included a detailed consideration of the number of events that had occurred, and for each event, identifying the geographical extent, and the population living in that region.
- One or more development variables: For each hazard, they had a different set of development variables. For floods, these were population density in the flooded region, and national gross domestic product (GDP); for droughts, it was percent access to safe drinking water; and for cyclones, it was percentage of arable land, and the United Nations Human Development Index (HDI).

They dependent variable in each case was the number of people who had died as a result of the hazards that they considered. In part because of the high level of spatial specificity in their hazard reconstructions, their statistical models were able to explain 80% in the variance of risk levels, for each of the hazards. Table 8.4 provides a summary of their results, while Figure 8.4 shows the fit of each of the models to the observed data.

	Drought	Cyclones	Flood
ln (population exposed to specific hazards)	1.26	0.63	0.78
ln (Proportion of population with access to improved water)	–7578		
ln (Percentage of arable land)		0.66	
ln (Human Development Index)		–2.03	
ln (per capita GDP)			–0.45
ln (population density in affected regions)			–0.15
Constant	14.39	–15.86	–5.22
Number of observations	15	32	90
R^2	0.81	0.86	0.70

Table 7.12: Regression results from UNDP (2004). The dependent variable in all cases was the number of people killed, while the three regressions covered different risks. *ln* refers to the natural logarithm. All coefficients are significant at the 99% confidence level.

The study contained a number of caveats, however. First, they were quite uneasy with the treatment of drought risk, because of concerns over data quality. The high coefficient value for the variable concerned with access to safe drinking water suggests a fundamental problem with the reliability of the results. Second, they cautioned against using any of the models in a predictive capacity. This may have been due to a problem of overspecification. For example, the variable percentage of arable land, which was important for predicting cyclone risk levels, may have been significant because it indicated the number of people living in coastal flood plain areas, susceptible to high storm surges and inundation. Changing the amount of land in these regions that is put to use in agriculture would not, ceteris paribus, have any effect on vulnerability.

The UNDP (2004) study represents an improvement on the two previous studies primarily in terms of offering higher R2 values, indicating a model that fits the data better. This is probably on account of the greater attention paid to obtaining precise values for the number of people exposed to particular threats, rather than simply assuming, as both Yohe and Tol (2002) and Brooks et al. (2005) implicitly did that the entire country was exposed. As with Brooks et al. (2005), the UNDP (2004) results offer limited lessons as to the drivers of vulnerability, namely that it is things people spend their money on (e.g. safe drinking water) that have a direct influence on lives saved or lost.

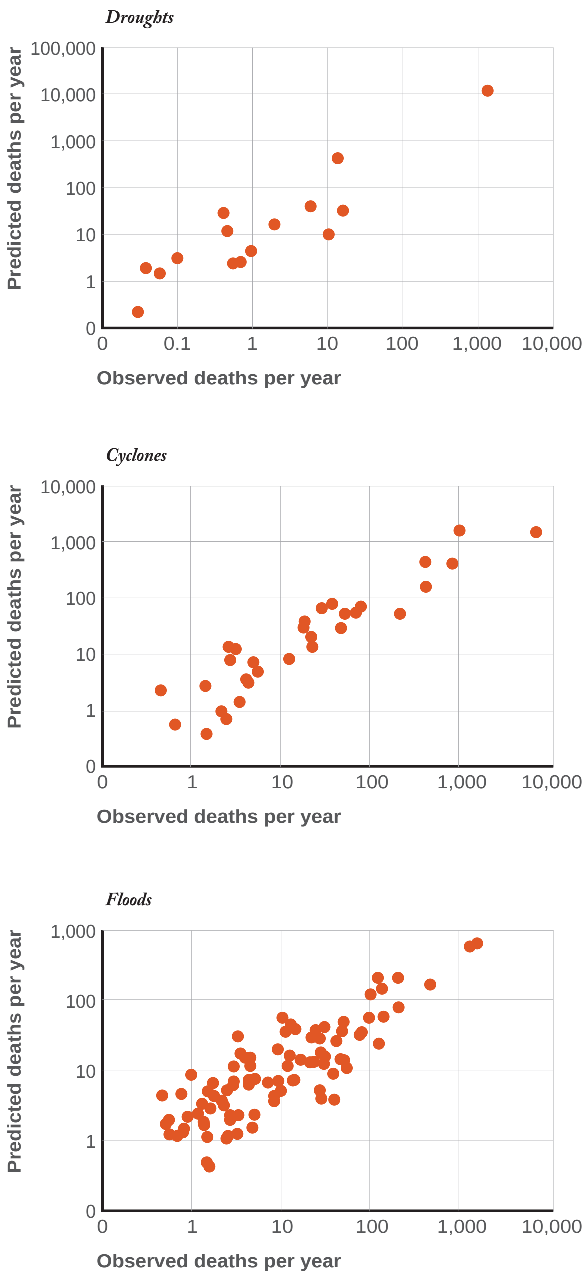


Figure 7.17: Model fits from the UNDP (2004) study. Each plot compares the number of people observed to have been killed due to a particular hazard in the countries that were considered, to the number of people that the model predicts. The tighter the grouping of data points around a diagonal line, the better the fit of the model to the data.

Vulnerability mapping and ranking

There have been a number of efforts to assess the vulnerability of Mozambique, and Africa more generally, in a way that supports adaptation and development planning and decision-making. All of these have focused on present vulnerability or vulnerability in the near future as a result of climate changes. We review these in order to gain perspective on what is already known, and not known, about Mozambique's vulnerability.

United Kingdom Department for International Development

The United Kingdom (UK) Department for International Development (DFID) sponsored a pan-African study designed to map vulnerability across the continent, reported by Thornton et al. (2006). In the first of two tasks, they identified areas prone to climate change impacts by using downscaled outputs from several general circulation models (GCMs) under different global socio-economic scenarios. Towards this, they estimate the change in the length of the growing season, considering changes in temperature and precipitation patterns, and interpret the results in a country-by-system breakdown. In the second task, they examined the biophysical and social vulnerability of those areas judged to be likely to suffer severe impacts. In both cases, they used a detailed geographic information system to consider impacts and indicators on a pixel-by-pixel basis, aggregating results up to the national level.

They did so by using a set of 14 indicators, developed in a workshop setting and guided by literature review and experience, listed in Table 7.13. Using principle component analysis, they identified 4 orthogonal factors, which they could then use to establish a weighting function. This in turn could be used to calculate an overall indicator of vulnerability through a weighted sum using the variance explained by the respective components as weight. The aggregate indicator of vulnerability was then normalised, allowing the grouping of countries into quartiles.

How did they view Mozambique? In the first stage of the analysis, they found Mozambique's exposure to climate impacts to be high, noting in particular an increased likelihood of failure of the growing season to generate useful rainfall. Analyzing the results of GCM projections out to 2050, they found a large variety of growing season length changes depending on the scenario assumed, the climate model used, and the region of the country, ranging from a 20% loss to over 20% gain. In the second stage of analysis, which added the comparison of socio-economic indicators, they ranked Mozambique in the second-highest quartile of vulnerability for Africa.

The DFID study came with a number of caveats. First, they noted the complexity and highly uncertain nature of the climate change impacts as a challenge to designing adequate adaptation measures. The authors cautioned against over-interpretation of the outcomes due to the uncertainty intrinsic to such analysis. Indeed, as far as Mozambique is concerned, a significant shortening of the growing season in areas of southern Mozambique was anticipated using the data from one of the models, while a significant increase in the growing season appeared in the same regions based on another model data input. The authors also note that macro-level analyses, while insightful, might mask important heterogeneity.

Class	Indicator	Hypothesized functional relationship with vulnerability
Natural capital	Pixel suitability for crop production	The higher the suitability, the higher the potential crop production, the more potential vulnerability of households to substantial changes in climate
Natural capital	Soil degradation	The higher the soil degradation potential, the higher the vulnerability
Natural capital	Internal water resources	The more internal water, the lower the vulnerability of the household
Physical capital	Accessibility to markets	The closer to the market, the more diversified income can be and the higher the resilience to shocks, even when farm sizes are small. Better access to markets also implies better service provision
Social capital	Human poverty index	Higher HPI-1 implies higher social capital available
Social capital	Governance	Better governance promotes foreign investment and creates more jobs. A higher index means more social capital
Human capital	Stunting	Stunting is one measure of food security and a proxy for poverty
Human capital	Infant mortality	Higher infant mortality rates imply higher levels of vulnerability
Human capital	% children underweight	Higher rates of underweight children imply higher levels of vulnerability
Human capital	Malaria risk	Areas with higher risk of malaria are more vulnerable
Human capital	Public health expenditure	Areas are less vulnerable with higher government expenditure on public health
Human capital	HIV/AIDS prevalence	Areas with higher prevalence of HIV/AIDS are more vulnerable
Financial capital	Agricultural GDP	Economies with higher dependence on agriculture are less diverse and more susceptible to climatic events
Financial capital	Global interconnectivity	Economies with higher dependence on imports are more vulnerable to climate change and extreme events

Table 7.13: Indicators of vulnerability used in Thornton et al. (2006).

Tyndall Centre for Climate Research

Katherine Vincent, a researcher at the Tyndall Centre for Climate Research, conducted a study in which she created a national-level index of social vulnerability across Africa (Vincent, 2004), and compared the national level indicator with bottom-up fine-scale analysis of a single South African village (Vincent, 2007). The analysis was related to the seminal work by Cutter et al. (2003), in terms of creating a index of social vulnerability at an aggregate special scale based bottom-up analysis of the primary driving forces of vulnerability. The indicator of social vulnerability (SVI) that she created was based on theoretical insights and stakeholder interviews and focus groups, much in the manner of other studies such as Thornton et al. (2006) and Brooks et al. (2005). As with Thornton et al. (2006), her primary purpose was not to conduct an empirical study of the correlations between different indicators and observed losses from climate related events, but rather to aggregate the indicators into a single SVI that could be used to inform adaptation planning.

Table 7.14 lists the indicators that the study evaluated. Based on a theoretical review, she adopted a cruder weighting methodology than that conducted by the Thonrton et al. (2006) study, namely assigning simple weights to each of the five classes of indicators: 20% to economic well-being and stability; 20% to demographic structure; 40% to institutional stability and strength of public infrastructure; 10% to global interconnectivity; and 10% to dependence on natural resources. The results of Vincent's (2004) ranking appear in Figure 7.18. Countries shown in black, with the highest values of the social vulnerability index, were determined to have the social, economic, an demographic features that would make them least resilient to any exposure to climate-related hazards; a hazard of given magnitude would potentially lead to the greatest amount of disruption.

Class	Indicator	Hypothesized functional relationship with vulnerability
Economic wellbeing and stability	Population below income poverty line, 2000. The % of the population living below the specified poverty line. Change in % urban population between 1975 and 2000, based on midyear population of areas defined as urban in a country.	The greater the population below the income poverty line, the greater the vulnerability. The greater the change in urban population the greater the vulnerability.
Demographic structure	Population under 15 and over 65 as % of total, refers to de facto population, i.e. all people actually present in a given area at a given time. Adults aged 15-49 living with HIV/AIDS as a percentage of the population aged between 15-49 in 2001.	The higher the dependent population, the greater the vulnerability. The higher the proportion of working population with HIV/AIDS, the higher the vulnerability.
Institutional stability and strength of public infrastructure	Public health expenditure as % of GDP in 1998 Number of mainland telephone lines per thousand population in 2000. Composite index using data from 15 sources from 9 institutions and perceptions of well informed people with regard to corruption, in 2002.	The higher the health expenditure as a proportion of GDP, the lower the vulnerability (inverse). The higher the number of telephones, the lower the vulnerability (inverse). The lower the score (i.e. the higher the corruption), the higher the vulnerability (inverse).
Global interconnectivity	Net trade in goods and services (BoP, current US$, 1999).	The more negative the trade balance, the higher the degree of vulnerability (inverse).
Natural resource dependence	Percent of rural population, defined as the difference between the total population and urban population in 1999.	The higher the rural population, the greater the vulnerability.

Table 7.14: Indicators of vulnerability used in Vincent (2004).

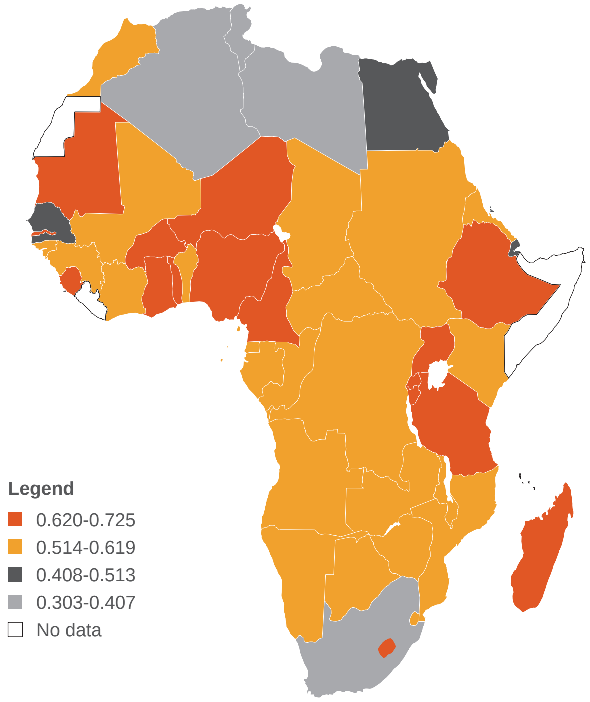


Figure 7.18: Social Vulnerability Index. The map shows the relative levels of vulnerability in Africa, using an index based on theoretical drivers of vulnerability. All of these drivers are social, economic, and demographic in character. Hence, the map does not take into account different levels of exposure to climate-related threats. *Source: Vincent (2004).*

It is worth noting that Mozambique did not fall into this most vulnerable category. The sub-indexes showed a high relative vulnerability of Mozambique compared to other African countries in terms of the following: economic wellbeing and stability, demographic structure, and global interconnectivity. In contrast, Mozambique performs well in relative terms in regard to institutional stability and strength of public infrastructure, which is what pushed it into the less sever vulnerability category. However, it is also important to note that the index does not include any analysis of the magnitude of exposure to different threats.

Human Development Report

As part of its research for the 2007/08 Human Development Report, UNDP sponsored a case study of vulnerability in Mozambique, reported by Bambaige (2007). The paper reviewed Mozambique's adaptation strategies to climate change, considering both its exposure to natural hazards, and the respective plans and roles of several institutions within the country.

The study identified four climate related hazards: floods, droughts, tropical cyclones, and sea level rise. Table 7.15 summarizes the primary findings of the report, for each of the hazards. The report drew particular attention to resources in coastal areas, such as water, agriculture and forests, would be negatively impacted by climate change. While an increase in ambient CO_2 concentrations could lead to a more productive growing season, the report suggested that the continued limited nitrogen availability, due to insufficient fertilization, could prevent such benefits from occurring. In terms of economic sectors, Bambaige (2007) suggested attention to agriculture, water, energy, and health. For instance, it identified crop diversification as an important vulnerability reduction measure in the agricultural sector. Also, it underlined the potential of renewable energy for providing local communities, particularly in rural areas, with access to modern energy in order to reduce the negative effects of deforestation.

In its institutional analysis, Bambaige (2007) focused on the Ministério para a Coordenação da Acção Ambiental (MICOA, Ministry for Coordination of Environmental Affairs) as the main governmental body dealing with issues of climate change. Its activities include those related to the United Nations Framework Convention on Climate Change (UNFCCC), capacity building programs, National Adaptation Plan for Action (NAPA). It also examined the Instituto Nacional de Gestao de Calamidades (INGC, National Disaster Management Institute), being the government agency dealing with natural disasters. The report suggested that there is a need for better coordination between these agencies, and different sectors more generally, in order to enhance the resilience of the poor in the face of climate change.

Climate related adverse effect	Sector / Area Impacted	Impacts
Floods	Agriculture, forest, water resources, health, livestock, coastal resources, tourism, ecosystems, infrastructure, flood plains of main river basins such as Limpopo, Incomati, Pungue, Save, Zambezi, Umbeluzi, Maputo, and Buzi	Loss of life, crops, ecosystems, property, human and animal habitate, outbreaks of pests and diseases, displacement of people, movement of land mines, destruction of infrastructure (communication network, schools, hospitals, houses, etc.), erosion, land degradation, etc.
Droughts	Agriculture, water resources, ecosystems, health, food security, livestock, and low lying areas	Crop failures, water scarcity, drying of water reservoirs (dams, fish pond, lake, rivers), famine, loss of human and animal lives, stresses in the marine living organisms, loss of biodiversity, environmental degradation, salt intrusion, erosion.
Tropical cyclones	Country wide, particularly along the coastal area, during rainy season	Loss of life from collapsing structures. Damage to structures (rural community houses, school blocks, hospitals, etc.) due to substandard constructions. Destruction of crops, forest plantations & natural trees. Bush fire enhancement in the dry season.
Sea level rise	Coastal area, river water resources	Loss of land and infrastructures, increased erosion, salt intrusion.

Table 7.15: Summarized findings of Bambaige (2007).

World Bank Factsheets

The World Bank maintains a series of online national level Climate Risk Factsheets, each of which contains a rudimentary analysis of the relationship between climate risks and economic conditions in the country. The Factsheet for Mozambique (World Bank, 2008) contains three interesting features. First, it compares the risk and vulnerability level of Mozambique with other countries, both worldwide and within sub-Saharan Africa. Consistent with other studies, it finds the socio-economic and demographic conditions to be moderate in Mozambique, meaning that country does not have among the highest of social vulnerabilities within Africa or the world. However, it does find that the degree of physical exposure to climate hazards, particularly flooding, to be very high. The Factsheet highlights the fact that Mozambique has an immense untapped agricultural potential, with only about 10% of the arable land currently in productive use (Comité de Conselheiros, 2003).

Second, the report examines the relationship between climate hazards and economic growth. As seen in Figure 7.19, there does appear to be a relationship between precipitation and economic growth, most likely a result of the link between precipitation and productivity in the agricultural sector. This mirrors findings from other African countries (Patt and Winkler, 2007). It suggests that if precipitation were to decrease in Mozambique, there could be a negative influence on economic growth. Fortunately, this is not what most GCMs predict for the majority of the country (Solomon et al., 2007); the World Bank (2008) cites Cline (2007) for this finding. Finally, the World Bank (2008) Factsheet presents a summary table of recommendations for improved management of climate risks. We reproduce this here in Table 7.16.

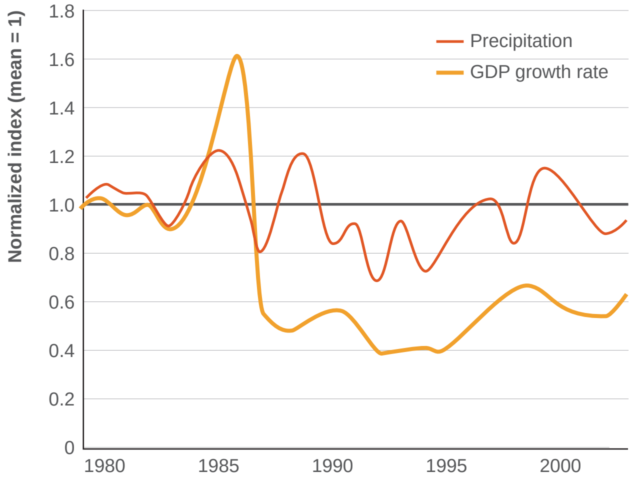


Figure 7.19: Correlation between annual precipitation and economic growth. The figure illustrates that there may be a lagged effect of high or low precipitation anomalies on economic growth. ***Source: World Bank (2008).***

Sector	Enabling environment / capacity building	Investments
Capacity Building & Cross-cutting	Develop and strengthen the Knowledge Base • Data and information – acquisition, analysis, dissemination, utilization • Enhanced hydro-meteorological monitoring systems, and improved and expanded human resources in the hydrological and meteorological services • Analytical tools and products tailored to sector needs • Information on adaptation options based on pilots, field tests and research • Early warning systems • Information exchange networks to enable access to and exchange of data and information between all levels of user and decision makers • Regional and National Networks – Networks of agencies and policy makers, experts, knowledge bases, data and information, research and field experience (pilots, tests) is crucial to stimulating and facilitating investment in adaptation	• Invest in enhanced disaster preparedness, in particular for the increased risk of cyclones and for floods, including disaster planning, preparedness, early warning and response systems, and disaster recovery • Introduce modern technology for data collection, transmission and assessment; Introduce the use of compatible standards and systems to enhance data and knowledge sharing across sectors; • Strengthen and expand systematic observations of meteorological and hydrological parameters; strengthen the technical capacity of hydro-met services including the development and dissemination of knowledge products to enhance the adaptation of project design and implementation to climate variability and change; • Strengthening and develop early warning systems for drought and flood hazards and natural disasters to improve preparedness, response and recovery in all the sectors (agriculture, health, natural resource, and energy)
Agriculture	• Develop flood, drought and drainage risk maps to enhance sector development planning • Combine risk mapping with river basin and sub-basin water resource assessments including rainfall variability • Build awareness and analytical capacities in sustainable land management	• Scale up investment in research and extension services to enhance production and farm incomes with a new emphasis on adaptation to climate variability and change • Pilot and invest in sustainable land management practices focused on building resilience by reducing erosion, enhancing watershed protection and improving land productivity • Pilot and scale up access to seasonal climate forecasts coupled with training in adaptive natural resource management practices • Scale up investment in the introduction of irrigation and water management systems and appropriate technologies, especially water conservation in drought prone areas • Pilot and scale up seed storage systems • Scale up investment in livelihood focused participatory rural develop including sustainable land management, watershed management and community driven development (CDD) approaches • Pilot risk insurance schemes including indexed crop insurance
Water Resources Management	• Improve technical capacity of water resource management agencies including hydro-met and groundwater management services • Enhance capacity to manage transboundary water resources • Institutionalize multi-sector, integrated water resources planning and management • Strengthen the analytical and modeling capability of water resource agencies to utilize enhanced hydrologic and metrological data acquisition and monitoring networks and support river basin and sector development and management planning	• Improve technical capacity of water resource management agencies including hydro-met and groundwater management services • Enhance capacity to manage transboundary water resources • Institutionalize multi-sector, integrated water resources planning and management • Strengthen the analytical and modeling capability of water resource agencies to utilize enhanced hydrologic and metrological data acquisition and monitoring networks and support river basin and sector development and management planning

Energy	• Strengthen electricity utilities to improve their efficiency and financial viability
	• Strengthen sector strategic planning to include a greater emphasis on climate vulnerability and climate change risk by introducing:
	  • Assessment of vulnerability of supply systems, including hydropower and the development of other renewable sources less sensitive to climate
	  • Assessment of climate change impacts on demand
	  • Expand off-grid expansion opportunities (potential for renewable energy)
	  • Grid extension
	• Carbon finance opportunities
		• Support the expansion and development of regional electricity grid interconnections
		• Scale up investment in electricity access and energy efficiency
		• Review the effects of climate variability and climate change on the reliability and capacity of existing and potential hydropower facilities and developments;
		• Accelerate expanded pre-investment studies of hydropower and other renewable sources for grid and off-grid electricity supply
		• Coordinate grid and off-grid electricity access planning with rural development and forestry sectors and SLM programs to support efforts to reduce fuel-wood harvesting and use

Table 7.16: Recommendations for climate risk management. *Source: World Bank (2008)*.

Sector	Enabling environment / capacity building	Investments
Transport	• Enhance the capacity of road and transport sector agencies in the area of strategic planning to identify and incorporate climate vulnerability into sector plans and project designs	• Review and revision of planning and design standards for river and stream crossing, and cross drainage, in regions with existing and potentially increased future flood hazard including increases in high intensity rainfall • Increase the use of flood, drought (greater access to network) and drainage risk mapping in sector planning in rural and urban areas • Introduce risk assessment into the selection of design standards including pavement type
Urban Development, Water Supply and Flood Management	• Enhance strategic supply planning capability of urban water supply utilities including climate vulnerability and risk assessment of water supply sources • Strengthen urban development planning based on improved flood and drainage hazard mapping	• Invest in infrastructure upgrading and improvement to mitigate and adjust to changing flood and drainage hazard patterns • Invest in urban services to reduce flood and drainage risks including housing relocation, reduced encroachment into flood hazard areas, secure solid water management
Health	• Develop/strengthen climate-related surveillance systems (as part of overall monitoring system) • Increase awareness of health related climate vulnerability and increase capacity to incorporate adaptation in to the health care system	• Invest in disease vector control systems • Invest in increased surveillance of existing and emerging threat areas affected by climate variability and climate change
Forestry, Biodiversity and Coastal Zone Management	• Strengthen capacity to monitor forest and biodiversity resources, evaluate their status and threats and formulate actions • Develop and test new governance arrangements for forest resources	• Invest in forest resource management to enhance climate resilience, enhance livelihoods of people living near and in forest areas, and promote resource conservation • Invest in reforestation and afforestation, and in their sustainable management • Invest in forest fire prevention, risk surveillance, and response

Table 7.16: Recommendations for climate risk management. *Source: World Bank (2008)*.

Ministry for Co-Ordination of Environmental Affairs (MICOA)

A document prepared by the Ministry for Co-Ordination of Environmental Affairs (MICOA, 2005) evaluated the vulnerability of the country to climate change, and described possible adaptation strategies. As causes for climate related extreme events, besides the obvious natural variability and anthropogenic interference to the climate systems, the report pointed to inappropriate agricultural practices. The nomadic agriculture currently practiced promotes deforestation in various regions. Furthermore, the lack of access to modern technology hinders the progress towards reducing the vulnerability of essential livelihood. Since about 80% of the energy consumption is based on biomass, areas neighbouring major urban centres suffer from overexploitation of natural resources. Other factors, such as the institutional capacity and the participation of local communities, also contribute to the high vulnerability of Mozambique to climate related disasters. The vulnerability to climate events is also affected by external factors, such as recurrent poverty level and the impacts of HIV/AIDS for instance.

The report provided maps of the country indicating areas prone to floods, droughts and cyclones. The flood mapping indicates that the areas vulnerable are mostly, but not only, close to the coast. The classification is based on a normative approach. For instance, regions in the first cluster of risk include areas of 20 meters of altitude and lower, as well as areas within a 10 km distance of a major river. Those represent 1.7 million hectares, or 6 % of the national territory. In terms of droughts, the south-western (west from the Gaza province) as well as the central (west from the Tete province) regions are particularly vulnerable to droughts. The drought mapping is based on statistical analysis of rainfall over several decades. Finally, the area most affected by cyclones is located between Pemba and Angoche. In the case of the cyclones, the map is designed based on records of occurrence over 75 years.

The document described the role of the different governmental (MICOA, INGC, SETSAN, CVM) and international (WFP, UNICEF, UNDP, etc.) institutions in promoting climate change adaptation in Mozambique. As adaptation strategies, the report suggested a move from a reactive attitude to pro-active actions to mitigate the effects of weather related events. It proposed a series of measures at sectoral level, notably in terms of water management and agriculture, to be implemented in a decentralized manner with the active participation of the local authorities and population.

FEWS-NET

The Famine Early Warning System Network conducted an assessment of livelihoods through Mozambique, in cooperation with the government of Mozambique (FEWS-NET, 2002c). The report described Food Economy Zone profiles, which involved analyzing food security at the household level using the food economy approach. The study aimed to improve the understanding of food insecurity by monitoring the current food security situation at the local level, and identifying populations at risk in order to suggest possible interventions. Underlying the report was the premise that food security plays a major role in households' vulnerability to natural disasters.

The study was carried out in collaboration with local experts in all regions of the country. Regional seminars were used to outline the food economy zones for each province in a participatory manner, resulting in the identification of 43 zones for the country in which the majority of households share the same characteristics in terms of access to food and income.

FEWS-NET (2002c) reported that the main source of income originates from animal sale, followed by the trade of cotton, tobacco and coconuts in certain regions. The study underlined the importance of access to the market as a means to generate income and improve the standard of living. The different Food Economy Zone baseline profiles accompanying the main report provided quantitative data in terms of wealth distribution, as well as the relative importance of different food and income sources. As a result of their study, the authors argued that administrative divisions are not adequate for food security analysis. They also suggested a set of actions to improve the livelihood options in each of the respective zones.

SETSAN

A recent series of natural disasters left communities suffering from food insecurity particularly affected. Under this premise, the Government of Mozambique recently launched a country-wide assessment of food security (SETSAN, 2008), which could serve as a baseline for considering climate vulnerability and the impact of natural disasters on that food security. The methodology was based on data collection and analysis from a series of interviews (quantitative information) and focus groups (qualitative information). Food security was quantified using three composite indicators: diet quality, survival strategy, and resources. The data were sorted into four food insecurity categories: acute, chronic, reasonable, and good. It was estimated that over 300,000 people are facing acute food insecurity and require immediate humanitarian assistance. Breaking the results down to the provincial level, Figure 7.20 illustrates the results of the study.

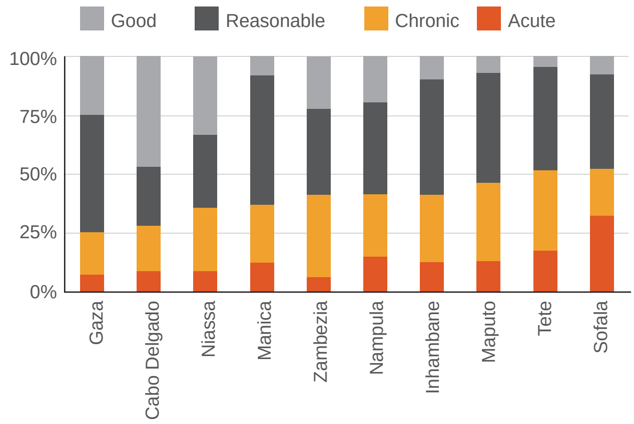


Figure 7.20: Food security by province. The figure shows the percentages of the population in each province that are food insecure (either acute or chronic) or relatively secure (reasonable or good). The provinces have been sorted from most secure to most insecure. *Source: SETSAN (2008).*

The authors found that the provinces of Sofala, Tete and Nampula suffer from the highest level of acute food insecurity, reflecting their vulnerability to the adverse effects of climate-related disasters and limited adaptive capacity. The provinces of Zambézia, Tete and Maputo, on the other hand, feature the highest level of chronic food insecurity, indicating persistent poverty and systemic food access issues.

The authors also explore the possible correlation of characteristics of food insecurity with a range of indicators, socio-economic notably. For instance, there seems to be a correlation between acute and chronic food insecurity and access to health care. Further decomposition analysis revealed that people with low level of food intake spend disproportionately on food. Also, the study demonstrated that low level of food intake is not only caused by a lack of financial resources, but also by an inadequate access to the market. Finally, the groups characterised by low level of food intake benefit of the most limited food reserve, further exacerbating their vulnerability in case of additional stress.

Overall, Mozambique remains a net importer of food. The imported wheat (100% of the domestic production), rice (74% of the domestic production), and corn is consumed mainly in urban areas where a price increase in traded food would be most detrimental, especially to the poorest.

Synthesis of findings

There are some patterns and trends in the assessments of Mozambique's vulnerability that stand out. Most importantly, the studies that we have reviewed focus primarily on risk and vulnerability levels that exist today, and do not extend detailed quantitative analysis into the future. Thus, while some studies (e.g.,World Bank, 2008) contain quantitative projections of physical impacts of climate change, they do not match this with quantitative projections of sensitivity. Indeed, most quantitative studies make the assumption that historical data and trends are good proxies for evaluating risk in the future; this assumes that the socio-ecological system will respond in a similar fashion to climate impacts in the future as it has in the past. Second, there has been a recent trend in vulnerability assessment to include detailed spatial analysis, using geographical information systems (GIS) methods. This is a positive development, and yet it is often difficult to make the transition between different scales of analysis. An important study on vulnerability, which we have not summarized because it had a very different geographical focus, suggested that vulnerability at the household level is far more heterogeneous and dynamic than that at higher levels of aggregation, such as the national level: thousands of households are moving in and out of states of acute vulnerability, but the aggregate effects of their movements shows up as a very slow trend in a single dimension at the national level (Eakin and Bojórquez-Tapia, 2008). Third, few if any of the studies explicitly take uncertainty into account. There are two main ways to do so: by attempting to construct probability density functions, including ranges of potential values; or by developing alternative illustrative scenarios. There is a clear need for both approaches. We hope that the second half of this report can contribute in this respect.

In terms of substance, the literature reviewed provided a consistent picture that Mozambique is particularly vulnerable climate change and variability. The direct impacts of extreme weather events combined with the indirect effects can have devastating effects of developing countries economies and recovery can be slow (DFID, 2004). It is however argued that the risks Mozambique faces in terms of climate related disaster do not significantly differ from other tropical regions but that its vulnerability is relatively high (Bambaige, 2007). The level of poverty is often mentioned as predominant factor to the high climate vulnerability, together with the reliance of the majority of the population on agriculture of subsistence (MICOA, 2005). Moreover, there is almost no irrigation system in place (Comité de Conselheiros, 2003), neither traditional nor modern, to mitigate the effect of erratic rainfall of agricultural yields. Inadequate infrastructure and weak institutional framework is also regularly quoted as important factors. The lack of appropriate natural resources management policies lead to the degradation of precious resources (erosion, loss of fertile soil, etc.). Uncontrolled burning for instance can go uncontrolled during periods of drought, devastating large areas (Ferguson, 2005).

Natural disasters do not affect all communities evenly, in that their impacts are correlated to the vulnerability of those communities (Republic of Mozambique, 2006). The particularly high vulnerability, combined with significant exposure to extreme weather events, makes adaptation of utmost importance for Mozambique. According to Bambaige (2007), the sectors that should be the focus of adaptation measures in order to increase the resilience of socio-economic systems are agriculture, water, energy, and health.

An exhaustive vulnerability mapping of the country of Mozambique requires the access to detailed and reliable datasets in regard to both exposure and sensitivity. While information related to the exposure of Mozambique is available at geographically disaggregated level, the same does not hold for sensitivity. Most studies in this regard either focus on inherent or social vulnerability at national level, or feature isolated local case studies that do not allow for comparison with other areas in the country. An explicit assessment of sensitivity at sub-national level necessitates data about the different factors that are assumed to play a significant role, such as the level of poverty or the share of rural population for instance, at a fine geographical scale. Such assessment would allow for formulating highly-specific recommendations in regard to adaptation strategies that are relevant at local scale (i.e. district level). Such data were, ultimately, not available for this study.

Hotspots of different risks

Flood

MICOA (2005) revealed that about 1.7 million hectares, representing 6 % of the national territory, are highly exposed to flooding, principally along the coast and the main river beds. Unfortunately, floodplains are commonly fertile areas where humans tend to settle. This is no exception in Mozambique. Many of the major towns are located close to the coast and along rivers. The areas identified as high risk of flood in MICOA (2005) overlap with relatively highly populated districts, such as on the coastal strip of the Gaza Province along the Limpopo River basin. The floodplain of the Zambezi River and confluents is potentially very large, although located in areas with lesser population density, with the notable exceptions of the districts bordering Malawi. Also, both the Licungo and Ligonha river mouths are situated in district with rather high population. The Buzí river, as well as the delta in Beira, are neighbouring districts with a relatively high level of poverty. Areas close to Maputo are combining the characteristics of high vulnerability to flood with acute poverty issues. Food insecurity plays a major role in both increasing people's sensitivity to climate related events and in limiting their ability to adapt. SETSAN (2008) reported a high level of acute and chronic food insecurity in the Sofala province which is, as mentioned above, prone to flooding along the major river basins and the coast. In the other side of the spectrum, the relative good situation of the Cabo Delgado province in terms of food insecurity represents an important asset for coping with possible floods along the Ruvuma, Messalo and Lúrio rivers.

Drought

According to MICOA (2005), mainly the southern part of Mozambique is facing high risk of drought. The annual average precipitations in the western regions of the Gaza province are especially low. The districts in those areas are relatively unpopulated compared to districts in the coastal zone of the same province. Also, poverty levels in the Alto Limpopo region are relatively low. In terms of food security, the access to the Limpopo river assists in mitigating the adverse effects of droughts in the area, which is one of the reason contributing to its classification as relatively secure in terms of access to food (FEWS-NET, 2002a). The north-west extreme part of the Sofala province and the south-western Tete also experience lower than national average rainfall. The risk of drought is combined there with the medium poverty level of the Tete province. Furthermore, the population is notably higher in those districts than in the Gaza province. Another area to suffer from relatively low precipitations is the northern coastal zone of Namputa province. The level of poverty in certain districts of the region is particularly high thus impeding people's ability to cope with climate stress. FEWS-NET (2002b) reports on a sub-zone where emergency food assistance was required. Indeed, it was estimated that poorer households might face a deficit of several months of food.

Cyclone—The mapping of the occurrences of cyclones featured in MICOA (2005) demonstrated the very high exposure of the coastal zones of the Nampula province, as well as the Zambezia, Sofala and Inhambane to a lesser extend. As mentioned above, important human settlements are gathered along the coast. Moreover, poverty is severe along the coast in the districts surrounding Beira, Quelimane, Moma, and Memba. A precarious standard of living impedes people's capacity to develop mechanisms to cope with stressors.

Multiple threats

People's vulnerability to climate hazards is a function of their exposure, sensitivity, and capacity to cope. In terms of exposure, some coastal areas in Mozambique combine the risk of flooding with the risk of tropical cyclones. In addition to that, the coastal area of Nampula further faces the risk of drought. As will be demonstrated in the section related on modelling social vulnerability, poverty plays a significant role in regard to the sensitivity to climate hazards. The districts around Memba feature relatively high level of poverty, while at the same time being exposed to drought, flood and cyclones. The districts along the coast north of Quelimane also combine a high risk of exposure to various natural extreme events with a relatively high level of poverty. It is not to say that other regions do not feature a high vulnerability to extreme weather events. But the areas abovementioned are characterised by a combination of high exposure and relatively high sensitivity, making them especially vulnerable to climatic risk.

Sectoral insights

Water
Despite significant progress there are still millions of people using unimproved water resources in southern Africa, with the largest proportion being located in Mozambique (Mutangadura et al., 2005). Eighty-one percent of the population have access to improved water source nowadays in urban areas whereas only 41 % in rural areas (UNESCO, 2006).

A significant proportion of the African population, up to one third, lives in drought-prone areas and several millions of Africans regularly suffer from the impacts of droughts and floods (United Nations, 2000). By affecting precipitation patterns, climate change will also affect water availability and might further exacerbate persistent water issues affecting a large portion of the population. Indeed, about 25% of the contemporary African population already experiences high water stress (Vorosmarty et al., 2005). Periods of drought or flood are exacerbated during El Nino events (Boko et al., 2007).

Mozambique is subject to the water management from neighbouring countries located upstream, where around 54% of annual surface water flow comes from (World Bank, 2008). Increasing capacity to manage trans-boundary water resources is therefore of utmost importance. There are plans for building new dams to increase the hydropower capacity, which also represents an excellent opportunity for regulating the water flow. The potential multi-use of dams (hydro-electricity, flood mitigation, water reservoir for supplying urban area and for irrigation, etc) is often seen as an important climate adaptation measure in the water sector. In general, integrated water management and planning has substantial advantages but require multi-sectoral coordination at institutional level.

Agriculture
Agriculture plays a predominant role in Mozambique. It supports 80 % of the population and contributes to 45 % of Mozambique's GDP (Bambaige, 2007). Potential adaptation strategies include notably an increase in the seed varieties, technological improvements, and the promotion of natural resources conservation.

Usam and Reason (2004) highlight the fact that the relatively high variability of water availability during the growing season imposes a significant degree of uncertainty on agricultural yields. Irrigation could therefore play a significant role in securing farmers' income. Another measure often quoted in the literature is the diversification of income.

Health
IPCC expects climate change and climate variability to also have an impact on human health by altering the ecology of disease vectors, such as those transmitting malaria in the case of southern Africa. It will add a burden on communities which are already impacted by health stresses (Boko et al., 2007). Outbreak of malaria and cholera are common during flood periods. The Ministry of Health is developing a strategy to effectively respond to those occurrences.

Energy
There is a large untapped renewable energy potential. Remote areas are particularly suited for small-scale renewable electricity generation. Currently, only a small proportion (less than 10%) of population has access to electricity (UNESCO, 2006). Its production relies essentially on hydropower which is also sensitive to climate. There is much evidence of the critical importance of access to affordable energy services for socioeconomic development. Providing the means for impoverished communities to benefit from electricity is another way of increasing their resilience to climate related stress. Carbon finance might provide an avenue for leveraging additional investments opportunities.

8.3.3.3 Adaptation

A major message from this review is the need for moving away from reposing on short-term emergency relief operations as strategy regarding to climate extreme events. A proactive approach that includes wide-ranging adaptation measures would be more appropriate in the long-term. The intrinsic relationship between disaster mitigation and other development goals is now widely recognised. Indeed, climate change adaptation measure should be integrated into broader development policies (Mirza, 2003). Also, investments in reducing climate risks are often compatible with broader sustainable development goal. Along those lines, the National Adaptation Plan of Action (NAPA) is seen as an opportunity to mainstream adaptation into national policies (Bambaige, 2007). The literature reviewed highlights the significant progress made in terms of institutional capacity building to deal with climate related extreme events.

The detailed analysis of concrete measures is largely beyond the scope of this report, but some general points remain clear. The literature reviewed suggests the construction of settlements in more elevated regions and away from rivers. Building standards should become more stringent and aim for cyclone-resistant construction. Alert systems are also frequently mentioned as effective prevention measures. Soft measures include capacity building and increasing awareness through workshops and courses. For instance, GTZ is implementation a project in this regard based on experience made in South America.

7.2d Assessing Mozambique's present and future climate vulnerability

We now turn to our own assessment of Mozambique's present and future vulnerability. As should be clear by now, there is a wide range of methods available to do so, each of which is more or less suitable for answering different questions. A useful starting point is to run through the list of axes of differentiation on Figure 8.2, identifying what point or points in the three dimensional space this assessment ought to fit. From there, it may be possible to identify a number of questions, appropriate to those points, that prior assessments have not answered. Having identified the questions, we can then turn to considering suitable methodologies for answering them.

This assessment effort is being coordinated by INGC, and funded by a number of development agencies (DANIDA, GTZ, UNDP). These are all operational agencies, concerned with reducing disaster risk and eliminating poverty now and in the future, and less concerned either with climate change mitigation or with developing theory. We can thus position this assessment as being one with the purpose of informing adaptation planning, now and into the future. Indeed, INGC has been clear that they are interested in looking out until 2060, in order to identify any long-term adaptation needs, planning for which ought to begin today. They have also been clear that they are interested in both the top-down and bottom-up perspectives. What are the interesting questions related to long-term adaptation planning that the top-down and bottom-up perspectives can answer?

The bottom-up perspective is useful for identifying the socio-economic system state variables that—based on a causal model of vulnerability—are driving vulnerability today, and how the trends in those variables will lead to more or less vulnerability in the future. Presently, it is clear that there is a great deal of heterogeneity within Mozambique in many of these variables. A bottom-up analysis of vulnerability can explore how, in the aggregate, this heterogeneity translates into differential social vulnerability across the different regions of the country. By disaggregating vulnerability into different drivers, it is possible to identify the most important factors driving present day vulnerability, especially in the country's most vulnerable regions. A bottom-up analysis can also explore how the trends in these variables, projected out into the future, will lead to greater or lesser sensitivity or adaptive capacity. This analysis can complement the top-down study by suggesting, again based on a causal model, what are the most important socio-economic trends that will influence vulnerability over the coming half-century.

The top-down perspective is useful for clarifying general trends in vulnerability, without necessarily considering a causal model. At this general level, it is clear that climate change (and changing climate variability) will lead to changing frequency and magnitude of many climate risks, and that couple with population growth and migration this will lead to changing levels of exposure. Existing analyses suggest that the level of exposure will likely increase over the next 50 years (Boko et al., 2007; Low, 2005). It is also clear that socio-economic developments will transform the country's sensitivity and adaptive capacity. Mozambique has, over the last decade, led sub-Saharan Africa with sustained economic growth, coupled with improvements in infrastructure, human capital, and per capita income and consumption (UNCTAD, 2004). If these trends continue, and there is reason to believe that they will, then they would suggest and increase in adaptive capacity, and a corresponding decrease in sensitivity to climatic risks (Yohe and Tol, 2002). An important question, then, is what the combined results of these changes might be on Mozambique's vulnerability over the next 50 years. Will increasing exposure dominate, meaning that the country grows more vulnerable over time? Or will the socio-economic change dominate, meaning that the country grows less vulnerable? Answering this basic question could suggest whether or not, at a national level, there is an urgent need to redirect resources towards vulnerability reduction, or whether continued attention to economic growth and development will lead to an improving situation.

With both top-down and bottom-up analyses, we build two separate scenarios consistent with those first developed and reported in the Special Report on Emissions Scenarios (SRES) of the IPCC (Nakicenovic and Swart, 2000). The SRES scenarios each rely on a storyline of future economic and social development over the next century as the basis for estimating a path of greenhouse gas emissions; it has become commonplace for researchers to base their own scenario-building efforts on one or more of these, in order to make it easier to compare results across different studies. There are four main groups of SRES scenarios, differing according to two main axes: prioritization of economic growth (A) versus environmental sustainability (B), and degree of global integration (1) versus regional distinction (2). We have chosen to follow two of these paths: the A2 storyline of high economic growth with little global integration, and the B1 storyline of greater sustainability and globalization. For Mozambique and in terms of important socio-economic drivers, B1 describes a relatively low population growth for the next couple of decades followed by stabilization and even a slight decrease thereafter. In contrast, A2 features a steady population rise throughout the 21st century. In regard to economic growth, GDP rises moderately in the case of the A2 scenario whereas a strong rise characterises B1. We provide more detail on these trends in the following sections.

Projecting the Social Vulnerability index

To examine future vulnerability from a bottom-up perspective, we make use of the indicator of social vulnerability developed by Vincent (2004), in which she constructed a composite index comprising different socio-economic and demographic indicators. Her selection of the indicators was theory-driven and was carried out based on expert judgments. The indices were first normalised, and then aggregated using weights for reflecting the perceived relative importance of the different indices. The sub-indices included: economic well-being and stability (weight: 20%), demographic structure (20%), institutional stability and strength of public infrastructure (40%), global interconnectivity (10%) and dependence on natural resources (10%). We have provided the full set of variables in Table 8.6, and shown the ranking of African countries on the composite index in Figure 7.18.

Using the Vincent's model, we extend the analysis by projecting the indicators of vulnerability into the future for Mozambique. Proceeding so allows comparing the evolution of vulnerability in Mozambique with the vulnerability of neighbouring countries today. The approach is coarse by nature, and projecting the indicators into the future entails a high level of uncertainty. Those limitations should be kept in mind while interpreting the results. Also, projecting the indicators from Vincent's model into the future implicitly assumes that the factors characterising vulnerability will not change over time. This might hold in the near future, but would not be true in the medium-term, since other elements might make people more or less vulnerable in the future. Nevertheless, this assessment provides valuable insights in terms of exploring which factors might play a role and to what extent.

Indicator projections

The data for this analysis are derived from the Vincent model for the formulation of the baseline. Different sources, such as the UN Statistics on-line database, World Health Organisation, various World Bank publications, the International Telecommunication Union database, IIASA's Greenhouse Gas Initiative (GGI) database and the World Bank Development Indicators, were consulted for the projections of the indicators into the future. Techniques such as regression analyses and extrapolations are used to extend the dataset to 2060 where required. Finally, the indicators are calibrated to the data used in the baseline to allow for meaningful comparison. The projections of the different indicators into the future are performed for two contrasting scenarios based on the SRES, namely A2 and B1. The two scenarios feature distinct socio-economic development, and are therefore adequate a framework for evaluating the evolution of inherent vulnerability while taking into account intrinsic uncertainty related to the way the future might unfold.

We made a number of assumptions to project the different indicators into the future based on both scenarios described above, and the level of confidence in those projections varies. Specifically, in regard to the poverty indicator, historical data combined with ambitious targets set by the government were extrapolated using an exponential regression curve and applied to the B1 scenario. For the A2 projection, the poverty reduction was calculated based on that of B1 and as a function of the difference in the economic growth between the two scenarios. The data for the indicators on the change in the share of urban population as well as the share of rural population are extracted from the GGI database, which provides country-level time series. The data for the dependent population criterion were derived from UN Statistic projections that are consistent with the population data of the respective scenarios. The share of public health expenditure was assumed to be constant over time in both scenarios. The share of governmental expenditure for health in Mozambique, 5% according to UN Statistics, is commensurate with other countries in the region. It is therefore fair to assume that there would be no significant change in the future in this regard.

As far as the proportion of the working population with HIV/AIDS is concerned, data from the World Health Organization show what appears to be a flattening trend over the past few years. There are, however, no future projections available, and assumptions about future developments are delicate. Because of the very low level of confidence on assumptions in this regard, we decided not to take into account the contribution of this particular indicator in the projection of vulnerability index. One can nonetheless assume in qualitative terms that, giving the current stabilising trend in HIV/AIDS prevalence in the active population, the future could be brighter and that therefore the model might slightly overestimate the vulnerability index in the future. Also, since the overall GDP increases over time, one can presume that the expenditure in absolute terms in regard to health will increase and have a positive influence, although delayed, on HIV/AIDS prevalence. Such effect would be stronger in the case of the B1 scenario than the A2 due to the difference in the economic growth underlying the scenario storylines.

The share of the population having a telephone or mobile phone connection is assumed to increase drastically in the future, to about 70 % in 2030 and over 80% in 2060 in both scenarios. The effect of the lower economic growth in the A2 could be counter-balanced by the fact that the population is more concentrated in urban areas and that therefore the infrastructure required to connect the same number of people is less significant. In regard to the trade balance, quantitative projections into the future are speculative at best. Because of the very low level of confidence in the estimates, the effect of this criterion is not taken into account in the projection of the overall vulnerability index. It would be however fair to assume that the trade balance in the B1 scenario could be more favourable due to the high economic growth on the one hand, as well as to the fact that such scenario features a world with more interaction and international trade on the other. In other words, if this specific criterion were to be taken into account in this analysis, the difference between the A2 and B1 projections of the inherent vulnerability index could be more favourable to the B1 projection.

Results

The results of the evolution of the different indicators are plotted in a graph in a cumulative fashion for each scenario, borrowing from the idea of the wedges (Pacala and Socolow, 2004). The outcome of the Vincent model is used as a baseline for Mozambique. Because it is not easy to picture what the evolution of vulnerability over time might mean, two neighbouring countries, namely Zimbabwe and South Africa, appear in the graph to facilitate the comparison with conditions of vulnerability that are graspable. Evaluating the evolution of vulnerability in other countries than Mozambique goes beyond the scope of this study. The vulnerability of those countries as calculated by Vincent is used as references in order to visualise how different drivers will affect vulnerability in Mozambique in the future.

Figures 7.21 features the Social Vulnerability Index of Mozambique, South Africa and Zimbabwe in 2000 (doted lines) based on the Vincent model. It also represents the cumulative contribution of the different indicators to the evolution of vulnerability over time for Mozambique, for an A2-like and B1-like scenario respectively. For instance, the area between the doted line (baseline) and the pink line shows the contribution of the poverty indicator in the evolution of the vulnerability index. The contribution of the urbanisation indicator is to be found between the pink and orange lines. The orange line therefore represents what the vulnerability would look like considering both the poverty and the urbanisation indicators together and leaving the rest aside. The same concept applies for the subsequent lines.

From these graphs, one can deduct that according to this model, the vulnerability of Mozambique would be similar to that of South Africa in 2000, if we are to consider the different indicators as they are expected to be in several decades. That is, it could take over three decades for the vulnerability of Mozambique to decrease to the level of South Africa in 2000 if no specific policies are deployed in the case of a B1 scenario, and up to 5 decades in an A2 scenario. Indeed, the level of the SVI in South Africa in 2000 is expected to be reached in 2030-2035 or 2045-2050 in Mozambique in the scenarios B1 and A2 respectively, according to this model. The vulnerability index seems to improve quicker assuming a B1 scenario than in the case of the A2 scenario. The vulnerability index decreases relatively sharply in the B1 scenario during the first couple of decades, whereas the A2 vulnerability index features a flatter curve.

Discussion

The difference between the two projections is explained mainly by the contribution of the poverty indicator to the index. Indeed, in the B1 scenario, strong economic growth in Mozambique, including in the rural areas, allows for a quicker, ampler poverty alleviation. In contrast, the reduction in poverty level in the A2 scenario is slower due to the moderate GDP rise expected in the country as a whole and the economic stagnation in rural regions. The criteria on change of urban population and dependent population also contribute to a faster reduction of the inherent vulnerability in the B1 scenario compared to the A2. In contrast, since the proportion of rural population and therefore the share of people dependent on natural resources is expected to be higher in the B1 scenario, the contribution to the reduction of the vulnerability index of that particular indicator is stronger in the A2 scenario.

Interestingly, the influence of some of the indicators is negative (towards increasing vulnerability) in some case. Indeed, the model suggests that the expected trend of urbanisation will have a negative influence on the positive evolution of vulnerability in the next 20 to 30 years in both scenarios. Another indicator, the share of dependent population, performs similarly although for a shorter timeframe. Those effects are offset by the performance of other indicators in the overall index. In other words, the benefits of other indicators are undermined by the bad performance in terms of dependent population and change in share of urban population.

There is not much policy can do to reduce the rate of dependent population in the short run. In contrast, policies geared towards promoting livelihood in rural areas can reduce the rate by which rural people move to cities. A win-win situation arises if such policies are geared towards promoting the resilience of rural population relying on natural resources. This analysis demonstrates that expected rates of urbanisation would exacerbate vulnerability in the next decades.

Another finding of this analysis is the relative importance of the different drivers of vulnerability. The poverty indicator seems to play a major role in reducing vulnerability, as well as the share of dependent population and the share of people dependent on natural resources. Again, while policy will have little influence on the share of dependent population, policies designed to reduce poverty will make a significant contribution to reducing vulnerability to climate change. Also, enhancing the resilience of people relying on natural resources also comes out of this analysis as a potential priority in order to reduce inherent vulnerability. Other indicators, such as the rate of urbanisation or the share of the population enjoying the benefits of telecommunication do not seem to play as big a role in reducing vulnerability.

Obviously, part of the relative importance of the different criteria is intrinsic to the model. Indeed, Vincent applies an additive framework using weights. Notwithstanding, modifying the weights does not alter the main findings of this analysis. We performed several sensitivity analyses in order to verify the robustness of the outcome. For instance, even by equally weighting all the indicators, the main drivers remain poverty, dependent population and rural population. Also, altering the weights only slightly shift the point in time when vulnerability in Mozambique is comparable to that of South Africa in 2000 further into the future. Furthermore, even by giving more importance to the criteria having a strong positive influence, the point in time when the vulnerability of Mozambique reaches that of South Africa in 2000 does not come earlier than about 2025. In any case, a B1-like scenario is distinctly more favourable to a reduction of inherent vulnerability than an A2-like scenario.

Top-down vulnerability scenarios

Our second and more detailed piece of analysis is the development of top-down vulnerability scenarios. This process involves three steps. The first of these is quite similar to that engaged in by Yohe and Tol (2002), Brooks and Adger (2004) and Brooks et al. (2005), and UNDP (2004), namely the analysis of past data on the vulnerability to climate hazards in order to develop a quantitative model that is useful for Mozambique. The second step involves making projections of each of the independent variables in the model out to 2060. The third step involves incorporating these projections into the model to develop scenarios of future vulnerability, and evaluating the results.

Analysis of past data

We begin with an analysis of past data in the manner of the other efforts to develop top-down models of vulnerability. As with each of these studies, we make use of the data set on natural disasters maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Louvain, and to be found at the www.emdat.be internet site. The CRED database has aggregated numerous records of natural and technological disasters since 1970, and maintains a record for each. It is possible to use their online tool to generate spreadsheets of disasters of different types, aggregated by country and by decade.

Data and methods

We have retrieved data on three kinds of disasters–floods, storms, and droughts–and for each have a record of the number of events observed, the number of people killed, and the number of people who were otherwise affected, the latter of which is defined as those requiring special assistance either during or after the event. We have chosen not to use data on economic losses, given the warnings about the poor quality of those data on the CRED website, echoed in UNDP (2004), and revealed in the very low R2 in Yohe and Tol (2002). Figure 7.21 provides a picture of the risk levels for African countries revealed by the data. The horizontal axis represents the risk of being affected by a climate-related disaster–droughts, floods, or storms–while the vertical axis represents the risk of being killed by these. As the data indicate, Mozambique was among the riskiest of countries in Africa during the period 1990–2007.

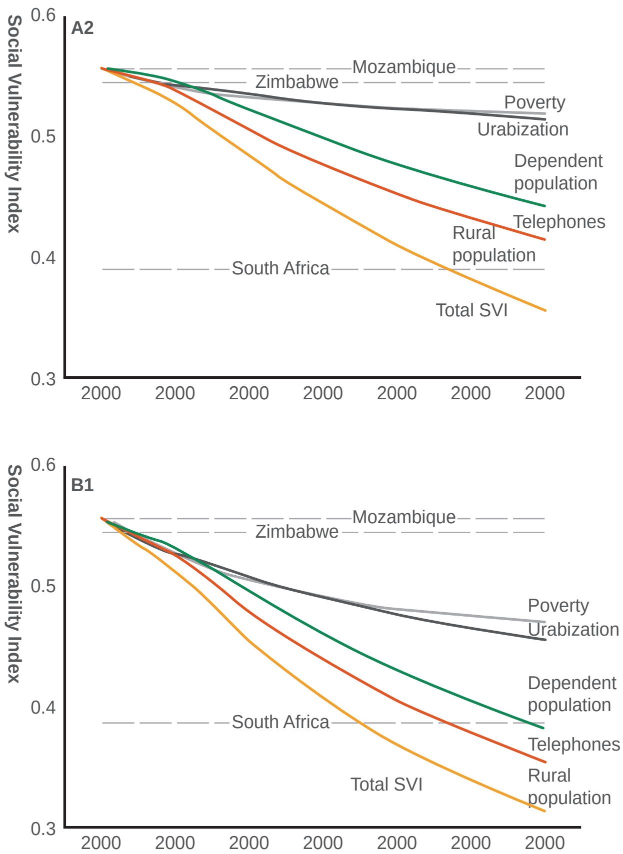


Figure 7.21: Observed risk levels in Africa to drought, floods, and storms. Each point shows the annual risk, in terms of number of people per million, for each African country, observed over the period 1990-2007. The horizontal axis depicts the risk of being affected by the disasters, while the vertical axis depicts the risk of being killed. Mozambique and its neighbors are labeled. *Source: CRED database, www.emdat.be*.

Figure 7.21 indicates risk levels in the past, and we assume that these risk levels are a function of different variables, representing exposure and sensitivity. Our analysis then turned to identifying the form of that function. By developing a more precise model, we will then be able to examine the sensitivity of vulnerability to changes in some of those variables. We take vulnerability to be the number of people killed or affected per year per million population. Consistent with previous top-down studies, we have adopted the basic model of vulnerability seen in Equation 1:

$$V_i = k \cdot E_i^{\beta 1} \cdot S_i^{\beta 2} \cdot \varepsilon i \cdot \qquad (1)$$

where *Vi* is the level of vulnerability of country *i*, *k* is a constant, *E* is physical exposure, *S* is sensitivity, β's are weighting parameters, and ε is an error term. This model takes vulnerability be the product of several factors. Taking the natural logarithm of each side of the equation yields:

$$\text{In}(V_i) = k + \beta_1 \text{In}(E_i) + \beta_2 \text{In}(S_i) + \varepsilon_i \cdot \qquad (2)$$

Equation (2) is a linear equation, allowing us to estimate the coefficient values using ordinary least squares multivariate regression. We further disaggregated both exposure and sensitivity into a vector of variables and associated coefficients. For exposure, we considered the number of climate-related disasters that occurred between 1990–2007, divided by the size of the country, as measured by its population. We expected that countries experiencing more disaster would also show higher vulnerability. We also expected to see smaller countries having higher relative vulnerabilities, because any given disaster would be more likely to be felt by all of the population. For sensitivity, we considered several variables, and settled on a limited number based on their significance, and on their improving the overall fit of the model to the data. For the model examining the number of people killed, the sensitivity variables were the Human Development Index (HDI) and the female fertility rate. We expected to see vulnerability lower for higher HDI levels, and lower for lower fertility rates. The latter was not because we expected fertility to influence vulnerability directly, but rather because we expected lower fertility rates to be correlated with higher female empowerment, and female empowerment to influence sensitivity (Patt et al., in revision). HDI we considered in quadratic form, given evidence that it is not the least developed countries, but rather the slightly higher developed countries, that are most at risk (de Haen and Hemrich, 2007; Kellenberg and Mobarak, 2008). For the model examining the number of people affected, the sensitivity variables were HDI and the proportion of the population that is urban. The latter variable we expected to show a negative correlation with vulnerability, based the literature review in Vincent (2004). Data for the sensitivity variables comes from the United Nations Development Programme database.

The CRED data are available for the period 1970–2007, although preliminary analysis suggests that the period 1970–1989 may be less reliable than the period 1990–2007. We have conducted the same analysis for the entire period, and for the restricted period 1990–2007; we obtained a much better goodness of fit for the restricted data set, and so have chosen to report these results, as we believe that they reflect better data quality. The CRED database contains separate entries for a large number of island territories (e.g. Guam, Guadeloupe), which the United Nations considers to be a part of a separate country (e.g. the United States, France); we have eliminated these islands from our dataset, because we were uncertain as to the local socio-economic indicator values.

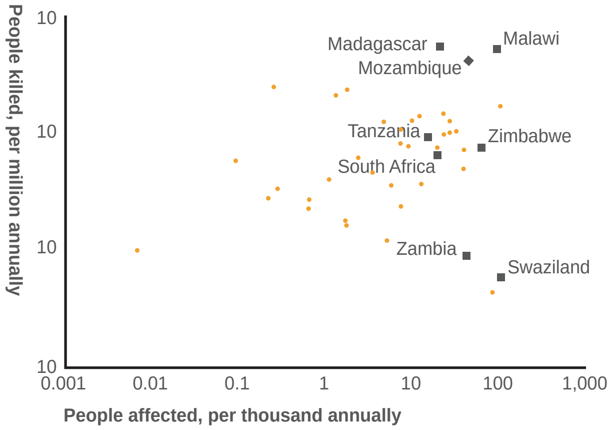
Results

	Killed	Affected
ln(number of events)	1.36* (0.15)	1.88* (0.19)
ln(population)	–0.56* (0.09)	–0.79* (0.11)
ln(HDI)	–5.97* (1.95)	–13.55* (2.16)
ln$(\text{HDI})^2$	–6.26* (1.52)	–9.82* (1.86)
ln(female fertility)	1.45* (0.43)	
ln(proportion urban population)		–0.41 (0.37)
Constant	–3.86* (0.49)	5.33* (1.71)
Number of observations	150	154
R^2	0.52	0.55

Table 7.17: Regression results. Dependent variables are the natural logarithms of people annually killed and otherwise affected by natural disasters in the period 1990–2007, normalized by the average population over that same period. ln refers to the natural logarithm. The 99% confidence level is indicated by *, and standard errors are in parentheses.

Table 7.17 lists the results from the two regression models. All of the coefficients except for one are significant at the 99% confidence level. The signs on the variables are consistent with the literature and our hypotheses. The R2 statistics, which measure the fraction of observed variance that the models explain, are higher than those obtained by Yohe and Tol (2002), which we attribute to our use of HDI and HDI2, rather than simply GDP. They are lower, however, than those obtained by UNDP (2004); this we would attribute to our failure to consider the populations exposed on a disaster-by-disaster basis.

In order to see the extent to which Mozambique and its neighboring countries are well described by the model, or are outliers, we compared the model predictions with observed values. Figure 7.22 shows the number of annual deaths from the three types of natural disasters predicted by the model on the horizontal axis, and number predicted by the model on the vertical axis. Each dot is a country, and for comparison sake we label Mozambique and its neighbors. Figure 7.23 shows the same for the number of affected people. Mozambique and its neighbors appear to fit well within the model.



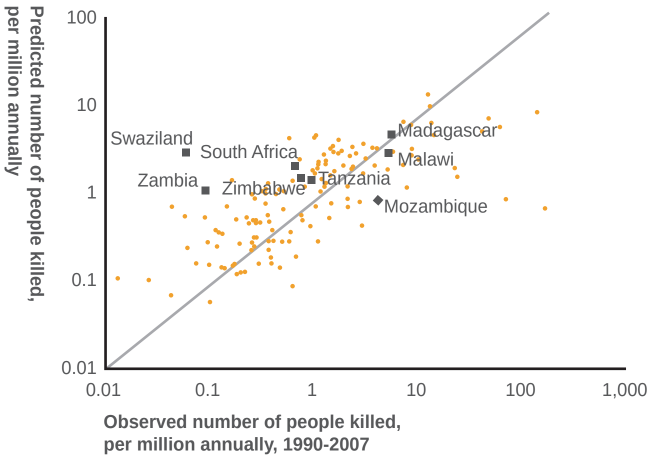


Figure 7.22: Goodness of fit of the model for numbers of people killed annually in each country. The vertical axis depicts the model predictions, while the horizontal axis depicts the number of people actually observed over the period 1990–2007. Mozambique and its neighbors are labeled.

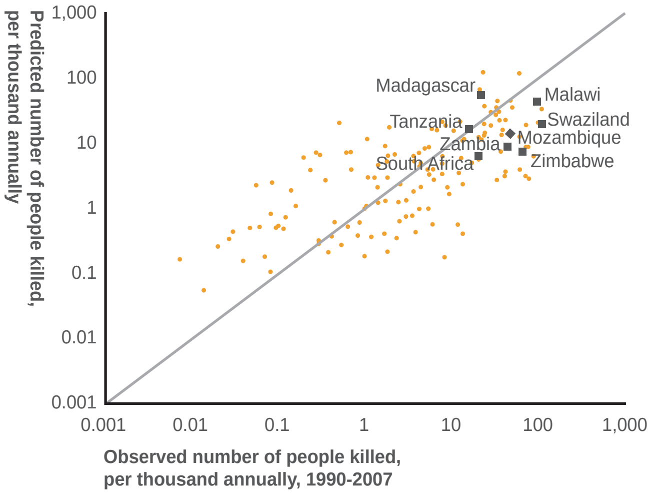


Figure 7.23: Goodness of fit of the model for numbers of people affected annually in each country. The vertical axis depicts the model predictions, while the horizontal axis depicts the number of people actually observed over the period 1970–2007. Mozambique and its neighbors are listed.

	Killed 1990s	Killed 2000-07	Significant difference	Affected 1990s	Affected 2000-07	Significant difference
ln(number of events)	1.17** (0.17)	1.21** (0.16)	no	1.36** (0.23)	1.73** (0.21)	no
ln(population)	–0.49** (0.10)	–0.57** (0.09)	no	–0.48** (0.13)	–0.85** (0.13)	yes
ln(HDI)	–7.20** (2.14)	–2.88 (2.09)	no	–11.42** (2.45)	–13.69** (2.47)	no
ln(HDI)^2	–6.66** (1.53)	–3.58** (1.72)	no	–7.42** (1.94)	–11.50** (2.27)	no
ln(female fertility)	1.17* (0.51)	1.66** (0.46)	no			
ln(proportion urban population)				–0.69 (0.42)	–0.96* (0.43)	no
Constant	–3.01** (0.56)	–2.94** (0.48)	2.93 (2.95)	7.10** (1.94)	8.88** (1.98)	no
Number of observations	131	140		140	144	
R^2	0.45	0.46		0.40	0.52	

Table 7.18: Regression results. Dependent variables are the natural logarithms of people killed and otherwise affected by natural disasters, normalized by the average population over that same period. ln refers to the natural logarithm. 95%, and 99% confidence levels are indicated by * and **, respectively, and standard errors are in parentheses. Significant differences between coefficient estimates are at the 95% confidence level. There is only one significant different, between the effect of population on numbers affected between the two periods.

The next step in the development of the model is validation and examination of residual error. Here, there are two important questions. First, does the model appear to be one that is equally valid in different time periods, or might it be over-specified, namely an artifact of the particular data that were observed in the particular time period. To examine this, we use a technique of splitting the data into two separate time periods, estimating models for each, and examining whether the models for the two periods are similar. Table 7.18 shows the results of this analysis. We have separately analyzed risks in the periods 1990–99 and 2000–07, and estimated models for the risk of death and the risk of being affected. For each risk, we calculate the difference in estimated regression coefficients, together with the standard errors on those differences. In all cases but one—the coefficient for HDI for the risk of being affected—there are no significant differences between the coefficients across the two time periods. We can conclude with some confidence that the model remains somewhat constant over time, which supports its use in a scenario-building capacity.

The second question concerns the residual variance or error term, represented by εi in equations 1 and 2, and observed as the horizontal distance between each country point and the diagonal line in Figure 7.23. On the one hand, this may be a result of pure chance; if we had a second set of data, representing another 37 years of disasters, we would not observe a correlation between a particular country's residual variance across the two data sets. This in turn would mean that for each individual country, the model prediction is an unbiased estimate of the actual vulnerability. On the other hand, the residual variance may be the result of omitted variables associated with each particular country, and that we would observe perfect correlation between the residual variance across two separate time series. To examine this question, we calculated the correlations between the residual variances across the four models shown in Table 10. Table 7.19 portrays the observed correlations. As we would expect, we observe no negative correlations. The strongest correlation is for the risk of being affected in the two time periods, indicating that there may be features associated with each country—such as the magnitude of hazards to which it is typically exposed—that determine the risk levels, and which are not part of our model. The serial correlation for the risk of death is lower, indicating that a higher proportion of the residual variance is a result of random chance, such as the failure to reach affected individuals in time to save their lives.

	Deaths 1990-9	Affected 1990-9
Deaths 2000-7	0.17	
Affected 2000-7		0.38

Table 7.19: Correlation of error terms. The table shows how the errors in predicted risk of death and being affected—the difference between the model predictions and the observed—correlate across the two categories of losses and periods of time. Both show correlation, but the correlation is stronger for the risk of being affected than the risk of being killed.

Based on the last piece of analysis, we conclude the model estimation phase by mapping out the vulnerability of Mozambique in comparison with other African countries. Figure 7.24 shows the results. The error bars cover the range of estimated risk levels for death and being affected, from the risk levels actually observed—and indicated in Figure 7.21—and the model estimates. Within that range, we have a selected single point as the best estimate of present vulnerability, taking into account the serial correlations in Table 7.19.

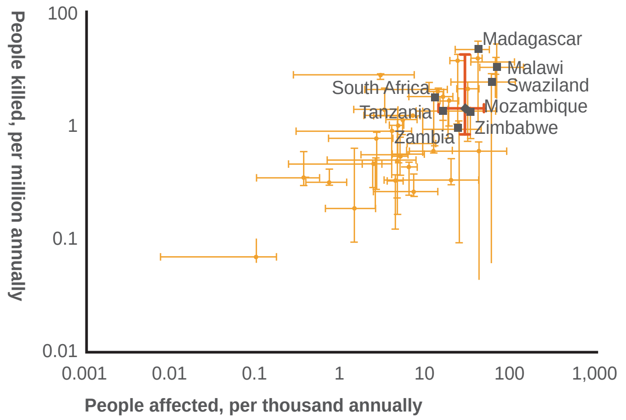


Figure 7.24: Relative vulnerability of African countries. Each point shows the annual risk, in terms of number of people per million, for each African country, observed over the period 1990-2007. The horizontal axis depicts the risk of being affected by the disasters, while the vertical axis depicts the risk of being killed. Each point represents a best estimate based on the analysis of serial correlation. The error bars represent the range between model estimates of risk, and observed risk over the period 1990-07, while the points lie within that range based on the analysis of serial correlation, and represent the best estimates of current vulnerability. Mozambique and its neighbors are labeled.

Socio-economic scenarios

The model developed in the previous section can then form the basis for generating scenarios of future vulnerability, concentrating on Mozambique. In order to do so, we need to generate scenarios for each of the independent variables—frequency of hazards, HDI, female fertility, and proportion of population that is urban—which can then be used to generate scenarios of actual risk levels. We take each variable in turn, beginning with the socio-economic ones.

HDI

The first variable that we consider is HDI, a composite of four separate indexes: life expectancy, functional literacy rate, combined primary, secondary, and tertiary school enrollment rate, and real per capita income. Estimates for life expectancy are available from the United Nations (UN) World Population Prospects web site (http://esa.un.org/unpp/). In most cases, the estimates run until 2050, and have high, medium, and low estimates. We take the low estimate to correspond to the B1 scenario, and the high estimate to correspond to the A2 scenario, and we extend the trends seen for both sets of estimates to 2060. For life expectancy at birth, however, the database contains a single set of projections, falling to a low of 42 in 2010, and then rising fairly linearly to 58 by 2050. We extend the linear trend to 2060. To estimate real per capita income, we take 2007 scenarios made by the International Institute for Applied Systems Analysis (IIASA) that build on the IPCC SRES numbers, and which provide scenarios for countries in 10 year time intervals for total GDP and for population. The IIASA population scenarios were developed using a different methodology than those of the UN Population Prospects, and so to check for consistency we compare the two in Figure 7.25. While the IIASA A2 scenario falls within the range projected by the UN, the B1 scenario falls below it. To maintain consistency with other studies, we adopt the IIASA population estimates, but point out that the B1 population estimates may be lower than can be expected under any conditions, and hence may lead to an upward bias of per capita incomes. Combining the IIASA GDP and population scenarios, we can calculate per capita GDP at market exchange rates. We apply trend analysis to correct these into purchasing power parity estimates, which we display in Figure 7.26.

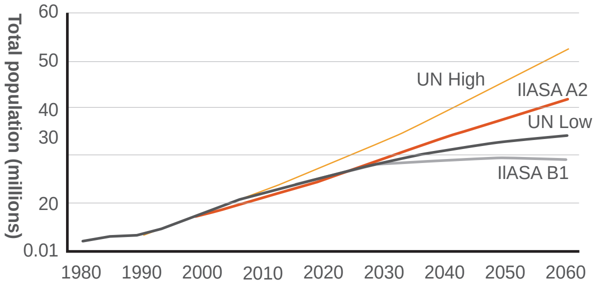


Figure 7.25: Population scenarios from the United Nations Population Prospects, and the International Institute for Applied Systems Analysis Greenhouse Gas Initiative (GGI) databases. The IIASA B1 estimate is below the UN estimate. For consistency with other studies, we use the IIASA estimates, but flag the potential for overestimating per capita GDP as a result of underestimating population.

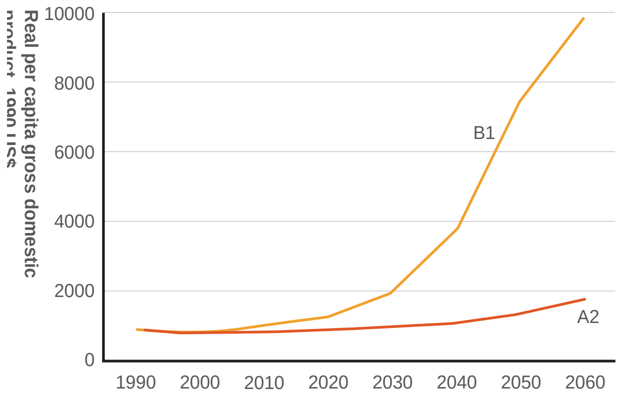


Figure 7.26: Scenario projections for per capita GDP, based on data from the IIASA GGI database.

The final element of HDI is education. The United Nations has made estimates out to 2030, and we subcontracted the same team of researchers that had generated those estimates, based within the World Population Program at IIASA, to generate similar estimates out to 2060. Following the methodology of the UN projections, they computed a range of values. We took the upper estimate to be representative of the B1 future, and the lower end to be representative of the A2 future. Combining these estimates with the other two indicators, we are able to obtain estimates of HDI. Figure 8.14 plots out the two scenarios, comparing them to the existing time series of Mozambique's neighbors.

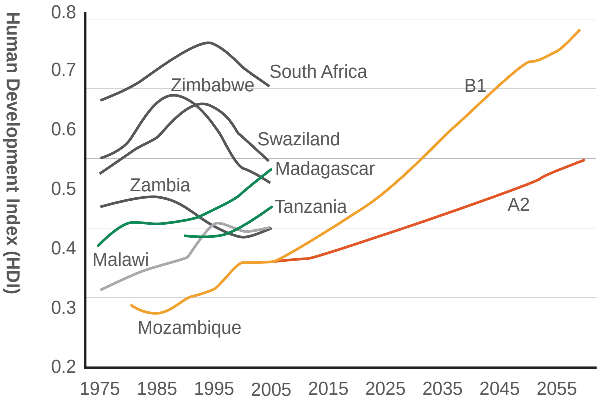


Figure 7.27: HDI scenarios for Mozambique. The figure plots out the two future scenarios for HDI in Mozambique, based on the subcomponent projections in Table 8.12. Mozambique's neighbors are there for comparison, based on the United Nations Development Programme database.

Female fertility and urban population

Female fertility projections are available from the UN Population Prospects database, in high, medium, and low variants, through 2050. We use the high and low variants as representative of the A2 and B1 scenarios, respectively, and continue the trend until 2050. Likewise, the IIASA GGI database contains scenarios of urban and rural population for the A2 and B1 futures. We use these to calculate the proportion of population that is urban. Table 7.20 contains the estimates of both variables for the two scenarios, as well as the base data that was used to calculate the scenarios of HDI.

	Life expectancy	Adult literacy rate	School enrollment	Per capita GDP	HDI	Female fertility	Urban proportion
2010 A2	42.85	45.43	57.5	798	0.380	5.36	0.434
2010 B1	42.85	47.19	58.0	992	0.396	4.86	0.434
2020 A2	46.6	48.04	57.5	843	0.410	4.60	0.521
2020 B1	46.6	54.97	64.0	1255	0.454	3.60	0.521
2030 A2	50.35	49.42	57.5	930	0.439	3.76	0.610
2030 B1	50.35	66.32	70.0	1975	0.532	2.76	0.572
2040 A2	54.2	50.12	60.0	1080	0.473	3.24	0.704
2040 B1	54.2	77.46	80.0	3852	0.626	2.24	0.613
2050 A2	58.15	50.42	60.0	1339	0.507	2.91	0.782
2050 B1	58.15	85.10	90.0	7428	0.713	1.91	0.631
2060 A2	62.1	50.48	62.0	1772	0.547	2.70	0.844
2060 B1	62.1	90.42	95.0	9794	0.768	1.80	0.641

Table 7.20: Subcomponents of the HDI projections. Estimates are made based on data from the UN Population Prospects database, the IIASA GGI database, and own calculations.

Hazard frequency projection

The next step is to examine potential future climate exposure. In the model estimates, exposure was the number of disaster events—droughts, floods, or storms—that occurred during the period 1990–2007 and were included in the EM-DAT database. The criteria for inclusion of a disaster event in the EM-DAT database is at least 10 people killed, at least 100 people affected, a call for international assistance, or a declared state of emergency. The challenge for our modeling is to make estimates of how the future frequency, by 2060, will be different than it is now. Our steps for doing so are as follows. First, we disaggregate the disasters that have occurred in the past into the different types, and into different regions, be examining each of the recorded events. Table 7.21 shows the breakdown of hazard events that occurred in each region during the period 1970 – 2007. As can be seen, the most common type of hazard is flooding, with a total of 20 events. Droughts are the least common, but have affected and killed the greatest number of people. It should be noted that of the single largest event was a drought in the South and Central region from 1981–85, which claimed 100,000 lives. It is unclear the extent to which these deaths can be attributed to the drought itself, or to the civil war which was occurring at the same time. Leaving out these deaths, as many studies do, suggests that droughts may in fact be less deadly than floods and storms.

Second, for each hazard, estimate the extent to which the frequency will change by 2060 based on input from the other team members. For each hazard, we use the input from team members to generate two scenarios: a *low* scenario, representing the results of the climate model or models showing the least increase (or greatest decrease) in event frequency, and a *best-estimate* scenario, representing an averaging of the model results. We also generate two addition scenarios. The first is the *trend* scenario, which assumes a linear continuation of the trend observed over the period 1970–2007. To generate that trend, we have totaled the number of hazards for each decade, and estimated a linear trend using ordinary least squares regression. We continue that trend through the decade of the 1960s. We show these trends in Figure 7.28. Finally, we construct an extreme scenario. For the extreme scenario, we assume that the effect of climate change will be 50% greater than that described by either the *best-estimate* or *trend* scenarios, whichever of the two is higher.

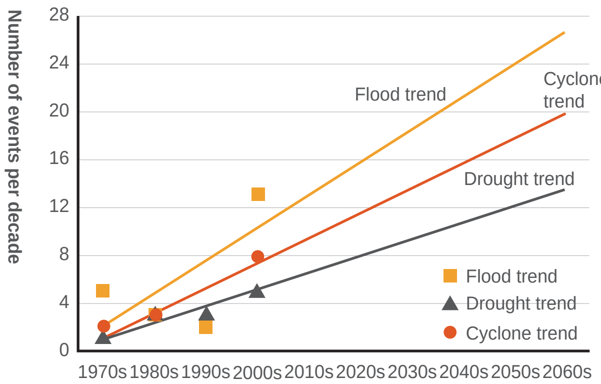


Figure 7.28: Hazard trends. The point observations represent the number of events for each hazard type in the EM-DAT database. The trend lines represent the estimated linear trend for each hazard type, with the assumption that 2009 will bring the same frequency of events as observed over the period 2000-2008.

		North	Central	South	Total
Floods	Events	3	12	5	20
	Affected	490,000	2,525,425	5,524,326	8,539,751
	Killed	71	12,703	1,180	13,954
Droughts	Events	1	3	5	9
	Affected	6,000,000	6,850,000	8,528,000	21,378,000
	Killed	0	100,150	50	100,200
Storms	Events	5	9	2	16
	Affected	121,050	2,531,350	390,000	3,042,400
	Killed	81	460	119	660
Total	Events	9	24	12	
	Affected	6,611,050	11,906,775	14,442,326	
	Killed	152	113,313	1,349	

Table 7.21: Overview of natural disasters in Mozambique, 1970 – 2007. The table shows the number of events that have hit Mozambique, according to type and location. Many of the events hit two or more locations, in which case we have listed them according to their center. For each type of event, we list the number that have hit, the number of people affected, and the number of people killed.

Flood frequency scenarios

To generate scenarios of changing flood risks until 2060, we work off of model results supplied to us by our team member, Kwabena Asante, using three climate models (IPSL, ECHAM, and EFDL) combined with a stream flow model. It is important to recognize how basin specific the results are, and also how speculative. Kwabene writes:

Average river flow in the northern basins is largely unaffected. Increased river flow is expected in central Mozambique. Major reductions in interior countries could significantly reduce flow in the upper Zambezi. The rivers of southern Mozambique are wetter in two models and drier in one model. However, the simulations do not show increased magnitude of flood peaks in any major basins. While increases are observed in isolated sub-basins, several major basins including the Zambezi and Limpopo show reductions in maximum flood peaks. Significant increases in frequency of flooding occur in portions of the Buzi and Save basins and slight increases are observed in several small basins in the north. Flood frequency is slightly reduced or unchanged in major portions of the Zambezi and Limpopo. Cyclone-induced rainfall is not reflected in this result.

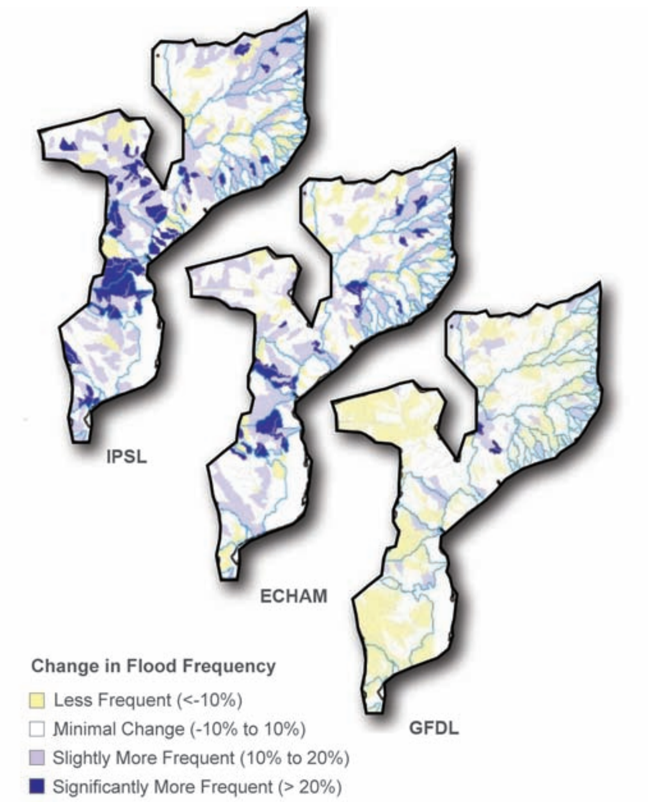


Figure 7.29: Floods frequency maps. The three maps show the calculated change in flood frequencies, for different river basins in Mozambique, based on three GCMs and river flow models.

Figure 7.29 shows the three model results, in terms of changing frequencies of flood events. As can be seen, IPSL model predicts the greatest positive change in flooding events, with about an even mix between those areas showing slight decrease to minimal change, slight increase, and significant increase. The ECHAM model shows less increase, with about an even mix between those areas showing an increase, and those showing minimal change or a slight decrease in frequency. The GFDL model shows about three-quarters of the areas with a minimal change to a slight decrease, and about a quarter with a slight increase. Combining these results qualitatively, we make four scenarios for flood risk changes:

- The *model low* scenario of the change in flood risk is for a decrease in flood frequency by 10% over current levels. Given 15 floods observed over the period 1980-2008, this would generate an expectancy of 14.21 floods over the 20-year period centered on 2060.
- The *model average* scenario of the change in flood risk is for an increase in flood frequency by 15% over that observed during the period. This would generate an expectancy of 18.18 floods over the 20-year period centered on 2060.
- The *trend* scenario sees the number of floods increasing by 2.45 each decade, generating an expectancy of 50.49 floods over the 20-year period centered on 2060.
- The *extreme* scenario calls for floods to increase in frequency 50% more than the trend. This would generate an expectancy of 68.23 floods over the 20-year period centered on 2060.

Drought frequency scenarios

To generate scenarios of the changing drought frequency, we have used the input from team member Mark Tadross. Mark downscaled 7 GCMs using rainfall station data in Mozambique, and with the downscaled model was able to estimate mean precipitation and potential evapotranspiration (PET) over the north, central, and southern regions of Mozambique, during the typical rainfed growing season of October – March. The difference between the two is a measure of water availability, and is plotted out in Figure 7.30. Also on Figure 7.30 are the periods of recorded droughts. It is clear that there is no 1-to-1 correspondence between average rainfall and recorded drought, but the comparison of the two time series suggests rough rainfall thresholds, which could be indicative of an increased likelihood of drought. These thresholds also appear on the figure. Mark then used the set of models to calculate the change in frequencies with which these thresholds would be passed during the 20-year period centered on 2055. These are plotted in Figure 7.31, sorting from the lowest average change to the highest. Averages are computed according to a weighting function, by which 10% of the droughts have been in the north, 30% in the central region, and 60% in the south. From these results we make the following four scenarios:

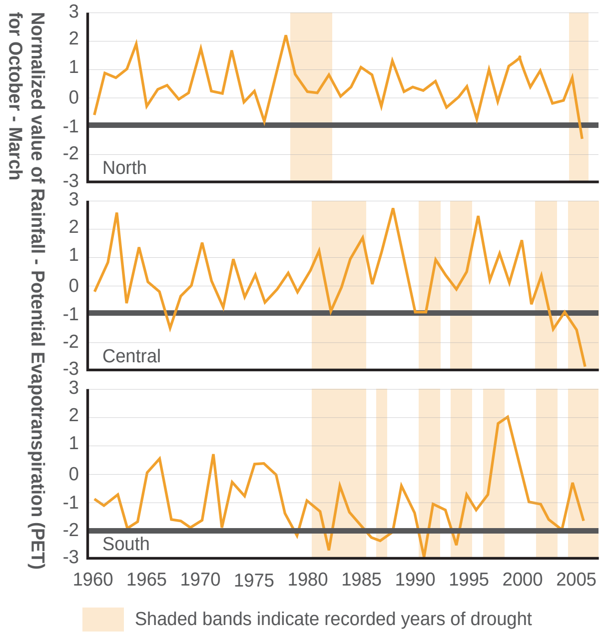


Figure 7.30: Historical food events in Mozambique. The time series lines represent the normalized difference between rainfall recorded at monitoring stations and modeled potential evapotranspiration (PET) at those stations, and hence indicate the degree of wetness or dryness averaged over the three geographic regions of the country. The shaded bands represent years in which droughts were recorded in each of the regions. There is clearly no perfect correspondence between dryness and recorded drought, but based on a visual analysis, we have set a wetness threshold for each region below which it appears that drought is likely to be observed. This forms the basis for evaluating the degree to which future conditions will be more or less drought prone than the past.

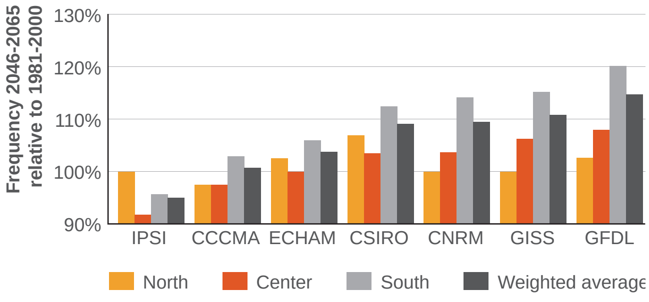


Figure 7.31: Drought frequency changes. The graph shows the change in frequency for crossing drought thresholds, for the three regions and from seven downscaled GCMs.

- The *model low* scenario for the change in drought risk to be no change in the likelihood of droughts over the country as a whole, and thus an expectancy of 9.42 droughts over the 20-year period centered on 2060.
- The *model average* scenario is for a 10% increase in the likelihood of droughts over the country as a whole, and thus an expectancy of 10.36 droughts over the 20-year period centered on 2060.
- The *trend* scenario sees the number of droughts increasing by 1.37 each decade, generating an expectancy of 25.39 droughts over the 20-year period centered on 2060.
- The *extreme* scenario sees the frequency of droughts increasing by 50% more than the *trend* scenario, generating an expectancy of 34.08 droughts over the 20-year period centered on 2060.

Cyclone frequency scenarios

To generate scenarios of the change in cyclone risk, we have used input from our colleague Geoff Brundrit. Geoff writes:

> *The results for the Indian Ocean show that there is … an overall tendency toward decreasing frequency of tropical cyclones, consistent with the direct simulations using global climate models, and storm intensity generally increase, as expected from theory and prior work with regional tropical cyclone models.*

Both theory and empirical evidence suggests that there is non-linear relationship between cyclone strength and the damage they cause, with damages increasing by the cube of the wind speed, and losses showing an increasing trend due to increasing strength, despite decreasing frequency (Emanuel, 2005). Since not all tropical storms are powerful enough to cause the extent of damage that qualifies them as a natural disaster, it may be that the increase in intensity more than outweighs the decrease in frequency. Table 7.22 shows the number of tropical storms in the Mozambique Channel, and the increase in the number of storms roughly falling into Category 1–2 and above matching both the overall number of storm disasters, and the increase over time seen in Figure 7.28 appears to match the increase, over the same time period, of the number of storms causing natural disasters. Recognizing that any scenarios for storm frequency are highly speculative, we generate the following four:

- In the *model low* scenario, the decline in storm frequency balances the increase in storm intensity, and there is no increase in the frequency of storms causing between now and mid-century. This generates an expectancy of 11.6 storms over the 20-year period centered on 2060.
- In the *model average* scenario, there is an increase of 25% in the number of storms that cause natural disasters, compared to the period 1990 – 2008. This generates an expectancy of 14.5 storms over the 20-year period centered on 2060.
- The *trend* scenario sees the frequency of storms increasing by 2.07 each decade, generating an expectancy of 37.38 storms over the 20-year period centered on 2060.
- The *extreme* scenario sees the frequency of storms increasing by 50% more than the *trend* scenario, generating an expectancy of 50.57 storms over the 20-year period centered on 2060.

	Tropical storm	Tropical Cyclone Cat 1-2	Tropical Cyclone Cat 3	Tropical Cyclone Cat 4	Tropical Cyclone Cat 5	Cat 3-5	Cat 1-5	Total
1980-1993	15	8	0	2	0	2	10	25
1994-2007	12	12	3	4	0	7	19	31

Table 7.22: Number of storms in the Mozambique Channel. The Table shows storms of different intensities. During the same period of time, there were 14 storm-related disasters in Mozambique.

Socioeconomic scenario	Climate scenario	2000 Pop. (mil)	2000 Deaths (/mil)	2000 Affected (/thou)	2030 Pop. (mil)	2030 Deaths (/mil)	2030 Affected (/thou)	2060 Pop. (mil)	2060 Deaths (/mil)	2060 Affected (/thou)
No social change	Low	17.56	1.4	27	17.56	1.4	27	17.56	1.4	17
	Average					1.6	34		1.8	41
	Trend					3.9	114		6.8	252
	Extreme					5.3	178		10.3	443
A2	Low	17.56	1.4	27	29.58	1.2	27	41.84	1.2	20
	Average					1.5	34		1.6	29
	Trend					3.5	112		6.0	18
	Extreme					4.8	175		9.1	319
B1	Low	17.56	1.4	27	28.30	1.5	32.56	29.27	0.7	5
	Average					1.8	41.31		0.9	8
	Trend					4.2	137.17		3.4	49
	Extreme					5.8	213.87		5.1	86

Table 7.23: Future vulnerability scenarios. The table shows the estimated annual risk levels to climate-related disasters for each of the 12 scenarios, in 2030 and 2060. Note that death risks are per million persons, while the risks of being affected are per thousand persons. The population estimates for each scenario are also included.

Figure 7.32 shows the cumulative result across the three types of hazards for the four different scenarios. It is clear that the major difference is between the *model average* and the *trend* scenario, while the *model low* scenario essentially captures a world with no increased climate hazard.

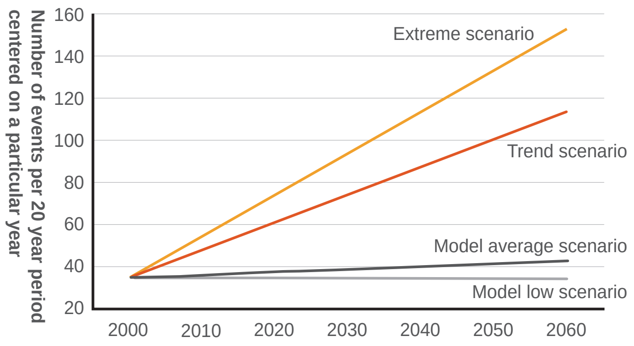


Figure 7.32: Hazard scenarios. The fours lines show linear trends in the numbers of hazards between now and 2060. Each point represents the number of hazards in a 20-year period, centered on a particular year.

Estimating future risks

In the preceding section, we developed two scenarios of socio-economic futures, and four scenarios of future climate conditions. Since the low climate scenario essentially captures a world in which there is no climate change, it allows us to view the marginal effect of socio-economic development on vulnerability. To the socio-economic scenarios we will then add a third—no social change—which freezes socio-economic and demographic conditions at their current levels, allowing us to view the marginal effect of climate change on vulnerability. Since the GCM model results are largely insensitive to socio-economic differences between now and 2060, we thus have a matrix of four climate scenarios and three socio-economic scenarios.

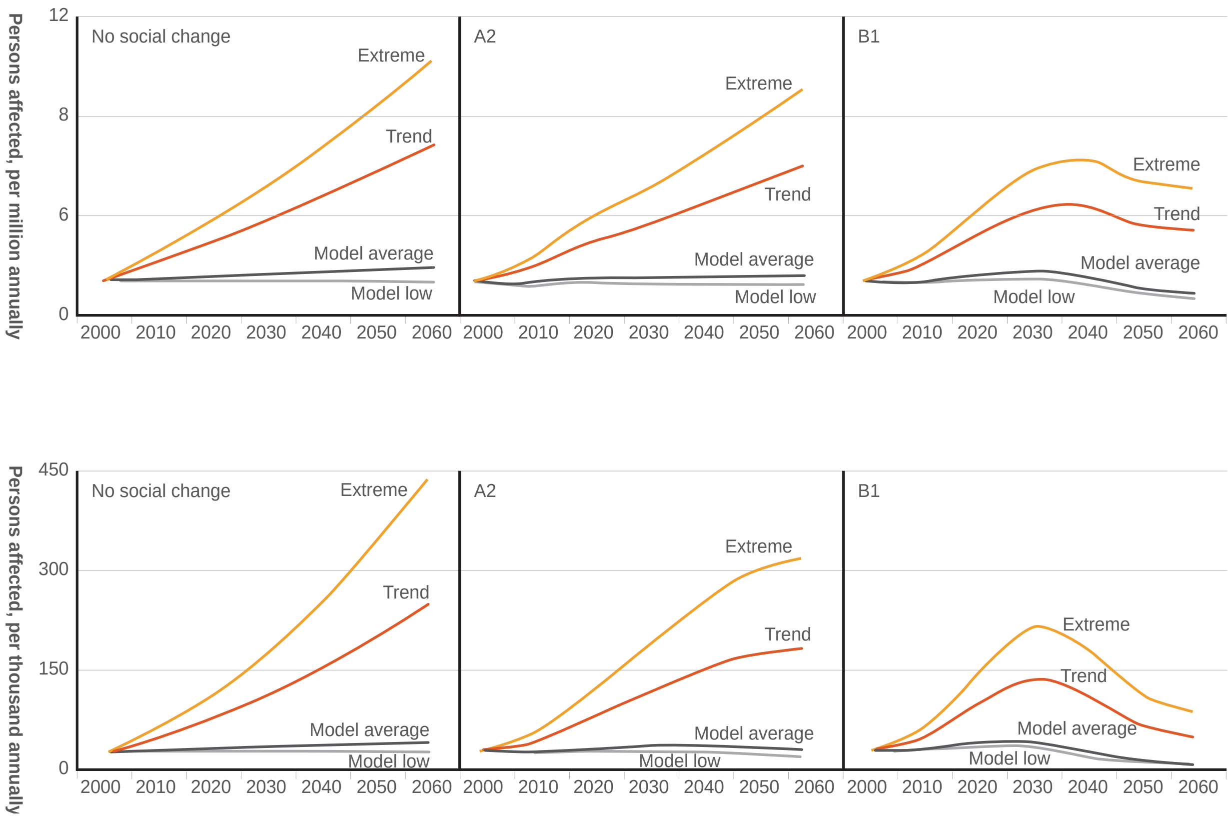


Figure 7.33: Vulnerability scenarios. The left hand plot the 12 scenarios for the risk of being killed by climate-related disasters in Mozambique, while the right hand charts plot the risk of being affected. All scenarios are based on a consideration of both socio-economic changes, and changes in climate-related risk levels.

Figure 7.33 shows these scenarios for the number of people killed annually in Mozambique, per million population, while Figure 7.34 shows the same for the number of people affected annually per thousand population, both for the aggregate of flood, drought, and storm risks. Beginning with Figure 7.33, the no social change set of scenarios provides the baseline. As one would expect, with neither social change nor climate change, there is no difference in risk levels, and this is what the model low scenario shows. The model average scenario shows a slightly increasing level of risk, while both the trend and extreme scenarios show risk levels to several times their current level. In the A2 scenario, changing sensitivity reduces risk levels in the model low scenario, cancels out the effects of climate change in the model average scenario, but does not keep up with changing risk levels in the trend and extreme scenarios. In the B1 scenario, the effects of development on sensitivity are more pronounced, especially after 2040. Both the model low and model average scenarios show decreasing risk levels, while the trend and extreme scenarios show risk levels falling after 2040. The results seen in Figure 7.34 are qualitatively the same across all scenarios, although many of the changes in risk levels, both positive and negative, are more pronounced. Also, in the B1 scenario, the fall in risk levels for trend and extreme climate change begins a decade earlier, after 2030.

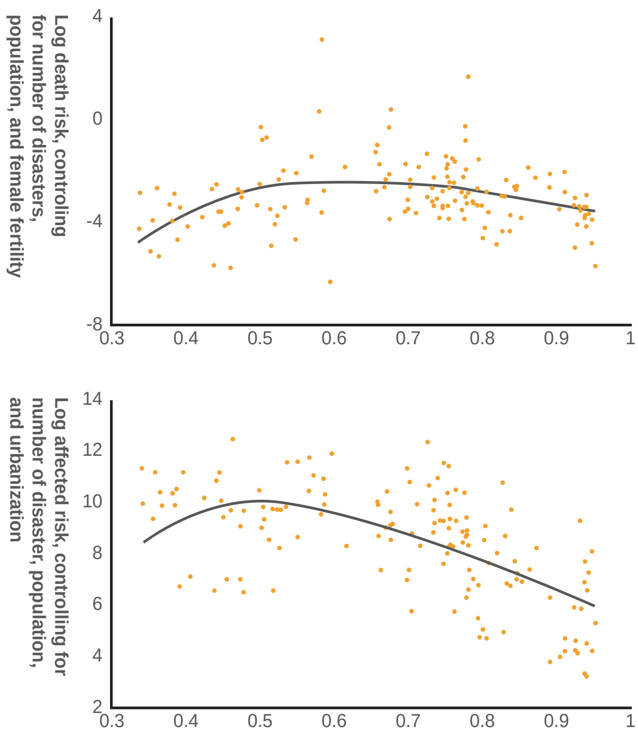


Figure 7.34: Relationship between risk and development. In both cases, after controlling for the number of events and other drivers of sensitivity, there is a quadratic relationship between risk and development. Each dot represents a country in the EM-DAT database during the period 1990–2007.

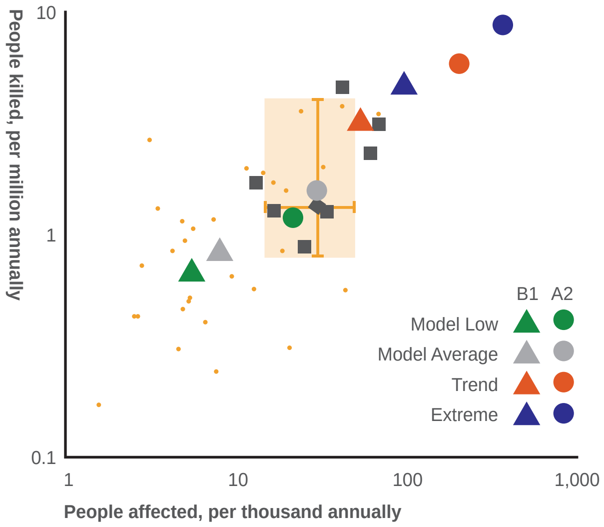


Figure 7.35: Future scenarios for Mozambique. The figure shows eight scenarios for Mozambique in 2060, illustrating the expected number of people killed and affected by climate-related hazards. It is possible to compare these scenarios with present day risk levels for Mozambique (indicated by a diamond) and neighboring countries (indicated by squares). As with Figure 12, the error bars represent the range of uncertainty associated with Mozambique's present vulnerability that is derived from the difference between observations and model predictions (but which ignores uncertainties in data quality or model regression coefficients). The shaded square regions shows this uncertainty space. Both of the model-derived A2 scenarios fall within this space, while the model-derived B1 scenarios show decreased vulnerability, while the trend and extreme scenarios all show increased vulnerability.

One of the more interesting features of these scenarios is exactly this rise and fall in risk levels seen in the B1 scenarios. This appears to be a direct result of the non-linear influence of HDI: at the lower end of the HDI scale, increases in development are associated with rising risk levels, perhaps as a result of high-risk development, while at the upper end of the HDI scale, increases in development are associated with falling risk levels, perhaps as a result of greater societal attention to safety. Figure 7.34 illustrates this. The two charts portray the expected risk level, after subtracting out the effects of exposure and either female fertility or urbanization, plotted against HDI. The points represent each individual country, while the solid curve represents the relationship estimated by the regression models. In the top graph, the highest estimated risk level for death is associated with an HDI of about 0.6, which is a level that Mozambique passes in the B1 scenario by 2035, but not at all during the 2000-60 timeframe in the A2 scenario (see Figure 7.37). In the bottom graph, the highest estimate risk level for being affected is associated with an HDI of about 0.5, which is a level that Mozambique passes in the B1 scenario by 2025, and in the A2 scenario by 2050.

Finally, we wanted to see how the changes in risk levels projected in the different scenarios compare with the risk levels currently experienced in other African countries, as well as with the range of uncertainty about risk in Mozambique today. Figure 7.35 shows this. As with Figure 7.34, it shows African countries as dots, although we have cut off the figure for lower levels of risk. Mozambique's neighboring countries are indicated with black squares, as in Figure 7.34. The range of uncertainty – arising out of the difference between observed and predicted risk levels for Mozambique for the period 1990-2007, is again represented with error bars, and highlighted as a shaded region, with the diamond near the middle of that region representing our best estimate of the current risk levels in Mozambique. Eight of the scenarios—we have omitted the scenarios without any social change—appear as points, representing risk levels projected for 2060. What we see is that for the A2 scenario, both model low and model average climate change scenarios result in risk levels within Mozambique's current range of uncertainty. In the B1 scenario, there is a significant falling if risk levels as a result of the model low and model average climate change scenarios. All of the trend and extreme scenarios reveal risk levels significantly higher in 2060 than they are now. We should also note that for the B1 trend and extreme scenarios, risk levels will be higher in 2030 than in 2060, as we observed in Figure 7.33.

7.2e Conclusion

The results from the literature review in section 3 suggest important, but not surprising, regional differences in vulnerability. The results from our original analysis—which due to data availability for the socio-economic indicators was done at a national scale—suggest a number of additional points that are relevant for policy.

Bottom-up analysis

The bottom-up analysis, making use of the Social Vulnerability Index (SVI), suggests what some of the most important drivers may be for future vulnerability in Mozambique. In both scenarios, the SVI falls significantly compared to its present level, but the difference is more pronounced in the B1 scenario, almost entirely as a result of more quickly falling levels of poverty. Across the two scenarios, the demographic shift—towards a population with a higher fraction of people of working age, and smaller fraction being dependent— is a major contributor towards a decreasing SVI. The two scenarios differ in terms of rates of urbanization, and this has two separate effects: a faster rate of urbanization implies greater social upheaval, and hence higher vulnerability, while a higher overall level of urban population implies lower vulnerability. The A2 scenarios include faster rates of urbanization, and relative to the B1 scenario the two effects balance each other out. Improvements in technology and communications, measured by the scenarios for telephone and mobile lines, has a visible but relatively minor effect on the change in SVI.

What are the policy implications of this analysis? The first is an unambiguously positive one: in either socio-economic scenario, the overall level of social vulnerability will be far less in the future than it is today, putting Mozambique by 2060 on par with the levels that the least vulnerable countries in Africa enjoy today. Of course, conditions will likely be improving in those other countries, and so at any point in time disparities will likely remain between countries, with Mozambique continuing to be among the more—but not most—vulnerable.

The second is that the main driver of this change can be, but is not necessarily, the reduction in poverty. No matter what the future holds in terms of social economic development, attention by the government and the organizations with which it collaborates towards poverty reduction can have an important impact on social vulnerability levels. Even if the world is headed in an "A2 direction," Mozambique can make sure that within its own borders, poverty reduction plays an important role, equal to or better than that seen in the B1 scenario.

An exhaustive vulnerability mapping of the country of Mozambique requires the access to detailed and reliable datasets in regard to both exposure and sensitivity. While information related to the exposure of Mozambique is available at geographically disaggregated level, the same does not hold for sensitivity. Most studies in this regard either focus on inherent or social vulnerability at national level, or feature isolated local case studies that do not allow for comparison with other areas in the country. An explicit assessment of sensitivity at sub-national level necessitates data about the different factors that are assumed to play a significant role, such as the level of poverty or the share of rural population for instance, at a fine geographical scale. Such assessment would allow for formulating highly-specific recommendations in regard to adaptation strategies that are relevant at local scale (i.e. district level). Such data were, ultimately, not available for this study.

Top-down analysis

We need to stress the speculative nature of the top-down analysis. First, the levels of vulnerability shown in Table 7.23 and Figures 33 and 35 are built upon scenarios of socioeconomic development, which in turn feed into the model projections of climate change. The scenarios are simply possible futures, and while the people who developed them made an effort to cover the range of potential development paths, one ought not to presume that they have succeeded. More fundamentally, however, the vulnerability scenarios are built on an empirical analysis that one should view with caution. First, there is reason to believe that the data available for disaster losses, in many countries, is poor. We have tried to deal with this problem by considering data only since 1990, which appears to be of higher quality, but there is still reason to worry. Second, there is reason to question whether the patterns observed in the data will continue into the future. One reason to question this is the fact that we have analyzed the effects of different variables across many different countries in a snapshot in time, rather than in a single country (or multiple countries) over successive time periods. Hence, while it appears that there is nonlinear relationship between HDI and risk, we simply do not know if this non-linear relationship also would become evident as a single country develops. Unfortunately, the lack of a long time series of reliable data makes it impossible to tell this. Another reason to question whether the patterns will hold into the future rests in the changing nature of society itself: the factors that cause people to be at risk now may be quite different than those that exist in 50 years. We have tried to validate the applicability of our model by testing it across two successive decades, and qualitatively we have observed the model remaining somewhat constant. But we simply do not know whether the changes in the model parameters that we observe from the 1990–9 to the 2000–07 time periods will continue, or whether they represent simply random noise. We have chosen to treat them in the latter manner, but others may disagree with us.

These limitations in mind, the top-down analysis remains interesting in two critical respects. First, it has contained original empirical finding with respect to the non-linear effects of development on vulnerability, as well as the relative contributions of socioeconomic and climate-related factors on risk levels. In terms of the former, the key new insight is that, even controlling for other factors such as fertility differences, urbanization, and the number of events, vulnerability increases with development at low levels of development, and decreases with development at higher levels of development. This is a general trend that has been observed by others, but our findings add greater weight by the controlling for other variables. This in and of itself has tremendous policy-implications, because of the causal factors that likely underlie this non-linearity. It seems likely, and the reports that we have cited, suggest that the increasing levels of vulnerability at low levels of development have to do with individual behavior: as very poor people become slightly wealthier, they increasingly engage in activities in high risk areas, such as flood plains and coastal regions. Moreover, the infrastructure that they construct in these areas may not be designed to withstand the natural hazards that they will encounter. Only at higher levels of development does this change, such as when the government steps in and mandates increasing safety in the form of land-use controls and the enforcement of building codes. But this is the past, and does not have to be the future. With deliberate attention, Mozambique can choose to regulate safety in the ways that rich countries already do, and achieve the falling levels of risk—seen in the B1 scenarios only after 2040—starting immediately. This would have the effect of completely canceling out the increases in risk that climate models predict will come from increased frequency of disasters, making Mozambique a safer place in the future than it is today.

Two other points stand out from the empirical analysis of the CRED data. The first is the likely importance of female empowerment on the risks to life. Work that we have cited suggests, based on empirical study, that women often make better decisions than do men about how to protect their children, their families, and themselves. Importantly, they are more likely to heed warnings and seek out safety, but only when they have the power within the family and the community to do so. The empirical analysis in this study suggests that this could have measurable effects on risk levels. Assuming the fertility rate to be a reasonable proxy for female empowerment—reasonable because it tracks levels of girls' education so well—we find that fewer people die when empowerment increases. This becomes yet another reason for Mozambique to pursue policies that lead to greater decision-making capacity among women. The second point is the impact of urbanization. We had expected to see urbanization play a major role, but this is not what we found. After controlling for other factors, including urbanization as a variable actually decreased the goodness of fit for the model of death risk. For the model of the risk of being affected, including urbanization improved the fit, but the variable itself did not appear significant at the 95% confidence level.

The second main set of interesting findings are from the scenarios themselves. The first is that within the range of climate futures predicted by GCMs, Mozambique does not face increasing risks from natural disasters: socio-economic development along the lines of the A2 scenario almost exactly cancels out increases in climate hazards frequency suggested in the *model average* climate scenario. Socio-economic development along the B1 path more than offsets the changes in risk from the *model average* climate scenario. If we believe the models, then the point is clear: Mozambique likely does not face growing a crisis in terms of climate change and disaster risks. Indeed, the difference between no climate change (the *model low* scenario) and the *model average* scenario have much less influence on vulnerability than the difference between the A2 and B1 development scenarios. Mozambique should concentrate on development.

The important question, however, is whether to believe the models. Far greater than the difference between the model estimates is the difference between these and the *trend* scenario, which carries the changes in observed hazard frequencies from the last 37 years into the future. One reason to be skeptical about the trend has to do with data quality: it may be that many of the disasters from the 1980s, and especially the 1970s, went unreported, and would have the effect of making the trend appear to be steeper than it in fact is. On the other hand, there are reasons to be skeptical about GCMs. They have a very difficult time capturing physical processes at the fine spatial and temporal scales necessary to make projections of the frequencies of extreme events. Moreover, by definition extreme events are rare, and hence the number of data points on which one can validate a model's projections are few. For these reasons, there is reason to believe that the range of values captured by the different models may in fact be too narrow. That would leave open the possibility that something like the *trend* scenario, or even the *extreme* scenario, may in fact come to pass. In that case, then the risks from climate disasters will increase dramatically in Mozambique, and far faster than socio-economic developments can likely keep up. The only way to minimize losses of life would be to take disaster-specific actions.

8

Legal framework and institutional response analysis

Rosa Sanchez, PhD and Telma Manjate

Legal framework and institutional response analysis

Rosa Sanchez, PhD and Telma Manjate

8.1 Analysis of the existing legal framework applicable to climate change

8.2 Analysis of the government's institutional response to natural disasters

8.3 Analysis of Community Response to Natural Disasters

8.4 Recommendations on Institutional Response to Adaptation to Climate change

8.1 *Analysis of the existing legal framework applicable to climate change.*

Summary for discussion

This section describes selected laws, policies, plans and parts of the Constitution of the Republic. The selection is based on relevance to climate change and disaster risk management, and includes resolutions and decrees outlining the responsibilities of the National Institute for Disaster Management and other institutions.

The Political Constitution of the Republic recognizes universal human rights and contains commitments of ethnic, gender, and environmental significance. Given the recent history of the country, its security concept reflects a military perspective that almost exclusively refers to the territory's defense. The defense policy is aimed at defending national independence, sovereignty and the country's integrity. Citizens' safety is referred to in the context of armed aggressions. In other countries, a similar constitutional basis has allowed for expansion of the safety concept to include risks pertaining to natural disasters, leading to the development of laws and policies with the concept of human security.

Among the organizational principles of the Constitution of the Republic are decentralization, the functioning of State bodies, the promotion of the use of available resources, the active participation of citizens and the encouragement of local initiatives. All these allow for initiatives that will strengthen local capacity for mitigation and adaptation. As declared in different parts of the Constitutional text, it is expected that the Constitution be developed further. This opens a window of opportunity for adding the concept of global change and climate change.

The laws, policies and strategies included in this selection summarize constitutional mandates, providing a legal framework that enables actions and decisions to incorporate variables such as the prevention and mitigation of natural disasters in a context of secure and sustainable development. The existing legal framework recognizes the need for a multi-sectoral approach targeted at vulnerable communities, as well as the need to create preventive norms and ensure institutional complementarity, guided by the constitutional principle of protecting human lives and the economy. A few of the newer laws mention climate change specifically, such as the Water Policy and the Policy of Disaster Management. However, most laws, policies and strategies do not incorporate the concept of climate change. The law of territorial planning, crucial in linking spatial planning to adaptation, does consider climate change. It is essential that the legal framework be updated to incorporate adaptation to climate change and mitigation, and to clearly define institutional roles and responsibilities. Considering the effects that climate change will have on people, ecosystems and the economy of Mozambique, institutional response to climate change requires a review of the existing legal framework, but also of secondary legislation with which roles and responsibilities are defined.

The current PARPA II does not include climate change as a priority. It is essential that the next PARPA mentions climate change adaptation as a priority, to facilitate donor funding and implementation and to ensure government budgeting for climate change in annual and five-year sectoral budgets.

MICOA (2005) has undertaken an analysis of the legal framework from a climate change perspective, and recommends that the following aspects of the legal framework be revised:

Legal instruments relevant to climate change (*)	
Legal instruments relevant to climate change	**Aspects to be improved**
• Land law • Forestry and Wildlife law • Forests Regulation • Pesticides, fertilizers and tobacco regulation • State organs law • Environment Law • Environment Policy • Environmental impact assessment Regulation • Tourism Law • Annual contingency plans • Environment Sector Strategic Plan • Other	• Legal framework of conventions within national reality • Context of concrete actions considering the national reality • Conventions' disclosure • Review of legal framework to incorporate the actions that should be undertaken, included in the conventions. • Staff training • Internal regulations of the activities foreseen in conventions, per sector • Educational materials on environmental topics

(*) Table 8.1: Recommended revisions to the legal framework from a climate change perspective. ***Source: Assessment of national capacity needs and potentials to fulfill the obligations of the United Nations Framework Convention on Climate Change (UNFCCC). MICOA, Sept. 2005.***

In specific terms of risk management, historically, institutions' responsibilities have been based on a reactive approach when facing situations already defined as natural disasters. Recently passed legislation recognizes the need for a proactive attitude which is based on prevention, and the need for change in institutions to enable them to respond rapidly and effectively.

Legal Frameworks

International Framework

United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) was set up in 1988 by the UN Environment Programme (UNEP) and the World Metereological Institute (WMO), to synthesize the scientific evidence for (or against) human induced climate change. The UNFCCC has as ultimate objective to stabilize concentrations of greenhouse gases at a level that would prevent dangerous anthropogenic interference with the climate system; and to allow natural ecosystem adaptation to climate change, ensure food production is not threatened and enable sustainable economic development. Although the Convention does not stipulate at which level the concentrations are a threat to the climate system, it indicates that this level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

To achieve this fundamental objective, the Convention lays down differentiated principles and obligations for the countries that ratify, accede, accept or subscribe to this treaty, which guide the international response to climate change. The differentiation is based on the fact that not all countries are at the same level of socio-economic development and therefore, countries' contributions to the problem of climate change are different as well as their ability to deal with this problem. It identifies three major areas of work: mitigation of greenhouse gas concentrations, adaptation to the impacts of inevitable climate change, and response measures (e.g. policy related).

The Convention stipulates the principle that all countries should protect the climate system for the benefit of present and future generations. In this process, the needs of the most vulnerable countries should be taken into account, which, while not contributing to the problem and not having capacity to deal with it, will have to bear a disproportionate burden of the harmful effects of climate change.

There are obligations common to all countries and there are specific obligations for developed countries. Being a developing country, Mozambique has to abide by common obligations, which are:

- To prepare and periodically update a national inventory of greenhouse gas emissions and sinks, using methodologies approved by the Conference of the Parties;

- To formulate, implement, publish and regularly update national and, where appropriate, regional programs to mitigate climate change and facilitate adaptation to climate change;

- To promote and cooperate in the development, application and diffusion of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases;

- To promote sustainable management and, to promote and cooperate in the conservation and enhancement of greenhouse gas sinks and reservoirs, including biomass, forests, oceans and other terrestrial, coastal and marine ecosystems;

- To cooperate in preparing for adaptation to the impacts of climate change;

- To take climate change considerations into account in relevant social, economic and environmental policies and actions with a view to minimizing adverse effects on the economy, public health and the quality of the environment;

- Promote and cooperate in scientific, technological, technical, socio-economic and other research, in the systematic observation and development of data archives related to the climate system and intended to further understanding and reduce or eliminate uncertainties;

- To promote and cooperate in full, open and prompt exchange of scientific, technological, technical, socio-economic and legal information related to the climate system and climate change. To promote and cooperate in education, training and awareness related to climate change.

The UNFCCC has published four Assessment Reports (1990, 1995, 2001, 2007) which progressively supply further scientific certainty that climate change is largely caused by human activity. The third assessment report led to the operationalization of the Kyoto Protocol, which came into force in 2005 and which:

- Sets legally binding targets and timeframes for Annex I (developed) countries, of 5% emission reduction by the end of 2012;

- Provides verification and compliance mechanisms;

- Uses ‘cap and trade’ and three ‘carbon credit’ trading mechanisms, including the Clean Development Mechanism (CDM) for project financing in developing countries.

The legally binding provisions of the Kyoto Protocol cover less than 40% of the world’s greenhouse gas emissions, due to the fact that the world’s largest GHG emitter (USA) did not join the Kyoto Protocol, and the fact that the largest growth in GHG emissions will emanate from seven countries which are not legally bound to any action within the international regime (China, India, Brazil, Mexico, South Africa, South Korea and Saudi Arabia).

Earlier on, in January 2005, 168 Governments adopted a 10-year plan to make the world safer from natural hazards at the World Conference n Disaster Reduction held in Kobe, Japan. The Hyogo Framework for Action (HFA) is a global footprint for disaster risk reduction efforts during the next decade. Its goal is to substantially reduce disaster losses by 2015 - in terms of lives, and in the social, economic, and environmental assets of communities and countries. The Framework offers guiding principles, priorities for action, and practical means for achieving disaster resilience for vulnerable communities. Priorities for action include:

1. Ensuring that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation;

2. Identifying, assessing and monitoring disaster risks and enhancing early warning;

3. Using knowledge, innovation and education to build a culture of safety and resilience at all levels;

4. Reducing the underlying risk factors;

5. Strengthening disaster preparedness for effective response at all levels.

The 2007 Bali Action Plan and Roadmap signify a new round of negotiations to determine the climate regime post 2012, with an end date of Dec. 2009. The outcome should elaborate the relationships between the four building blocks of the climate change regime: Adaptation, Mitigation, Technology and Finance). Many developing countries, including Mozambique, used 2008 to undertake the in-depth impact analyses required for the negotiations in Dec. 2009. India, Brazil, China, Mexico South Korea and South Africa all published their work on developing national climate change response plans.

The December 2009 negotiations at the Fifteenth Conference of Parties in Copenhagen, Denmark should address the following challenges:

- A shift to implementation of adaptation, supported by significant financing, technology transfer and capacity building;
- New emission reduction targets from 2012 for Annex I countries under the Kyoto Protocol;
- U.S.A. to commit to legally binding quantified emission reductions;
- Framework for mitigation actions by developing countries, supported by technology, finance and capacity building
- Address the issue of unintended consequences of climate change response measures on the economies of other countries.

National Framework

The below lists the legal framework of Mozambique as it relates to climate change.

1. **The Political Constitution of the Republic** was approved by the Assembly of the Republic on November 16th, 2004. Article 59 recognizes that in the Republic of Mozambique, all citizens have the right to security; article 90, the right to environment. All citizens have the right to live in a balanced environment and the duty to defend it. The state and municipalities, with the collaboration of associations of environmental protection, must adopt environmental protection policies and ensure the rational use of all natural resources.

   Article 102 assigns to the State the promotion, knowledge, and the appreciation of natural resources, the inventory as well as the determination of the conditions of their use and exploration, acting as a safeguard of national interests. Article 103 recognizes agriculture as the basis for national development. Article 109 states that the land is owned by the state; it cannot be sold, transferred, mortgaged or pledged, and, as a universal means of wealth creation and social welfare, the use and enjoyment of land is right of the people of Mozambique. The right to use the land is granted to individuals, personal or collective, but taking into account its economic and social purpose.

   Article 117 gives the state the promotion of initiatives to achieve ecological balance and conservation and environmental preservation. It states that in order to ensure the appropriate environment in the context of sustainable development, the State shall adopt policies to: a) provide and control the pollution and erosion, b) integrate environmental objectives into sector policies, c) promote integration of the values of environmental policies and educational programs d) ensure the rational exploration of natural resources while safeguarding its capacity for renewal, the ecological stability and the rights of future generations, and e) to promote regional planning directed towards proper allocation of economic activities and a balanced economic and social development.

2. **Law 18/97 of 01.10.97 of National Defense and Armed Forces** refers to the safety of citizens against any armed threat or aggression. It regulates engagement of armed forces and defines situations of war, but also regulates armed forces involvement in emergency response.

3. **The Environment Law** 20/97 of 01.10.97 seeks to define the legal basis for use and proper management of the environment and its components. Its intention is the creation of sustainable development of the country, to ensure an integrated overview of the environment, citizen participation, equality between men and women in its use, legal responsibility for those who degrade the environment to repair the damage and compensate. It also includes specific measures of environmental protection, including the environmental heritage and biodiversity. It defines prohibitions for the establishment of housing infrastructure, or other, which may cause significant adverse impact to the environment. It sets parameters and the minimum content of environmental impact assessments.

4. Presidential Decree No. 2 / 94, December 21st establishes the **Ministry for the Coordination of Environmental Action (MICOA)** in order to have better coordination of all sectors of activity, and encourage a proper planning and use of natural resources. MICOA is tasked to:
   - Prepare policies for sustainable development with the respective legislation, and coordinate its implementation;
   - Enable sectors to include environmental principles into projects and work programs;
   - Establish rules, regulations, and supervise activities related to natural resources.
   - Monitoring to maintain the quality of the environment;
   - Build the capacity of local communities in the sustainable use of natural resources;
   - Ensure access of local communities to fertile land, water and other natural resources.

   The National Council for Sustainable Development - CONDES - established in 1997, has as its purpose to ensure effective and proper coordination and integration of the principles and activities of environmental management in country development.

5. Resolution No. 5 / 95 of August 3rd approves the **National Environment Policy**. It is considered the basis for sustainable development. It takes into account the specific conditions of the country, focuses on the eradication of poverty, improvement of quality of life and reducing damage to the environment, through an acceptable and realistic compromise, between economic progress and environmental protection. It is the instrument through which the Government acknowledges the clear and unambiguous terms that define the interdependence between development and environment. The policy aims to:
   - Ensure an adequate quality of life for citizens;
   - Ensure natural resources management in order to maintain its functional and productive capacities for present and future generations;
   - Develop environmental awareness with the population, to enable public participation in environmental management;
   - Ensure the integration of environmental considerations in socio-economic planning;
   - Promote local community's participation in planning and decision making on use of natural resources;
   - Protect essential ecosystems and ecological processes;
   - Integrate regional and global efforts in the search for solutions to environmental problems.

   In order to make the policy operational, several laws, strategies and action plans were approved, being the following instruments of special emphasis: Territorial planning policy, Urban Environment Management Action Plan (under preparation), Integrated Coastal Zone Management Strategy (under preparation), the Prevention of Pollution and Protection of Marine and Coastal Environment Regulations, and the Prevention and Control of Erosion and Uncontrolled Fires Action Plan, approved by the Council of Ministers, in its 32nd Session of December 4th 2007.

6. The Council of Ministers Resolution No. 18/99 of June 10th approves the **National Policy for Disaster Management**. The Disaster Management Policy now includes threats of droughts, floods and cyclones, but leaves open the possibility of others, called "fortuitous", such as fires, earthquakes and others. It provides a systemic approach to indicate "... a system of prevention, rescue and rehabilitation", which requires harmonization and effective multi-sector coordination. It considers prevention, rescue, rehabilitation and reconstruction as services that the state must provide, and takes a proactive approach instead of a reactive one. It proposes general and specific objectives, strategies, plans and standards for institutional complementarity. It aims to attain a greater degree of harmonization and the development of a new legal framework consistent with current reality, which seeks to integrate the prevention and management of disasters with the global efforts for socio-economic development. " (See also the draft Law of Disaster Management)

The principles of the disaster management policy are:
a) The affected community should play an important role in planning, programming and implementation of disaster management activities;
b) The prevention or response measures should be endorsed and implemented on the basis of mobilized resources, according to the criteria of population and assets at greatest risk, as well as its negative effect on the economy;
c) The free emergency aid will be distributed to the most vulnerable populations;
d) In case of emergency, there will be a clear definition of focal points for all actions at all levels, with coordination of the organs of the State, with adequate powers;
e) The avoidance of parallel structures, ensuring a close relationship between emergency and multi-sector institutional reinforcement actions, under a resource maximization perspective;
f) The promotion, by the government, of the active participation of civil society in all phases of managing disasters.

The strategies adopted under this policy are:
a) Involvement of civil society in the design of programs and action, prevention, rescue and rehabilitation plans;
b) Integration of prevention actions in development programs;
c) Development of sector plans by type of disaster, especially droughts, floods, hurricanes, epidemics and forest fires plans;
d) Implementation of programs targeted to the communities, and promotion of appropriate technologies.
e) Training and civic education of the population on the major threats of disasters, and those related to preventive measures, as the active participation of media and use of local languages.
f) Encourage the adoption of risk insurance mechanisms and other prevention and assistance instruments;
g) Institutional capacity building with appropriate technical staff, material means and equipment for prevention and rescuing in case of disasters;
h) Establishment of financial and materials reserves, considering the areas most prone to the occurrence of specific disasters.

Presidential Decree 5 / 99 of 10.06.99 reinforced and increased the institutional level of the structures for managing disasters, creating the current **Coordinating Council for Disaster Management (CCGC)**. The CCGC is an organ of the Council of Ministers with the general mandate to coordinate the activities of multi-sectoral management of disasters, including prevention, mitigation, emergency relief and rehabilitation, and post-disaster reconstruction.

7. Decree 38/99 of 10.06.99 establishes the **National Institute of Disaster Management (INGC)**, as an institution of public administration and administrative autonomy, aimed to deal with natural and cyclical disasters. Its areas of action are: prevention, mitigation, and support to the development of arid and semi-arid areas. The action plan proposed for the INGC emphasizes three strategic structural lines, namely: lack of water resources, food and nutritional balance, and managing emergency.

8. Decree 52-2007 – Organic Statute INGC – 27.11.07 Pub. approves the **Organic Statute of INGC**.

   The responsibilities of INGC are the coordination of disaster management, more specifically: prevention, assistance to victims, reduction of vulnerability of people, infrastructure and property exposed to the negative effects of disasters, rehabilitation, specific plans for the arid and semi-arid areas, preparation of contingency plans, to operate and coordinate its civil protection unit UNAPROC; perform management actions of humanitarian assistance, support and coordinate the participation of other entities involved in actions to mitigate the effects of disasters and relief in a national emergency, to propose the adoption or updating of legislation on the prevention and mitigation of natural disasters, ratification of international conventions relating to disasters and adherence thereto; mobilize financial resources to implement projects and programs related to the reduction of vulnerability, prevention and mitigation of the effects of natural disasters; set the conditions to be met by technical staff of national or foreign bodies in the preparation of studies, reviews or projects. Promotes and coordinates actions to reduce vulnerability, prevention and mitigation of the effects of droughts in arid and semi-arid areas.

   The Master Plan for the Prevention and Mitigation of Natural Disasters is both an institutional and political guidance document. It includes vulnerability reduction and mitigation actions which should be considered in combination with the actions of sectoral ministries.

   The Master Plan should be considered as a supplement to the PARPA. It specializes in risk management and interventions to reduce absolute poverty in the country. Topics include the design of Resource and Multiple Use Centers; operationalization of the National Civil Protection Unit; information management systems; establishment of the Fund for Rehabilitation of Lands and Marginal Economies; and the creation of food reserves in the country.

9. Resolution 10/99 of July 7th, the **Forestry and Wildlife Law**, establishes general principles and basic standards for the protection, conservation, sustainable use of forest resources. It defines “sustainable use” as a rational and controlled use of these resources. It combines with the land law which creates and defines protection zones, parks, nature reserves and zones of use and historical and cultural value.

10. Law 29/2007 of July 18th 2007. **Law of territorial planning**, approved by the Parliament on 11 May 2007.

    This law creates a legal framework for territorial planning in accordance with the Constitution of the Republic, and leads to the policy on land use. It applies to the whole territory, regulates the relations between the various levels of government, other public and private subjects, including the communities. It ensures the organization of the public domain, territorial waters, sacred places, nature protection zones, beaches of use and of military interest, borders, ports, airports, national monuments and other. It encompasses levels of intervention within the territory: national, provincial, district, municipal. The public disasters are among the exceptional cases in which the instruments of land planning may be wholly or partially suspended.

    Under this law, the **National Plan for Territorial Development** defines and sets the perspective and general guidelines that should orient the use of the whole national territory and intervention priorities on a national scale. Land planning spatial plans establish the parameters and conditions of use of areas such as spatial, ecological or economic continuity, within an interprovincial range.

    Both the regional planning policy, adopted by the Council of Ministers through Resolution No. 18/2007 of 30 May and the territorial planning law have as main objectives the rational and sustainable use of natural resources, the preservation of environmental balance, the promotion of national cohesion, the appreciation of each region’s potential, the promotion of citizens’ quality of life, the balance between quality of life in rural and urban areas, the improvement of housing conditions, infrastructure and urban systems, the safety of the population vulnerable to natural or provoked disasters. The policy states that natural disasters must be addressed with the participation of affected populations in order to minimize the negative impacts, through the establishment of warning, defense and assistance systems in times of crisis. It further states that the resettlement of affected populations can be considered in cases of irreversible calamitous phenomena or when the population favors such a solution.

11. Resolution No. 10/95 of February 28th. **The National Land Policy** and its respective strategies for implementation reflect and support the main objectives of economic and social policy of the government, regarding the need to increase domestic production as part of fighting absolute poverty. It takes into account the main uses of land, including agricultural use, urban, mining, tourism infrastructure for social and productive, taking into account environmental protection.

12. The **Erosion and Uncontrolled Fires Prevention and Control Action Plan**, approved by the Council of Ministers, the 32nd Session of December 4th 2007, recognizes that fires contribute to greenhouse gas emissions and to the reduction of sinks for such gases. About 90% of uncontrolled burns occurring in the country are caused by Man. Thus, the Plan establishes actions to be implemented to reduce current rates of uncontrolled fires to 30% from 2008 to 2012, from 30% to 20% from 2012 to 2015 and 10% between the years 2015 to 2018. The Plan identifies the main types of erosion occurring in the country and their causes, and proposes actions for restoration of eroded areas by 20% between 2008 and 2012.

    With these plans, Mozambique aims to reduce its direct emissions resulting from the uncontrolled fires and soil degradation and therefore improve the conservation of forests, biomass and other terrestrial deterrents of greenhouse gases. Additionally the plans have the element of disclosure and awareness of the harmful effects of burns and erosion as well as measures to spread best practices.

13. Resolution 19/97 of October 1st. **The Land Law** considers the land as the most important and valuable resource the country possesses for its development. It establishes the areas of public domain, considered to be areas of partial or total protection. It provides a legal basis for the demarcation of areas for protection, conservation and preservation. It states that for the areas of partial or total protection, land use rights cannot be acquired, except through the emission of special licenses. On this basis it has issued licenses for eco tourism in sea areas and around certain islands. However, the limited supervision capacity allows a tourism that depredates the land and that puts in danger the objectives of creating these areas of protection or public domain (MICOA, 2007).

14. Resolution No. 23/97 of August 19th. **The Industrial Strategy** and policy value the use of natural resources whether coming from agriculture, forestry, fisheries, mineral or energetic. It considers that the industrial development must pay respect to ecological balance, protection and preservation of the environment. It foresees environmental impact assessments for any industrial project.

15. Resolution No. 5 / 98, March 3rd. The **Energy Policy** has the following objectives: a) to ensure the provision of a reliable service at the lowest possible cost to meet needs for economic development, b) to increase the availability of energy for the energy sector, in particular, coal and oil for lighting, gas and electricity; c) to promote the revival of the country, in order to increase the availability of firewood and charcoal, d) to promote viable economic programs for the development of energy resources (hydroelectricity, coal and natural gas), e) to promote the development of technologies for energy conversion and use of renewable energies (solar, wind and biomass energy).

16. Resolution No. 14/2002 of June 26th. The **Mine Law** governs the rights and obligations relating to the use and exploitation of mineral resources in relation to the environment, focusing on rational use and benefit of the national economy. It requires a use of natural resources that avoids environmental degradation.

17. Resolution 04/2004 of June 17th. The **Tourism Law** seeks to promote economic and social development, but always respecting the forest fauna, mineral and archaeological heritage, which must be preserved; and contributing to a balanced development.

18. Resolution 03/2001 of October 3rd. The **Oil Law** indicates that regarding the environmental protection and safety, the holder of rights to exploration and production shall carry out operations in accordance with good practices, specifically concerning the oilfield and environmental law. It seeks to ensure that the resources are not destroyed by ecological oil operations, but that when they are inevitable, are made in accordance with accepted international standards. Mitigation measures to reduce impact are foreseen.

19. Proposed **Disaster Management Law**. This is the result of a consultation process with industries and provincial governments, economic operators and civil society, conducted between May and August 2001. It proposes a legal regime for the management of disasters including prevention and mitigation of the destructive effects of disasters, and preparation and response actions (relief and assistance, and reconstruction and rehabilitation of affected areas). It proposes a multi-sectoral and multidisciplinary approach, and the prevention of effects of disasters through a proactive posture. Its objectives are:
    a) To ensure the development of policies, strategies, plans, legislation and operational programs for prevention, relief and rehabilitation in case of disasters;
    b) To reduce the levels of risk and vulnerability and to ensure the implementation of preventive measures, through a continuous, integrated multi-sector and multidisciplinary process, which is based on an appropriate communication and information systems. It proposes the creation of a central body for disaster management to coordinate these actions in the risk areas or those affected by disasters, without compromising the specific competencies of other State institutions or the involvement of private entities and civil society.

    The following are considered tools for disasters management: the disaster management plans, identification of hazards by quantified levels, inventories of human, material and financial resources. Measures of exceptional character are included, as well as compulsive measures (evacuation, demolition), declaration of emergency, risk transfer, participation of the armed forces, scientific and technical research agencies cooperation, civil society volunteers and international cooperation.

20. The **Urban Environment Management Action Plan** (in preparation), is intended to be a national reference tool and a guide for planning interventions aimed at improving the quality and sustainable management of urban environment. Issues addressed by the Plan that contribute to the mitigation of emissions of greenhouse gases include: solid and liquid waste management, air pollution, industrial pollution and green areas management. As for adaptation, the provision of water services and sanitation and urban development and management of green spaces are included. The Plan recognizes the harmful effects of industrial pollution on the climate and it recommends the obligations assumed by the country under the climate change context.

21. The **Coastal Zone Integrated Management Strategy** (under preparation), is intended to promote and harmonize the development actions in the coastal zone, from the perspective of reducing poverty and promoting sustainable development.

22. The **Pollution Prevention and Coastal and Marine Environment Protection Regulation**, approved by the Council of Ministers through the Decree number 45/2006 of November 30th, contributes to a sustainable management, conservation and enhancement of greenhouse gases sinks, as it regulates prevention and limitation of the pollution caused by illegal discharges from ships, platforms or sources based on land, off the coast of Mozambique and the establishment of legal bases for the protection and conservation of areas that are public domain: sea, lake and river, the beaches and ecosystems.

23. The **National Water Policy** approved by the Council of Ministers through Resolution No. 7 / 95, August 8th, recognizes that water is a vital resource that should be used in a rational and sustainable way, to promote national development. The Integrated Water Resources Management is one of the main policies, as this ensures the optimization of benefits for the communities, taking into account the interests of both current and future beneficiaries. It emphasizes the consideration of environmental impacts and conservation of water resources for the future.

24. The **National Water Resources Management Strategy** (ENGRH) approved by the Council of Ministers at its 22nd Session, August 21st 2007, considers that the challenges Mozambique faces in order to achieve the goals of the Absolute Poverty Reduction Action Plan (PARPA) and the Millennium Development Goals include: drinking water and sanitation, water for food security and rural development, water pollution prevention, ecosystems conservation, natural disasters mitigation and risk management, management of cross border water resources and sharing benefits. The main objective of the National Water Resources Management Strategy is the effective implementation of the Water Policy, which aims to satisfy the basic needs of water for human consumption; sanitation improvement; efficient use of water for economic development; water for environmental conservation; reducing vulnerability to floods and droughts; and promoting peace and regional integration, as well as ensuring water resources for the development of Mozambique.

    The ENGRH recognizes that the country is vulnerable to the occurrence of extreme events such as floods and droughts and that such events will increase in frequency. It defines policies that help mitigate and manage these events.

25. The **Industrial Policy and Strategy**, approved by the Council of Ministers through resolution 23/97 of August 19th, has as industrial development objectives the appreciation of natural resources, increasing their added value, diversification of the domestic industry; intermediate goods import substitution and exports promotion. Environmental preservation is one of the guiding principles of industrial development. As such, the policy defines that industrial development shall happen in compliance with the ecological balance, defence and preservation of the environment. To that end, it recommends that all industrial projects be subjected to environmental assessments before they are approved. The policy states that the use of natural resources, particularly forest resources, shall be under a management that will ensure its sustainability and renewal. Special attention will be given to the problem of industrial pollution.

26. **Action Plan for Absolute Poverty Reduction – PARPA – (2006-2009)**

    The PARPA aims for poverty reduction based on 4 pillars and 8 crosscutting axes. The pillars are: human capital, social capital, economic development and governance. The axes are: gender, HIV / AIDS, environment, food safety, nutrition, science and technology, rural development, and mine clearance.

    The Environment Axis contains the following priorities:
    - Sanitation;
    - Land Planning;
    - Erosion prevention;
    - Natural resources management;
    - Fire control;
    - Education and environmental legislation;
    - Reduction of water and land pollution;
    - Disaster reduction and prevention;
    - Reflection and action on the effects of environment and poverty, which arise as a result of business and industry intervention;
    - Gradual introduction and dissemination of alternative technologies for construction, cultivation and fertilization of the earth;
    - Renewable energy sources;
    - Promote land fertility, planning, and flora conservation;
    - Establish alliances with civil society at regional and local levels, to stimulate the adoption of environmental management principles that promote the inclusion of communities in the design, implementation and monitoring of environmental programs.

In this axis mention is made to actions stated in the national food security and nutrition strategy (ENSAN):
- Sufficient availability of food;
- Sufficient purchasing power and production at household level;
- Capacity of human organism for biological use of food and absorption of their nutrients.

The strategy for disaster risk reduction:
- Rehabilitation of the hydro-meteorological stations networks;
- Installation of floods warning systems;
- Mapping of areas at risk of flooding;
- Rehabilitation of dams;
- Increase water storage capacity and regulation of the Limpopo River, Incomati and Pungué;
- Construction of large dams based on previous technical studies;
- Construction of dams in the rivers mentioned.
- Reduce the number of human casualties and loss of goods;
- Consolidate the prevention culture;
- Give the country the means for prevention and mitigation;
- By the government, provide means of prevention through information systems - which means training and warning – to the most common disasters;
- Information for response (evacuation, rescue);
- Other measures are to strengthen institutional, regional and international coordination;
- Implementation of SAT’s in the basins that present greater vulnerability;
- Start of climate training and education processes;
- Increase and upgrade firefighting services.

Climate change is not mentioned specifically in the PARPA II, although some strategies list issues of importance to climate change adaptation. It is essential that the next PARPA mentions climate change adaptation as a priority, to facilitate donor funding and implementation and to ensure government budgeting for climate change in annual and five-year sectoral budgets.

8.2 Analysis of the government's institutional response to natural disasters

Summary

Mozambique has had a background similar to that of other countries which have experienced war or armed conflict. The institutional response in the post-conflict period has been oriented towards rehabilitation of productive infrastructure and care to the conflict victims. In the transition period between the end of the war and the beginning of development, actions dedicated to the theme of reconstruction were kept. Decisions on policies for risk management from 1999 reflect the transition from a reactive to a proactive approach, with an emphasis on prevention and mitigation.

INGC's mandate and responsibilities give it the possibility to guide current and future tasks regarding adaptation to climate change from the perspective of protection, prevention and mitigation of natural disasters. Other ministries have sectoral responsibilities related to protection of natural resources and response in the event of natural disasters. The ministry of environment MICOA has the overall coordinating mandate for all environmental issues, but is not an implementing body. Overlapping mandates with respect to climate change may result in delays in the design and implementation of adaptation to climate change.

Climate change has to be institutionalized systematically across many ministries, with clear roles and responsibilities defined which is not the case yet. While the existing legal framework provides for inter-institutional coordination, there is no institutional culture that focuses on adaptation as an inter-sectoral matter, which covers both the public and private sector.

At the same time, clear leadership in the implementation of adaptation measures must be established. Existing technical and coordination councils should be made use of rather than establishing new government coordination mechanisms, which can take years. A coherent government structure which can receive and manage large-scale and complex donor funding, manage and guide adaptation projects and ensure compliance and performance, must be set up as a matter of urgency to guide upcoming donor initiatives.

A fact to take into account in adaptation strategies is that the urban population in Mozambique is approx. 30% of the total urban population, and that, according to the projected rate of urbanization, 50% of the Mozambican population will live in cities by the year 2025.

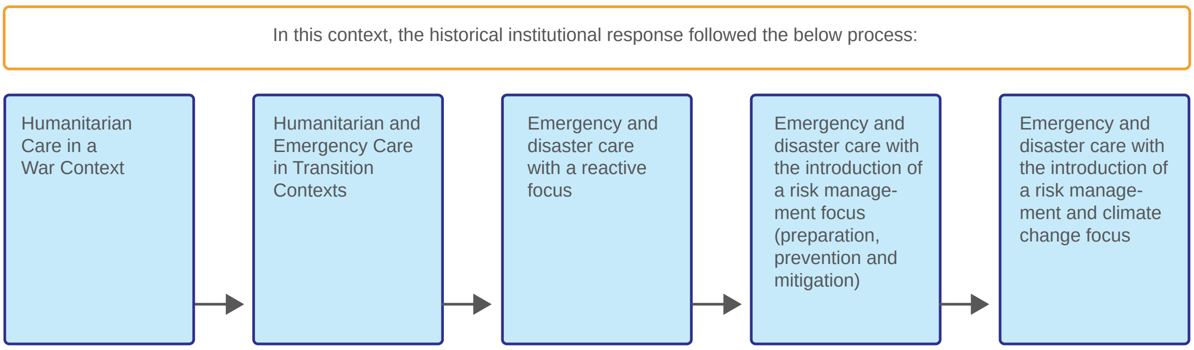


Figure 8.1: Historical institutional response.

Institutional response to natural disasters

Mozambique has a background similar to that of other countries that have experienced war or armed conflict. The institutional response in the post-conflict period has been oriented towards rehabilitation of productive infrastructure and care to the conflict victims. The end of the war in 1992 was followed by a period of recovery and reconstruction. Decisions on policies for risk management from 1999 reflect the transition from a reactive to a proactive approach, with an emphasis on prevention and mitigation.

The change in focus was reflected in the creation of a specific disaster management institution, INGC, with the responsibility for the coordination of prevention and response rather than emergency aid, and with the logo: 'to prevent is better than to cure.'

Most of the documents that examine the institutional response of Mozambique to natural disasters make reference to events occurring after the floods of 2000, because of the large amount of damage caused by cyclone Eline and the greatest floods in recent history; and because prior to that date, there were no systematic historical records.

Barriers to adequate mitigation of disasters during the 2000 floods included (Matsimbe, 2003):

- Lack of institutional coordination to respond to extreme situations;
- Weak communication mechanisms between different Administration levels;
- Lack of an effective channel to spread information to the communities;
- Decision-making centralization at a national level and inflexible bottom-up information flow mechanisms. As a result, many of the decisions taken do not reflect the needs and expectations of the population in the fields;
- Weak and inconsistent relationships between different authorities;
- No clear definition of roles between administrative and traditional authorities.

Since the floods of 2000, INGC has dedicated itself mostly to the coordination of disaster response and to taking an active role in prevention and mitigation. The INGC structure for prevention and mitigation is as follows:

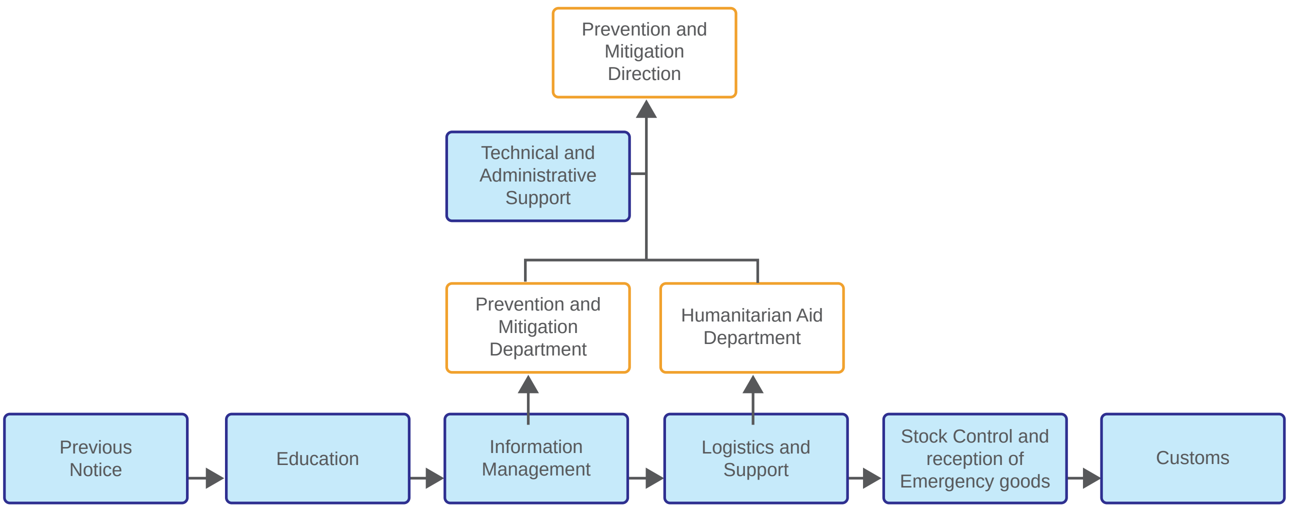


Figure 8.2: INGC structure for disaster prevention and mitigation.

INGC's responsibilities in the area of prevention and mitigation of natural disasters are to:

a) Coordinate the relevant multi-sector activities relevant for the actions of INGC;

b) Managing state-given funds and the donations from national and foreign entities, to relieve situations of emergency;

c) Propose and comment on relevant legislation, regarding disaster risk management;

d) Propose and coordinate the design of plans and programs for disaster risk management;

e) Encourage national volunteering as a way of ensuring community participation in implementing programs to support communities in vulnerable areas;

f) Coordinate with the Ministry of Education and Culture (MEC), the inclusion of materials on disaster management in school curriculum;

g) Promote education on disasters risk management, together with the local committees;

h) Encourage public and private universities to research the best ways of reducing vulnerability to disasters;

i) Ensure that humanitarian assistance is provided in a timely manner to affected populations;

j) Coordinate with the Ministry for Coordination of Environmental Action (MICOA), the monitoring of environmental impact caused by disasters.

k) Coordinate with the institutions involved, the population search and rescue actions, through the National Civil Protection Unit (UNAPROC);

l) Ensure the functioning of UNAPROC at a national and regional level, with the participation of civil society, governments and international bodies involved (UNAPROC);

m) Mobilize and organize, under its responsibility, the material and financial resources management for a rapid intervention in case of disasters (UNAPROC);

n) To undertake response actions and emergency management through the National Operative Emergency (CENOE);

o) Mobilize resources for the post-disaster rehabilitation and reconstruction activities, in close link between emergency and development (GACOR);

p) Ensure a quick rehabilitation process by mobilizing resources for the resettlement of humans and infrastructures affected (GACOR) ...” (Projecto de Regulamento Interno, 2008: 3).

INGC's responsibilities for arid and semi-arid areas are to:

a) Promote technologies adaptable to arid and semi-arid areas;

b) Coordinate the development of arid and semi-arid areas;

c) Promote water abstraction techniques to supply the people;

d) Promote moisture conservation and agro-forestry agriculture;

e) Promote ways of processing and storing agricultural products;

f) Promote the use of agricultural crops and varieties tolerant to drought, as well as domestic crops with nutritional value;

g) Promote studies on climate change;

h) Promote research of existing natural resources to guide the population as well as public and private institutions, for its better use …” (Boletim da Republica 47, Nov. 2007).

From the above and from internal regulations of the institution which are currently under discussion it can be noted that, seen from the perspective of climate change, INGC has the possibility to guide current and future tasks regarding adaptation to climate change, from the perspective of protection, prevention and mitigation of natural disasters.

The work of institutions like INGC in other countries has been strengthened by measures which at the same time strengthen and consolidate other institutions, especially those which are responsible for scientific research and monitoring of threats. This strengthening has included the unification of this work in a single institution.

In the Mozambican case, INGC already works in close coordination with the meteorological institute INAM, which has the competence of monitoring meteorological activities, with particular emphasis on climatology, agrometeorology, aeronautics, sea and air quality monitoring. A project on risk management in Buzi, showed that INAM's information, given to organized communities, was taken into account in planning prevention and mitigation activities. Nevertheless, one can still speak of institutional vulnerability to climate change, since “... the effort to generate, monitor, and transfer information has no correlation with the reduction of impact of events at the community level, either because it is not enough or because the population has no capacity to interpret it, or because there is no action to create trust in the source... “(Benessene, 2008).

The occurrence of extreme weather events has allowed the creation of mechanisms and institutions focused on Early Warning and mitigation of the effects of disasters. Mozambique is the only country in Southern Africa that has a contingency plan and annual plans (PP.70). Its interaction with other countries of southern Africa, has led to seasonal forecast issuance through SARCOF (South Africa Regional Climate Outlook Forum). A new weather radar is being installed in countries in order to allow a warning of hurricanes and tropical storms. Mozambique is also in the HYCOS (Hydrological Cycle Observation System) network, run by the National Directorate of Water (DNA), formed by 50 stations connected by satellite, thus covering strategic points of the main rivers of the Southern Africa region.

The discussions that took place in 2007 to add wild fires to the national centre of emergency operations CENOE, showed that scientific research is widespread in many institutions. Nevertheless, the discussions served to highlight the problems of information management for the purposes of applying risk management. There was a clear need for the collection and processing of information from the various institutions to make it available on time to other institutions, at the national and sub-national level.

Inter-governmental and Non-Governmental Institutions with Disaster Risk Reduction Approach

(i) Red Cross of Mozambique - CVM

CVM is active in assisting the most vulnerable groups in collaboration with the government (Ministry of Agriculture, Health, Welfare and INGC) to reduce vulnerability and prevent disasters. Its primary function is not to develop; in its activities to pre-disaster planning it concentrates efforts on promoting access to water and food. In post-disaster situations CVM has supported the provision of health care.

In preparation and mitigation, CVM has a Disaster Preparedness Program (DPP) which has as main objective to provide the communities with the skills necessary to reduce the negative effects of disasters on their lives and be able to better deal with the consequences of disasters when they occur. The DPP aims to:

- Evaluate and update the material and human resources across the country;
- Increase the capacity and ability to work on issues related to preparedness and response;
- Establish disaster management systems;
- Support communities to reduce vulnerability and increase their capacity.

The CVM has an office in each province and is represented in 144 districts. The more than 4,000 volunteers are trained in primary health care and social assistance activities, including search and rescue in case of occurrence of a disaster.

(ii) World Food Program - WFP

The World Food Program in Mozambique is involved in disaster management, through emergency and development actions, with the use of food aid. The activities of this UN agency have as their main goal to reduce the vulnerability of individuals and communities suffering from food insecurity. It works in cooperation with twenty-nine national and international non-governmental organizations, in areas affected by drought. The WFP is involved in various activities related to disasters, including free food distributions, food supplements for children under 5 years of age and pregnant women; School Feeding Program, which includes distribution of food in schools, take-home rations for girls and orphaned children; support to individuals and families affected by HIV / AIDS through food for work programs, food for training and distribution of food.

The recipients of aid to LDCs are identified by the Vulnerability Analysis and Mapping conducted regularly by the institution, through its Unit for the Analysis of Vulnerability (VAM UNIT).

(iii) United Nations Fund for Children, UNICEF

UNICEF has cooperated with the government in reducing vulnerability of women and children to natural disasters, and in strengthening mechanisms for preparedness, protection and response to emergencies and natural disasters across the country, through protection initiatives especially in the area of water, sanitation and hygiene promotion and prevention of diarrheal diseases. In case of disaster, UNICEF is involved in emergency activities, to help the affected populations and restore access to health care, temporary housing, educational activities and adequate sanitary conditions.

(iv) United Nations Development Program - UNDP

UNDP provides technical assistance to the government in strengthening the coordination capacity of INGC and the National Institute of Demining - IND, and participates in the strengthening of policies to manage water and the environment, which includes support for the National Water Directorate (DNA) in Emergency activities related to droughts and floods and support to the implementation of the National Program for Environmental Management.

UNDP has supported government capacity building to respond to emergencies since the mid-1980s. This project is an integral part of the UNDAF strategy and, as such, it is rooted in the initiatives undertaken by various agencies, having UNDP as coordinator.

UNDP has a capacity building program with the following objectives: Preparation of a National Plan for Disaster Management, establishing a support network through NGOs, public institutions and local government to encourage and support local community initiatives and disaster reduction places; Establishment of a fund to support local and community initiatives for disaster-reduction; Production of geographic and population information about the areas at risk of disasters.

The government and UNDP launched the first national strategy against vulnerability. The strategy was designed as a tool to deal against food insecurity, HIV / AIDS. It is a multi-sector approach to reducing vulnerability and seeks to combine political action with community activities. It is targeted to individuals and institutions as it seeks to strengthen the capacity of institutions to provide services.

(v) Food and Agricultural Organization

FAO is leading a One UN project on mainstreaming climate change in Mozambique. It is a $7 million project which aims to create awareness, mainstream climate change in policy formulation, and implement adaptation at the district level in Southern Mozambique. Aside from this project, FAO provides technical assistance notably in the area of agriculture.

(vi) Fewsnet Mind (Mozambique Integrated Information Network for Decision-making)

The main objectives of FewsNet in Mozambique are:

- Promoting the implementation of improved early warning systems;
- Improving access and use of integrated information on early warning and reduction of disaster risk;
- Work with ARA-SUL to ensure that the efforts of flood modeling and monitoring of new equipment are reflected in early warning systems at local level;
- Support for the Department of Early Warning (DAP) in MADER, in the improvement of monitoring and information dissemination systems about the agricultural season;
- Working with the SETSAN in the coordination of the food safety and nutrition network;
- Support INGC in disaster management, through:
- Realization of profiles on survival means in areas at risk of disasters;
- Production of national maps on extreme events;

(vii) Deutsche Gesellschaft für Technische Zusammenarbeit - GTZ

This was the first organization to implement a community based disaster management strategy by establishing local committees for risk management in Búzi. GTZ has concentrated its activities in strengthening capacity of local community based organizations in managing disaster risk, through the use of traditional mechanisms adopted by communities. Other activities of the Disaster Risk Management Program include:

- Provision of basic kits to local communities, with tools for early warning in order to improve the rescue and response system;
- Promotion of workshops and training for local activists in disaster prevention, preparedness and response;
- Introduction of new seeds and agricultural techniques as well as promoting the use of local seeds for the reduction of vulnerability;
- Promotion of workshops with local authorities on risk management;
- Promoting the use of community radio for dissemination of weather forecasts and warning bulletins.

The experience and lessons learned in Buzi, have served as a model that is being extended to other areas of the country. So far, it works in the Zambezi Valley in Caia and Chemba and in Govuro, and in the basins of the Save river.

A recent internal assessment showed that in the case of Caia, the 6 initial committees have won a place in their communities and in the district. They have matured and are recognized by the community. A slow change of attitude in the population is apparent, first, expressed in the committee's credibility, second, in looking to the committee for information about possible harmful events to the community, and thirdly, the fact that credibility was demonstrated during the floods, when people left areas of flooding earlier and faster, taking their property and animals. The same assessment also identifies a perception that these committees only exist in case of emergency without identifying or presenting information on their work in mitigation terms, throughout the year, for example, in the resettlement centers.

The work of INGC has also earned the attention in performing drills. In the last one conducted in Caia representatives of OCHA were present, to gather information on the work of the committees, their action during the drill, and the possibilities of replicating the model of Mozambique (GTZ report: 2008).

Both in Buzi as in Govuro this model has included, with their variants, the role of a community radio seen as an actor in risk management, including the information management and transfer. In Buzi, the wide program that existed has been canceled, but the community still has a role in information transfer. In Govuro, an appropriation of the topic has been achieved, being recognized the role of the youth association in the radio station management.

Other projects: In addition to the above there are several other institutions whose activities include disaster management components, such as World Vision, Care International, Save the Children and Doctors without Borders. Most of these activities are still targeted to emergency and humanitarian aid, with few mitigation and prevention activities. Due to the existence of many national and international institutions as well as bilateral / multilateral ones, and to the lack of systematic information on their activities in Mozambique, it was not possible in the timeframe of this study, to accurately identify which other non-governmental actors are involved in disaster risk reduction.

Barriers to the inclusion of climate change issues in institutional response

In 2005 MICOA evaluated the progress of Mozambique in fulfilling the UNFCCC commitments, and summarized the constraints encountered in the process as follows:

A study by the World Bank (Sietz, et al, 2008) examines the impacts of climate change on the goals of development aid, and explores the limitations of institutions in the context of climate change adaptation. The table below summarizes the main barriers to mainstreaming climate change into development assistance in Mozambique.

Actions that have been taken	Actions to be taken	Barriers / Constraints
• Community training to reduce the pressure on natural resources • Reproduction of plants for reforestation that are distributed to communities • reforestation to reduce the excessive use of woody biomass in curing tobacco • Environmental education to traditional fishermen • Monitoring of meteorological parameters through stations network • Measurement of tides' height, temperature and salinity • Elaboration and adoption of the regulation of periodic inspection of vehicles • Inventory of greenhouse effect gases • Public institutions training to implement the CDM • Re-settlement areas planning, taking into account the vulnerability to extreme events • Issue of opinions on environmental impact assessment, taking into account the protocol of Kyoto for industrial licenses • Facilitation of negotiations on protocols • Prevention and reduction of suffering of people facing natural disasters • Support the protection of conservation areas of parks • Education and awareness raising of communities on burns, and the value of protected areas • Support to companies for the implementation of the Clean Development Mechanism (CDM)	• Dissemination of international instruments • Operationalize the monitoring of sea temperature surface by satellite • Creation of a database of vehicles in service, out of service or in transit. Types of fuel used and its quality • Training in matters related to the conventions • Assessing the impact of military activities in terrestrial and marine environment • Take inventory of the national heritage submerged • Establish agreements between institutions to improve disclosure of conventions • Replacement of industrial equipment to adjust them to the environmental requirements • Increase awareness of companies to abide by the standards of environmental certification • Disposal of obsolete pesticides already inventoried	• Lack of a national action plan so that the institutions can implement the conventions • Finalize the development of the National Program of Prevention and controlling fires for agricultural purposes • Lack of a national action plan for the institutions that complement the conventions • No legal instrument to insert the activities envisaged in the conventions, in national plans and sectoral plans of the institutions • Lack of inter-institutional coordination • Limited financial resources • Lack of funds for specific training in environmental issues • Lack of multidisciplinary perspective in research • Lack of dissemination of the opportunities under the Conventions • Lack of clear guidelines on the commitments made by Mozambique in this Convention

Table 8.2: Mozambique's progress to fulfilling the UNFCCC commitments. *Source: based on the information contained in the document Evaluation of the National Training Needs and potential to fulfill the obligations of the United Nations Framework Convention on Climate Change (UNFCCC). Mozambique. MICOA, September 2005.*

Perceived barriers to mainstreaming	Donors	National
Individual		
• Lack of human resources within relevant institutions	+	++
Organisational		
• Insufficient data and information availability	++	+++
• Weak data and information management	++	++
• Inadequate data and information dissemination	++	++
• Erosion of institutional memory	+	+++
Enabling environment		
• Lack of inter-institutional coordination and communication	+++	+++
• Gaps and overlaps in mandates of institutions	+++	+
• Short-term development goals are given a higher priority	++	++
• Scarce sources of adaptation funding	+	+++
• Lack of communication with and participstion of local communities	+	++
Example: Disaster risk management		
• Absence of a coordinated strategy for disaster risk management	+++	++
• Predominant culture of emergency response	++	+++
• Lacking transparency in planning and implementing processes	++	+
• Lack of disaster management at local and district level	++	+

Table 8.3: Main barriers to mainstreaming adaption into development assistance perceived by donor and national experts. (Level of perception; +++ high, ++ medium, +low).

8.3 Analysis of Community Response to Natural Disasters

In Mozambique, the war period "... impeded systematic research (social and cultural) leaving the government without the minimum information necessary for development of political programs ..." (Arthur, et al., 1999: 11). This reflects the lack of information on historical community forms of emergency management.

The post-war era, notably since 2000, provides substantially more institutional information. Literature reflects the tendency of communities becoming increasingly the recipients of community and emergency aid, the latter being handed out to "affected communities" of floods or droughts.

Diallo (1999:35) states that in traditional Africa, "... society issues .... (are managed) by a strict form of democratic management, based on what we call consensus .... ". This is reflected, for example, in community decisions about relocations to safe areas, .the election committees members, team management models, or decisions to identify threats, risk areas, areas considered safe to travel, etc..

Evaluations show that the coordination mechanisms between national institutions, and between national and international organizations working at the local level, are poor and in turn, vulnerable, and that this is where the community organization, social networks and local actors, play an important role in risk management. (Matsimbe, 2003).

In this context, two forms of response to disasters are identified: one, at the community level in traditional societies, where natural disasters are part of their means of life; the other, which corresponds to decentralization processes of some state institutions, which seek the formation of community structures with specific objectives. The latter category includes local risk management committees.

The organized community risk response from the management committees in Buzi has been considered as an adequate mechanism to disseminate alert notices and evacuation orders in some areas. However, it has been shown that to be truly effective, additional work is necessary for all people to receive one and the same message and to ensure full coverage of the population.

In community response, one can find strategies to deal with climate change. Community response through the formation of committees has included:

- Preparation for emergencies;
- Committees organization and training;
- Some community based alert systems;
- Establishment of links between committees of different communities;
- Relationships between committees and institutions at the district level;
- Initiatives to extend work to prevention and mitigation activities;
- Integrating the committees work with district planning.

The term "coping" refers to the multiple ways in which people choose, apply their knowledge and capabilities, and define a method to continue surviving, presently, in face of climate change. These are local methods which develop to deal in the short term with changes that affect their lives, and to which they must adapt in the longer term.

What can be seen now are community actions that are coping mechanisms and -strategies, because the State still has no structural presence, or a coverage that meets the needs that present themselves in face of climatic events that correspond to the so-called "emerging standards." This situation imposes the development of new survival strategies.

The Technical Secretariat for Food Security and Nutrition (SETSAN) defines vulnerability as (SETSAN 2007):

a) The degree of exposure to risk of natural (shock) events, especially hurricanes, droughts, floods and pests, and,

b) The coping ability of families to deal with these events.

SETSAN undertakes yearly vulnerability assessments, in coordination with ministries, national and international institutions such as FAO and WFP, placing emphasis on food security. These assessments are described in more detail in the Vulnerability Analysis component of the INGC project.

A 2006 study on urban vulnerability issues a warning that urban growth also poses serious problems in terms of poverty, inequality and environmental degradation. Coping strategies of people in urban neighborhoods are characterized by a high degree of flexibility and mobility, both at household as individual level. Research in Maputo shows that families are large and complex, with an average of 7.9 members, and have a high proportion of women as heads of household of up to 37%; and that markets, and the relationships between families, friends, neighbors and colleagues, including relations with the countryside and relations with the State, with civil society and aid organizations are the most important coping strategies.

The study states that the urban population in Mozambique is 30% of the total urban population, and notes that, according to the projected rate of urbanization, 50% of the Mozambican population will live in cities in the year 2025. In geographical terms it is also noted that Beira, the second largest city (CARE, 2006:10), is particularly vulnerable.

According to CARE (2006) "... while local strategies succeed in dealing with climate change in the short term, few Mozambicans will be able to adapt to more frequent and severe weather events, without assistance ....".

8.4 Recommendations on Institutional Response to Adaptation to Climate change

Existing recommendations

The policies and plans of different ministries and institutions, including the INGC Master Plan, identify the causes of the country and its population's vulnerability, and propose mitigation and adaptation measures, which, if implemented, would become relevant as immediate response to ongoing climate change. The below table summarizes existing proposals which appear in Mozambique's First Communication on Climate Change (UNFCCC, 2003):

Sector	Proposals	Area
Agriculture (Corn)	Adjustments in management practices, types of culture, location, development of intensive farming, mechanization, promotion of crop varieties tolerant and susceptible to drought areas, development of infrastructure for irrigation, pest monitoring and control, promotion of cultivation and harvest technologies.	Chokwe
Water	Development of integrated management plans for each basin, construction of small dams, public campaigns for the conservation and rehabilitation of monitoring and early warning systems, flood and drought areas mapping.	Limpopo, Incomati, Pungué, Zambezi,
Coastal resources	Inventory of coastal areas and development of a data center, strengthening of its legal and institutional framework, establishment of an institution for integrated management.	Beira
Pasture	Alternative pasture systems, changes in the supply percentage, changes in the pasture period, changing the cattle genotype, farms improvement, and feeding grass.	Chokwe
Forests	Intensive and extensive reforestation using weather compatible species.	Chokwe
Hydrology / Meteorology	Strengthen climate prediction capacity, promoting the collection and use of meteorological information and warning systems, particularly in areas susceptible to disasters.	Chokwe

Table 8.4: Mozambique's First Communication on Climate Change: existing proposals. *Source; UNFCCC, 2003.*

The PARPA states that when facing the threat of drought, the country is to determine the scarcity of water both for use of the population and agricultural activities, in order to allow for the construction of facilities to conserve rainwater (PARPA II: 68). When facing the threat of floods, it is proposed to strengthen water management programs to reduce vulnerability to floods; rehabilitate the meteorological stations network; establish flood warning systems; map areas susceptible to flooding; rehabilitate dikes and shelter platforms; Increase water storage capacity; regulate the Limpopo, Pungué e Incomodai river basins, in order for these water reserves to be used based upon the performance of studies for the future construction of large dams (Mapai, Bue Maria and Moamba Major) (PARPA: 112).

Main aims of the PARPA included the development of agriculture with high productivity and the establishment of links between the national and rural agricultural economy. Both objectives can be considered as recommendations of measures for adaptation.

The Ministry of Agriculture and Rural Development (MADER) has also proposed some measures to reduce the impact of lack of rain (drought): including the expansion of areas with perennial crops, through the production and distribution of plants; Intensive production of vegetables and other annual crops; Multiplication of sweet potato branches and cassava cuttings and material tolerant to drought and the replacement of susceptible varieties to cassava radices rot disease; local production and multiplication of seeds; Realization of seed fairs; acquisition and supply of kits, and equipment to protect from and to combat pests diseases; intensive use of water resources through the construction and rehabilitation of irrigation systems, dams and water sources, and the acquisition and installation of irrigation equipment (e.g. foot pumps) to ensure sustainable operations.

The Action Plan for the Prevention and Control of Wild Fires is included in the Government Five Year Plan for the Environmental Management Sector. The prerequisite for the success of the actions outlined in the Action Plan for prevention and control of uncontrolled fires 2008-2018, is the active role played by communities and local authorities.

It is widely acknowledged that soil erosion affects the country extensively, resulting in material damage, including the degradation of social and economic infrastructure, loss of soil fertility, disturbance of sensitive ecosystems, among others. Accordingly, various actions have been undertaken in trying to control soil erosion through distinct actions of corrective nature, and a few actions of preventive nature such as reforestation and construction of gabions. However, the actions are isolated and of insufficient scale.

Stakeholder consultations for this study in November 2008 at the level of heads of ministerial departments and at the technical level revealed across the board a lack of understanding of climate change, lack of understanding of their ministry's role, and hence a lack of thought about adaptatation measures of relevance for their ministries. The typical reasoning was that as long as the impacts of climate change on Mozambique specifically were unknown, it was not possible to identify ways in which their ministries could start preparing for climate change.

The following is a summary of recommendations found in existing documentation on Mozambique.

Key Themes	Adaptation measures
Risk management and vulnerability reduction.	Major mitigation measures such as urban and regional planning. Strengthening of local technical teams on practical measures to implement these measures on site, especially the construction codes, regulation of land use, and implementation of other measures which are already stated in the national legal framework. The information is made available and feeds back planning for disasters and vulnerability reduction. Ensure constant monitoring of threats and vulnerability. Through support and training, maintain the ability and capacity to assess risks to communities.
Preparedness and response to disasters	Expansion of floods early warning systems to other risk areas. Ensure the understanding, approval and transfer of information in real time. Strengthen the communities' management of early warning systems. Strengthening the Municipal Commission for the prevention and management of risk situations and emergencies: training, preparation, evacuation plans, drills and simulations. Update the inventory of human and material resources available to respond to emergencies. Implementation of the Emergency Operations Center CENOE and its committees, to work at all levels. Warning systems: Ensure community capacity building on procedures in emergency situations, which includes alert levels, alert mechanisms for evacuation, safe areas for concentration of the affected, and shelter locations. Ensure the collection of data on diseases associated with floods and its relation to more frequent events.
Climate variability	Reviewing current agricultural practices notably burning of the land. Protection of coastal areas. Expand warning systems to the main basins with the involvement of community organizations
Droughts	Preparing for more complex droughts with water sources protection measures, reservoirs, setting up shade areas for livestock, expansion of drip irrigation systems, use of seeds more resistant to droughts and pests. Increased ability for the INGC to address conflicts for water or due to increased demand.
Biodiversity	Support efforts to rescue valuation, revaluation and dissemination of traditional and native seeds.
Social dimensions	Mitigation measures against economic impacts with the promotion of agricultural diversification and support to income-generating activities. Support of high income generation crops. Strengthening emergency response capacities. Urgent measures for institutional strengthening regarding decentralization, especially in INGC. Increasing INGC capacity to deal with violent conflicts derived from access to water, other natural resources, food and emergency services.
Means of living	Short-term mitigation measures to face crop reduction due to water shortage or higher temperatures. Mechanisms of immediate intervention facing crisis derived by the increase in pressure on the water resource as a result of high rates of evapo-transpiration, changes in rain frequency, pollution of water sources by saline water intrusion, damage to the ecosystems, etc. Internal displacement at different levels, due to sea level rise, land reduction for the people historically settled in coastal areas, high ocean temperature, salinity and acidity with reduction in fish stocks.
Internal Displacement	Develop policies for voluntary resettlement, especially considering local perceptions of risk and local knowledge. Establishing a specific fund and strengthening INGC for care for the 'climate displaced'. Internal migration derived from food insecurity.
Water supply security.	Protection of natural ecosystems Sustainable management of natural resources and agricultural crops, Intensive and priority programs to ensure local supplies
Governance	Local governance focusing on mechanisms to institutionalize conflicts from the uncertainty in access to water. Mechanisms, capabilities and institutional structures decentralized Clear definition of responsibilities Strengthening operational binding mechanisms between public administration levels, especially in times of crises and emergencies.
Risk assessment	At national level, systemic focus on the gathering, use, management and distribution of information. At local level, community-based risk assessments with community definition of priorities. Introduction of a risk management focus in health institutions with the capacity to assess risks coming from changes in water quality, its accessibility and availability, food consumption patterns.

Key Themes	Adaptation measures
Knowledge, education, training and empowerment..	Enhance local capacities to resist the impacts of disasters based on specific vulnerabilities. Assessment and information of impact vulnerability. Maintain the capacity and ability to assess threats and risks through community-based support and training. Management and dissemination of information on sub-national levels.
Adaptation and coping strategies"	Food security: attention to vulnerable groups to prevent the deterioration of nutritional status Meet the contents or use the food and nutrition guides in emergency situations Strengthen the local ways of obtaining information on rainfall, the river level and climate. The people have this information because of their coexistence with the risks. Improve yields and access to food
Risk transfer	Develop the measures already included in the Master Plan of the INGC that refer to the collective insurance against disaster as an instrument of climate change adaptation. Generation of micro financial instruments (credit and insurance). Implementation of measures and strategies for self protection of small producers and to improve their resistance when facing climatic shocks.

Table 8.5: Summary of recommendations on institutional response to adaption to climate change.

The recommendations presented in the table above can also be organized by main area of action:

a) Strengthening institutions responsible for scientific aspects linked to climate change;

b) Institutionalization of the risk management and climate change focus (threat and vulnerability);

c) Implementation of concrete adaptation activities, technology transfer and capacity building, especially in those areas that are considered a priority for the country (poverty, food insecurity, HIV / AIDS).

d) Institutional strengthening related to the creation and / or strengthening capacities for decentralization at all levels;

e) Based on the findings of impact analysis of this study, priority must be given to the construction and / or strengthening of local capacities to cope with and adapt to future climate change, but especially to manage emergencies and disasters and their implications on food and water security. This priority must consider both the sudden extreme events as those which slowly develop, as well as social conflict derived from its immediate and long term effects.

Additional recommendations for institutional response

The following are recommendations which have not been identified as such in existing literature, or on which it is felt additional emphasis must be placed.

(i) It is important that reactive attitudes and perceptions, developed over the course of the years as the dependence on government response, donor organizations and humanitarian aid increased be changed to a proactive approach involving local committees or networks, a risk management approach, and an internalization of values related to the advantages of early warnings and community organization, self support, etc.. Therefore, another recommendation is to strengthen local capacity on implementing adaptation strategies and to stimulate links with government institutions.

It is recognized that vulnerability is dynamic, since it reflects the reality of societies, which change constantly. Many useful variables to assess vulnerability are included in national statistics, such as health, education, income, employment, among others. Nevertheless, and precisely because of the dynamic nature, local diagnoses are often most relevant to guide centralized decision-making. There is an ancestral knowledge reservoir expressed in daily practice that has allowed people to face different types of threats and reduce the risk derived from them (Sánchez del Valle, 2006).

(ii) In the INGC Master Plan, brief reference is made to a subject that is already considered in other countries as an instrument of climate change adaptation, but in Mozambique, has yet to be developed: the collective insurance against disaster.

Collective insurance works as micro-credit or micro finance (GTZ 2007:25) (Inwent, 2007) where the State provides the link between small-family units, that without its brokerage cannot access the benefits from financial products (health, agriculture, stocks, or non-agricultural businesses insurance). Often it is demanded that farmers introduce practices to reduce the risk or reduce it in their starting-up, reproduction, and market stages, in order to also deal with price risk. Micro-finance instruments (credit and insurance) are needed to complement the strategies of self protection of small farmers and improve their resistance to climatic shocks.

The above helps reduce possible damages, production losses and farming profitability when facing catastrophic events. Besides a risk transfer mechanism, this is considered an adequate measure to cope and adapt to long term climate change.

(iii) FEWSNET has also promoted local risk management capacity building. One of the activities in this area was a research (community risk assessment) which was held in an area vulnerable to disasters, Govuro. It showed that the community perceives the drought as the major disaster and that between floods and cyclones there is only a slight difference. The evaluation indicated that beliefs and values play a central role in building the perception on disasters, along with environmental, economic and political factors, lack of opportunities and unsustainable means of living, limited infrastructure and basic services.

One of the main results of the research was that communities also develop local and indigenous mechanisms for early warning, for example, the position of the new moon, which is an indicator of time of rain or the absence thereof, the colors of the rivers that are an indicator of approximation of cyclones, or even increase in the number of weeds in rivers, which is an indicator of the occurrence of floods. The communities combine formal and informal systems of notice. (Abdula 2005:21-28).

(iv) The analysis of the relationship between women, means of living and climate change is important, particularly in countries where a high percentage of heads of household are women. Another important factor to this analysis is the percentage of the workforce in agriculture represented by women, and the major role of women in production and distribution, especially of subsistence items. Many women have no knowledge on the potential damage of climate change on their livelihoods.

In the case of Mozambique, an increase in economic insecurity of women has been evidenced, in part because they require more time to recover from the economic losses, or because the gender barriers represent an obstacle to the tasks of reconstruction. Natural disasters increase their workload, either because men migrate or because it reduces their access to resources, or because they spend more time looking for water, food or firewood. They have to deal not only with the economic consequences of dysfunctional livelihoods, but also with the emotional and social effects resulting from death, disease and scarcity of food that inevitably occur during and after disasters.

Measures are proposed to improve women's access to information on best practices in agriculture and facilitate their access to resources. Both points can be found in strategic plans, but there is no concrete approach linking women to dealing with the impacts of climate change. It is recommended to politically recognize their vulnerability, undertake measures of economic empowerment, and directly make them part of local natural resources management.

In planning and designing climate change mitigation and adaptation strategies, the different forms and causes of vulnerability of women and men, must be taken into account, as well as potential consequences of proposed adaptation options for men and for women. (O'Keefe and Wilson: 2004), (Abdula 2005:35,36)).

Recommendations for INGC

- INGC should be strengthened its ability to identify and implement adaptation measures and in encouraging other sectors to be responsible of implementing at a national level.
- Increase decentralization capacity.
- Have an initial strategy and action plan with guidelines for prevention and mitigation, with emphasis on social aspects and introducing new criteria like risk transfer in priority sectors.
- There are important lessons learned in terms of reducing environmental degradation, the strengthening of institutions like INAM, the establishment of warning systems, and community organization. However these must now be adjusted to include climate change criteria and an information system as the basis for decision making.
- The consultations with experts reinforce the principle of strengthening the adaptation measures for the coastal zone considering its development potential.
- Actively promote the review of policies to include sector specific responsibilities for adaptation to climate change, including water resources conservation measures, conflict resolution etc.
- Actively promote a greater participation from civil society
- Identify priority actions based on climate change scenarios and impact analysis, and criteria for prioritization
- Support the creation of an appropriate internal dynamic in institutions so that the subject of climate change is considered a priority and part of the objectives of the action of individuals, organizations and society and not of a specific sector;
- Anticipate and prepare but especially centralize resources and assess potential adaptation measures.

Recommendations per threat:

Floods

Implications for INGC

Expected increase in the population affected by floods
Expected increase in the number of the population displaced
Expected increase of areas affected by floods
Expected increase of the demand for emergency infrastructure
Expected increase in conflicts for access to humanitarian aid
Expected demand for increased installed capacity at regional and provincial level

Current Strategies

Characterization of vulnerable groups
Isolated resettlement projects
Flood warning systems in some of the main basins
Training in search and rescue

Proposed actions

Define the priority areas for additional scientific research, particularly on adaptation options to climate change
Strengthen threat monitoring.
Increase capacity for information analysis, monitoring, prognosis, and dissemination.
Contribute to the development of the legal framework and corresponding policies
Development of a voluntary resettlement program
Public information on prevention campaigns, information dissemination to communities at risk
Review and strengthening of the budget for response to disasters
Risk management - raise preparation and adaptation capacities in priority areas

Droughts

- Expected reduction of the planting area and yields
- Expected increase in the number of displaced population
- Expected increase of the areas affected by drought
- Expected increase in the demand for infrastructure
- Expected management of conflicts for access to humanitarian aid
- Expected increased need for alternative income

Current strategies

- Characterization of vulnerable groups
- Identification of survival strategies by the vulnerable group

Proposed actions to undertake

- Define the areas to promote scientific research, particularly on adaptation to climate change
- Contribute to a National program to reduce human, social, economic and environmental losses, due to drought
- Methodologies and tools for risk assessment adjusted to deal with climate change
- Awareness raising of decision-makers and the general public
- Increasing capacity in the tasks of analysis, monitoring, prediction, vulnerability assessment and prevention
- Contribute to the development of the legal framework and corresponding policies
- International and intra-regional alliances. Networking between regional and international actors

Population

- Expected increase of population settled in areas at risk
- Expected intrusion of sea water in the agricultural soil leading to reduced yields
- Expected temporary and permanent inundation
- Expected internal displacement of populations of affected areas
- Expected increase in favorable conditions for vector borne diseases
- Expected increased need for evacuation of people

Current Strategies

- Determining areas and populations at risk
- Identifying protection measures

Proposed Action

- Coastal protection incorporating climate change risks
- Ensure adaptation is in sectoral budgets
- Planning of human settlements, incentive structures
- Integrated coastal management regulations
- Revise legal framework particularly land planning
- Increased preparation in areas at risk
- Standards for settlement in areas at risk

Annexes

Annex I: Extreme indices

Extreme indices calculated at each synoptic station annually and for the SON, DJF, MAM, JJA seasons:

txav	Tmax médio
tnav	Tmin médio
tav	Tmean médio
trav	amplitude térmica media diurna
trq10	amplitude térmica diurnal no 10º percentil
trq90	amplitude térmica diurnal no 90º percentil
txq10	Tmax 10º percentil
txq90	Tmax 90º percentil
tnq10	Tmin 10º percentil
tnq90	Tmin 90º percentil
tnfd	Número de dias gelados Tmin < 0 degC
txice	Número de dias sem degelo (ice dias) Tmax < 0 degC
tgdd	Dias de graus crescentes> limiar
tiaetr	Amplitude térmica extrema inter-anual
tgsl	Duração crescente da estação
txhwd	Duração de onda de calor
txhw90	Duração de onda de calor do 90º percentil
tncwd	Duração de onda de frio
tncw10	10th Percentile Cold Wave Duration
tnfsl	Duração da estação de gelo (0 degC)
txf10	% dias Tmax < 10º percentil
txf90	% dias Tmax > 90º percentil
tnf10	% dias Tmin < 10º percentil
tnf90	% dias Tmin > 90º percentil
pav	Precipitação climatérica média (mm/dia)
pq20	20º percentil de quantidade de chuva (mm/dia)
pq40	40º percentil de quantidade de chuva (mm/dia)
pq50	50º percentil de quantidade de chuva (mm/dia)
pq60	60º percentil de quantidade de chuva (mm/dia)

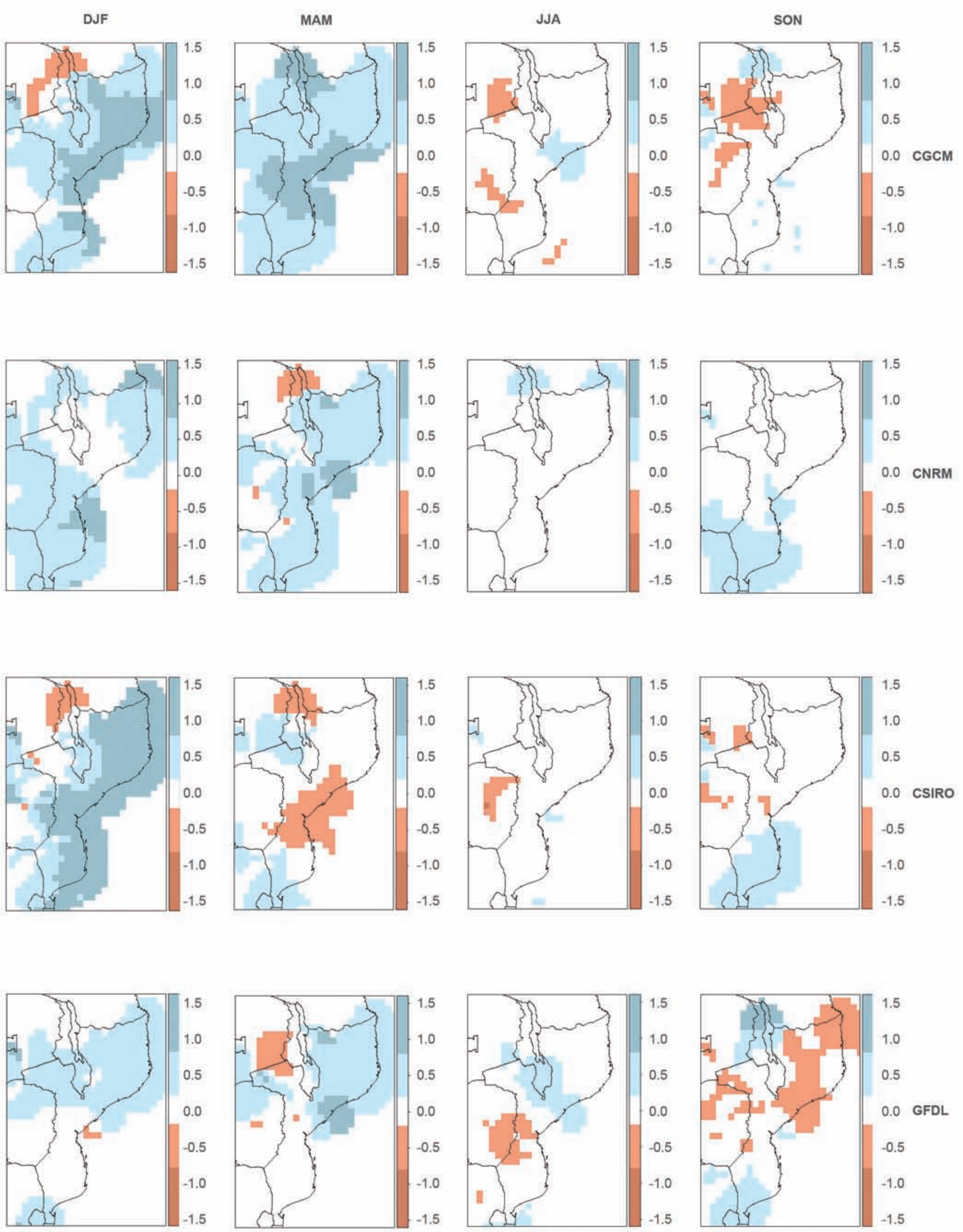
pf80	Fraction of total precipitation above annual 80th percentile
pf90	Fraction of total precipitation above annual 90th percentile
pf95	Fraction of total precipitation above annual 95th percentile
pn10mm	No. of days precip >= 10mm
pxcdd	Max no. consecutive dry days
pxcwd	Max no. consecutive wet days
ppww	Mean wet-day persistence
ppdd	Mean dry-day persistence
ppcr	Correlation for spell lengths
pwsav	mean wet spell lengths (days)
pwsmed	median wet spell lengths (days)
pwssdv	standard deviation wet spell lengths (days)
pdsav	mean dry spell lengths (days)
pdsmed	median dry spell lengths (days)
pdssdv	standard deviation dry spell lengths (days)
px3d	Greatest 3-day total rainfall
px5d	Greatest 5-day total rainfall
px10d	Greatest 10-day total rainfall
pint	Simple Daily Intensity (rain per rainday)
pfl90	% of total rainfall from events > long-term 90th percentile
pnl90	No. of events > long-term 90th percentile
pdssdv	desvio padrão da duração de seca feitiço (dias)
px3d	Pluviosidade total dos 3 maiores dias
px5d	Pluviosidade total dos 5 maiores dias
px10d	Pluviosidade total dos 10 maiores dias
pint	Intensidade simples Daimente (chuva por dia de chuva)
pfl90	% de pluviosidade total de eventos> 90º percentil de longo prazo
pnl90	No. de eventos > 90º percentil de longo prazo

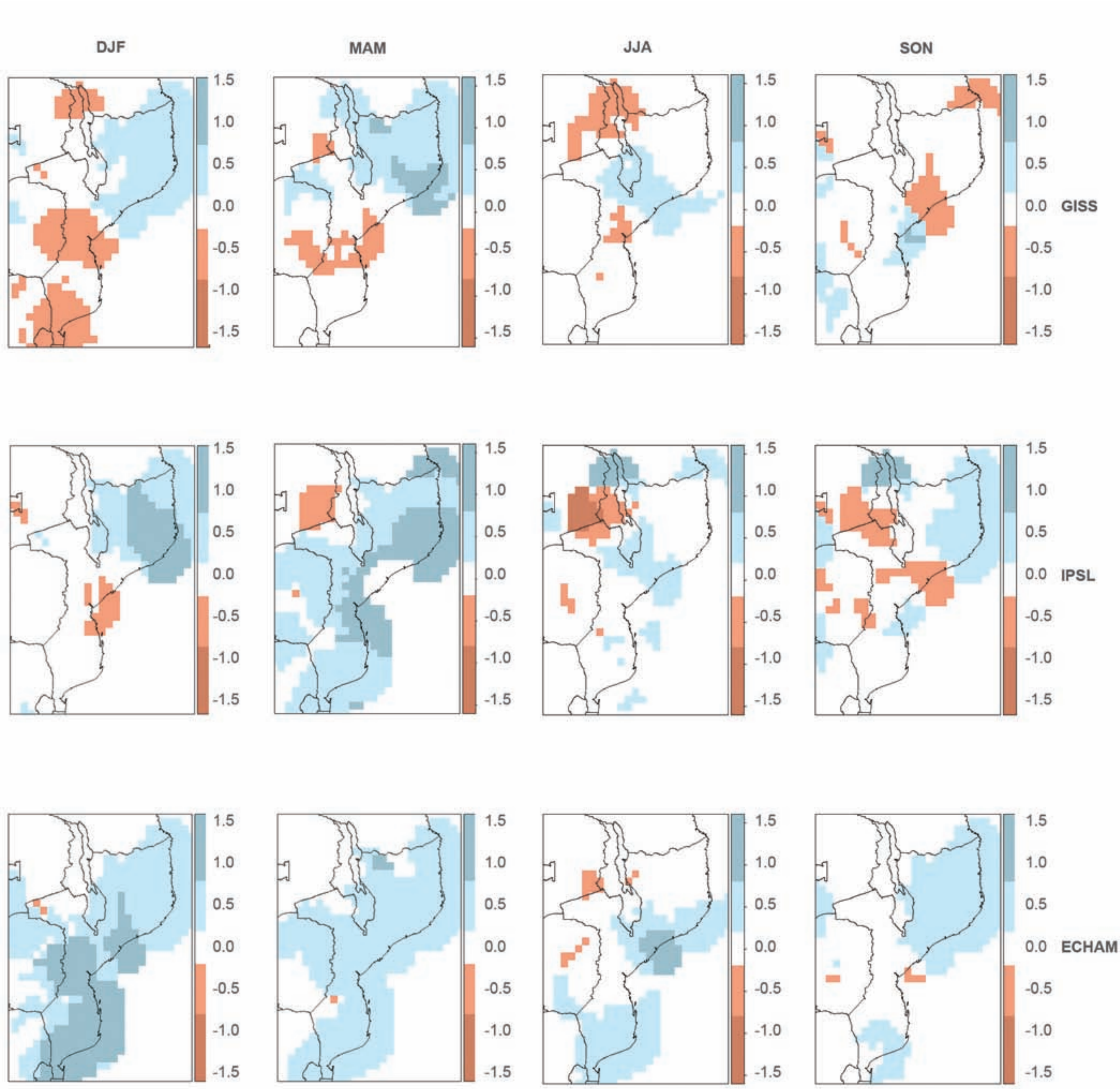
Annex II: Stations outside Mozambique used in the analysis

Station ID and locations of station data outside Mozambique used to provide a regional perspective of scenarios and interpolate to regions with sparse data coverage within Mozambique.

Station ID	Latitude	Longitude
WMO stations		
Mean Tmax	**Mean Tmin**	**Mean Tmean**
68496	-28.50	32.40
68296	-24.98	31.60
67991	-22.22	30.00
67977	-21.02	31.58
67983	-20.20	32.62
67881	-18.53	32.13
67781	-17.42	32.22
67779	-16.78	31.58
67765	-16.83	29.62
67665	-15.32	28.45
67663	-14.45	28.47
67581	-13.55	32.58
67693	-15.68	34.97
67586	-13.78	33.77
67489	-11.45	34.02
WRC stations		
10th Percentile Cold Wave Duration	**Frost Season Length (0 degC)**	**% days Tmax < 10th percentile**
0725756AW	-23.10	31.43
0639474_W	-24.40	31.77
0483545_S	-26.08	31.82
0446766_S	-26.77	31.93
0483702_S	-26.20	31.90

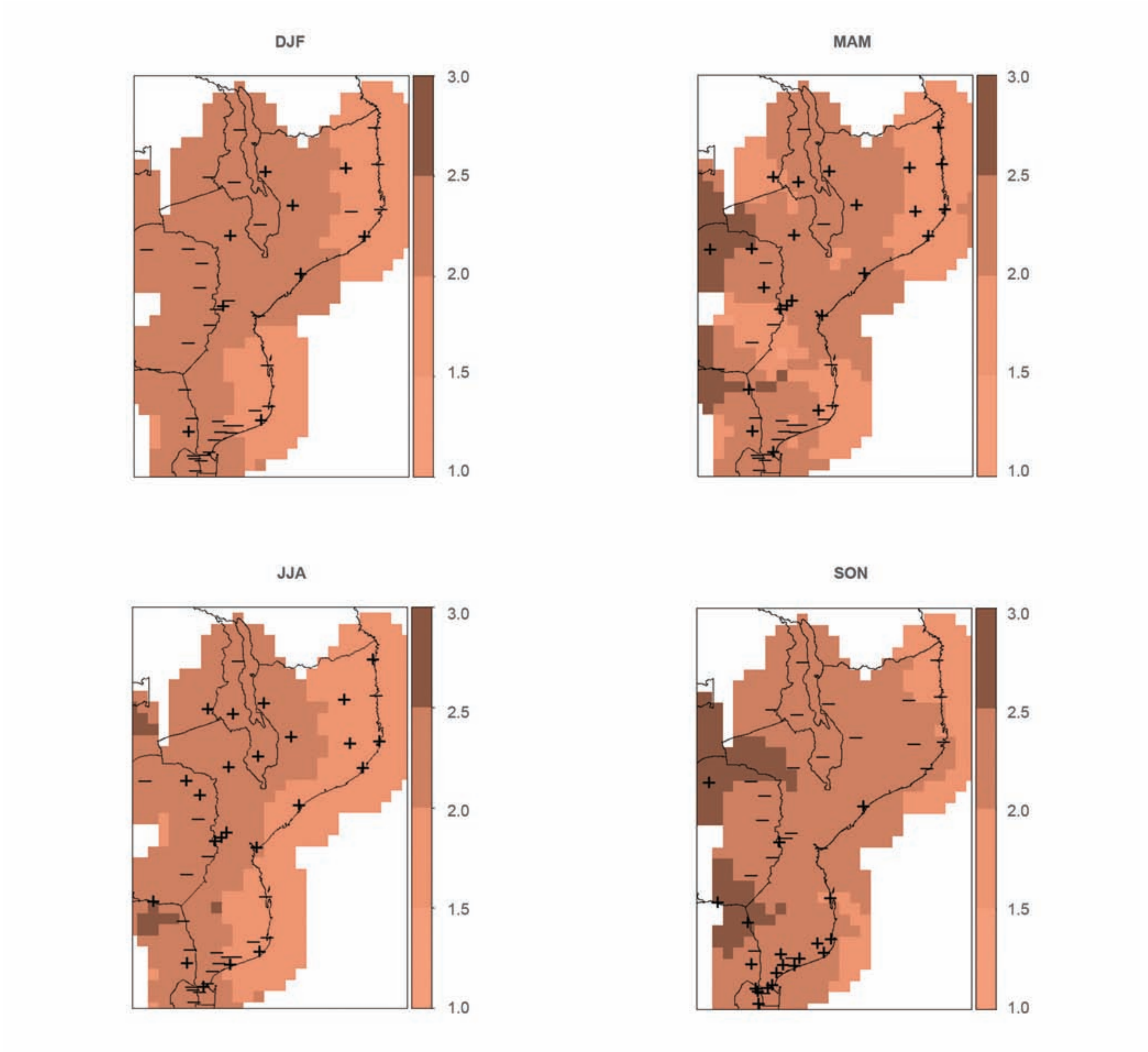
Annex III: Changes in rainfall for each GCM





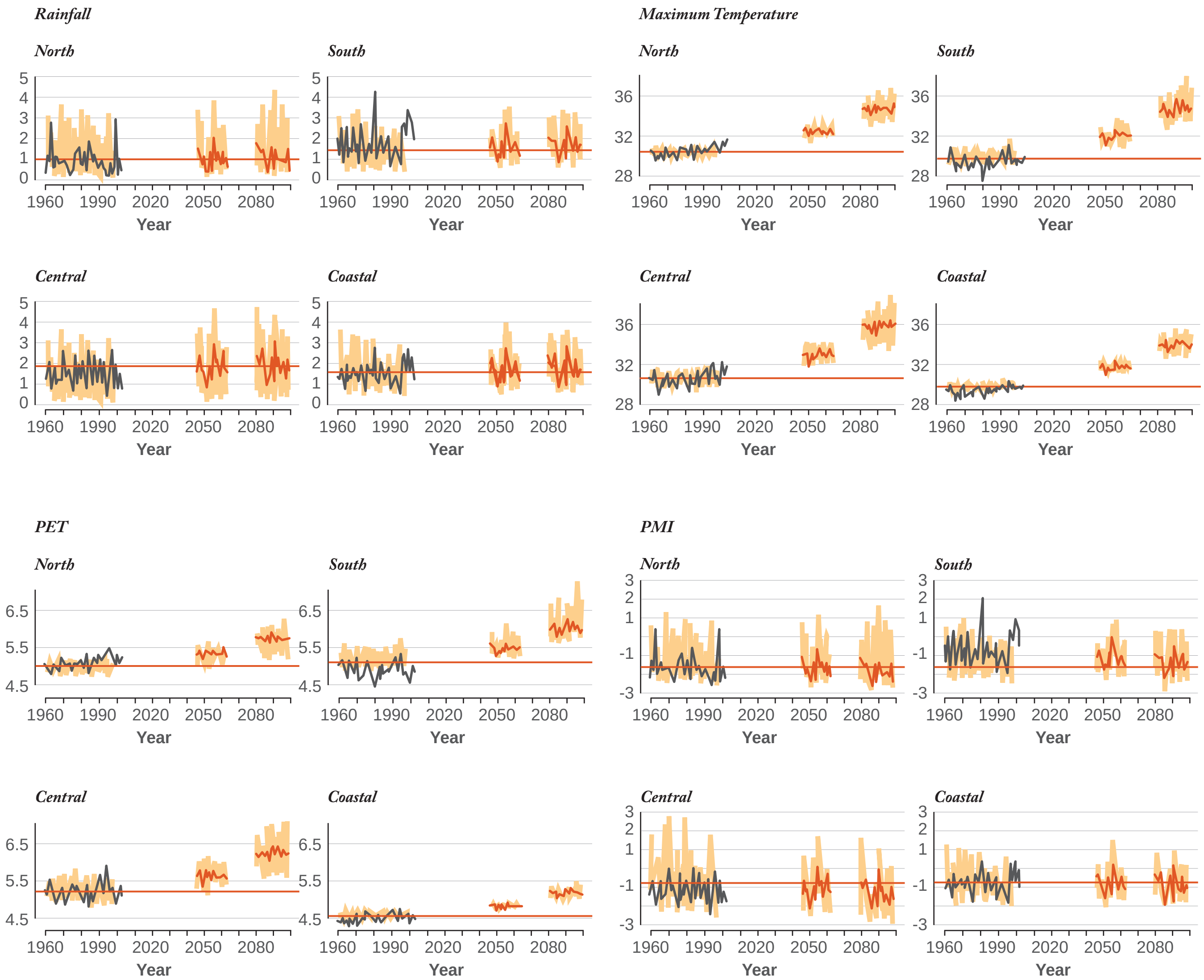
Downscaled seasonal changes in future rainfall (mm day-1) for each of the 7 GCMs

Annex IV: Changes in minimum temperature



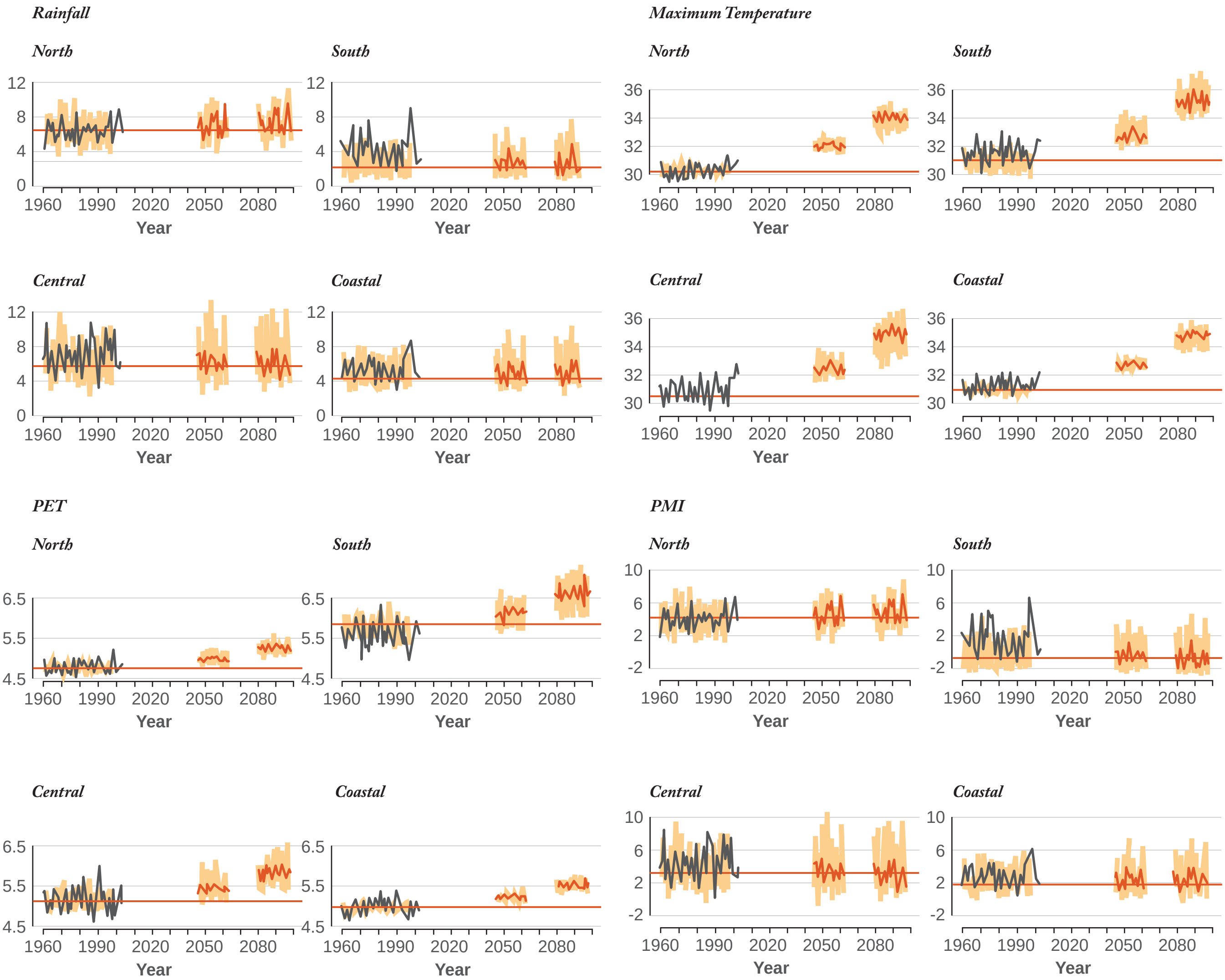
Median changes in future minumum temperatures from 7 GCMs (2046-2065 period). “+”/”-“ indicates whether seasonal variability is expected to increase/decrease in the future.

Annex V: Regional changes in rainfall, temperature and PET per season



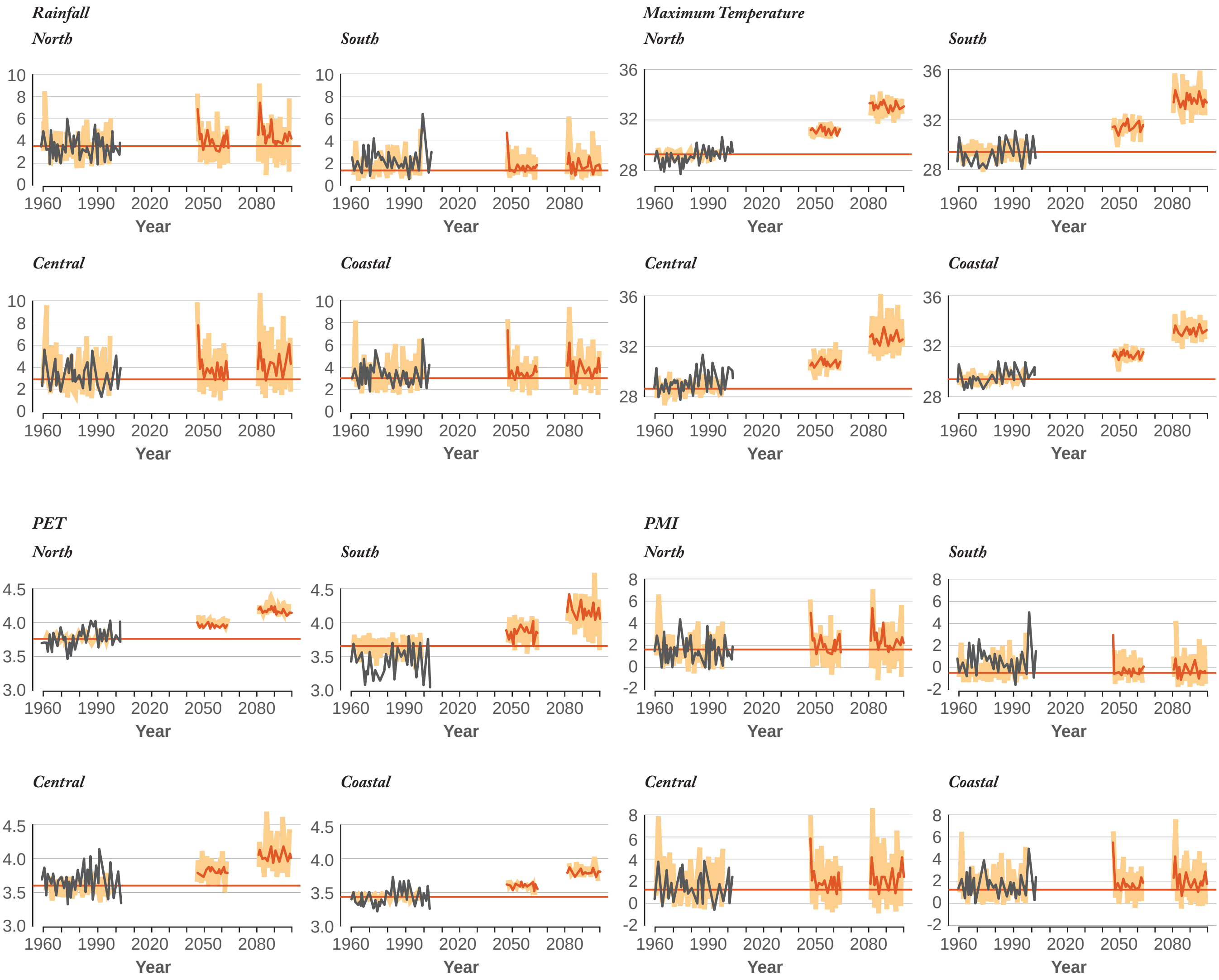
Interannual variability for the SON season for each of the 4 regions: a) Rainfall (mm day-1); b) Maximum temperature; c) PET (mm day-1) and d) Rainfall – (0.5*PET) (PMI) (mm day-1). Orange shading is the GCM intermodel range, dark orange is the median of the models and the black line is the station observations. Horizontal orange line is the mean of the 7 GCM control climate simulations.

Annex V: regional changes in rainfall, temperature and PET per season (continued)



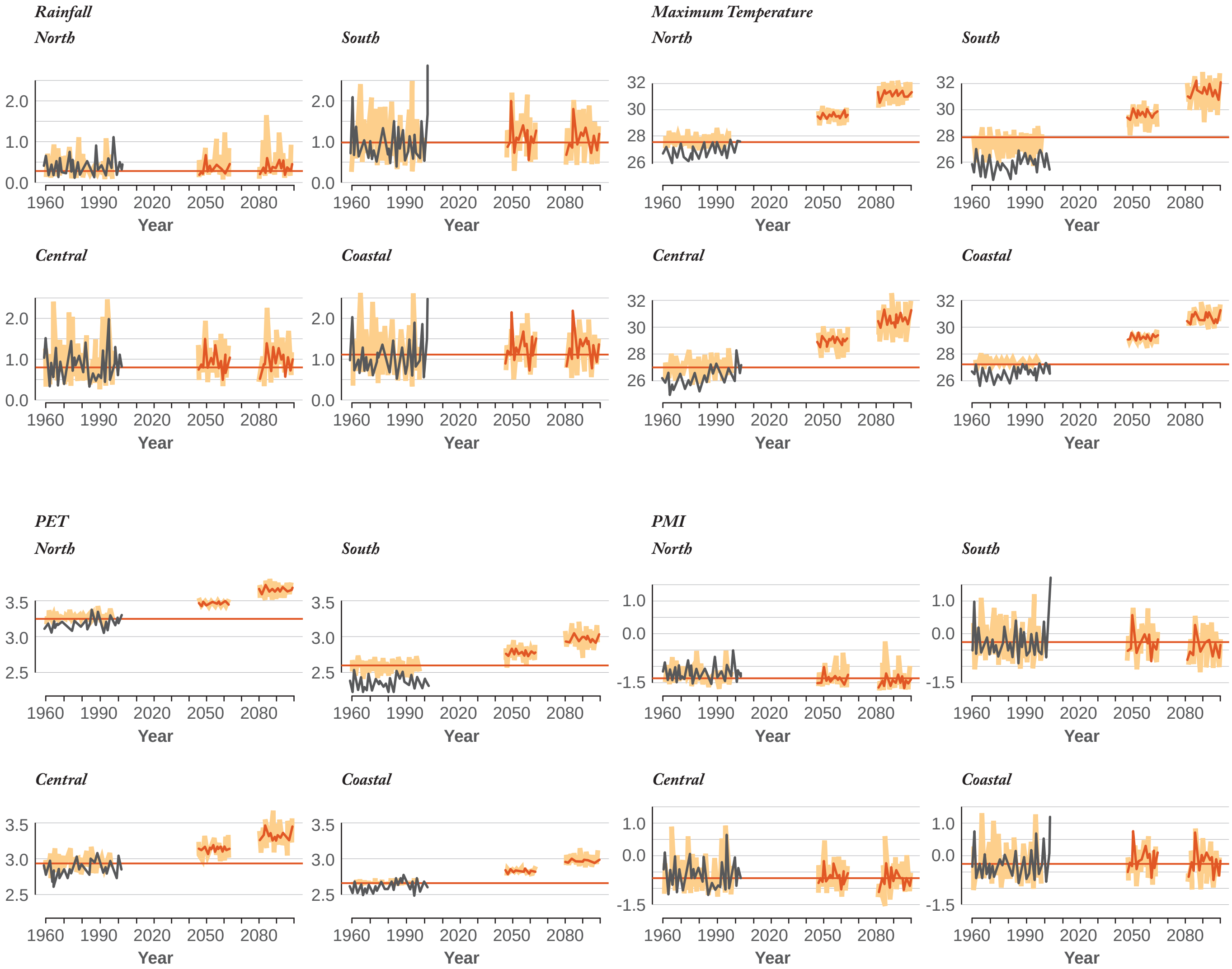
Interannual variability for the DJF season for each of the 4 regions: a) Rainfall (mm day-1); b) Maximum temperature; c) PET (mm day-1) and d) Rainfall – (0.5*PET) (PMI) (mm day-1). Orange shading is the GCM intermodel range, dark orange is the median of the models and the black line is the station observations. Horizontal orange line is the mean of the 7 GCM control climate simulations.

Annex V: regional changes in rainfall, temperature and PET per season (continued)



Interannual variability for the MAM season for each of the 4 regions: a) Rainfall (mm day-1); b) Maximum temperature; c) PET (mm day-1) and d) Rainfall – (0.5*PET) (PMI) (mm day-1). Orange shading is the GCM intermodel range, dark orange is the median of the models and the black line is the station observations. Horizontal orange line is the mean of the 7 GCM control climate simulations.

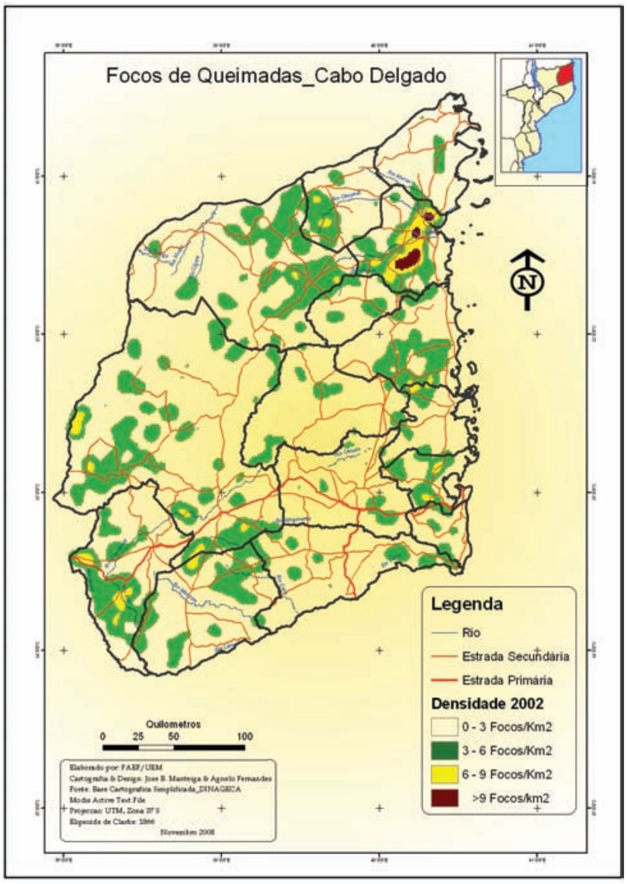
Annex V: regional changes in rainfall, temperature and PET per season (continued)

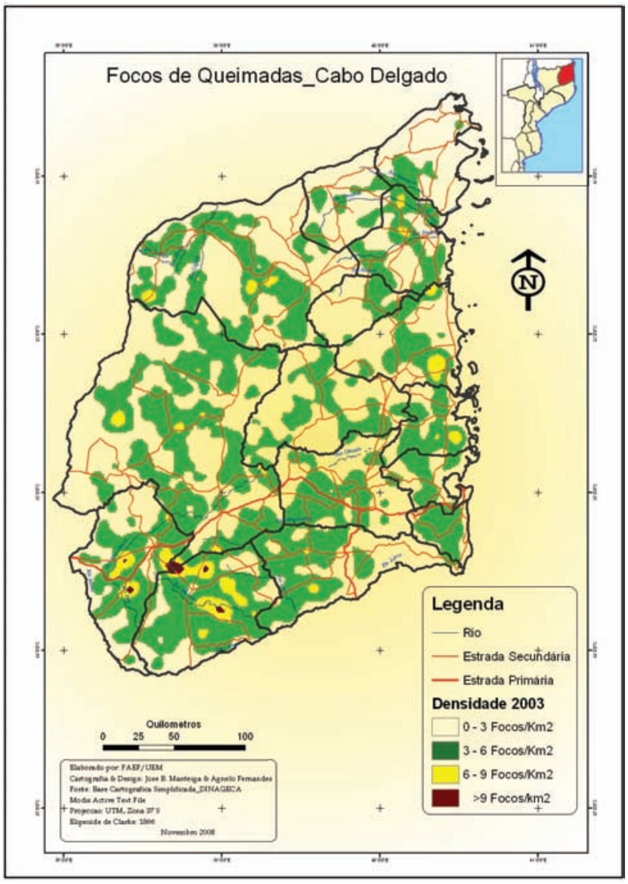


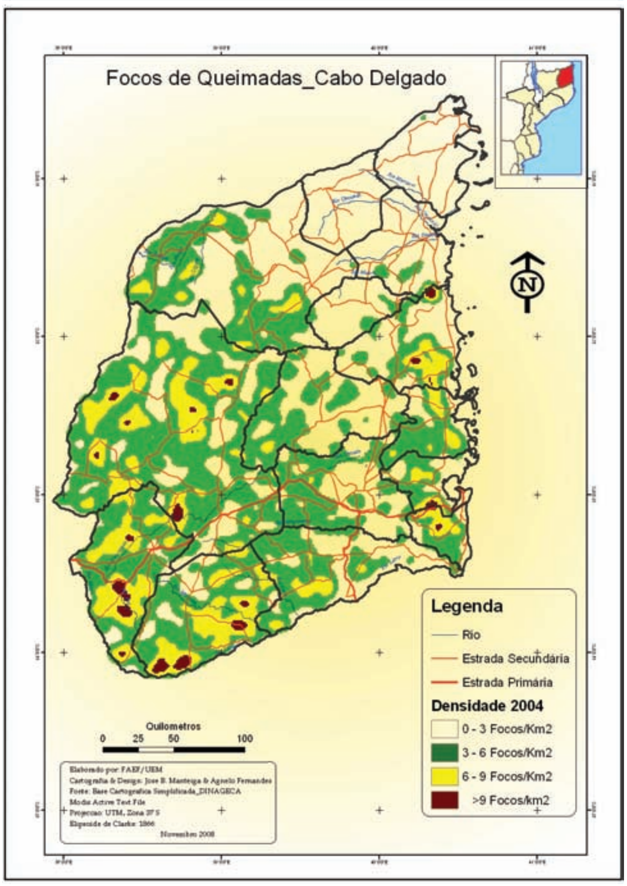
Interannual variability for the JJA season for each of the 4 regions: a) Rainfall (mm day-1); b) Maximum temperature; c) PET (mm day-1) and d) Rainfall – (0.5*PET) (PMI) (mm day-1). Orange shading is the GCM intermodel range, dark orange is the median of the models and the black line is the station observations. Horizontal orange line is the mean of the 7 GCM control climate simulations.

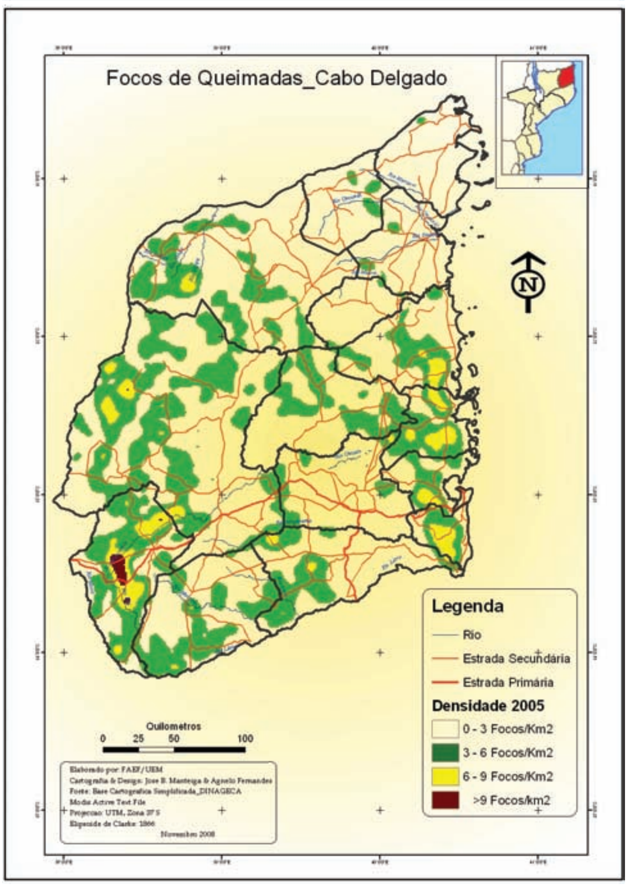
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

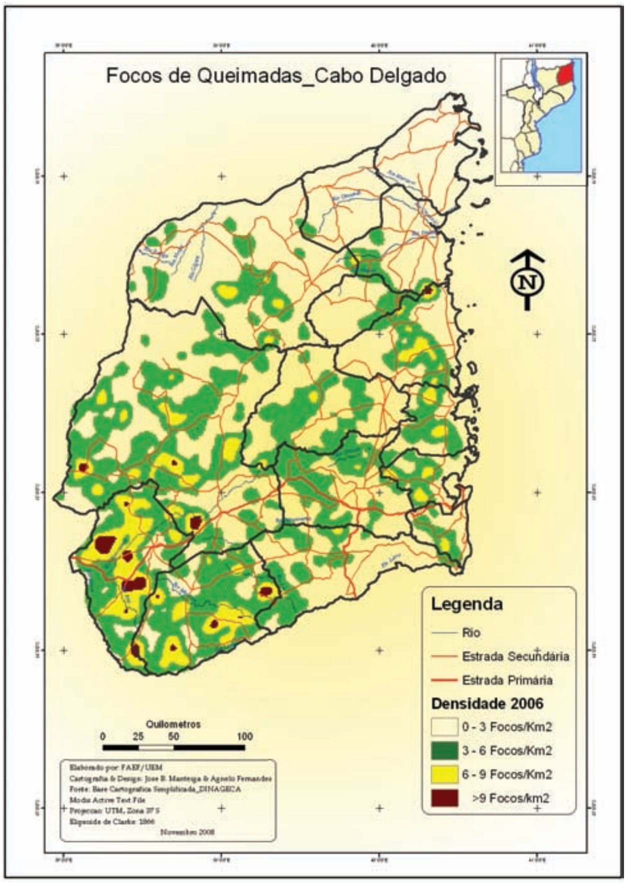
Cabo Delgado







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Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
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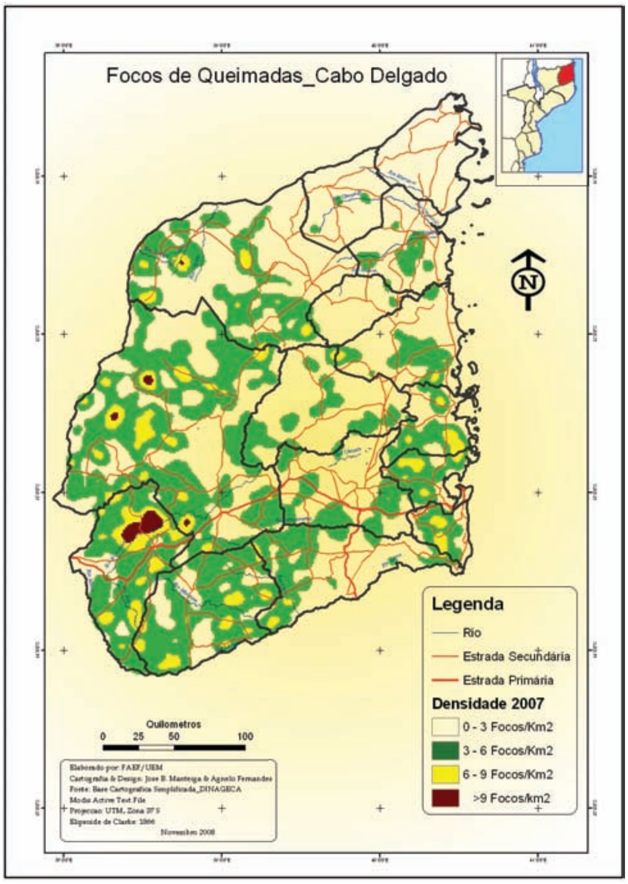
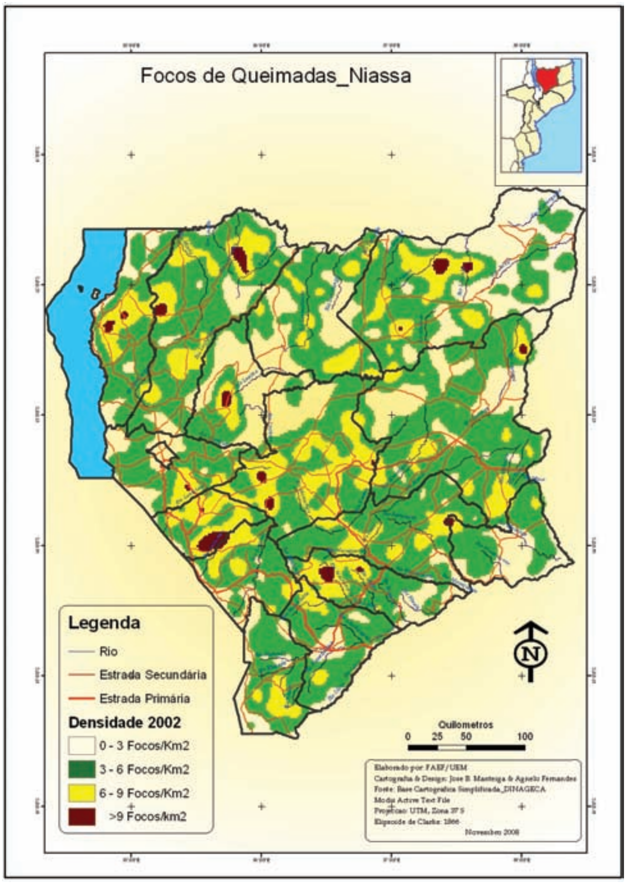
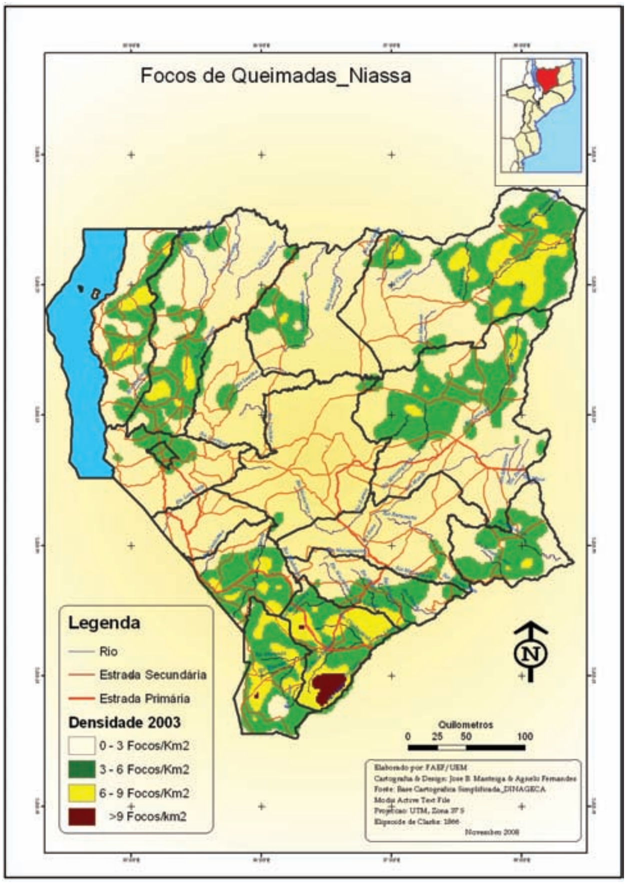
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

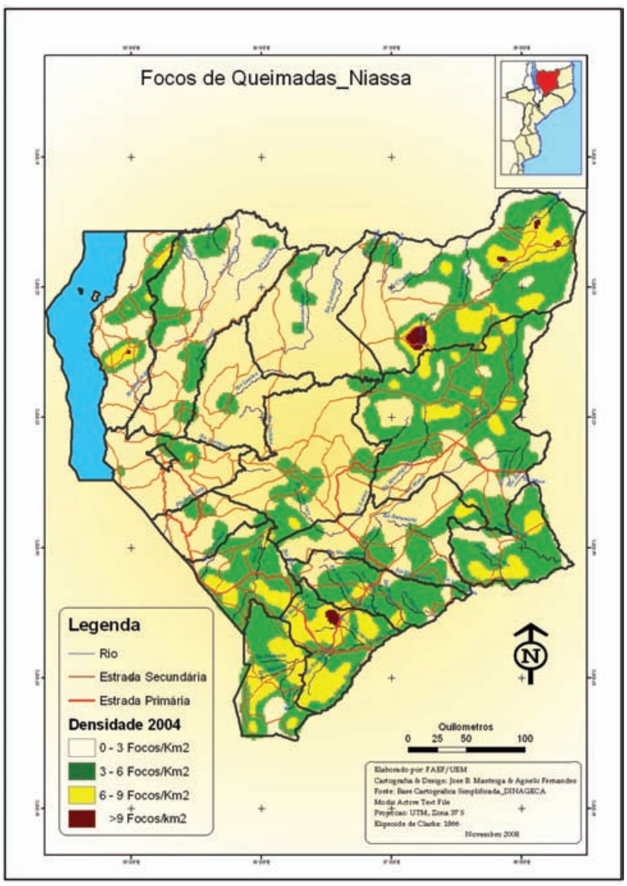

Focos de Queimadas_Cabo Delgado
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

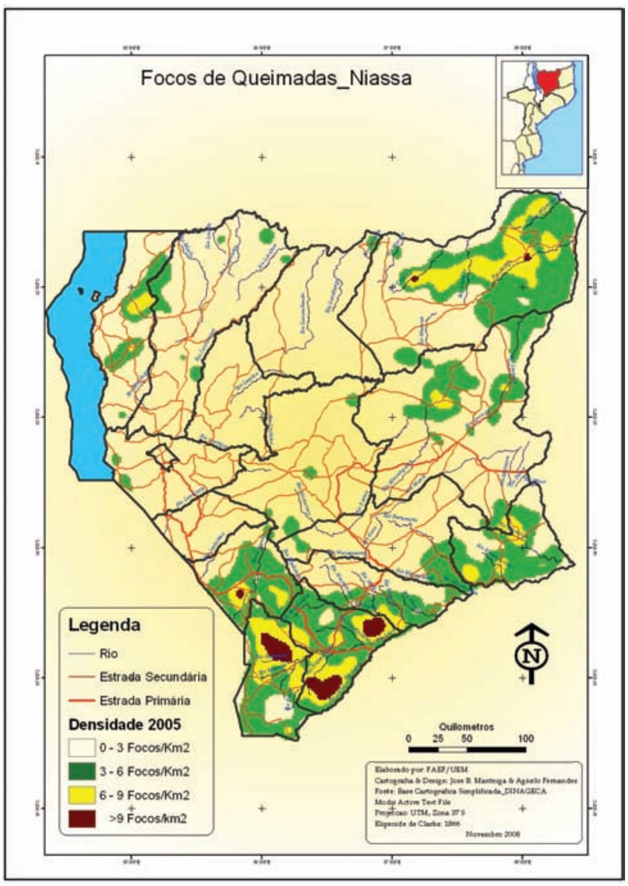
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

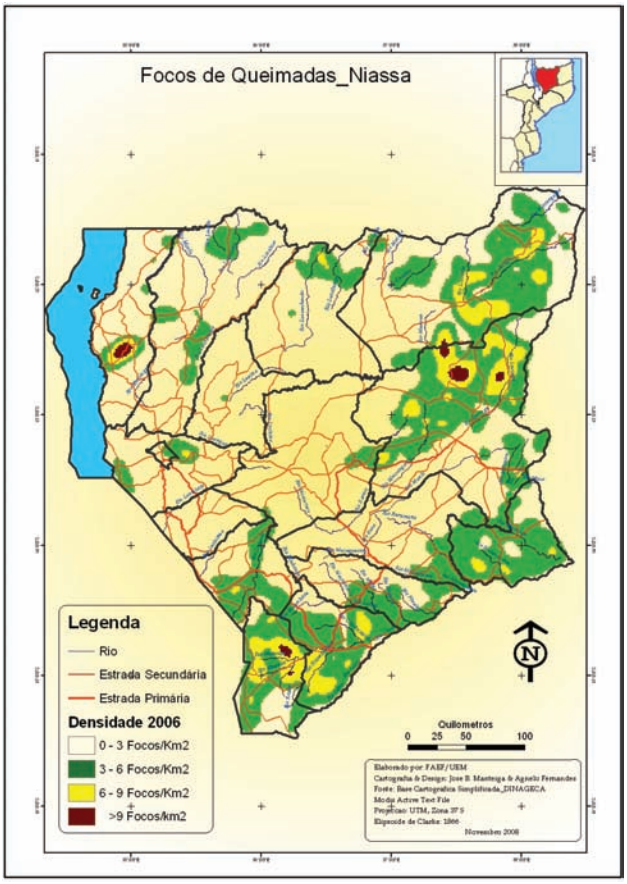
Niassa










Focos de Queimadas_Niassa
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
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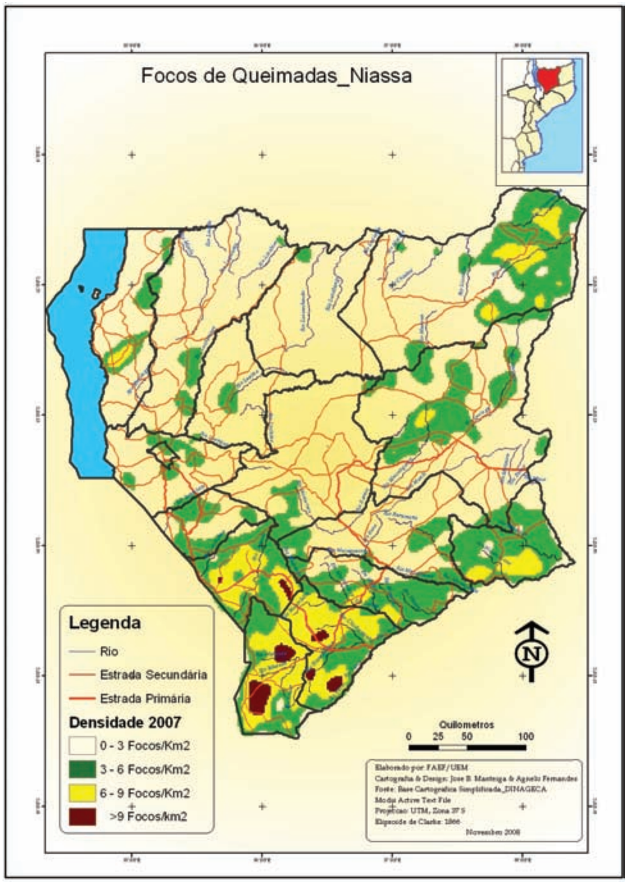
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100
Elaborado por FAEF/UEM
N


Focos de Queimadas_Niassa
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
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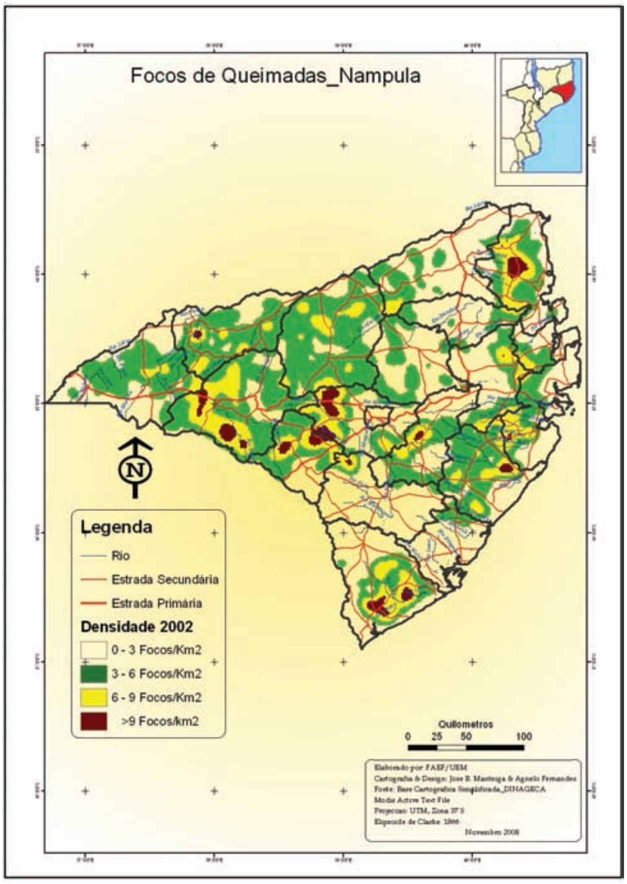
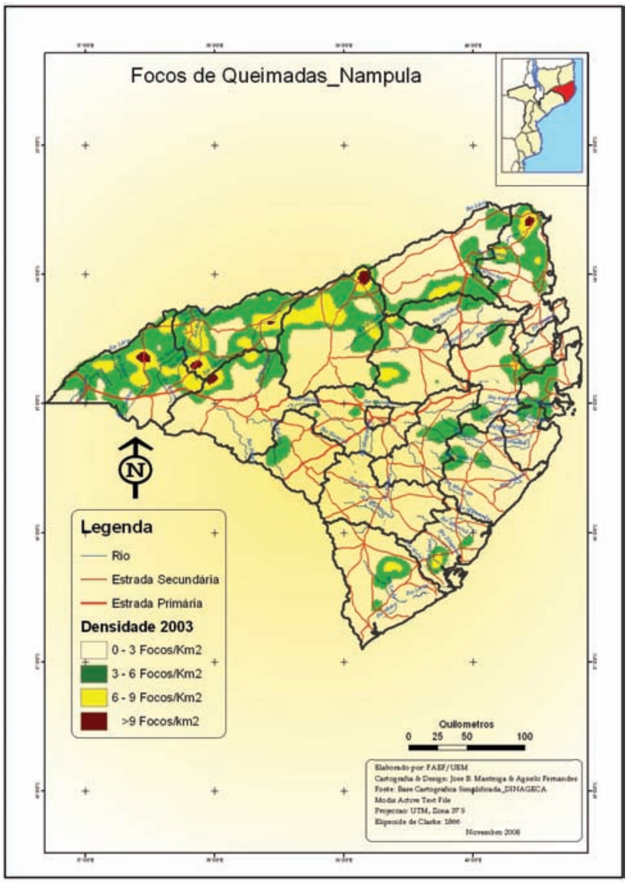
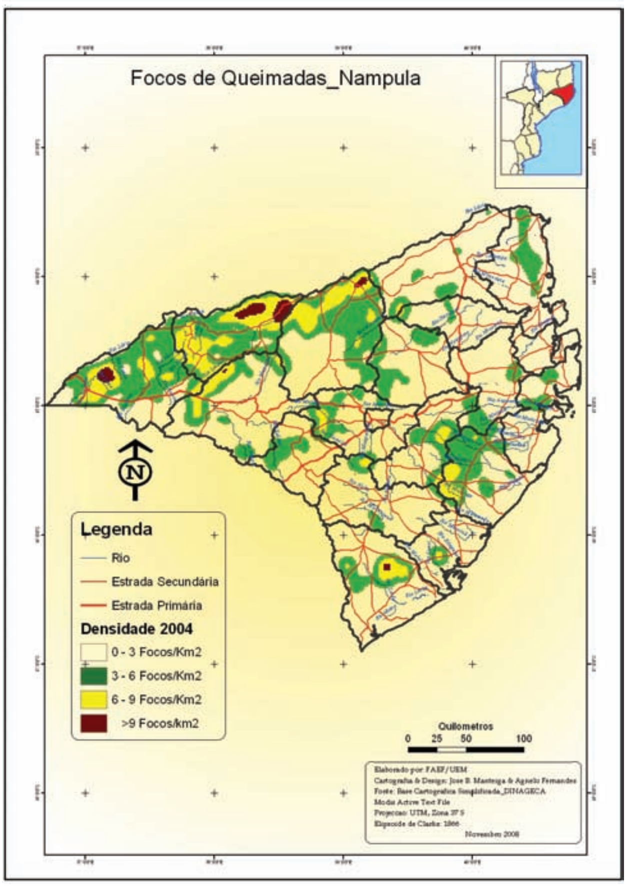
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100
Elaborado por FAEF/UEM
N

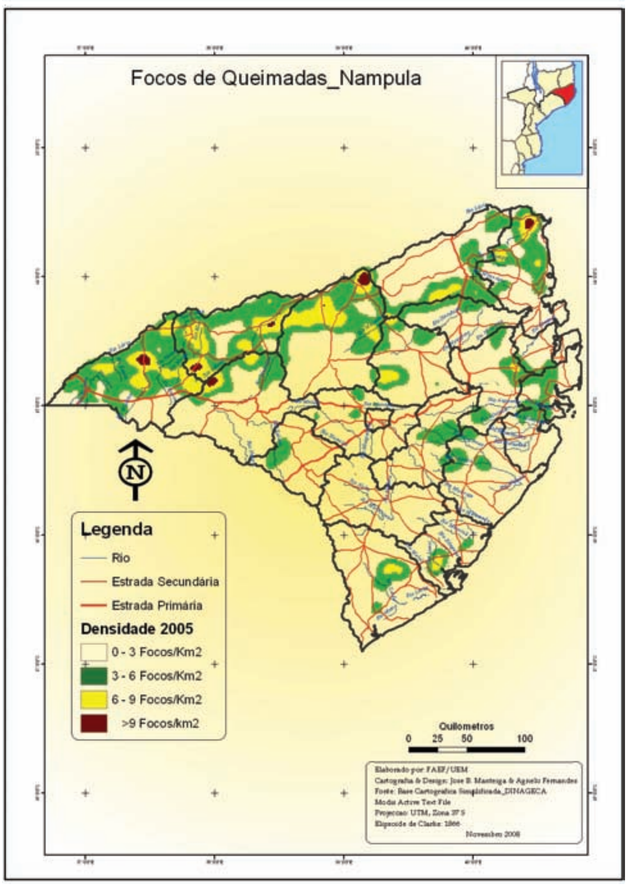
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

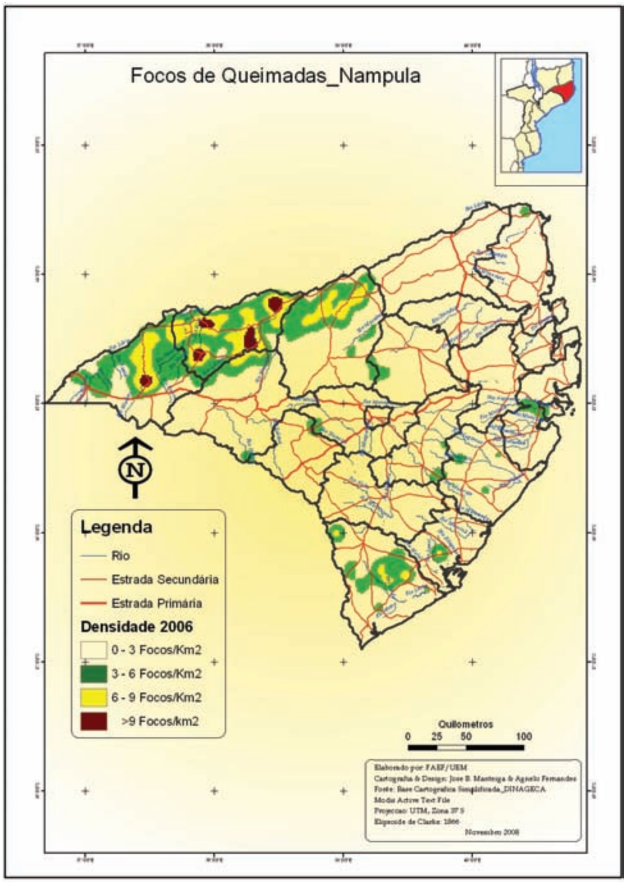
Nampula







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Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
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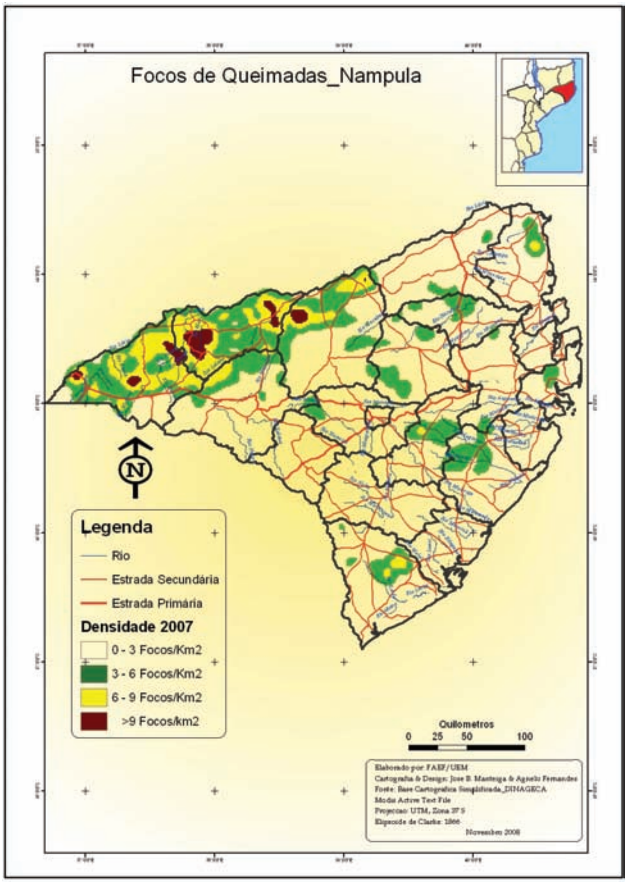
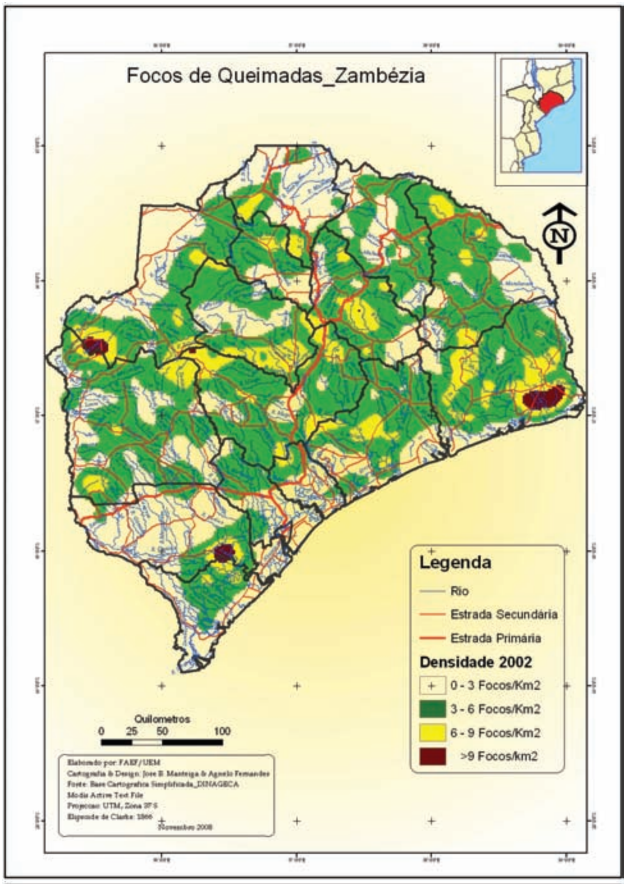
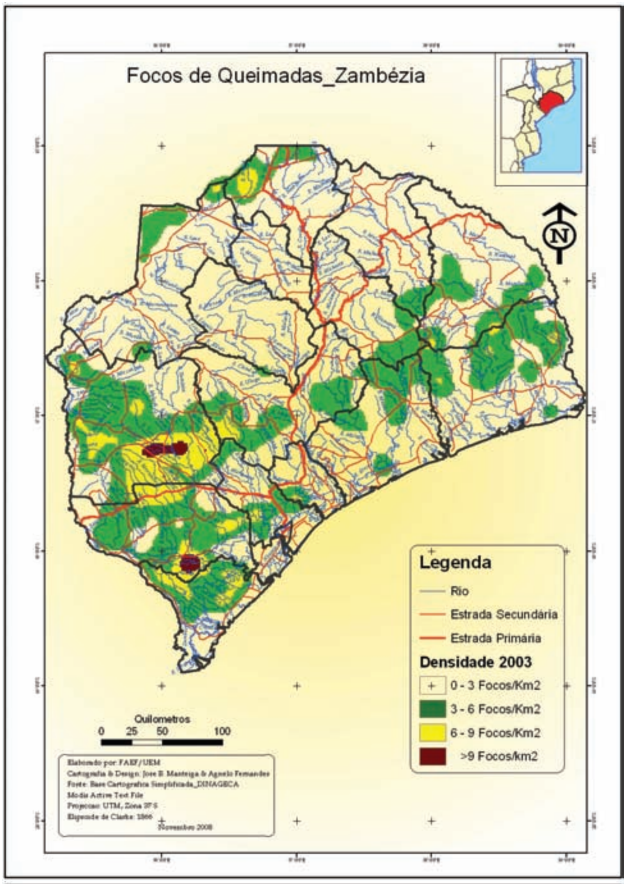
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

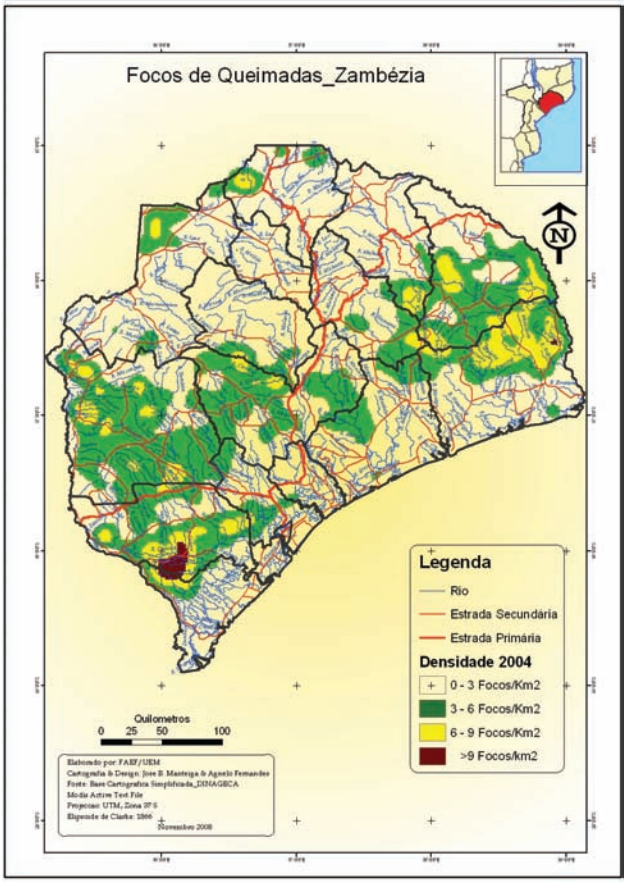

Focos de Queimadas_Nampula
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

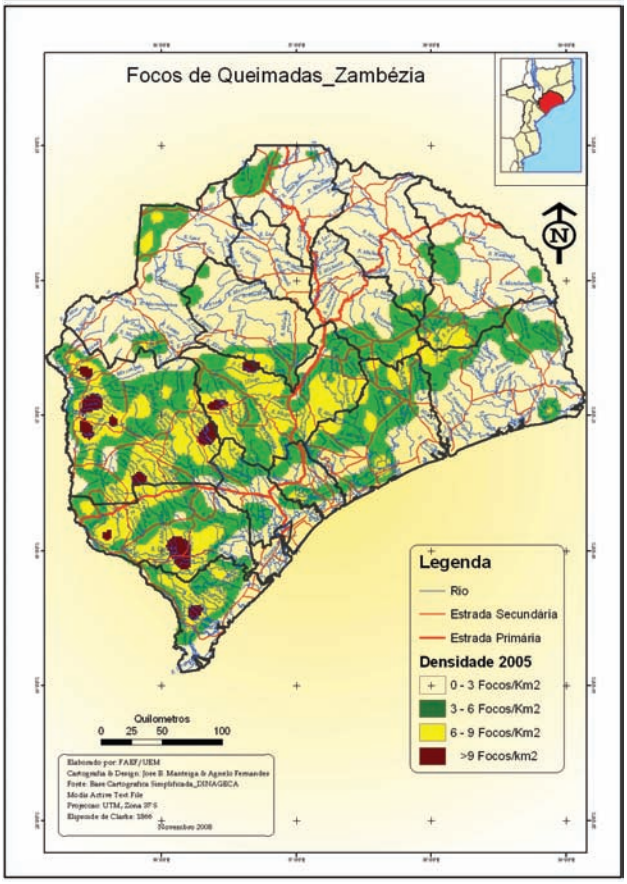
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

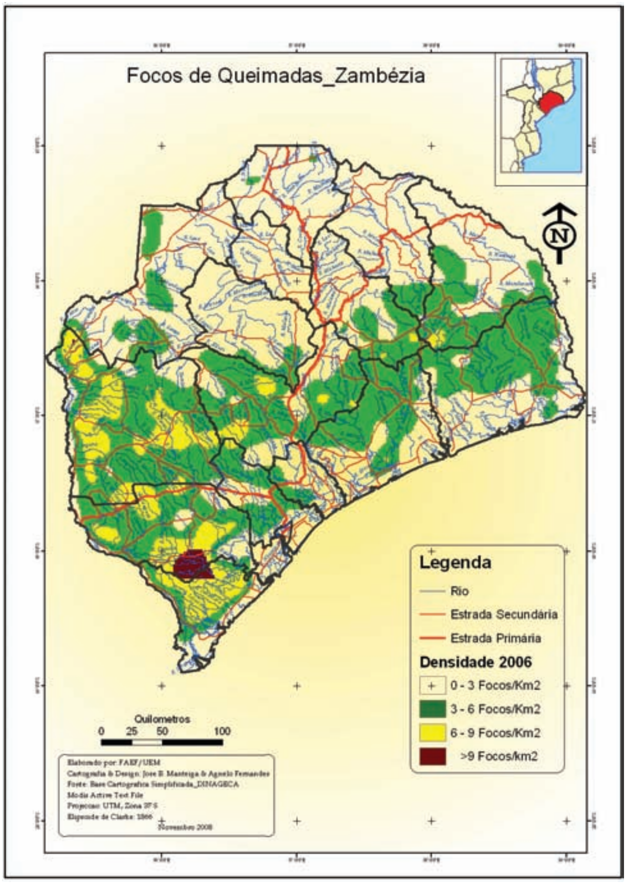
Zambezia







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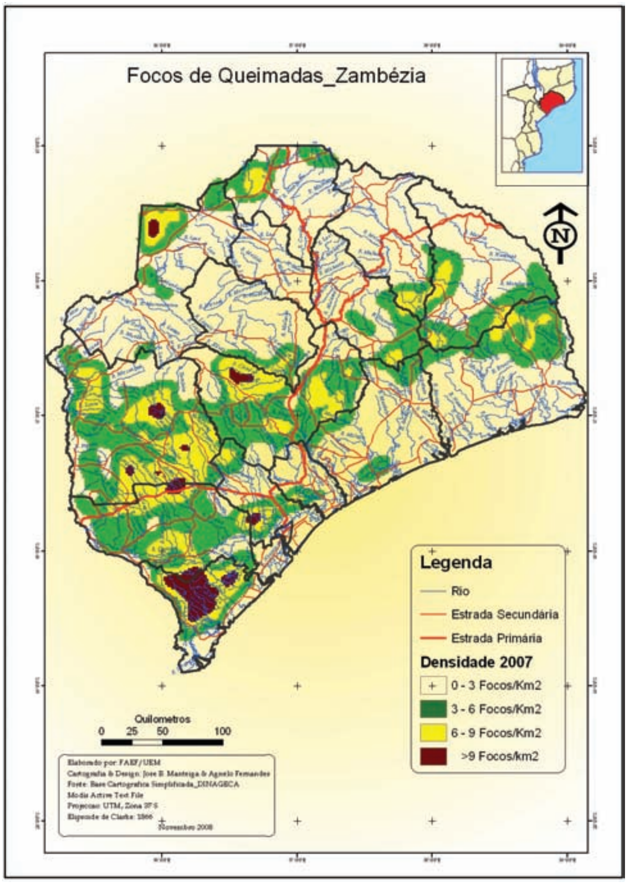
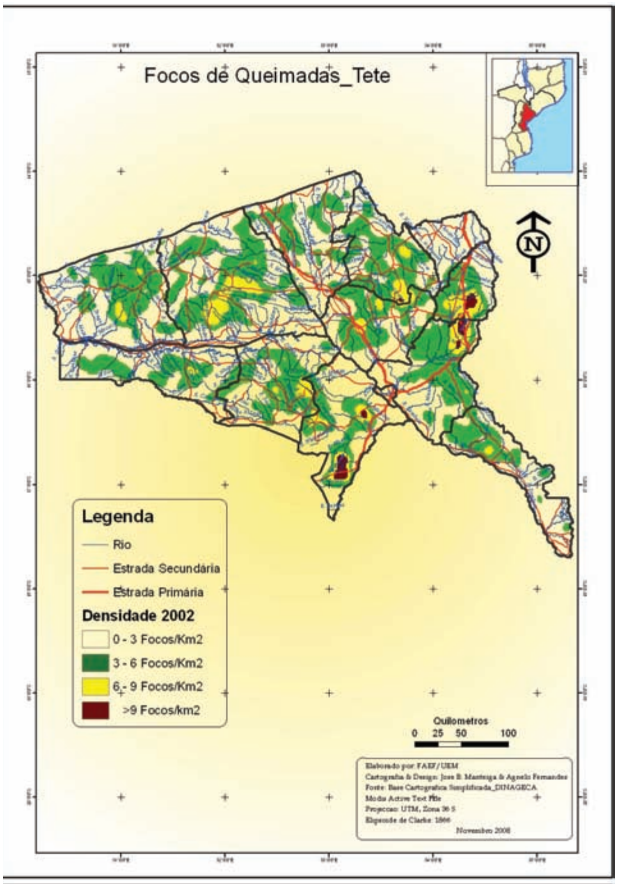
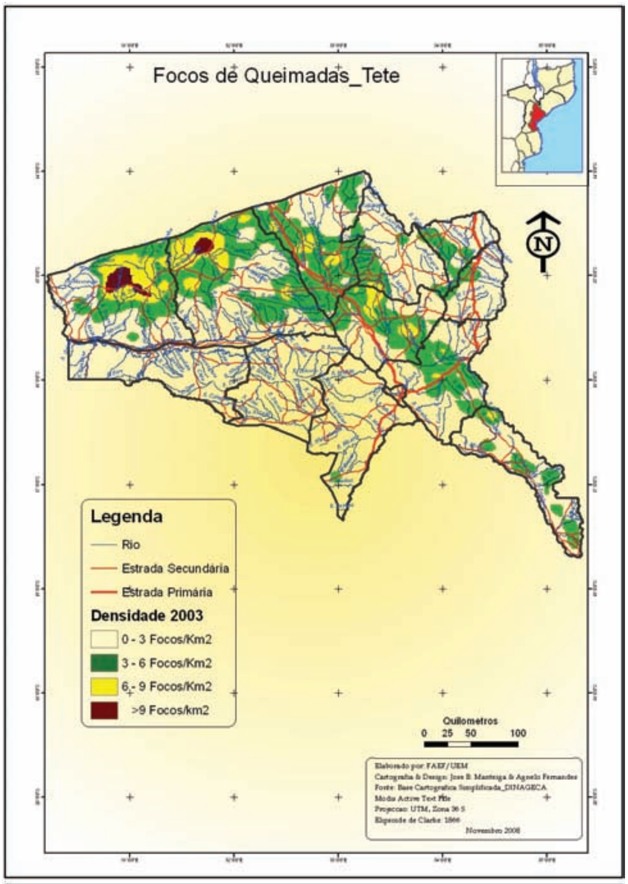
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

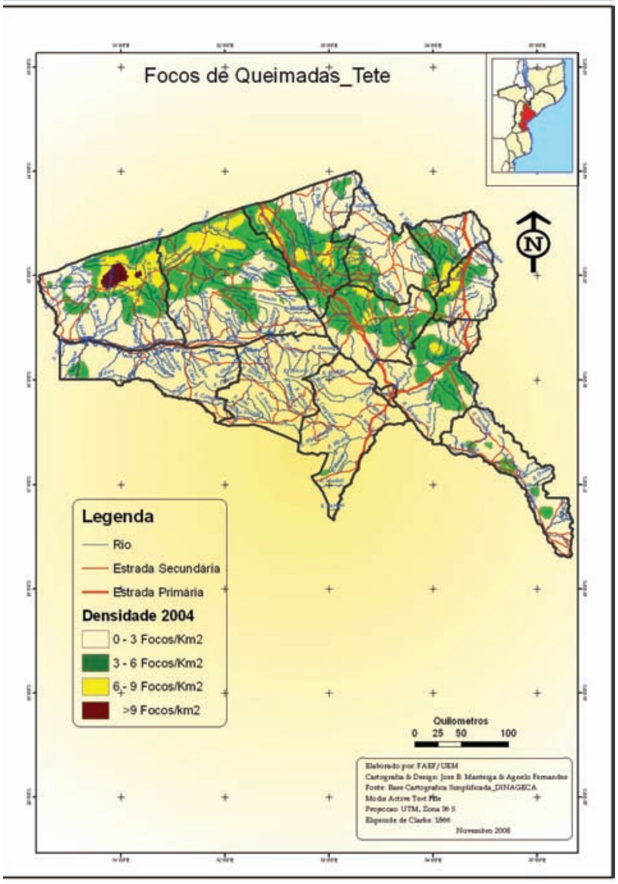

Focos de Queimadas_Zambézia
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100

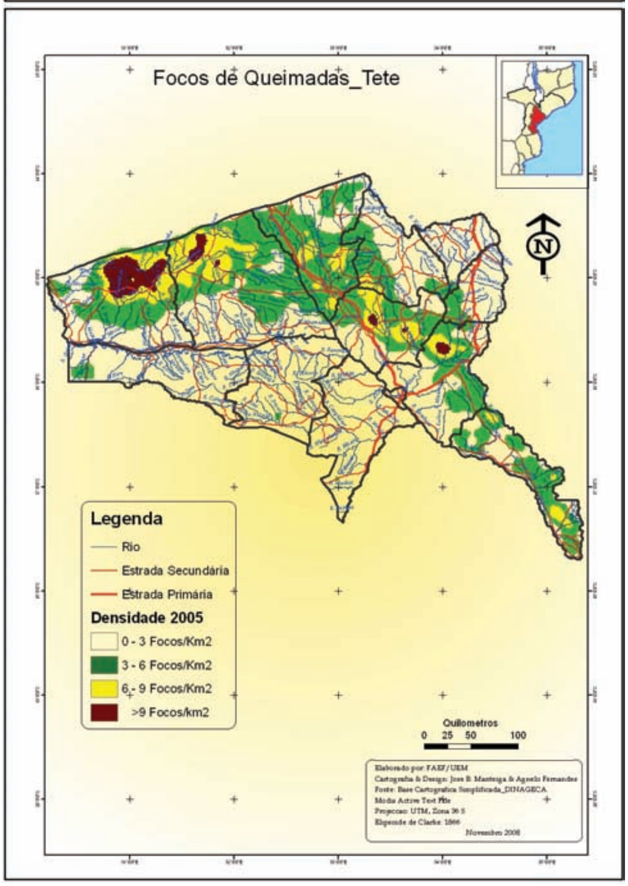
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

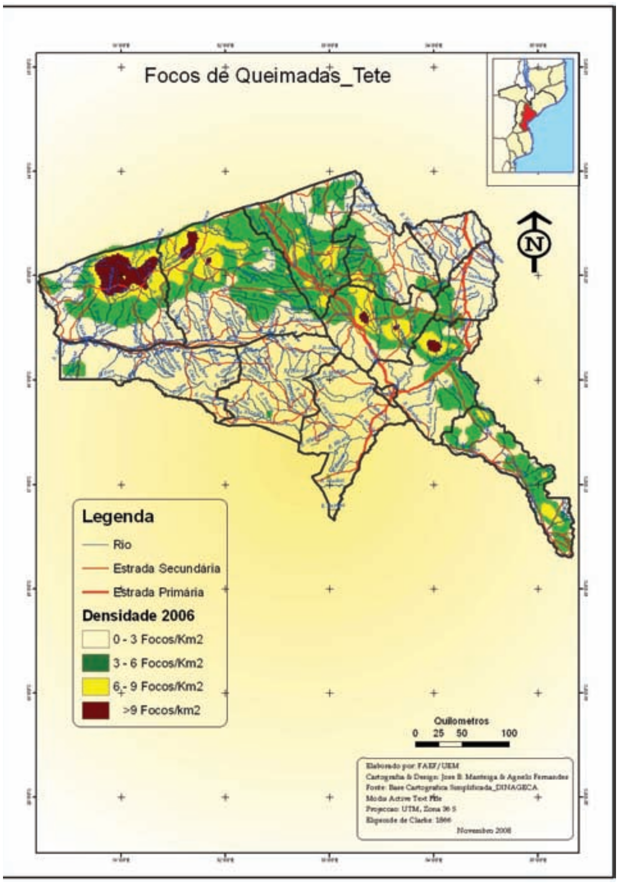
Tete







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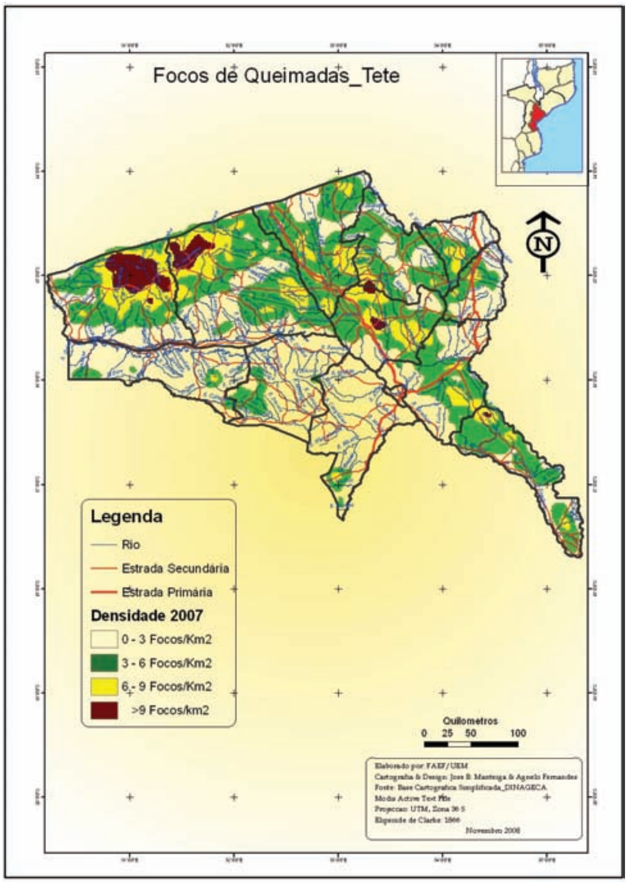
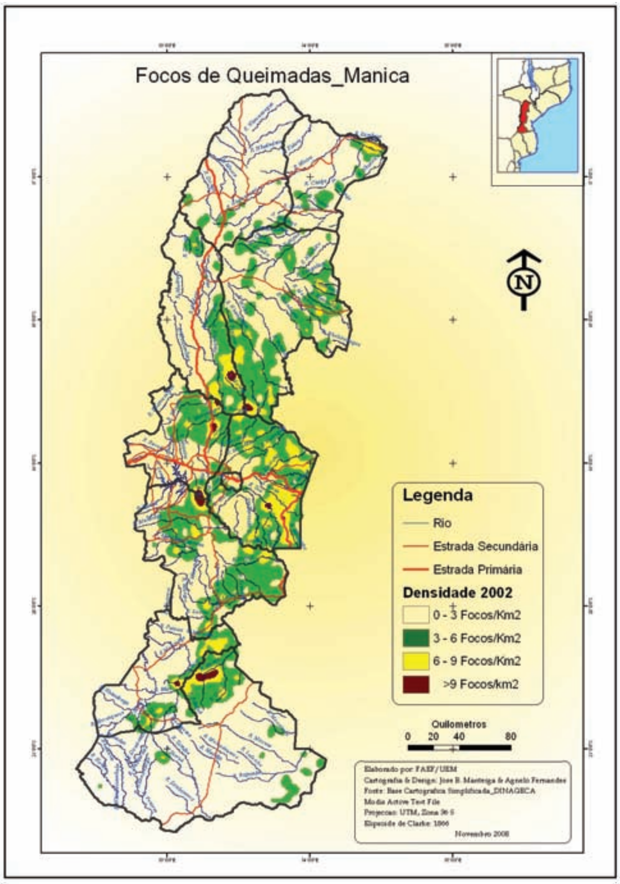
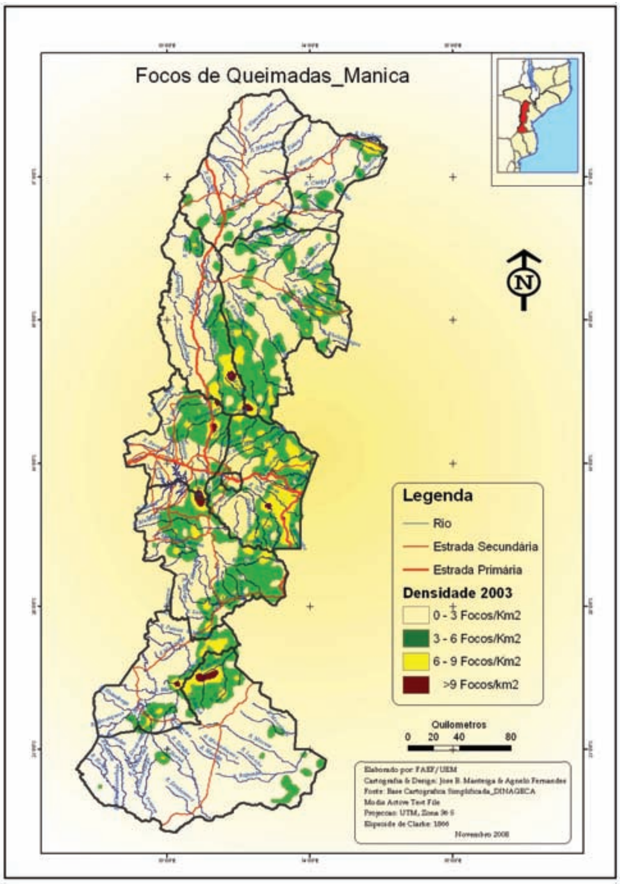
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100
Elaborado por: FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

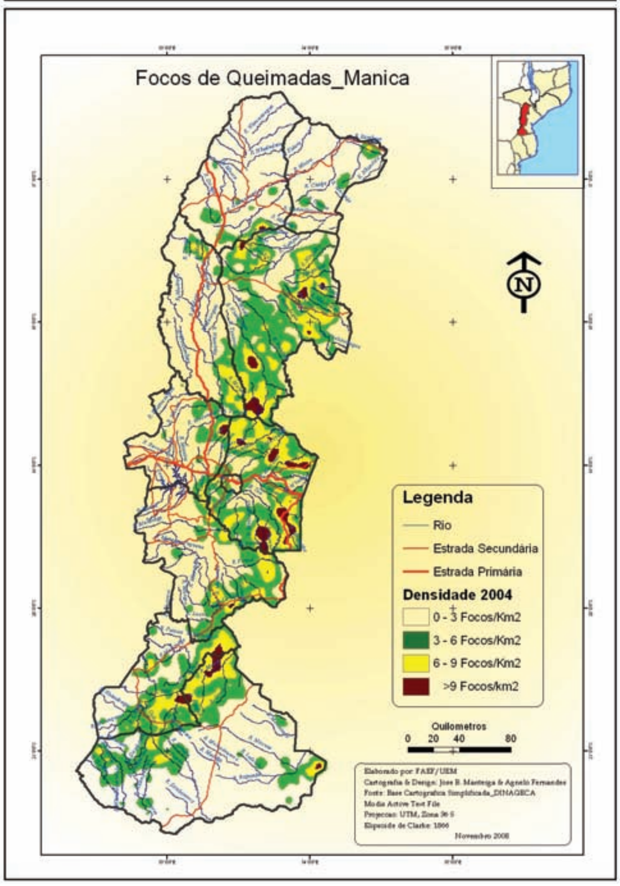

Focos de Queimadas_Tete
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 25 50 100
Elaborado por: FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

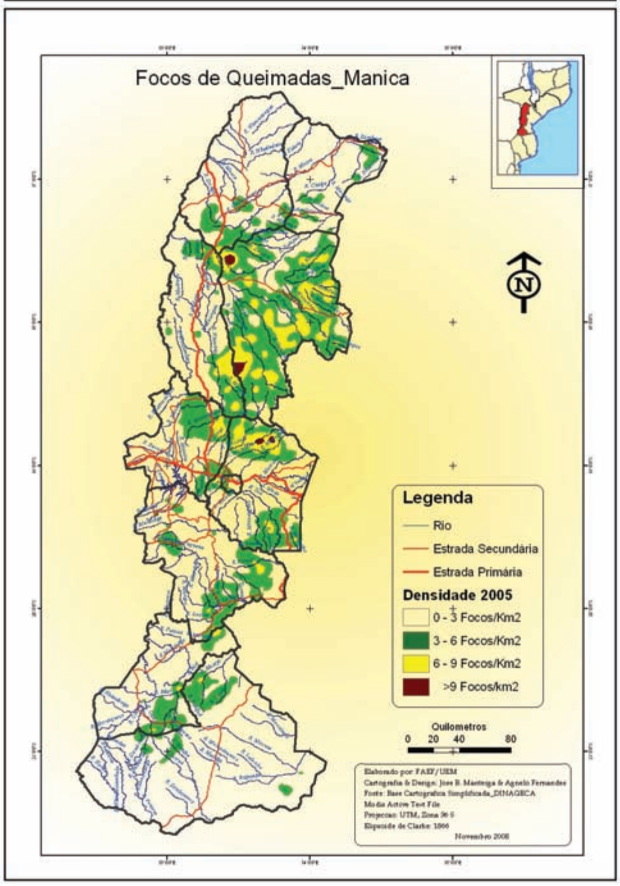
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

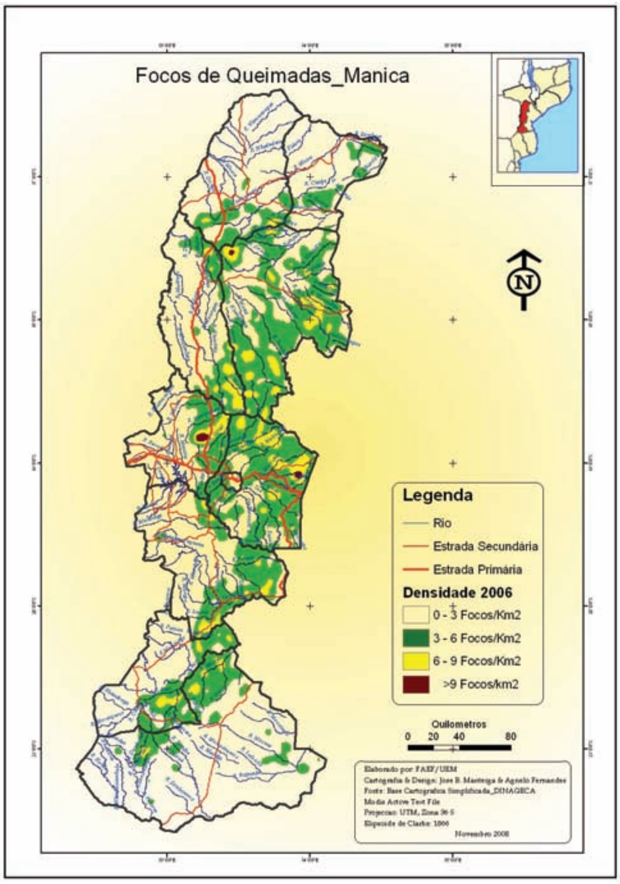
Manica







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Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
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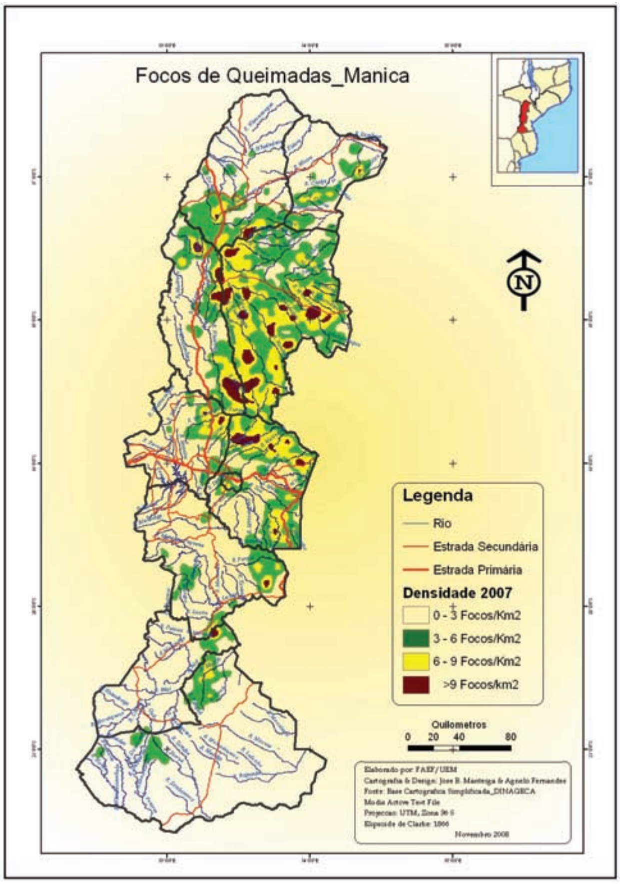
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80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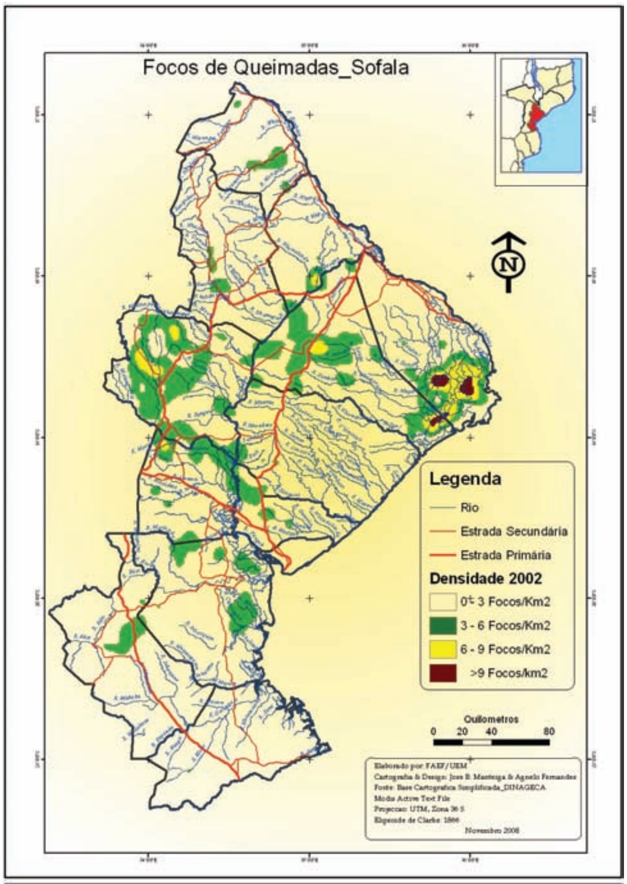
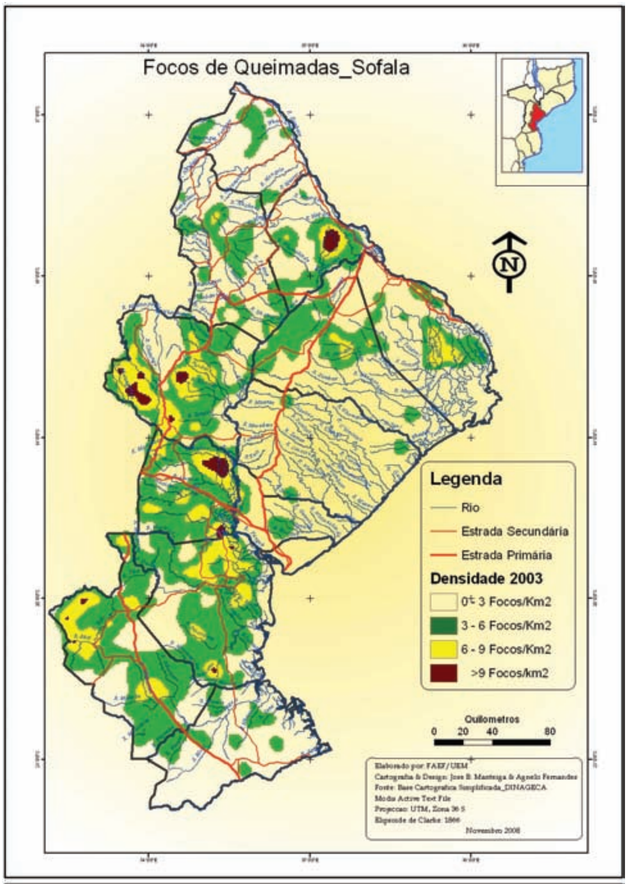
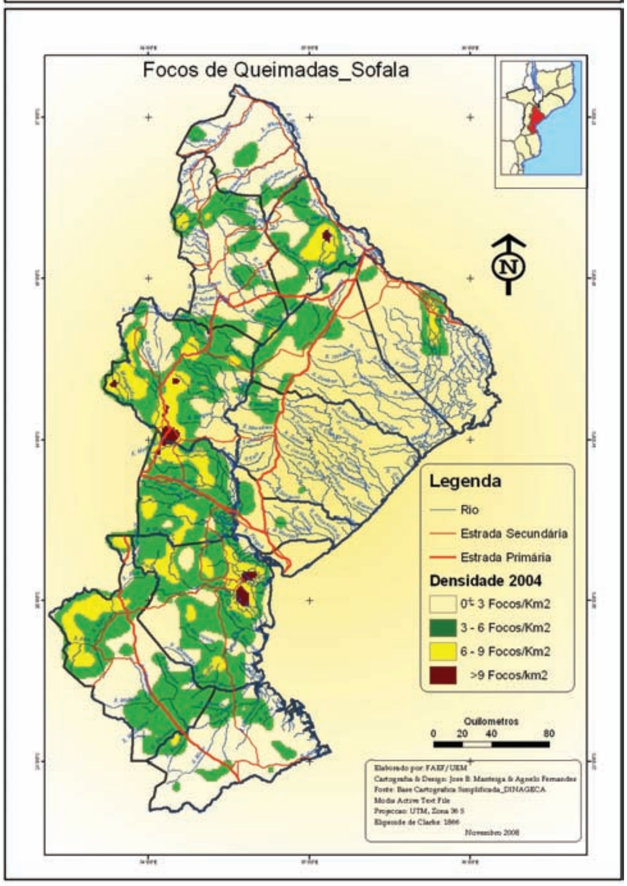
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80

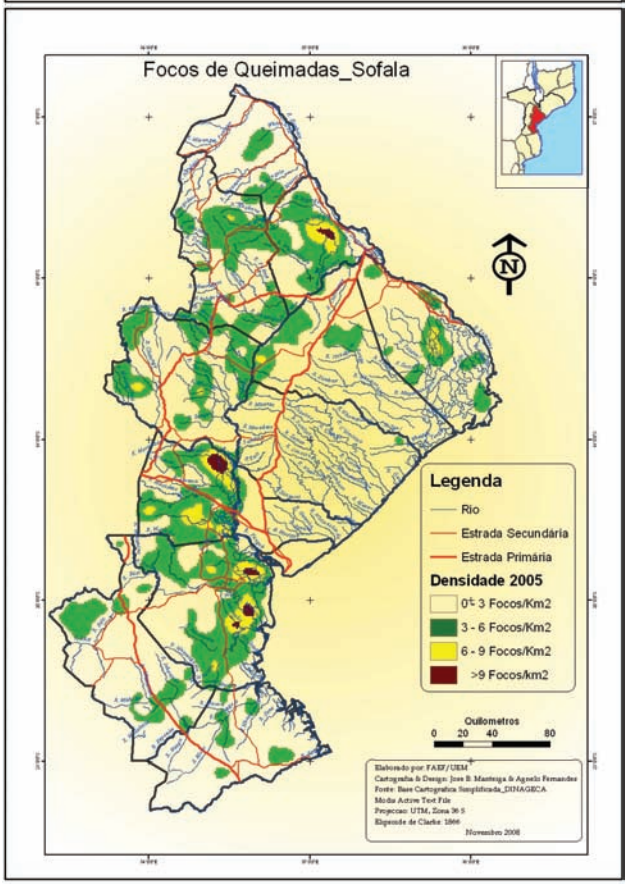
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

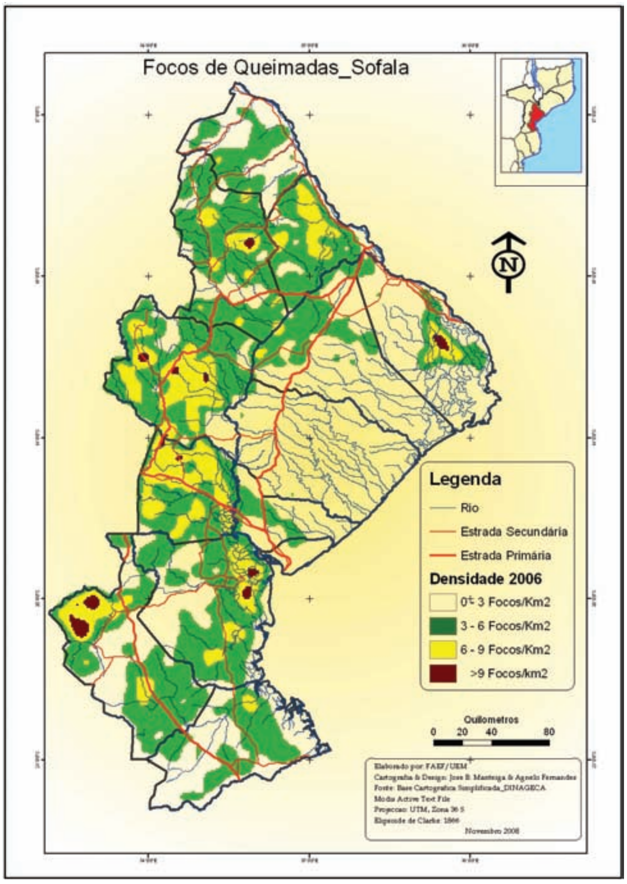
Sofala







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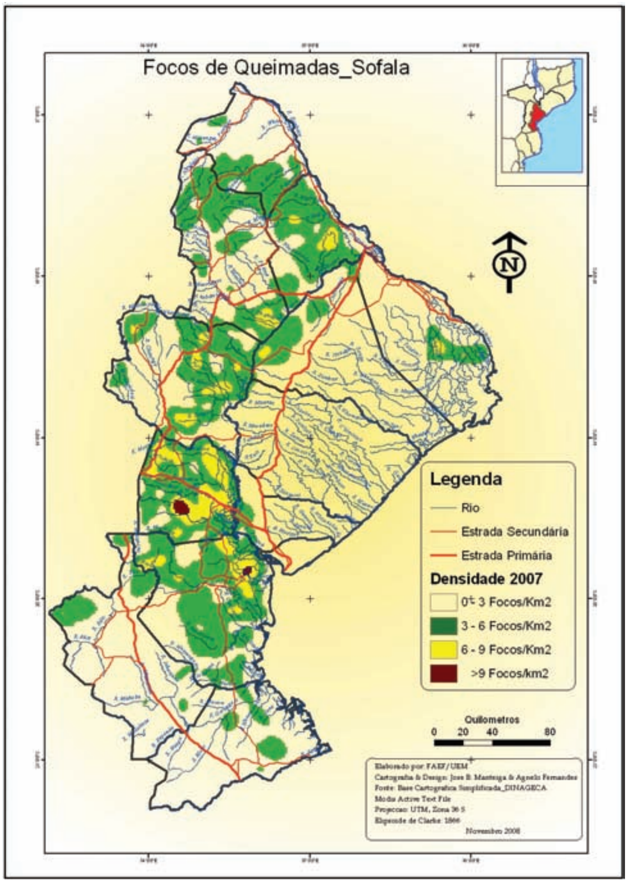
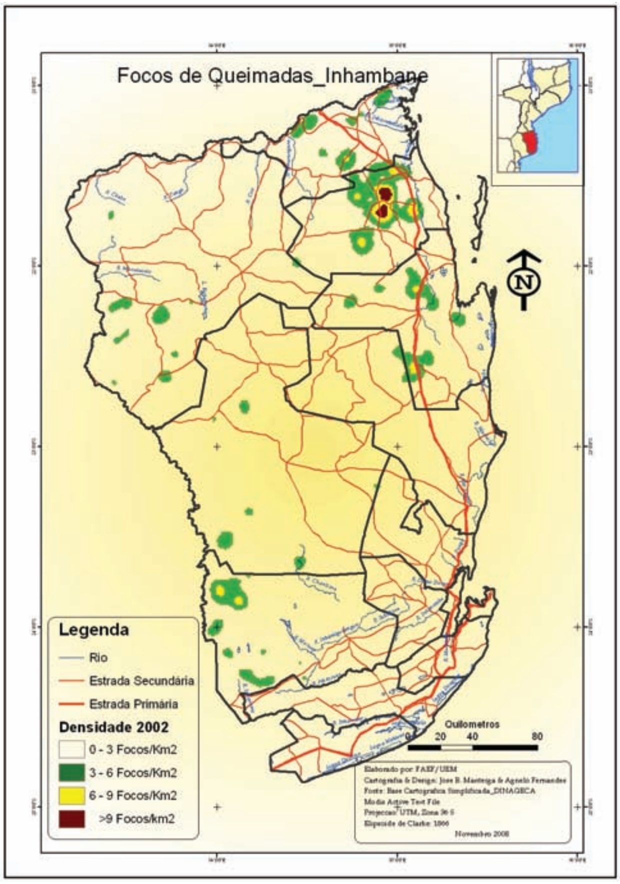
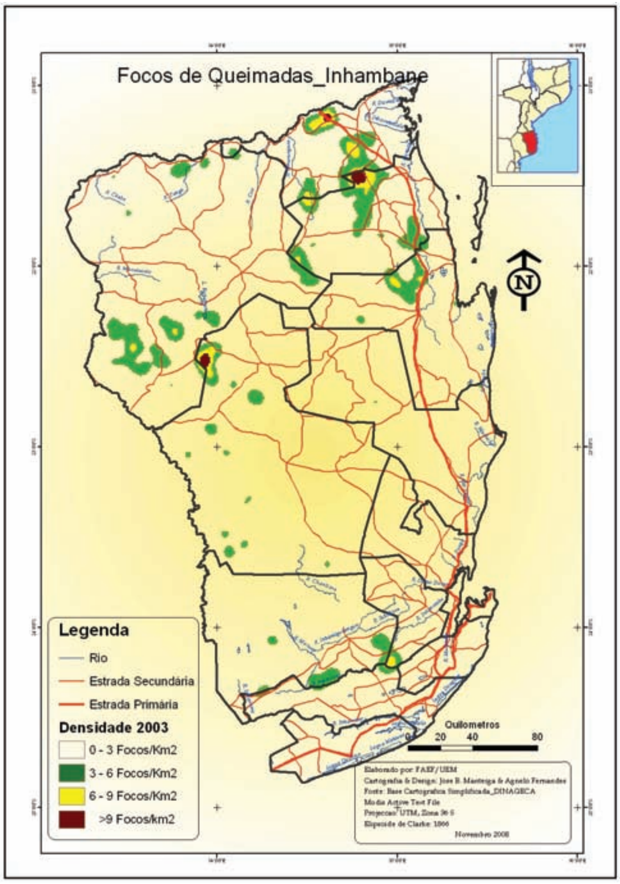
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

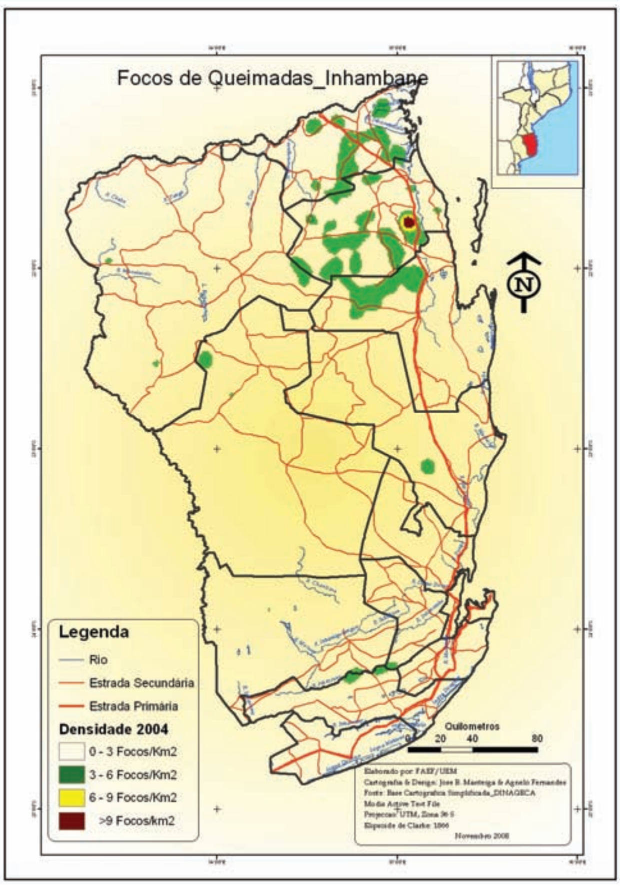

Focos de Queimadas_Sofala
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

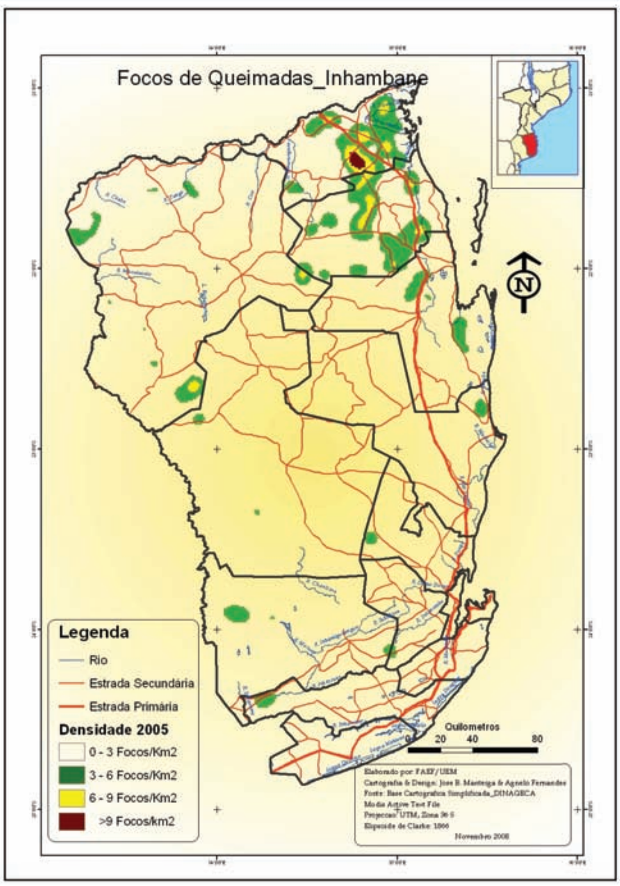
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

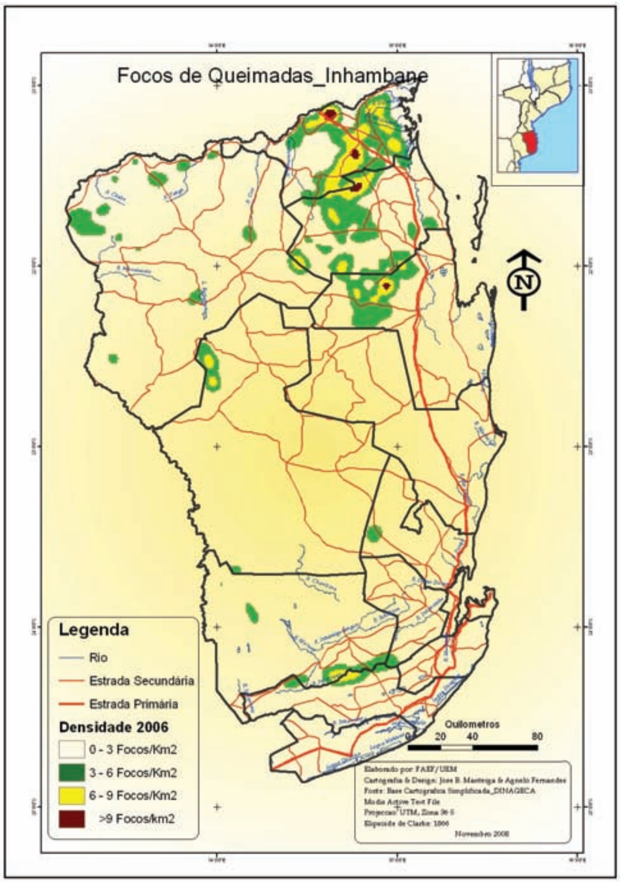
Inhambane







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Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
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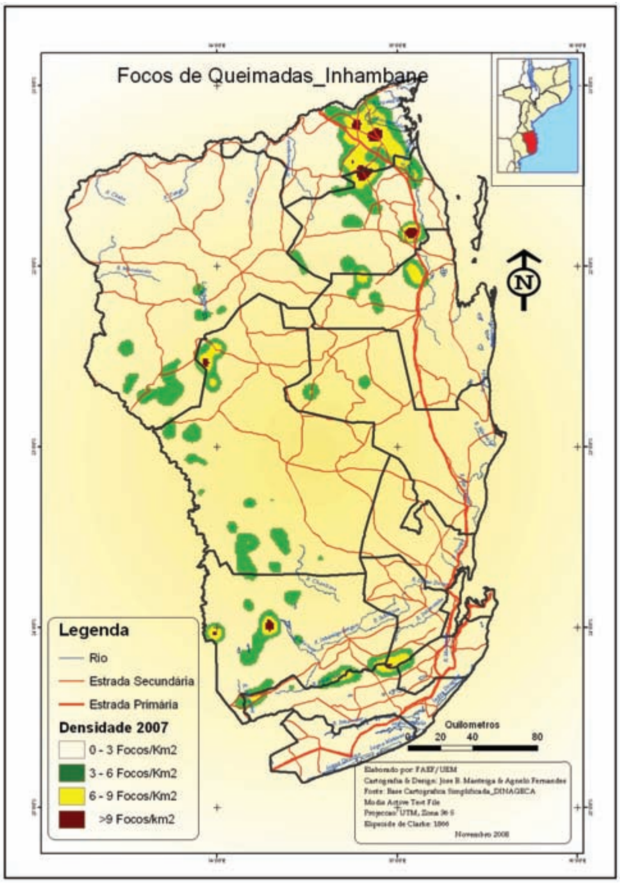
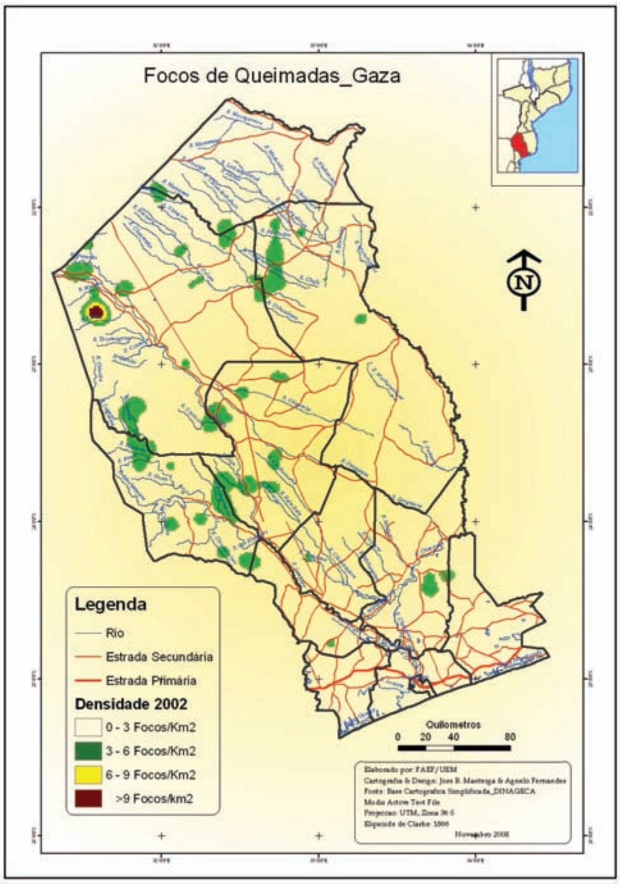
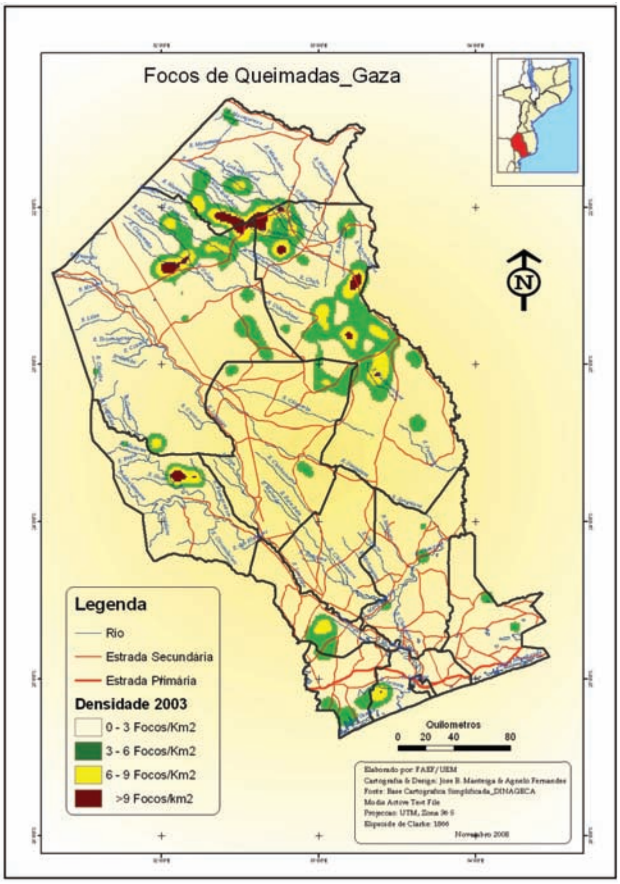
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80

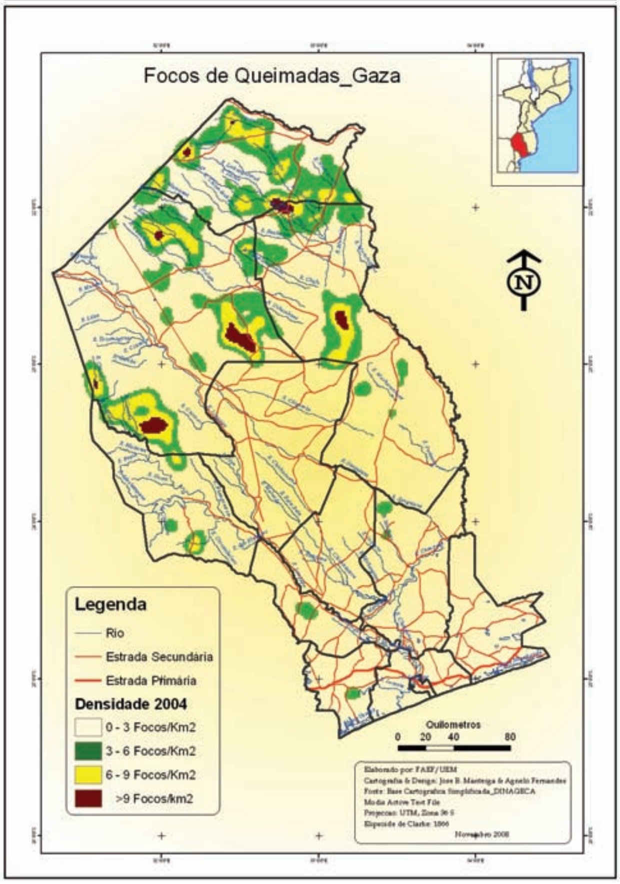

Focos de Queimadas_Inhambane
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80

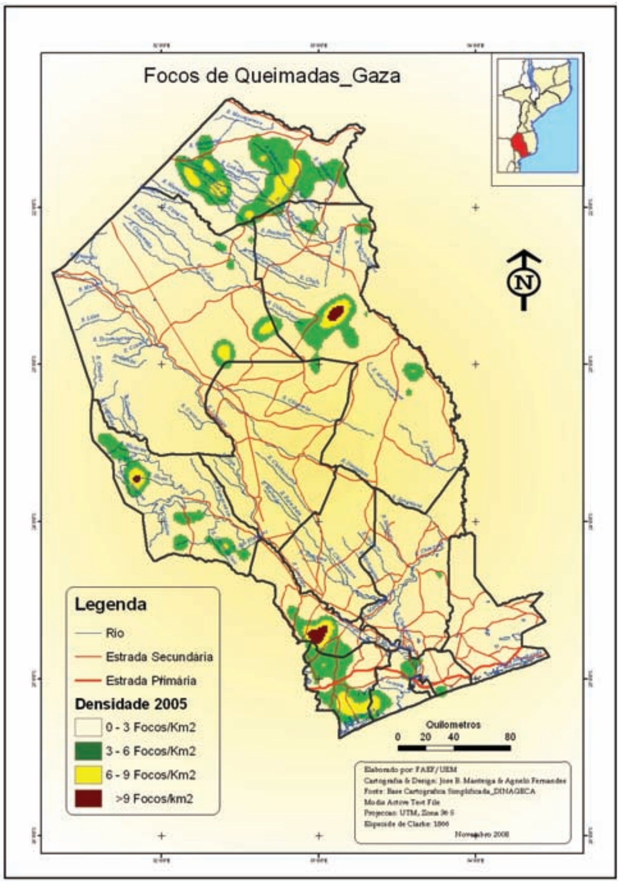
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

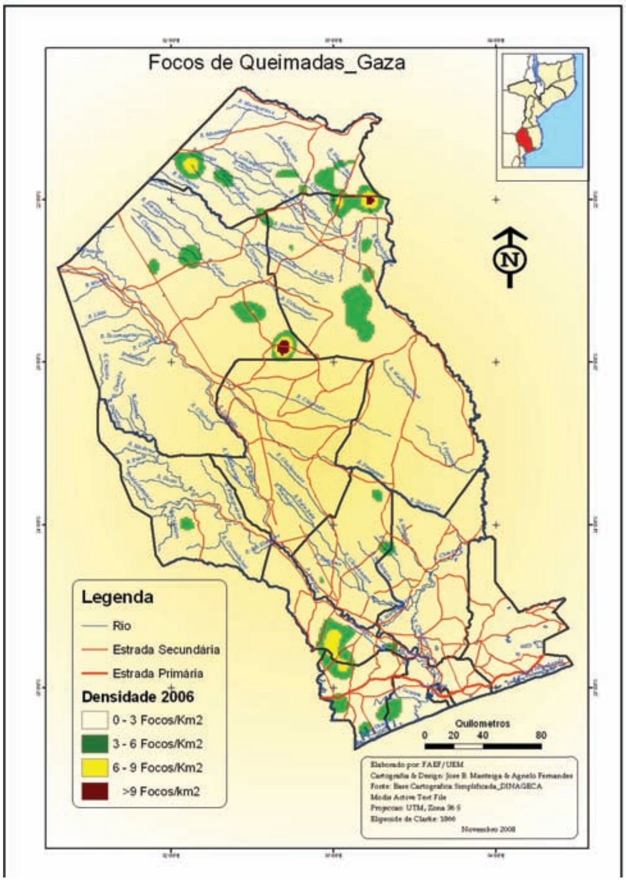
Gaza

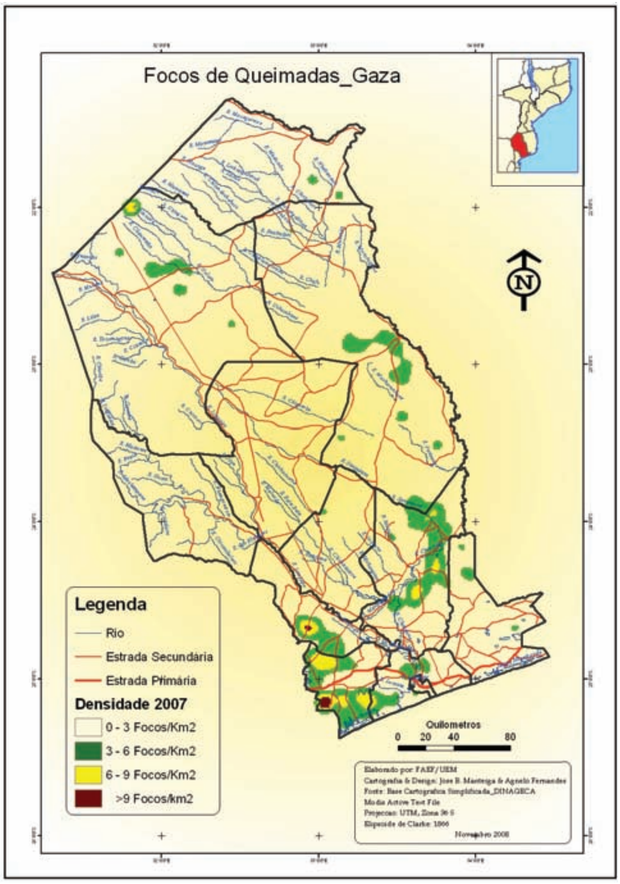






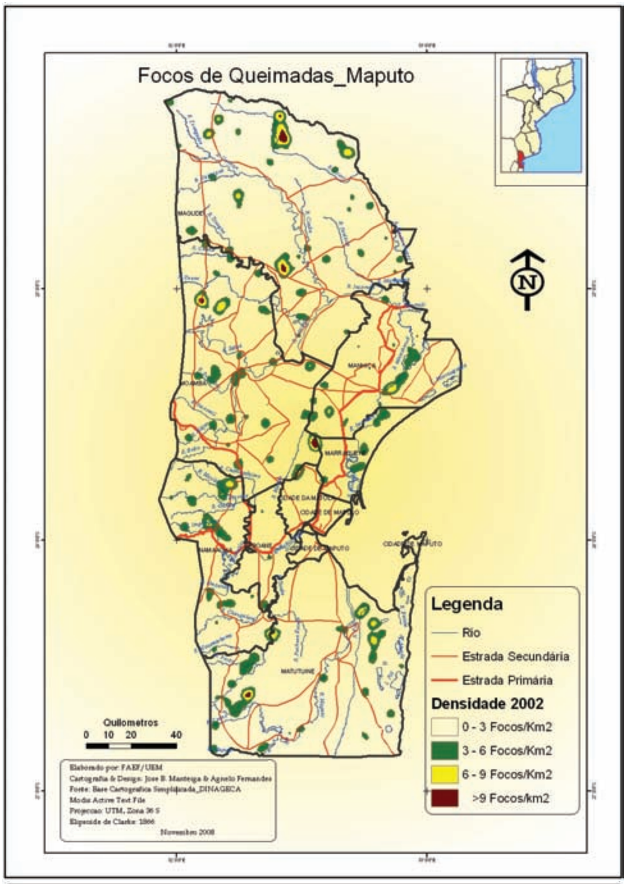


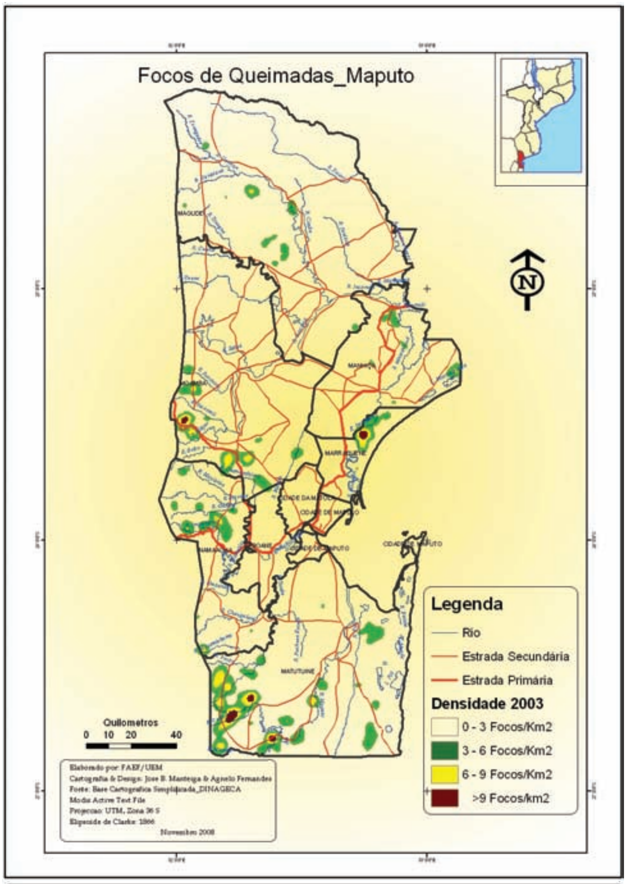

Focos de Queimadas_Gaza
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80

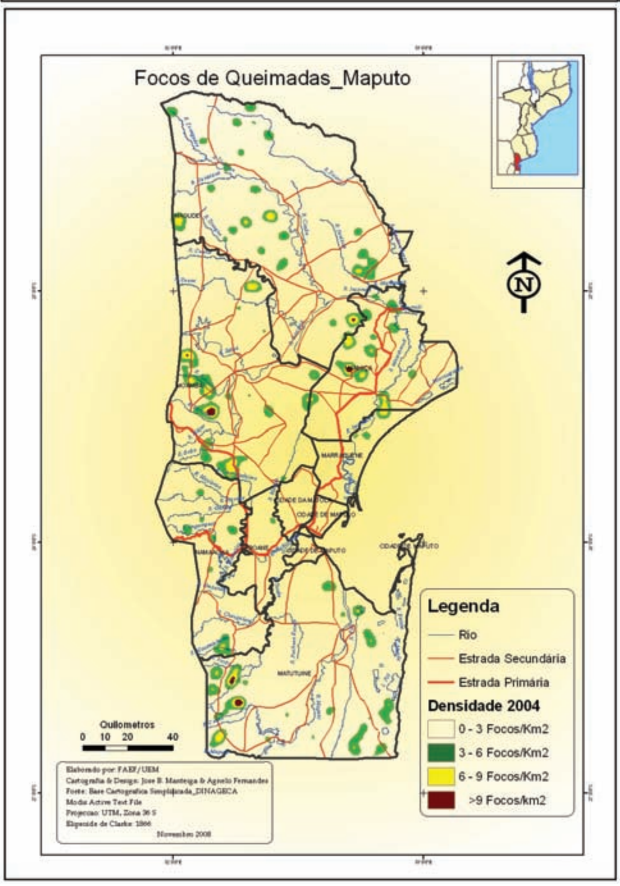

Focos de Queimadas_Gaza
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 20 40 80

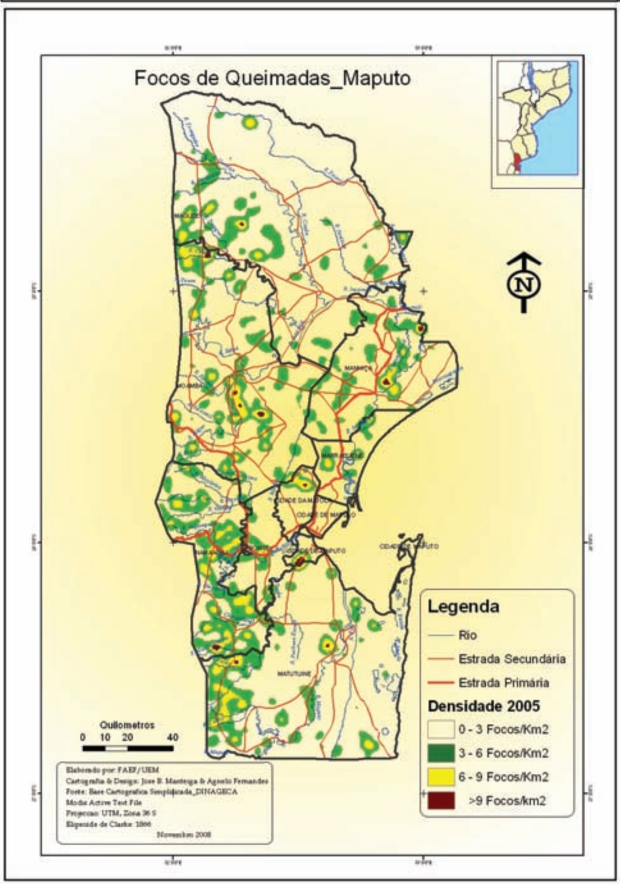
Annex VI: Spatial distribution of outbreaks by province (2002-2007)

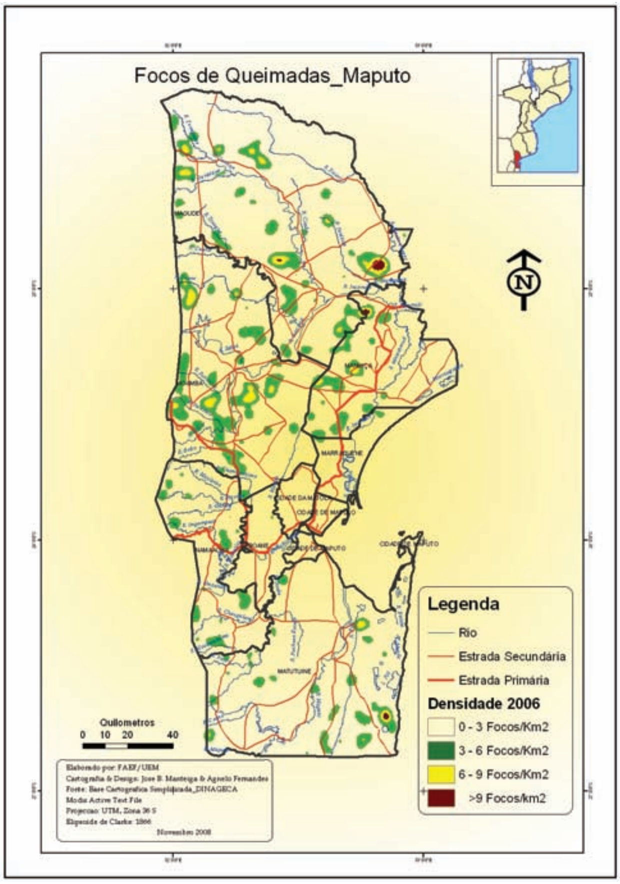
Mauto



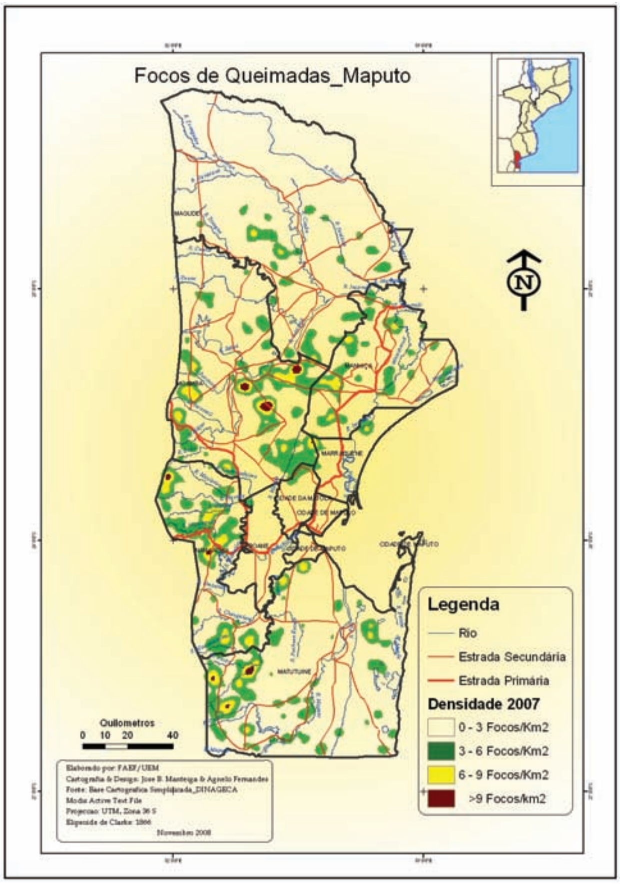








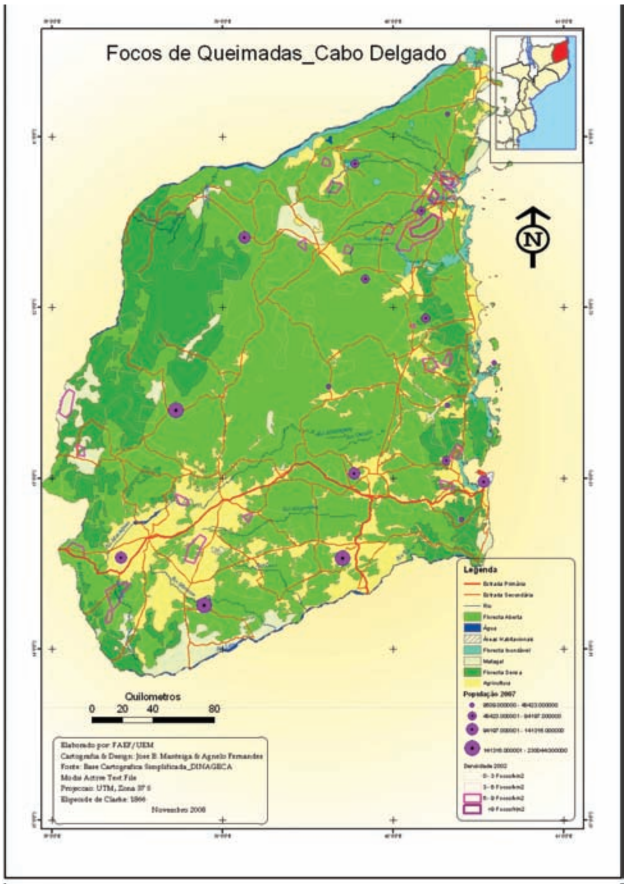
Focos de Queimadas_Maputo
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 10 20 40

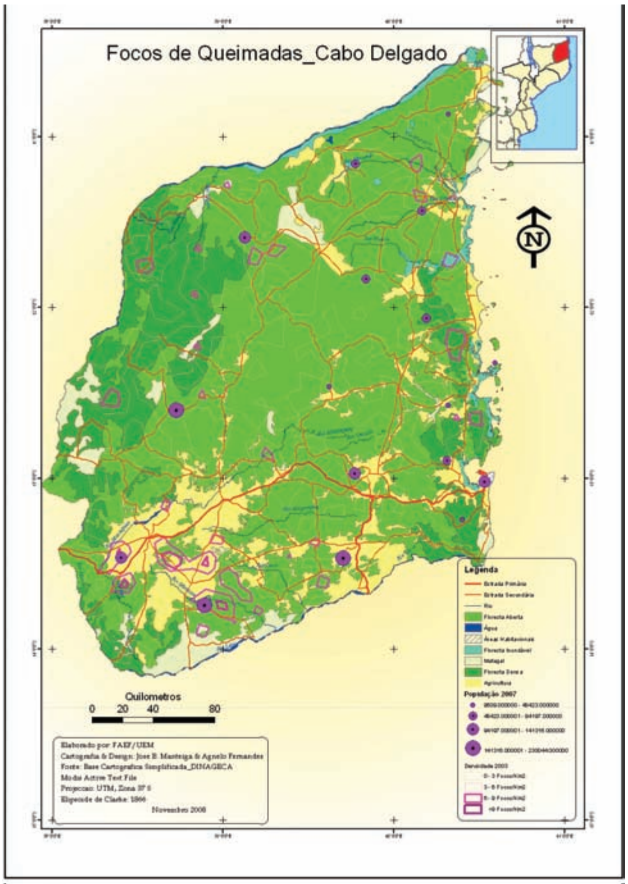


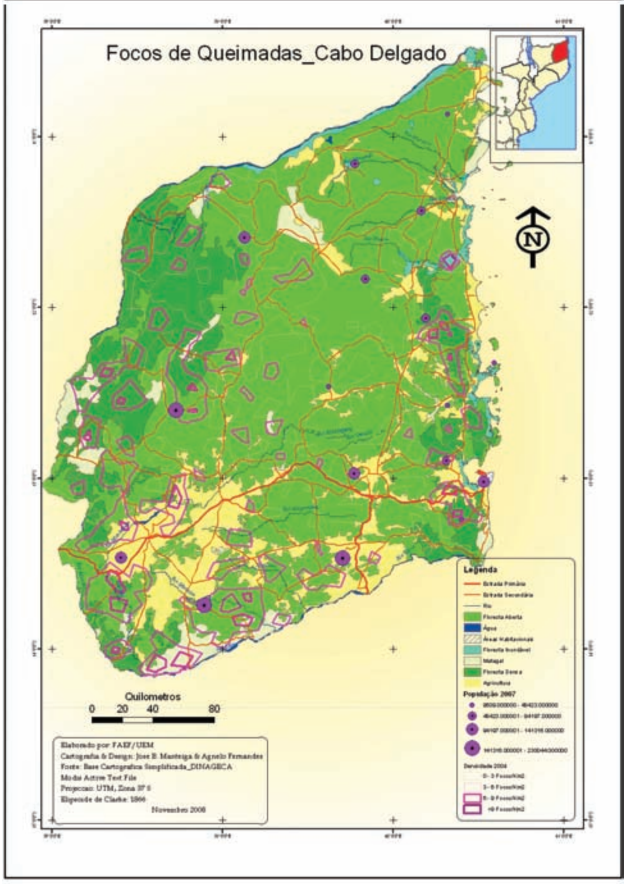
Focos de Queimadas_Maputo
Legenda
Rio
Estrada Secundária
Estrada Primária
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/km2
Quilometros
0 10 20 40

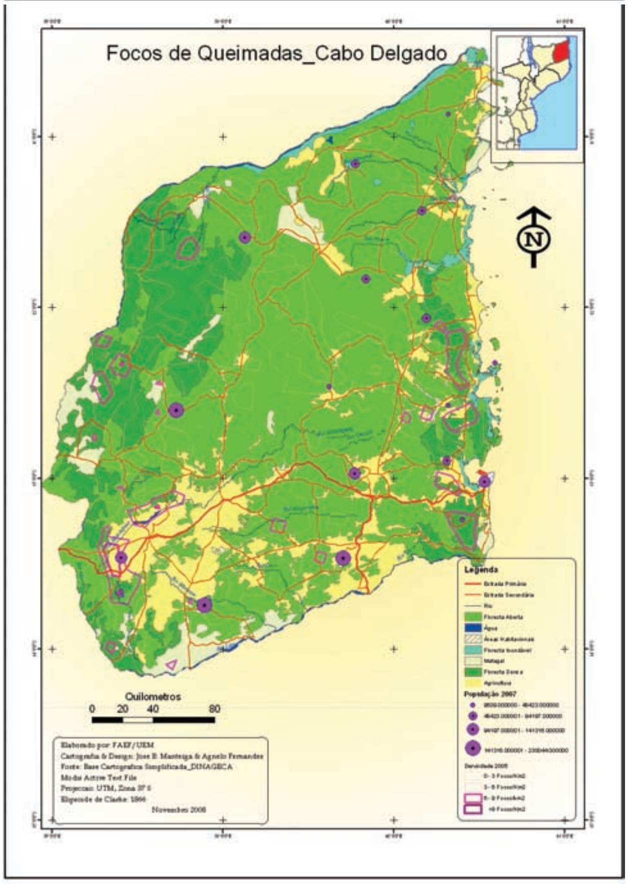
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

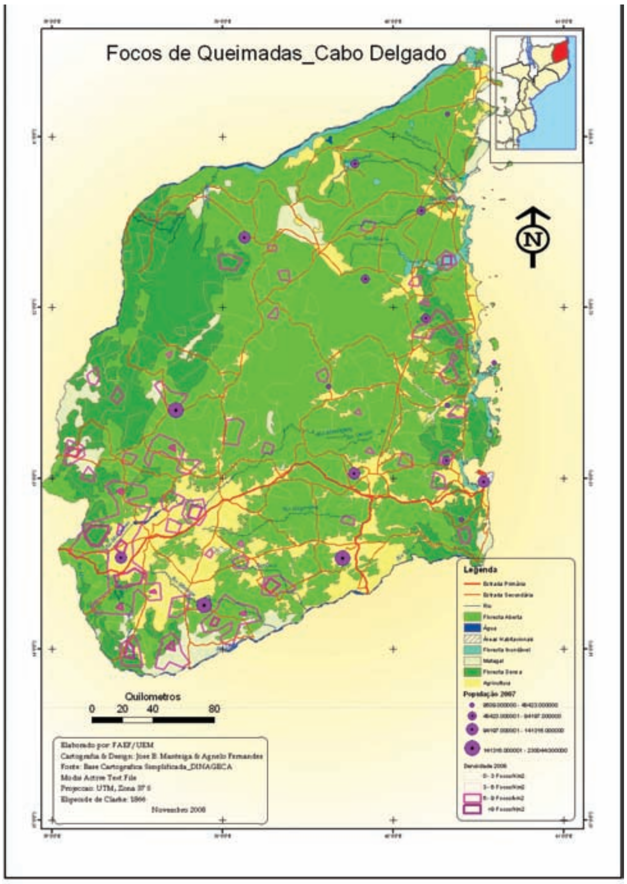
Cabo Delgado

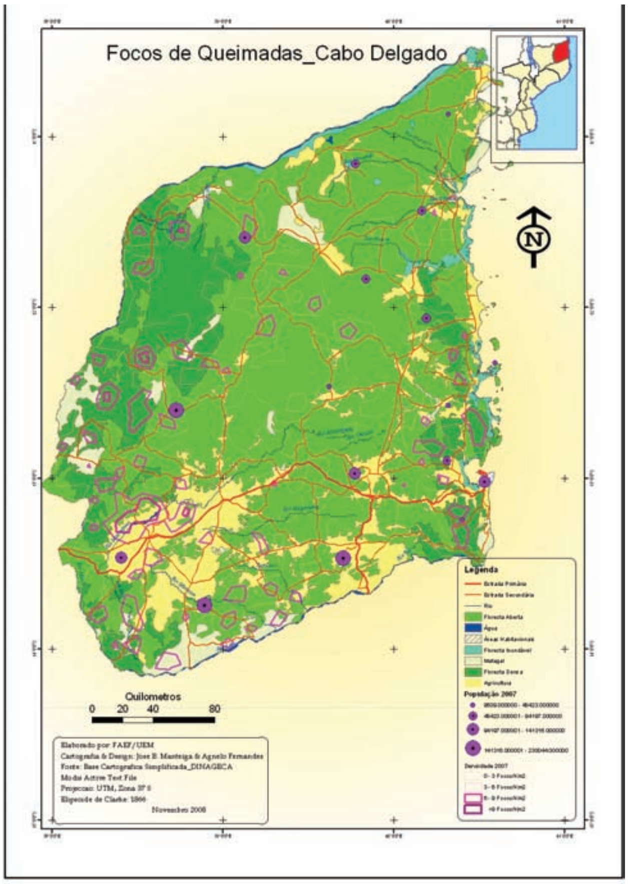






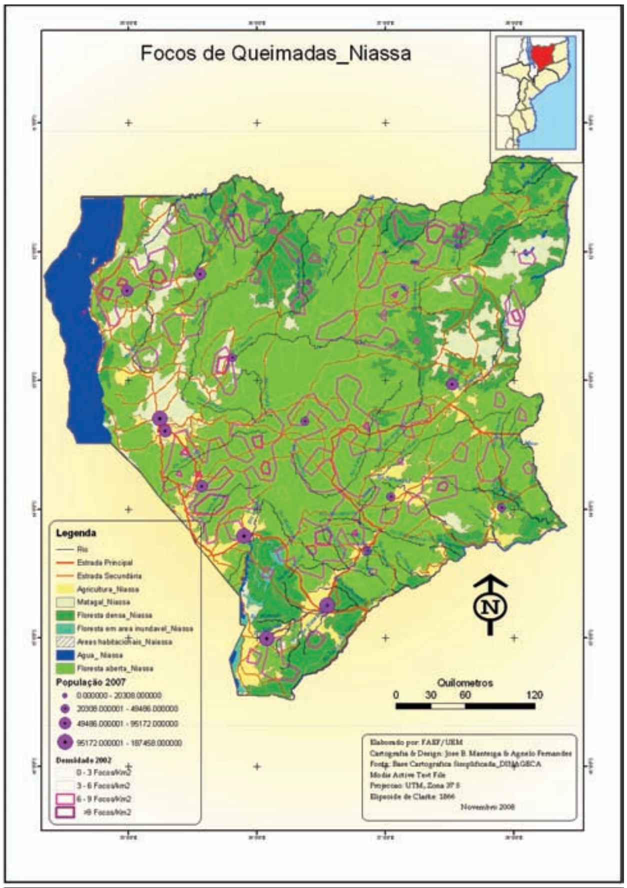


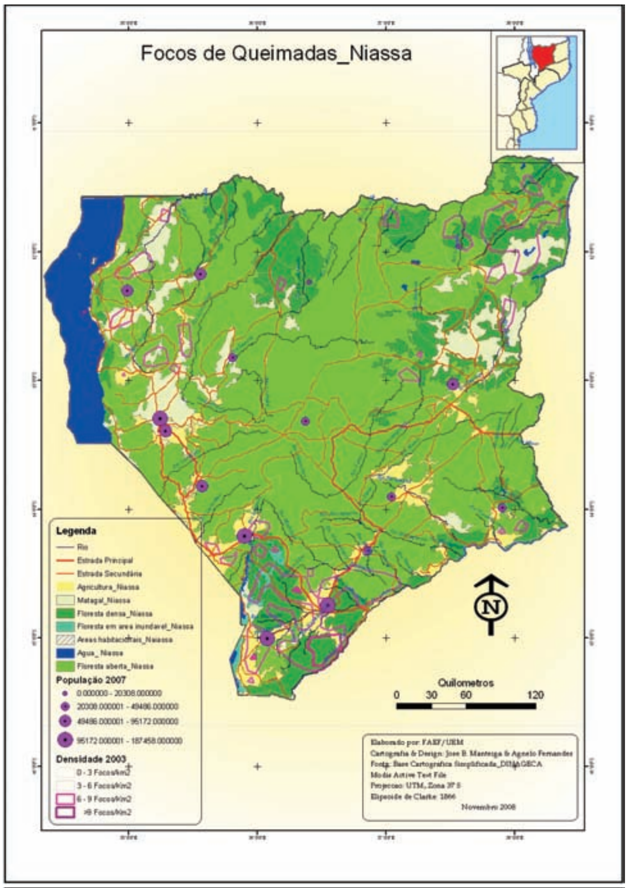

Focos de Queimadas_Cabo Delgado
Legenda
Quilometros
0 20 40 80
Elaborado por FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Novembro 2008

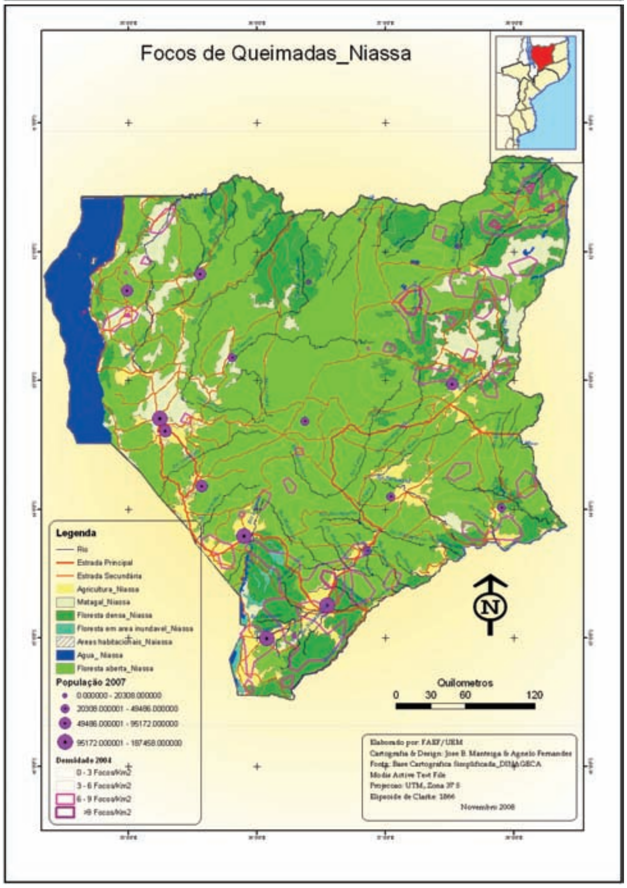

Focos de Queimadas_Cabo Delgado
Legenda
Quilometros
0 20 40 80
Elaborado por FAEF/UEM
Fonte: Base Cartografica Simplificada_DINAGECA
Novembro 2008

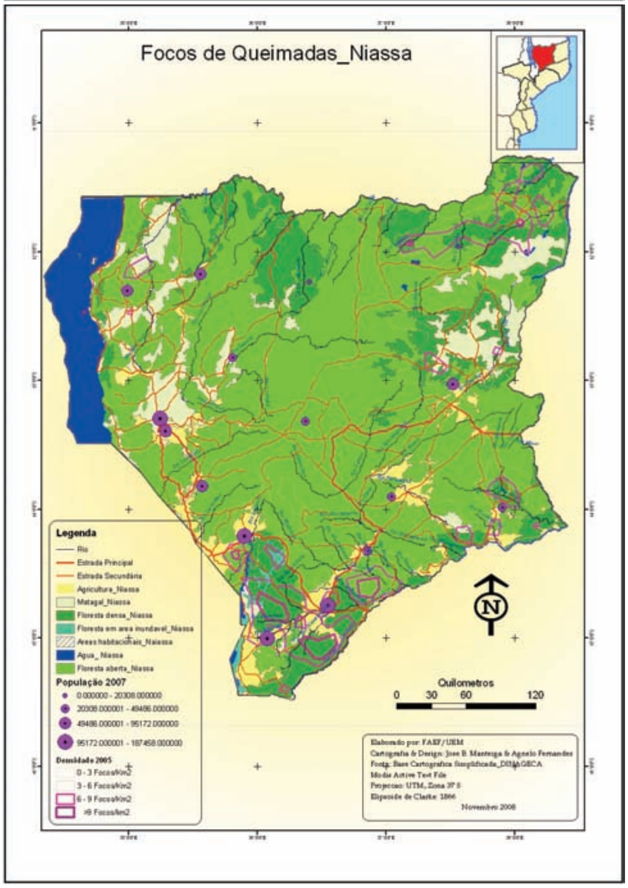
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

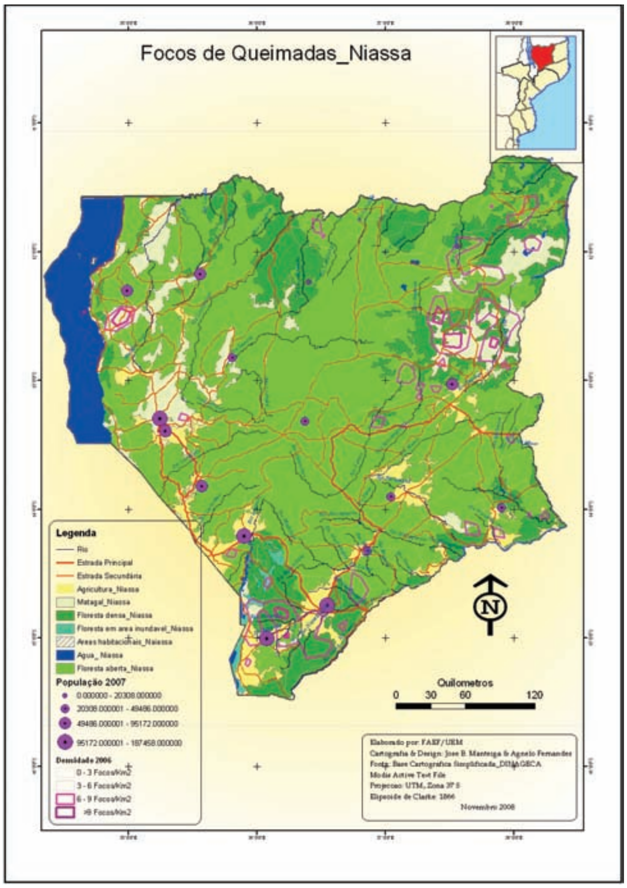
Niassa

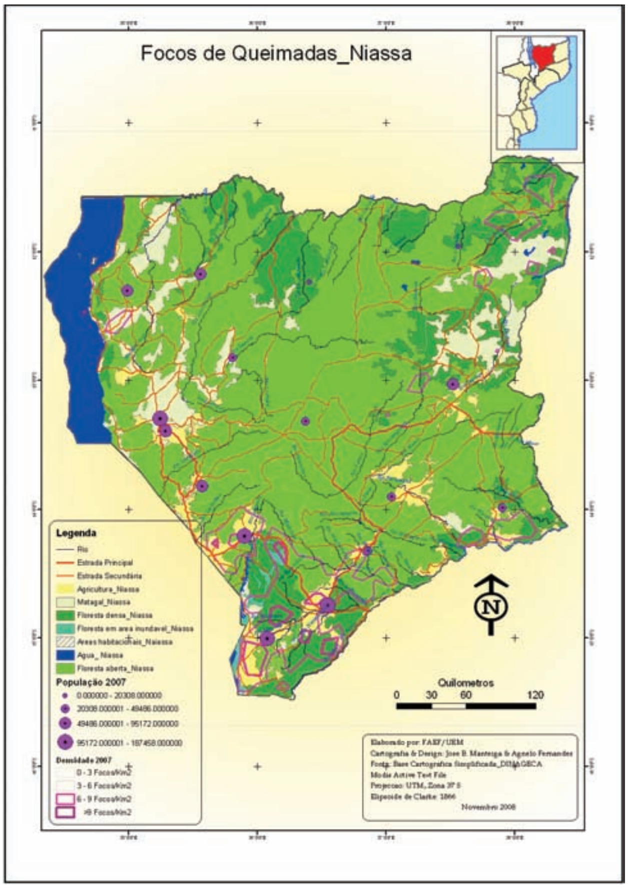






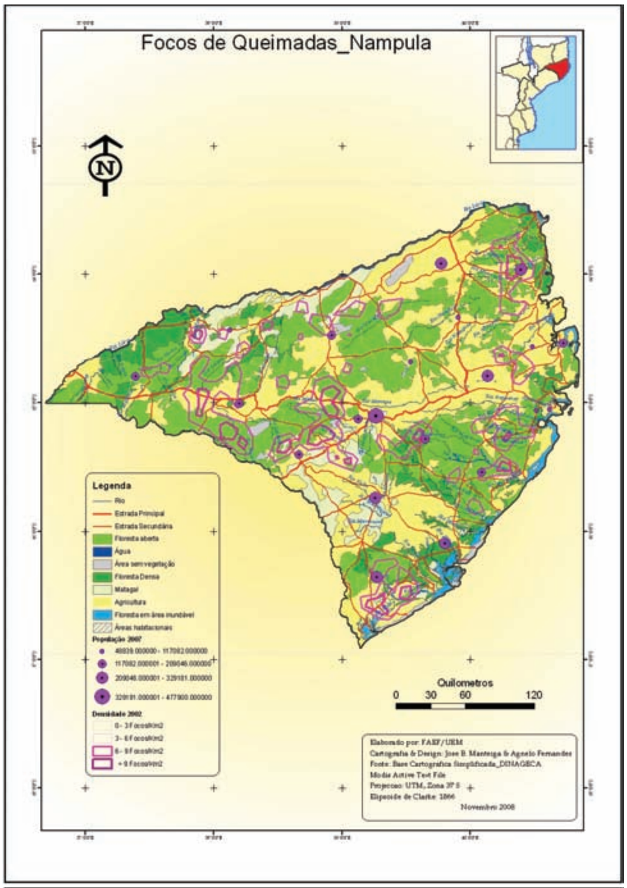


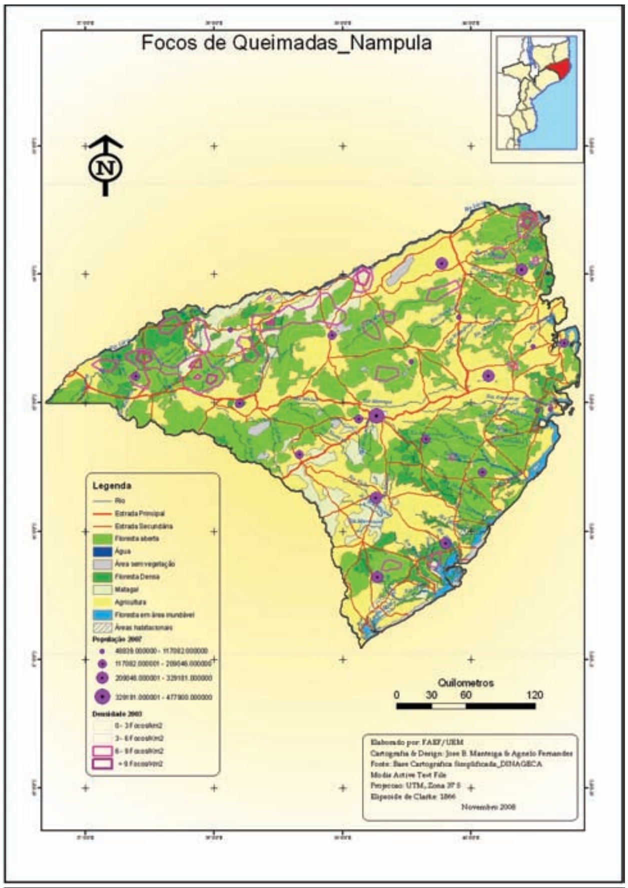

Focos de Queimadas_Niassa
Legenda
Rio
Estrada Principal
Estrada Secundária
Agricultura_Niassa
Matagal_Niassa
Floresta densa_Niassa
Floresta em area inundavel_Niassa
Areas habitacionais_Niassa
Agua_ Niassa
Floresta aberta_Niassa
População 2007
0.000000 - 20308.000000
20308.000001 - 49486.000000
49486.000001 - 95172.000000
95172.000001 - 187458.000000
Densidade 2006
0 - 3 Focos/km2
3 - 6 Focos/km2
6 - 9 Focos/km2
>9 Focos/km2
N
Quilometros
0 30 60 120
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Projecao: UTM, Zona 37 S
Novembro 2008

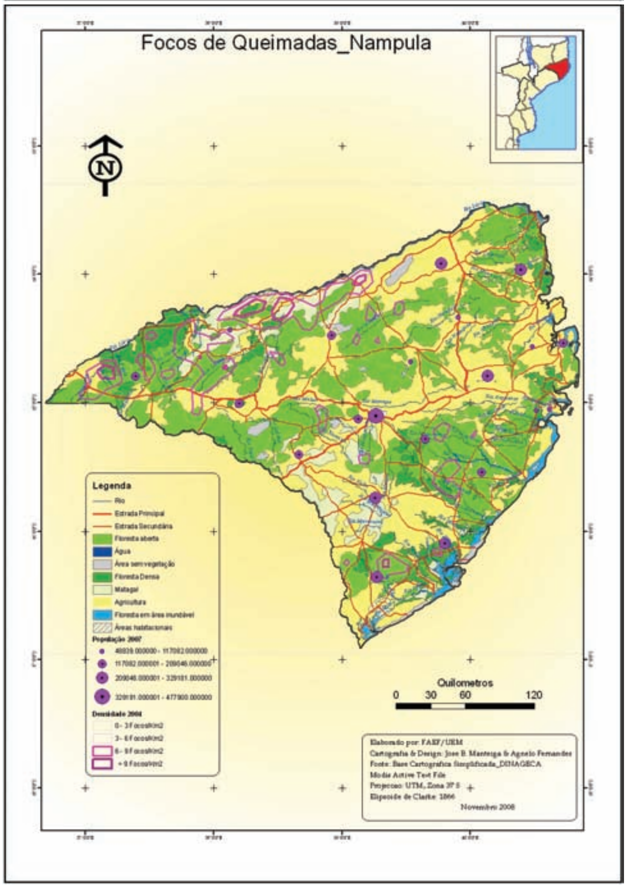

Focos de Queimadas_Niassa
Legenda
Rio
Estrada Principal
Estrada Secundária
Agricultura_Niassa
Matagal_Niassa
Floresta densa_Niassa
Floresta em area inundavel_Niassa
Areas habitacionais_Niassa
Agua_ Niassa
Floresta aberta_Niassa
População 2007
0.000000 - 20308.000000
20308.000001 - 49486.000000
49486.000001 - 95172.000000
95172.000001 - 187458.000000
Densidade 2007
0 - 3 Focos/km2
3 - 6 Focos/km2
6 - 9 Focos/km2
>9 Focos/km2
N
Quilometros
0 30 60 120
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Projecao: UTM, Zona 37 S
Novembro 2008

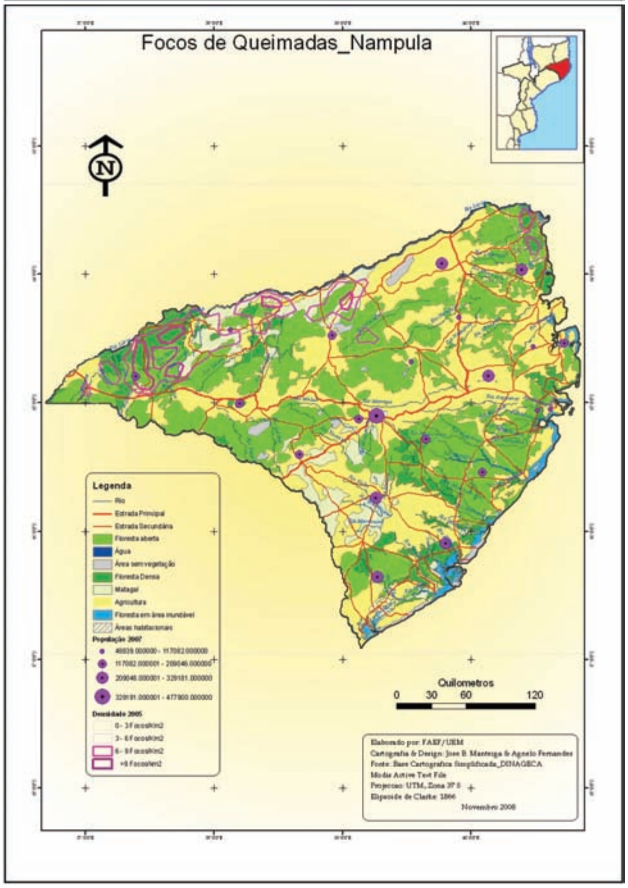
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

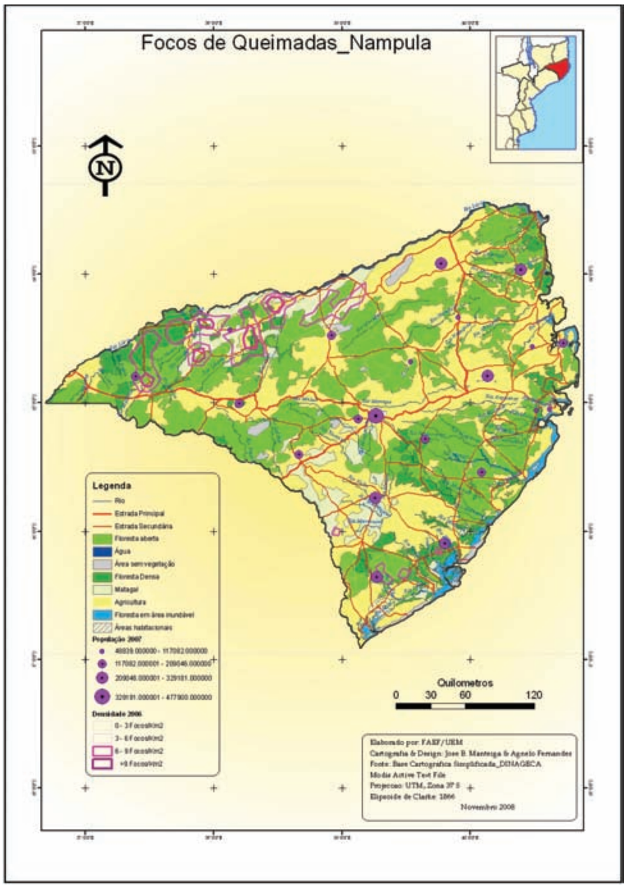
Nampula

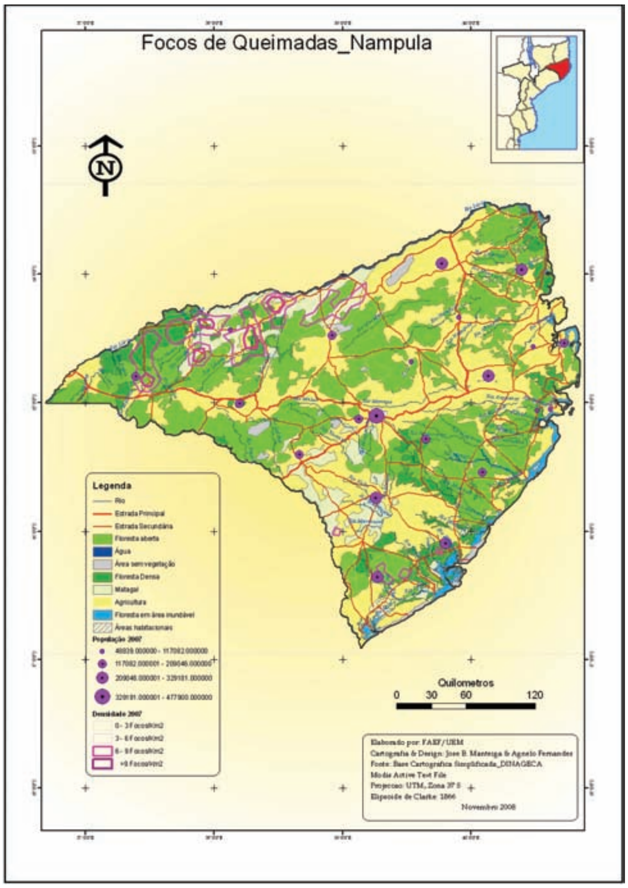






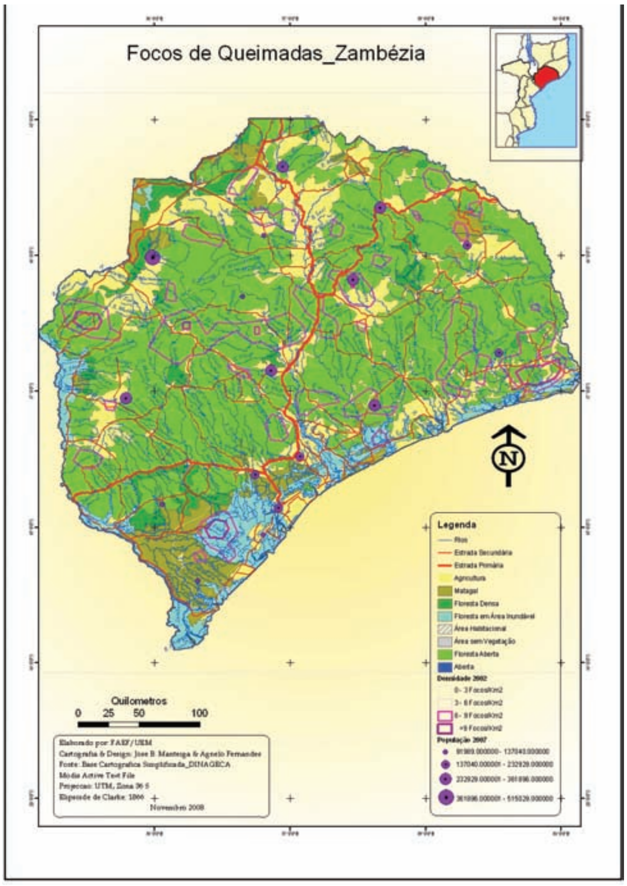


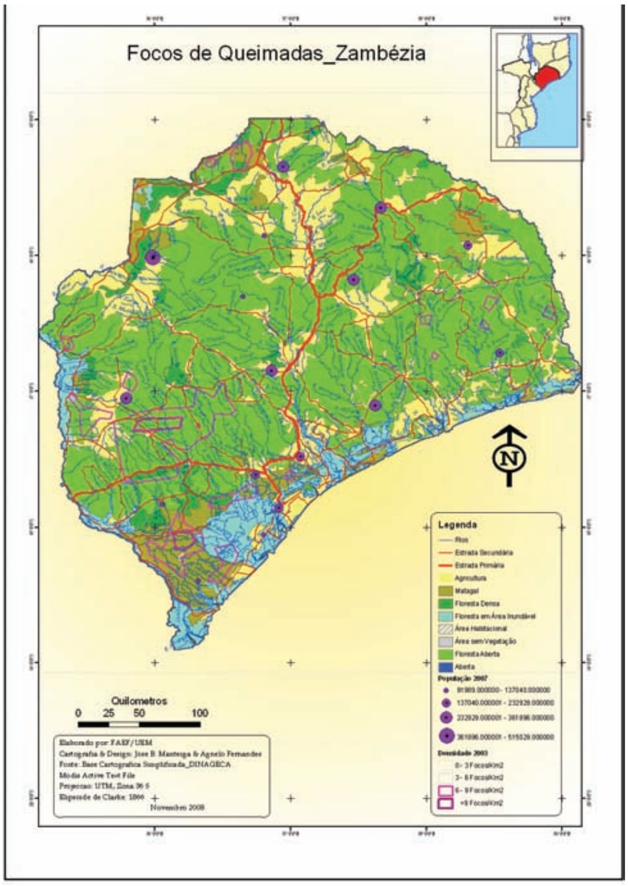

Focos de Queimadas_Nampula
Legenda
Rio
Estrada Principal
Estrada Secundária
Floresta aberta
Água
Área sem vegetação
Floresta Densa
Matagal
Agricultura
Floresta em área inundável
Áreas habitacionais
Densidade 2006
Quilometros
0 30 60 120
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 37 S
Elipsoide de Clarke 1866
Novembro 2008

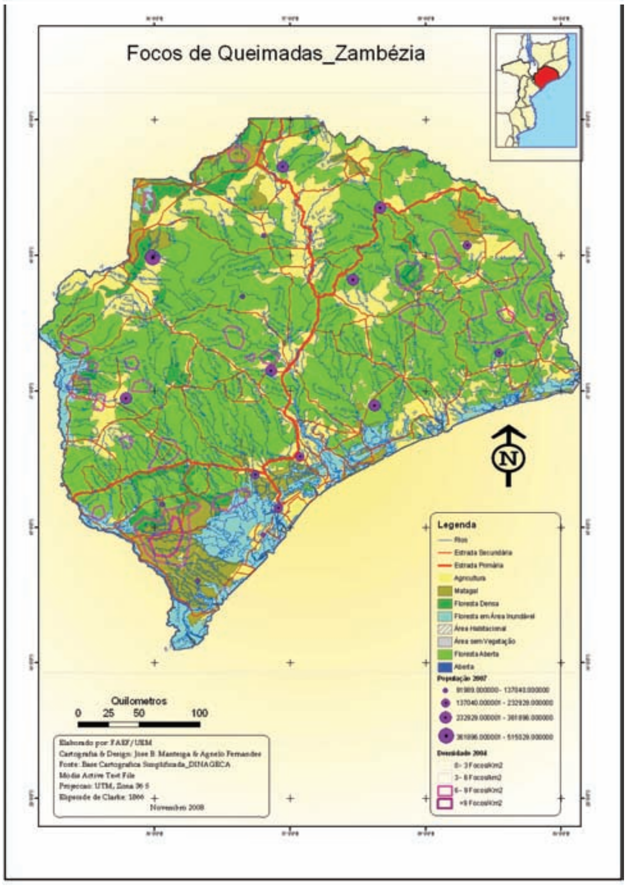

Focos de Queimadas_Nampula
Legenda
Rio
Estrada Principal
Estrada Secundária
Floresta aberta
Água
Área sem vegetação
Floresta Densa
Matagal
Agricultura
Floresta em área inundável
Áreas habitacionais
Densidade 2007
Quilometros
0 30 60 120
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 37 S
Elipsoide de Clarke 1866
Novembro 2008

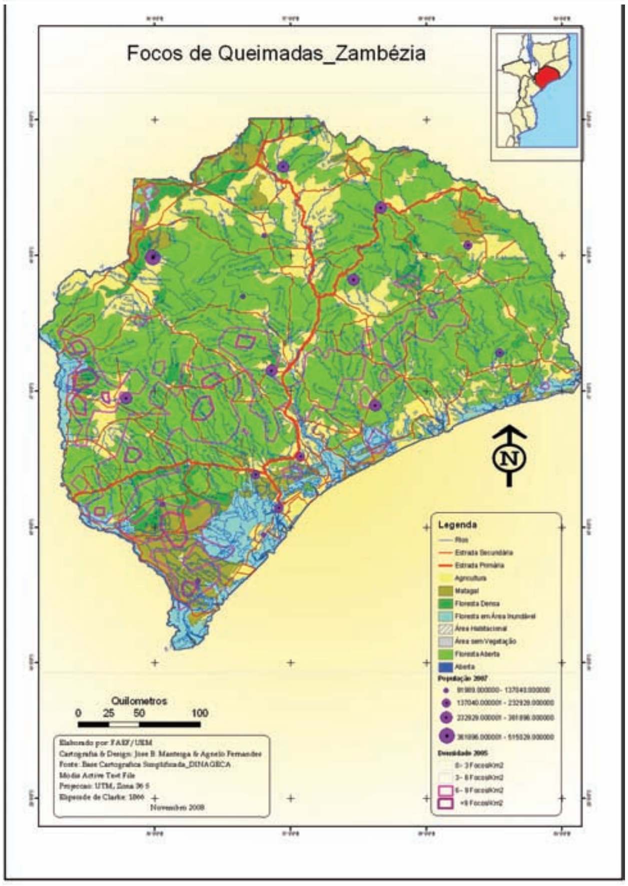
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

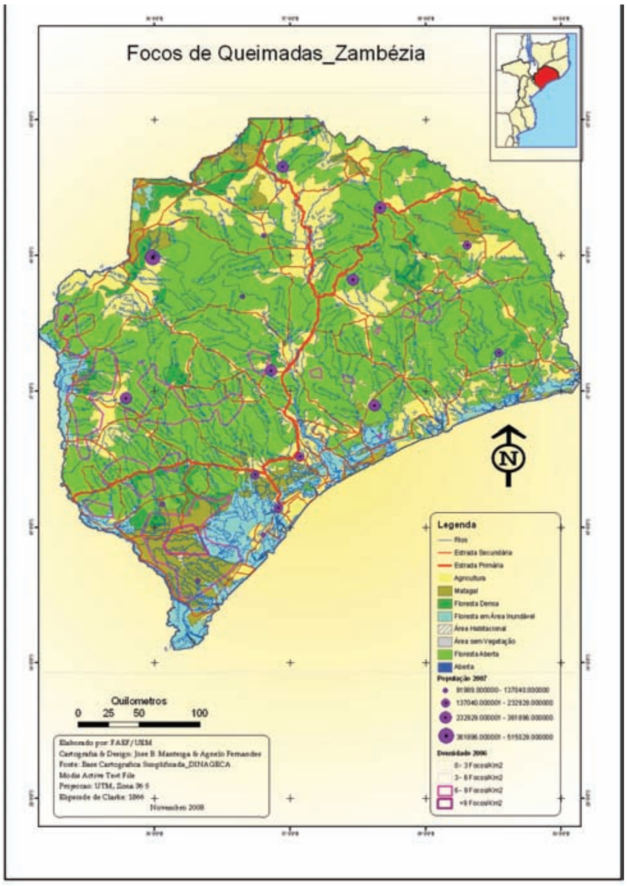
Zambezia

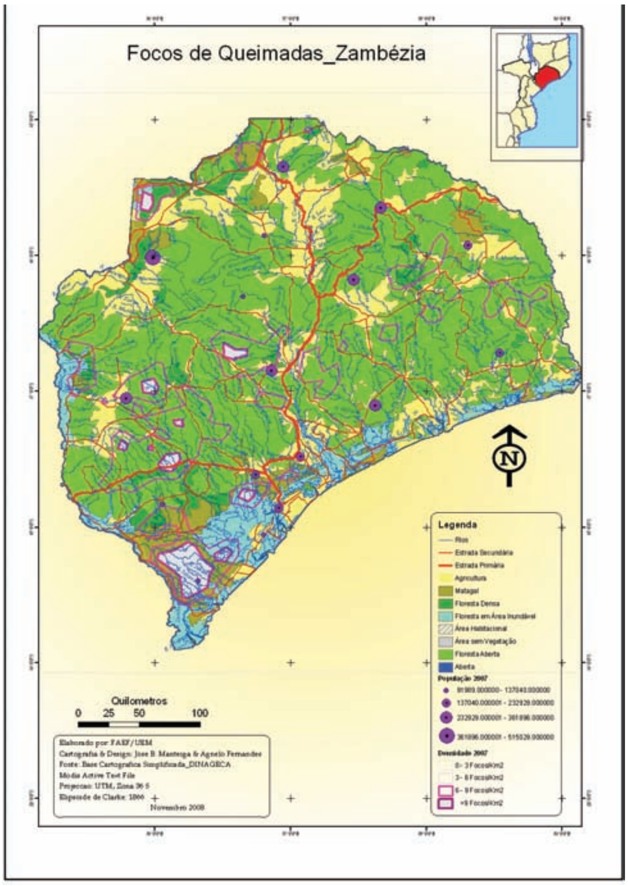






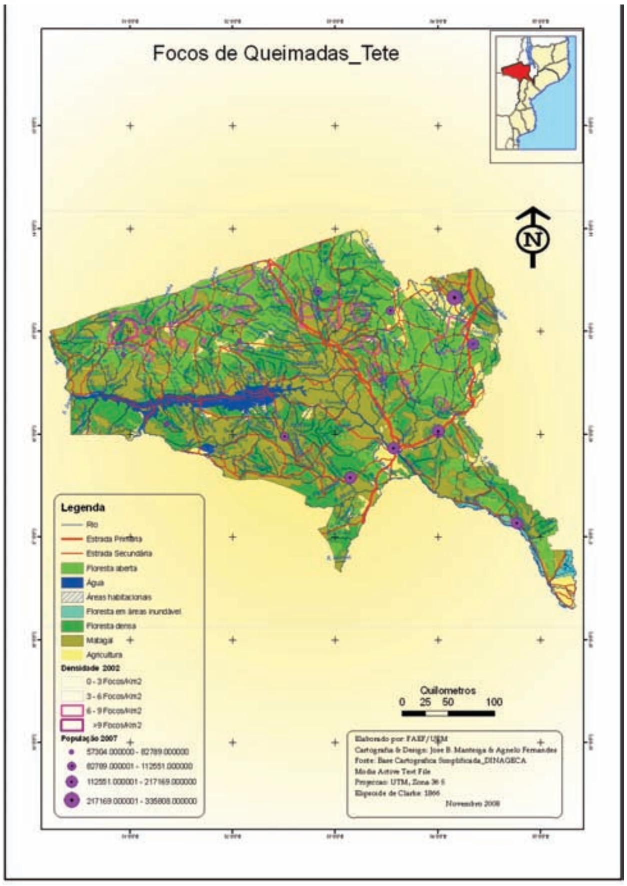


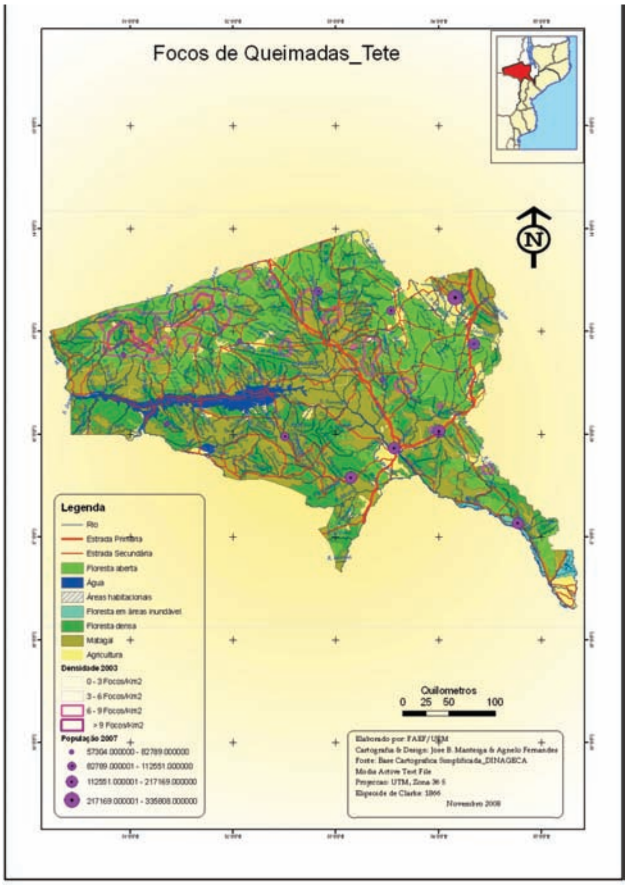

Focos de Queimadas_Zambézia
N
Legenda
Rios
Estrada Secundária
Estrada Primária
Agricultura
Matagal
Floresta Densa
Floresta em Área Inundável
Área Habitacional
Área sem Vegetação
Floresta Aberta
Aberta
População 2007
91989.000000 - 137040.000000
137040.000001 - 232929.000000
232929.000001 - 361896.000000
361896.000001 - 515529.000000
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
+9 Focos/Km2
Quilometros
0 25 50 100
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Mantenga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modis Active Text File
Projecao: UTM, Zona 36 S
Elipsoide de Clarke: 1866
Novembro 2008

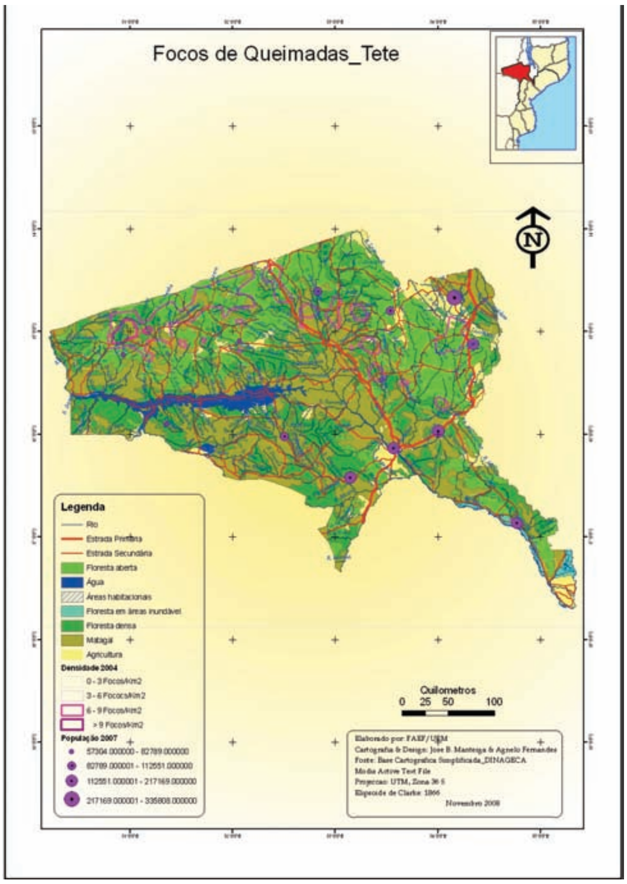

Focos de Queimadas_Zambézia
N
Legenda
Rios
Estrada Secundária
Estrada Primária
Agricultura
Matagal
Floresta Densa
Floresta em Área Inundável
Área Habitacional
Área sem Vegetação
Floresta Aberta
Aberta
População 2007
91989.000000 - 137040.000000
137040.000001 - 232929.000000
232929.000001 - 361896.000000
361896.000001 - 515529.000000
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
+9 Focos/Km2
Quilometros
0 25 50 100
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Mantenga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modis Active Text File
Projecao: UTM, Zona 36 S
Elipsoide de Clarke: 1866
Novembro 2008

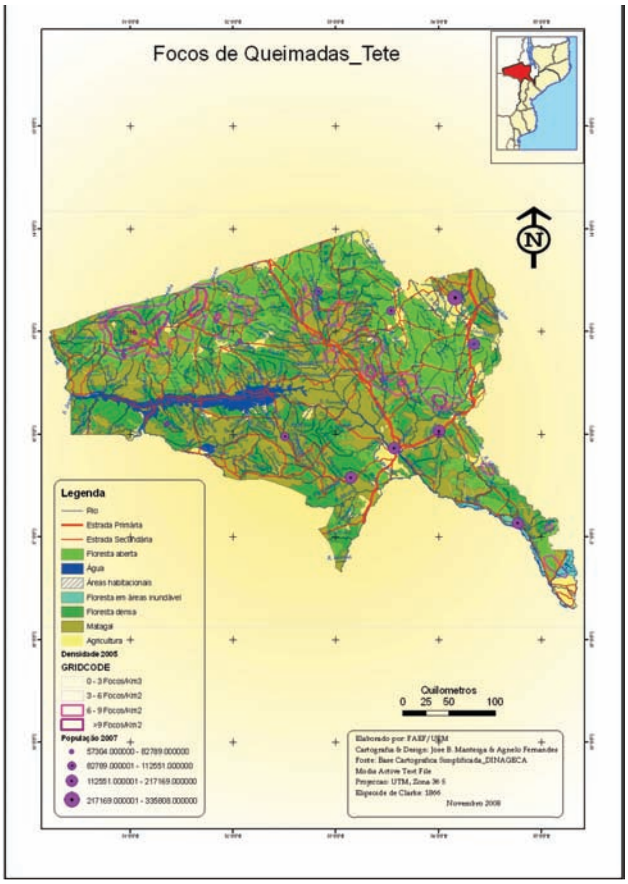
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

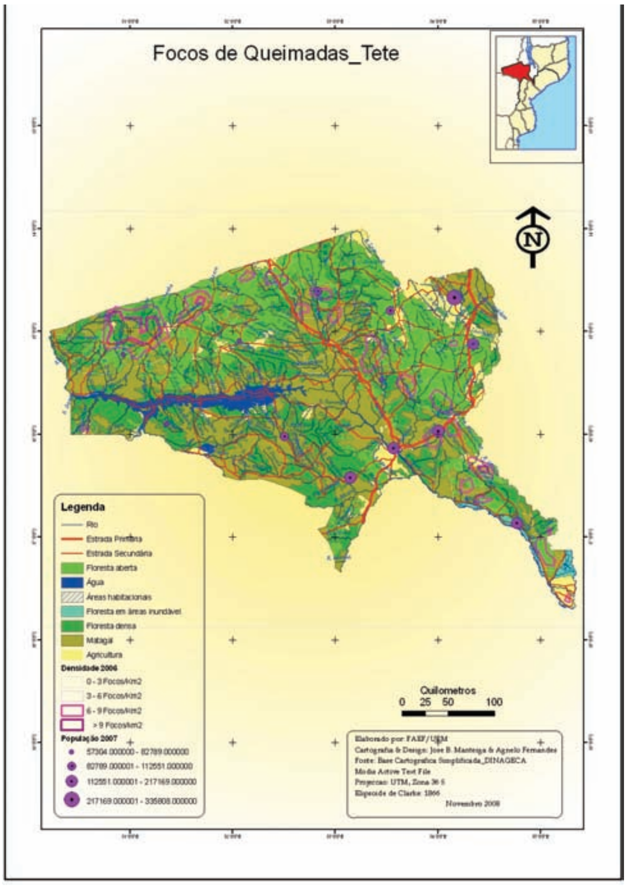
Tete

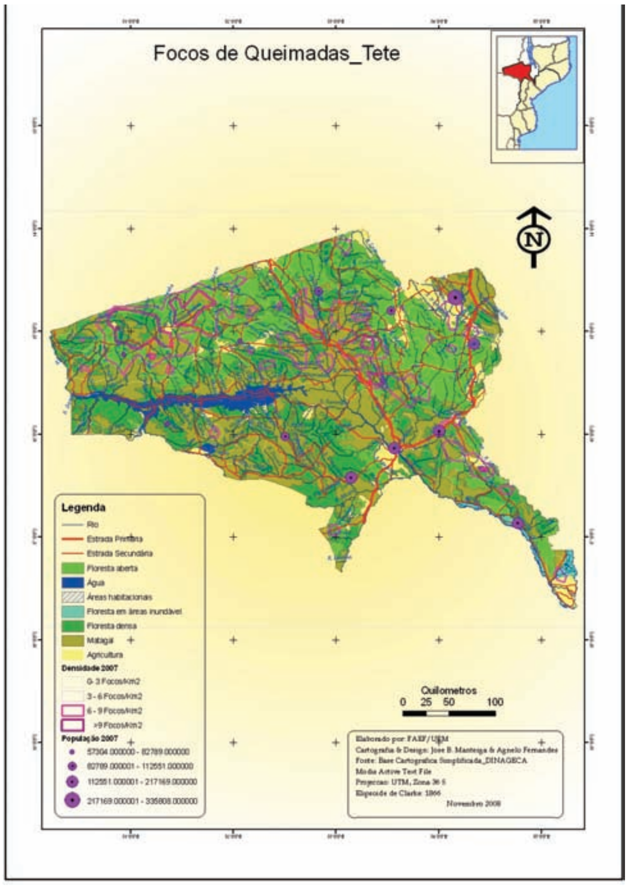






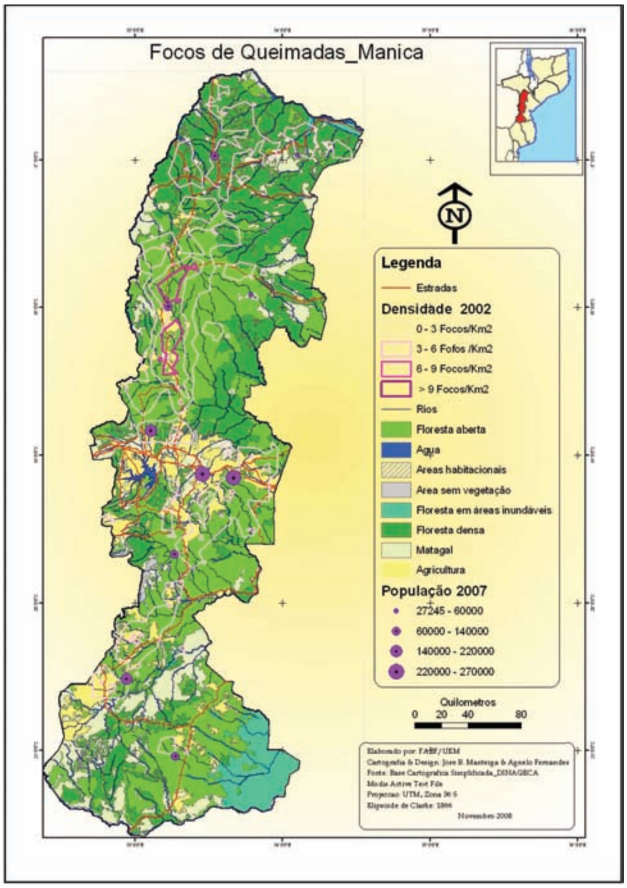


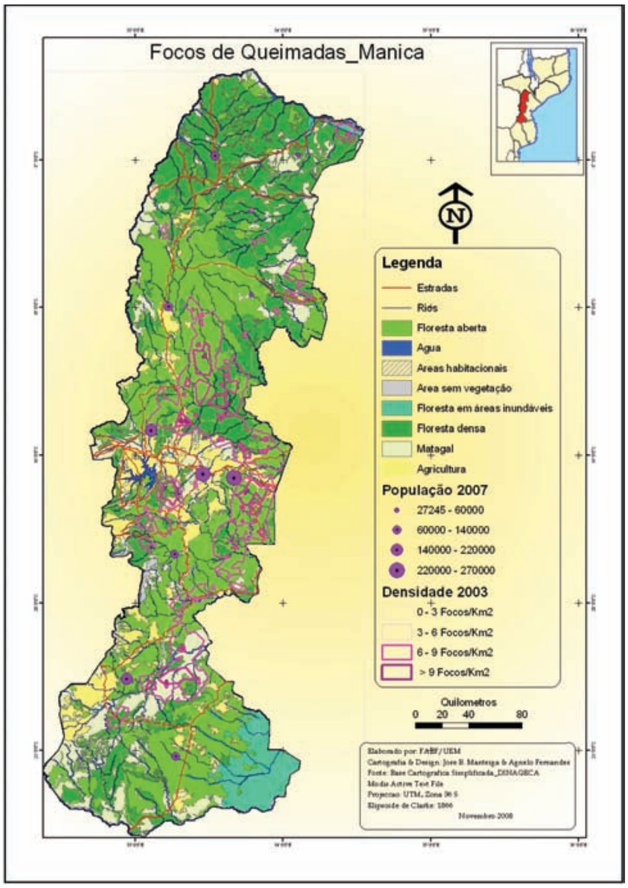

Focos de Queimadas_Tete
Legenda
Rio
Estrada Primária
Estrada Secundária
Floresta aberta
Água
Áreas habitacionais
Floresta em áreas inundável
Floresta densa
Matagal
Agricultura
Densidade 2006
0 - 3 Focos/km2
3 - 6 Focos/km2
6 - 9 Focos/km2
> 9 Focos/km2
População 2007
57304.000000 - 82789.000000
82789.000001 - 112551.000000
112551.000001 - 217169.000000
217169.000001 - 335808.000000
Quilometros
0 25 50 100
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modo Active Text File
Projeccao: UTM, Zona 36 S
Elipsoide de Clarke 1866
Novembro 2008

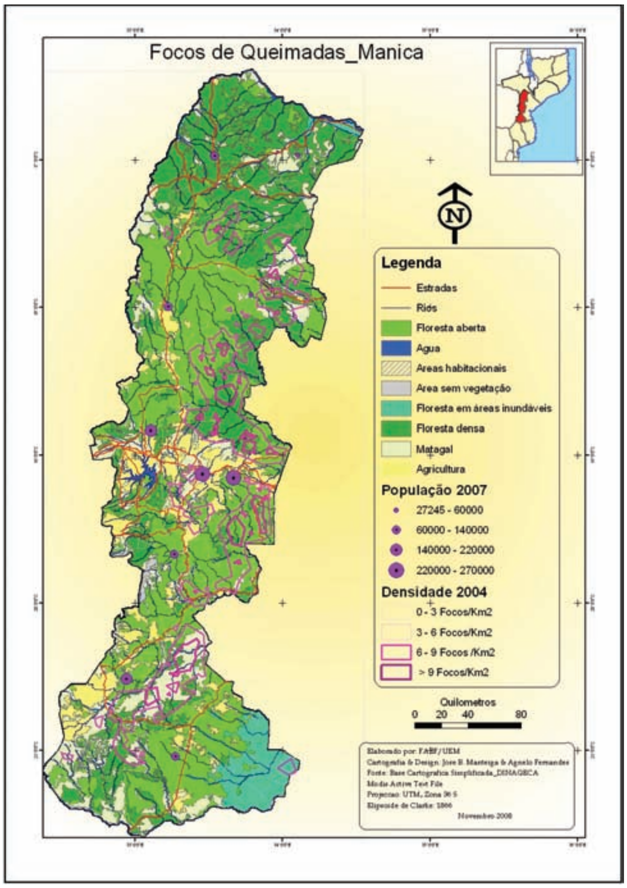

Focos de Queimadas_Tete
Legenda
Rio
Estrada Primária
Estrada Secundária
Floresta aberta
Água
Áreas habitacionais
Floresta em áreas inundável
Floresta densa
Matagal
Agricultura
Densidade 2007
0- 3 Focos/km2
3 - 6 Focos/km2
6 - 9 Focos/km2
>9 Focos/km2
População 2007
57304.000000 - 82789.000000
82789.000001 - 112551.000000
112551.000001 - 217169.000000
217169.000001 - 335808.000000
Quilometros
0 25 50 100
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modo Active Text File
Projeccao: UTM, Zona 36 S
Elipsoide de Clarke 1866
Novembro 2008

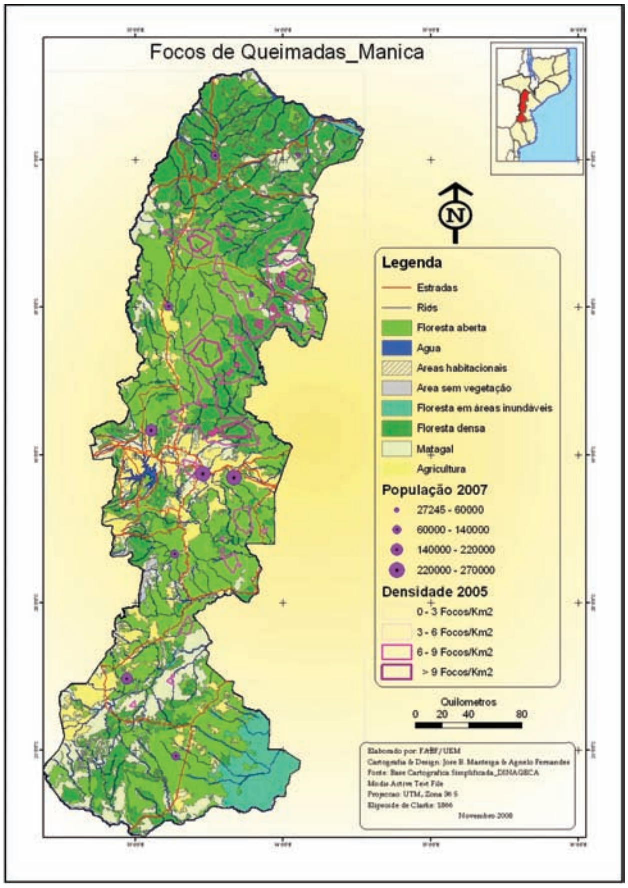
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

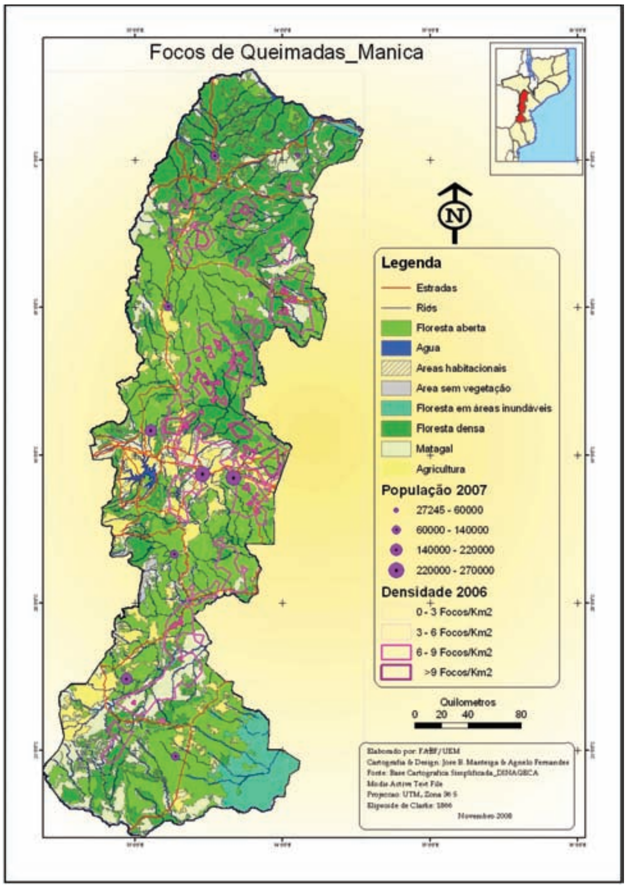
Manica

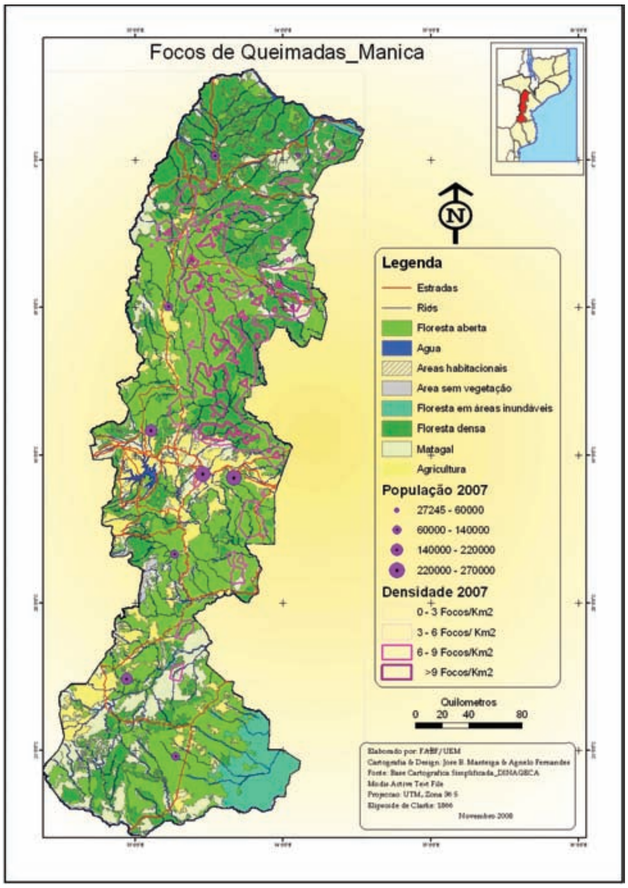






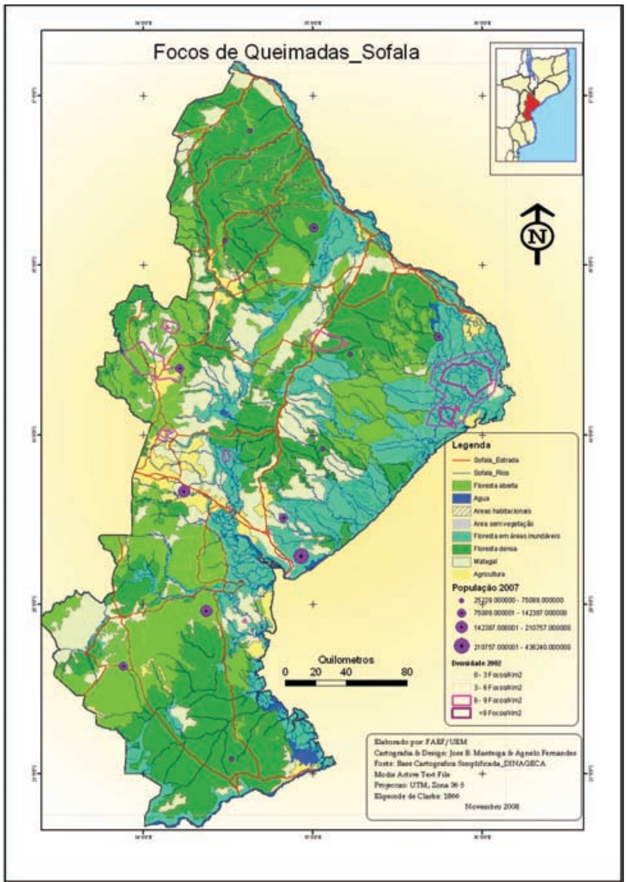


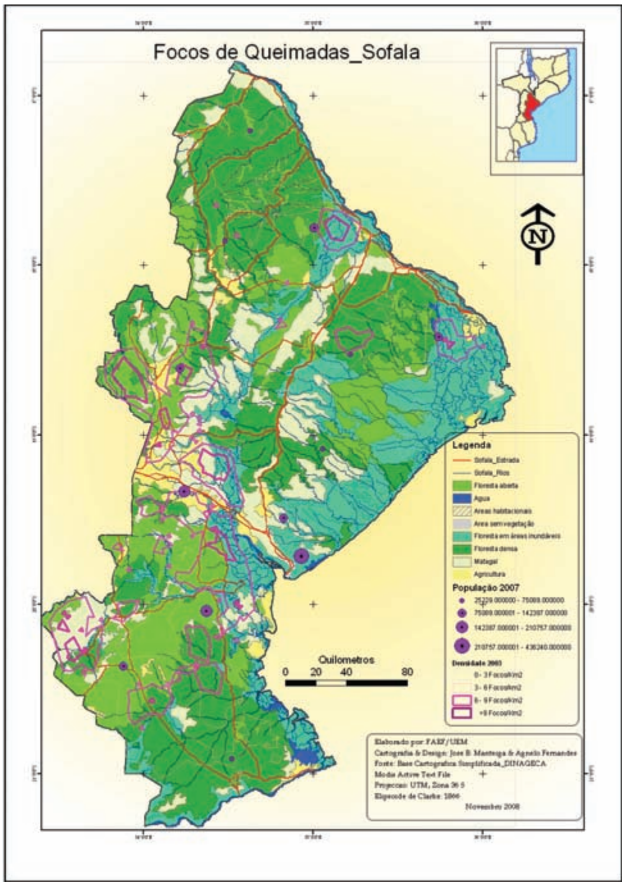

Focos de Queimadas_Manica
N
Legenda
Estradas
Rios
Floresta aberta
Agua
Areas habitacionais
Area sem vegetação
Floresta em áreas inundáveis
Floresta densa
Matagal
Agricultura
População 2007
27245 - 60000
60000 - 140000
140000 - 220000
220000 - 270000
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/Km2
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM

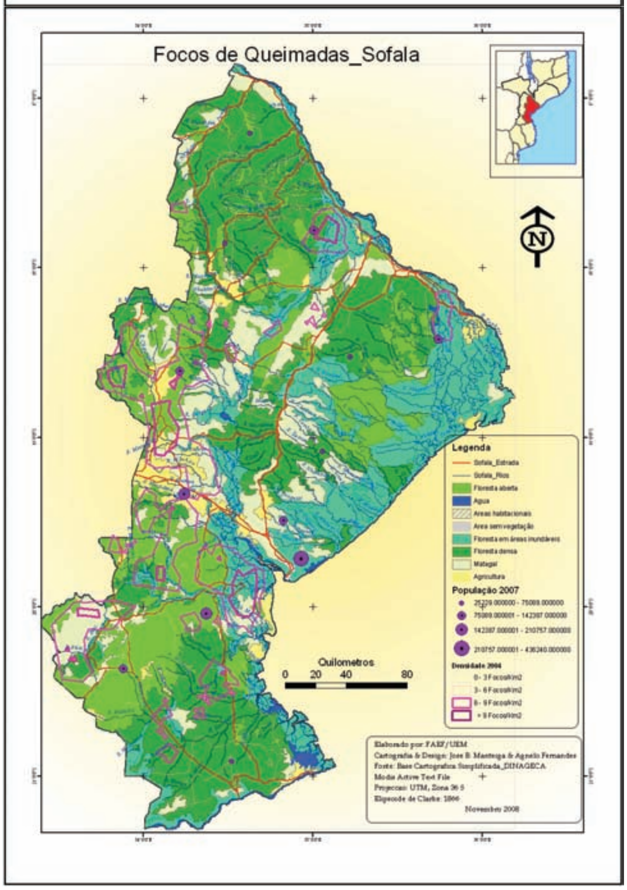

Focos de Queimadas_Manica
N
Legenda
Estradas
Rios
Floresta aberta
Agua
Areas habitacionais
Area sem vegetação
Floresta em áreas inundáveis
Floresta densa
Matagal
Agricultura
População 2007
27245 - 60000
60000 - 140000
140000 - 220000
220000 - 270000
Densidade 2007
0 - 3 Focos/Km2
3 - 6 Focos/ Km2
6 - 9 Focos/Km2
>9 Focos/Km2
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM

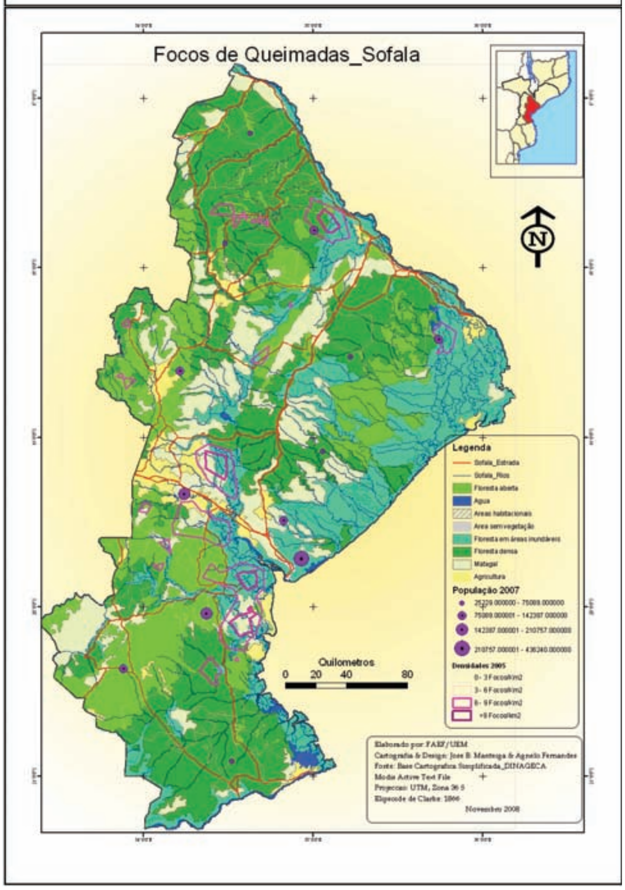
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

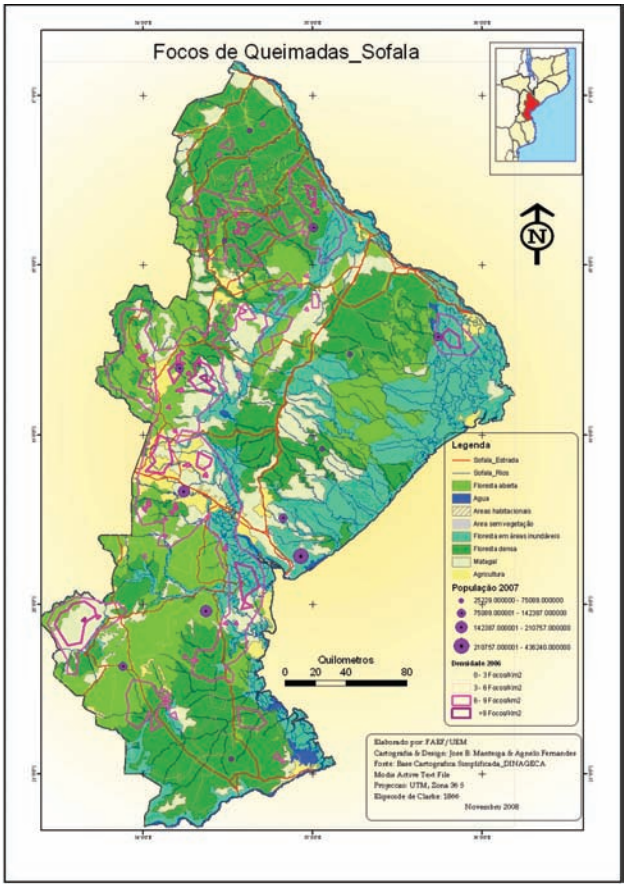
Sofala

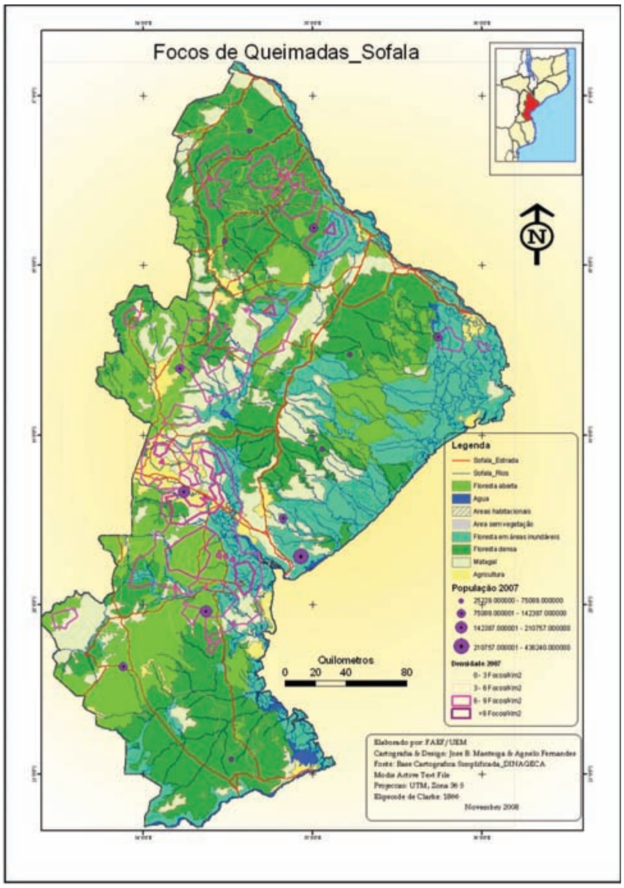






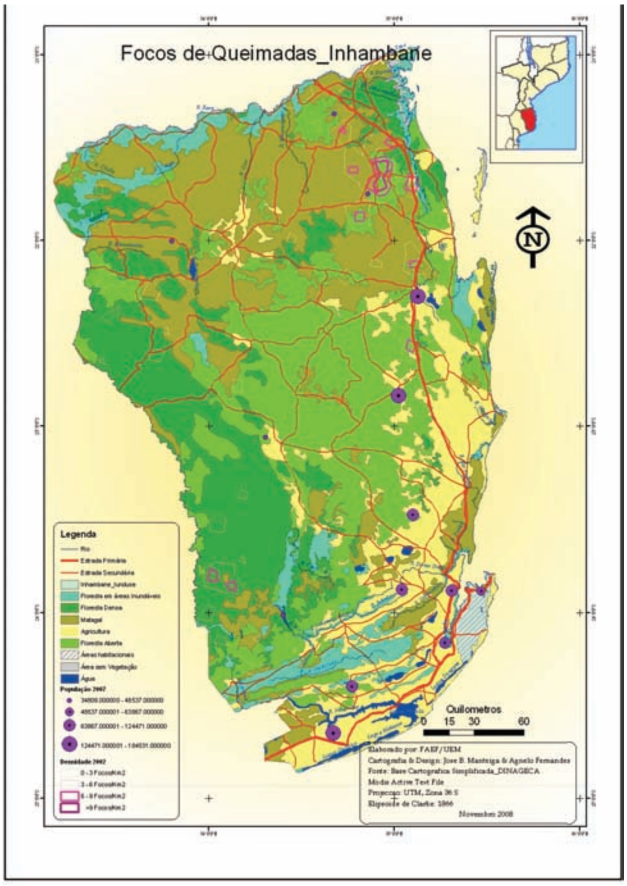


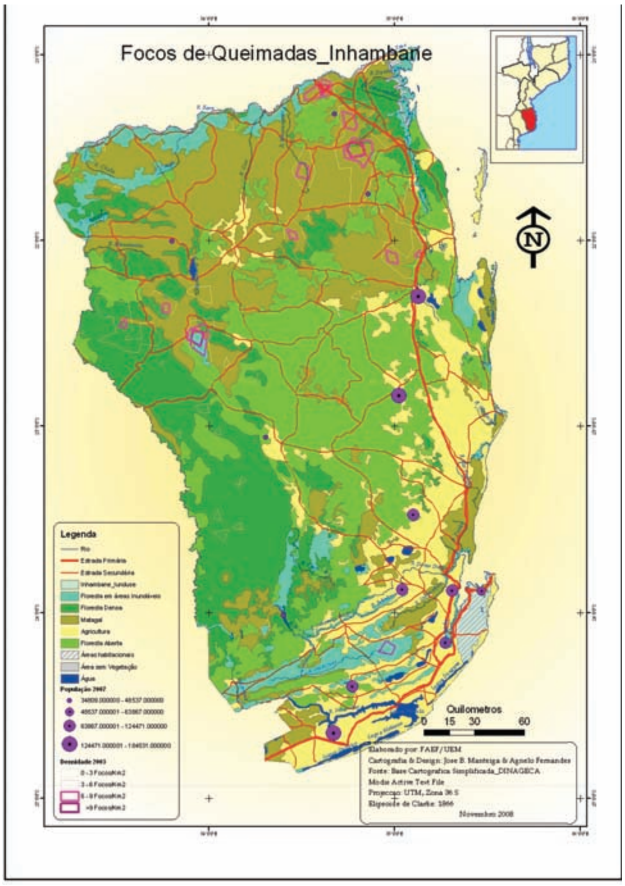

Focos de Queimadas_Sofala
N
Legenda
Sofala_Estrada
Sofala_Rios
Floresta aberta
Agua
Areas habitacionais
Area sem vegetação
Floresta em áreas inundáveis
Floresta densa
Mategal
Agricultura
População 2007
25229.000000 - 75089.000000
75089.000001 - 142387.000000
142387.000001 - 210757.000000
210757.000001 - 436240.000000
Densidade 2006
0- 3 Focos/km2
3- 6 Focos/km2
6- 9 Focos/km2
+9 Focos/km2
Quilometros
0 20 40 80
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

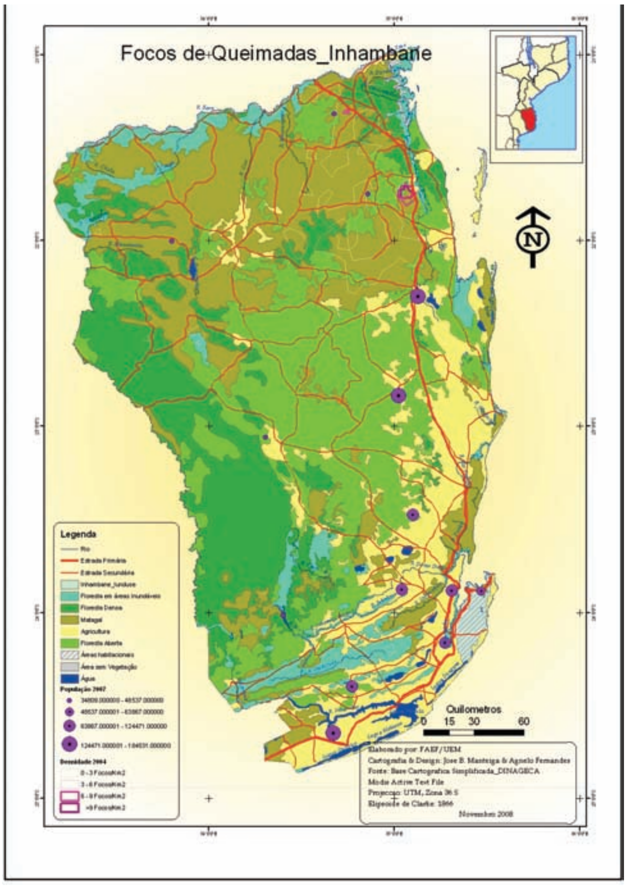

Focos de Queimadas_Sofala
N
Legenda
Sofala_Estrada
Sofala_Rios
Floresta aberta
Agua
Areas habitacionais
Area sem vegetação
Floresta em áreas inundáveis
Floresta densa
Mategal
Agricultura
População 2007
25229.000000 - 75089.000000
75089.000001 - 142387.000000
142387.000001 - 210757.000000
210757.000001 - 436240.000000
Densidade 2007
0- 3 Focos/km2
3- 6 Focos/km2
6- 9 Focos/km2
+9 Focos/km2
Quilometros
0 20 40 80
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Projeccao: UTM, Zona 36 S
Novembro 2008

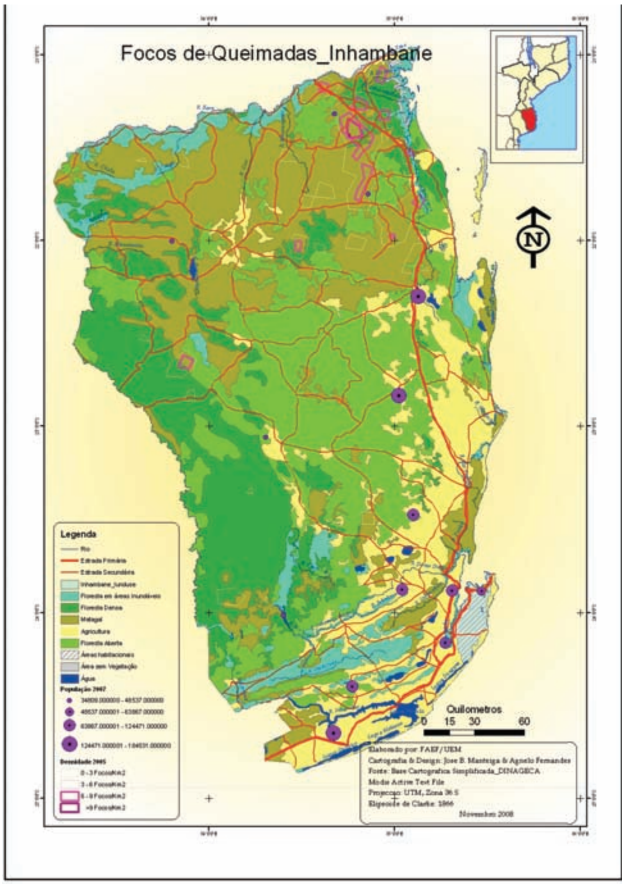
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

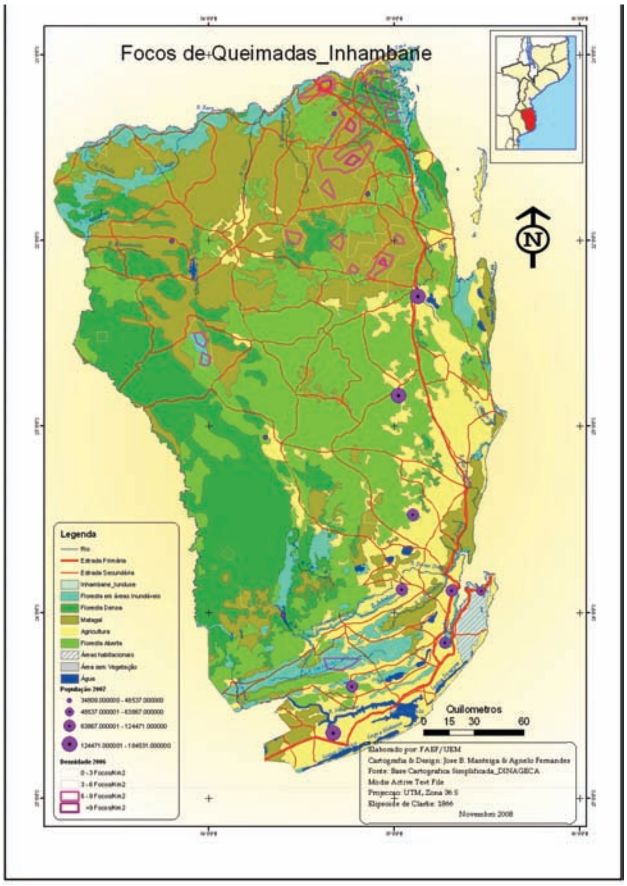
Inhambane

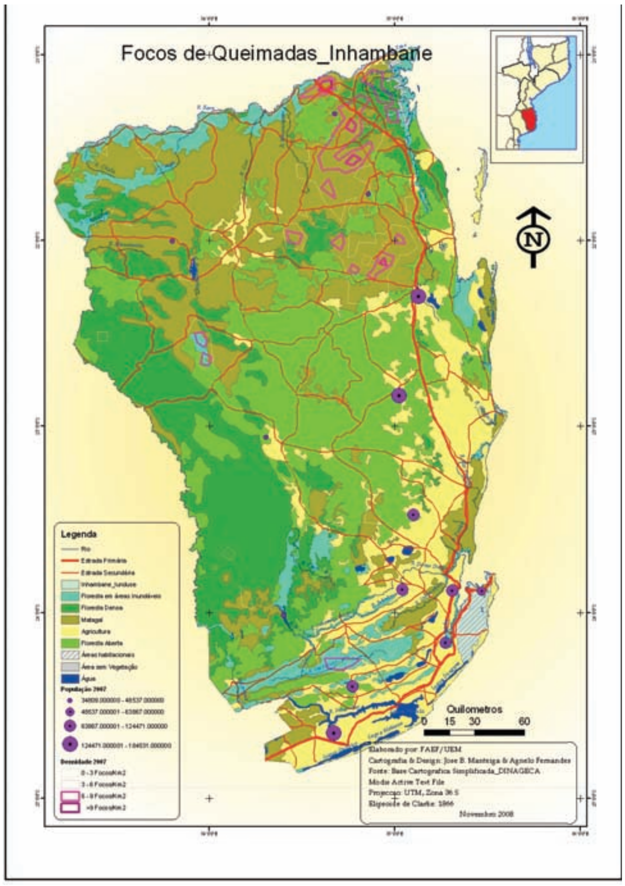






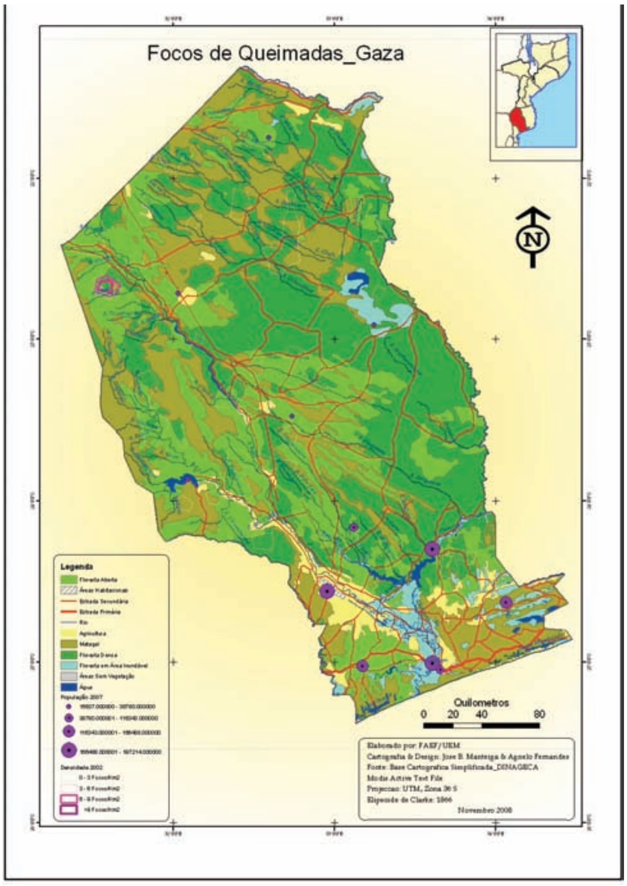


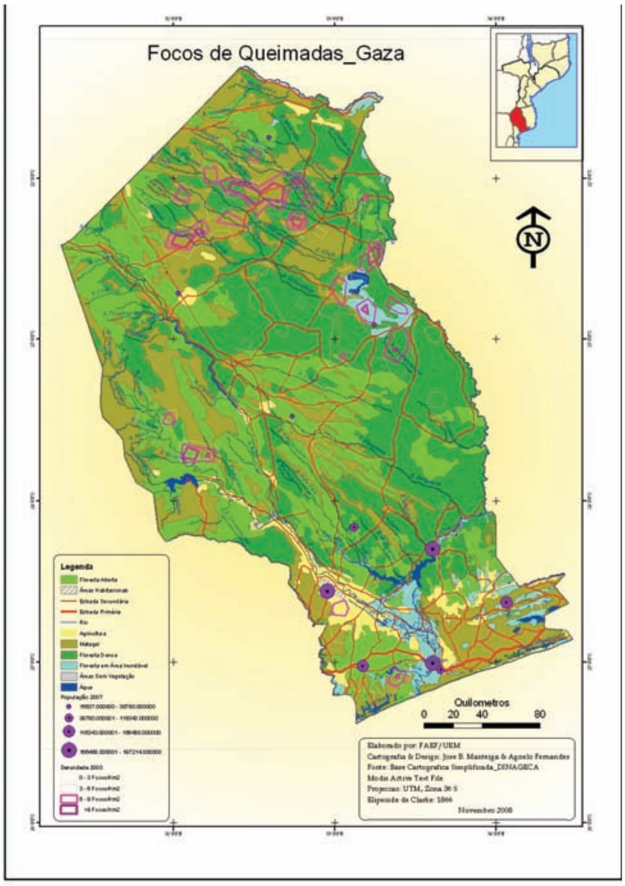

Focos de Queimadas_Inhambane
Legenda
Rio
Estrada Primária
Estrada Secundária
Floresta em Áreas Inundáveis
Floresta Densa
Matagal
Agricultura
Floresta Aberta
Áreas habitacionais
Área sem Vegetação
Água
Quilometros
0 15 30 60
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modo Active Text File
Projecção: UTM, Zona 36 S
Elipsoide de Clarke: 1866
Novembro 2008

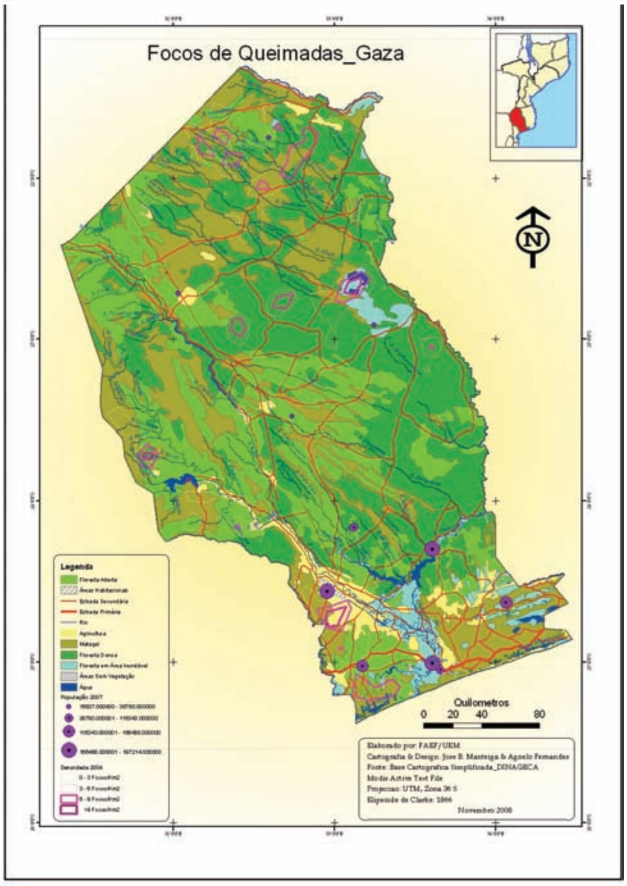

Focos de Queimadas_Inhambane
Legenda
Rio
Estrada Primária
Estrada Secundária
Floresta em Áreas Inundáveis
Floresta Densa
Matagal
Agricultura
Floresta Aberta
Áreas habitacionais
Área sem Vegetação
Água
Quilometros
0 15 30 60
Elaborado por FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modo Active Text File
Projecção: UTM, Zona 36 S
Elipsoide de Clarke: 1866
Novembro 2008

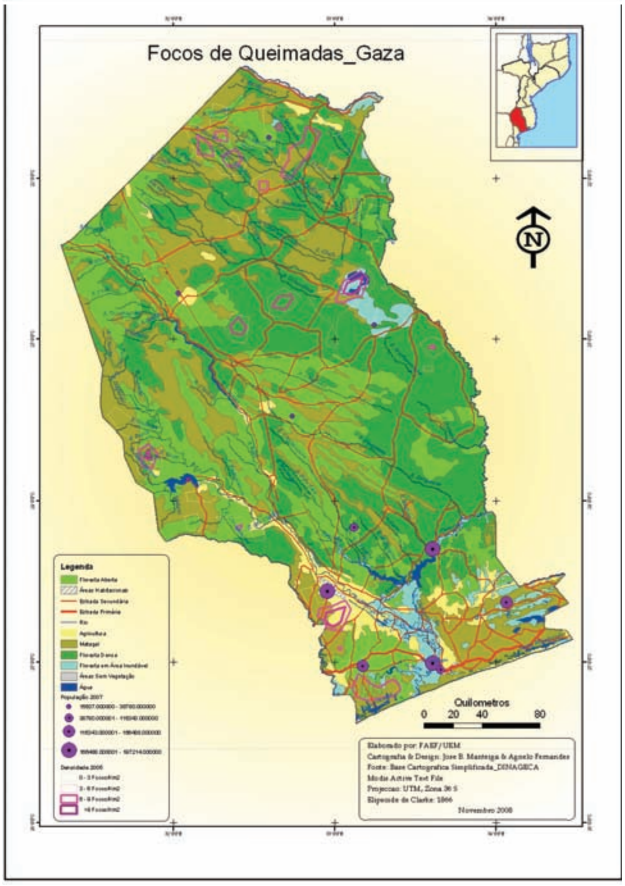
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

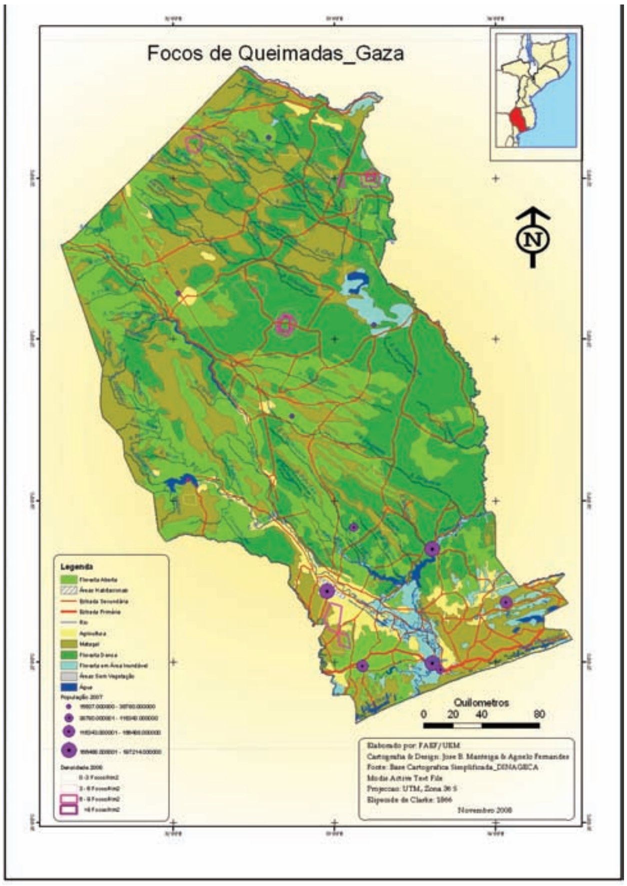
Gaza

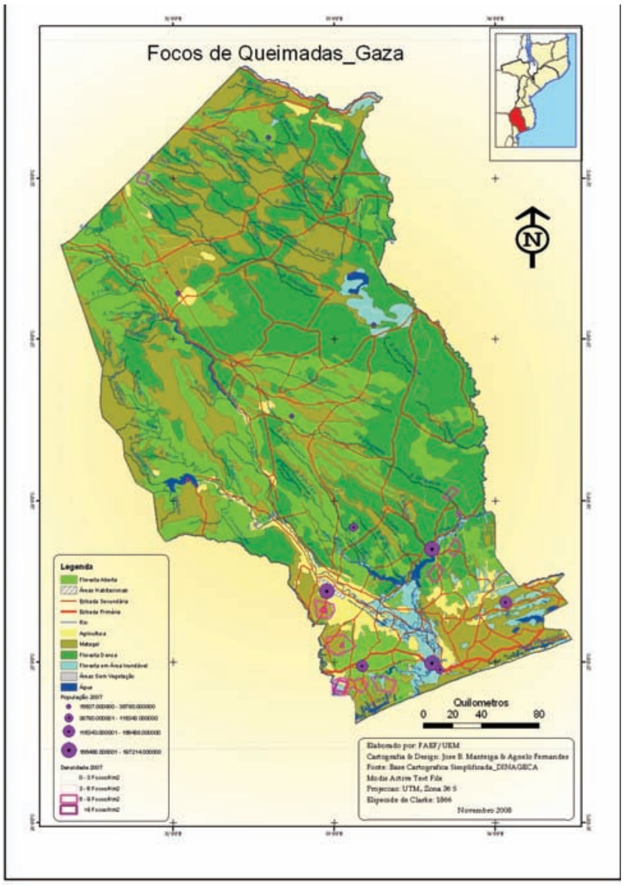






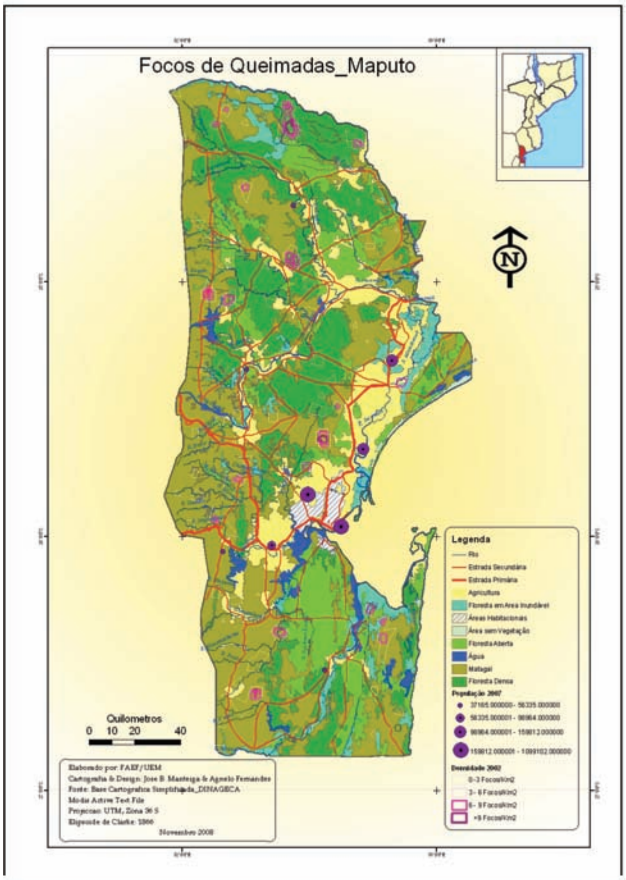


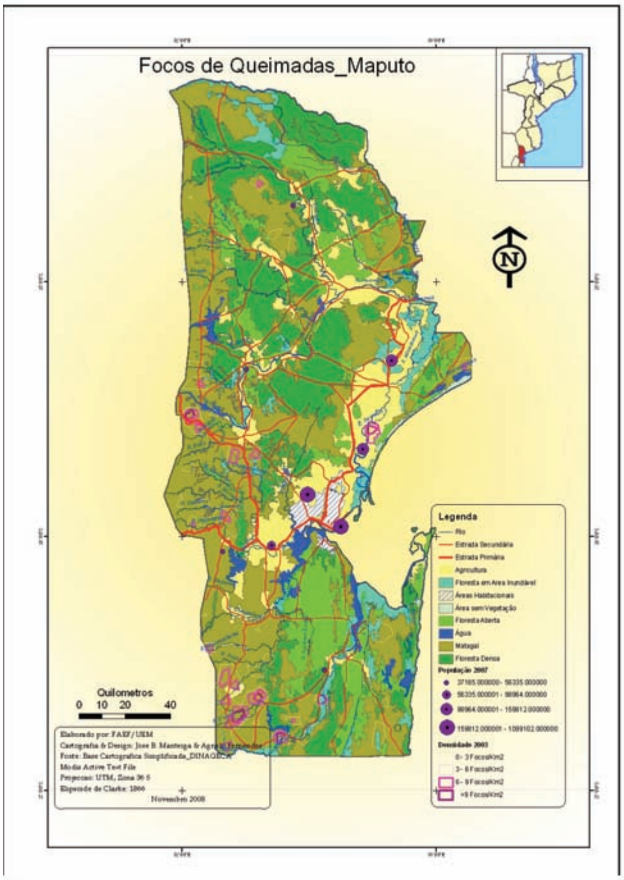

Focos de Queimadas_Gaza
Legenda
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM
Projeccao: UTM, Zona 36 S
Novembro 2008

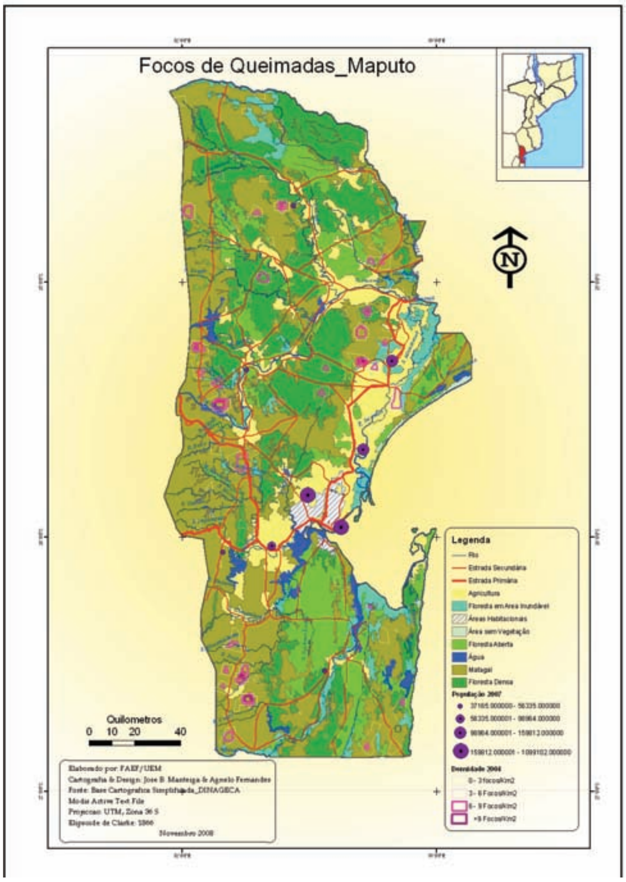

Focos de Queimadas_Gaza
Legenda
Quilometros
0 20 40 80
Elaborado por: FAEF/UEM
Projeccao: UTM, Zona 36 S
Novembro 2008

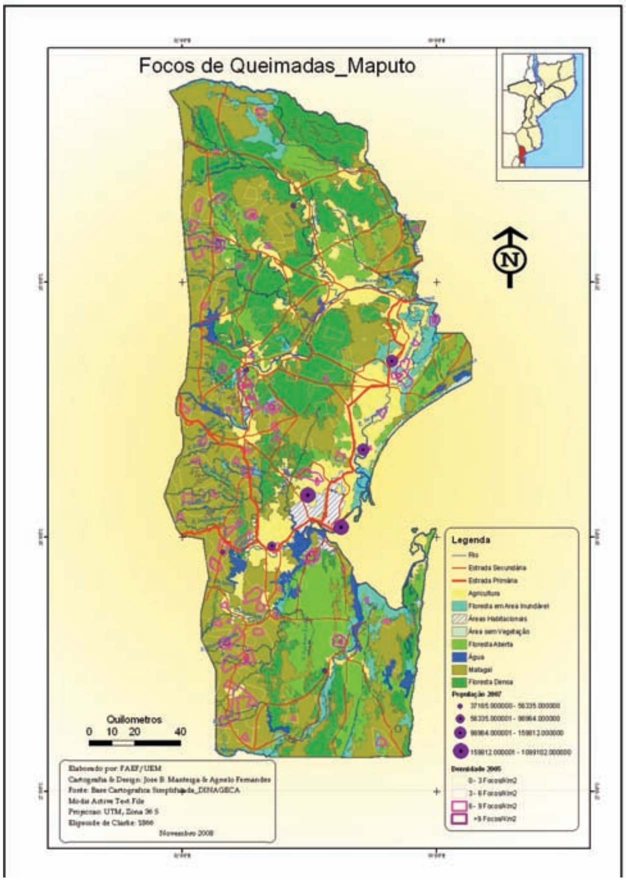
Annex VII: Spatial distribution of vegetation in outbreaks by province (2002-2007)

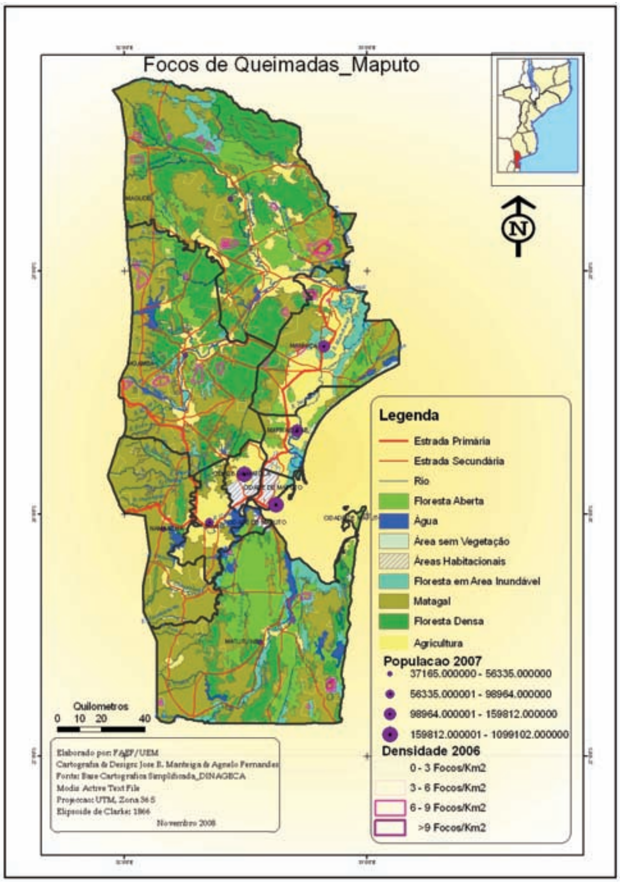
Maputo

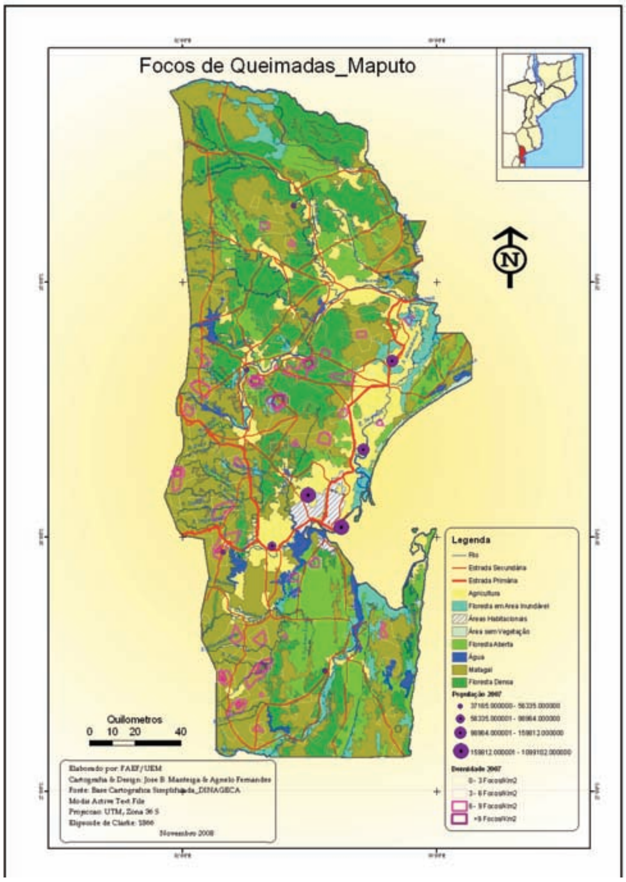









Focos de Queimadas_Maputo
Legenda
Estrada Primária
Estrada Secundária
Rio
Floresta Aberta
Água
Área sem Vegetação
Áreas Habitacionais
Floresta em Area Inundável
Matagal
Floresta Densa
Agricultura
Populacao 2007
37165.000000 - 56335.000000
56335.000001 - 98964.000000
98964.000001 - 159812.000000
159812.000001 - 1099102.000000
Densidade 2006
0 - 3 Focos/Km2
3 - 6 Focos/Km2
6 - 9 Focos/Km2
>9 Focos/Km2
Quilometros
0 10 20 40
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Fonte: Base Cartografica Simplificada_DINAGECA
Modo: Active Text File
Projeccao: UTM, Zona 36 S
Elipsoide de Clarke: 1866
Novembro 2008


Focos de Queimadas_Maputo
Legenda
Rio
Estrada Secundária
Estrada Primária
Agricultura
Floresta em Area Inundável
Áreas Habitacionais
Área sem Vegetação
Floresta Aberta
Água
Matagal
Floresta Densa
Quilometros
0 10 20 40
Elaborado por: FAEF/UEM
Cartografia & Design: Jose B. Manteiga & Agnelo Fernandes
Novembro 2008

Annex VIII: Examples of earlier scenario studies

Global studies

At the global scale, a wealth of scenario studies have been carried out in recent years. The following selection is based on work by Rashkin (2005) who compiled an overview of existing global scenario studies as a background to the Millennium Ecosystem Assessment. Rashkin et al. used five criteria for selecting scenario studies: (1) they should integrate across social, economic and environmental dimensions; (2) key variables should be quantified, (3) they should span a long time horizon; (4) they should be global in scope, but offer regional disaggregation; (5) they should explore multiple futures. Below, five sets of global scenarios that meet these criteria are briefly discussed.

Special Report on Emissions Scenarios

The SRES report (Nakićenović et al. 2000) of the IPCC scenarios covers the main driving forces of human-induced climate change and their implications for energy-related and land-use emissions (http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf). Four basic scenarios are provided, along with numerous variants on the basic set. Six modeling groups estimated greenhouse gas emissions for the scenarios, including the IMAGE team (IMAGE team, 2001) who also provided extension of the quantification to various non-climate issues.

Millennium Ecosystem Assessment

The Scenarios Working Group considered the possible evolution of ecosystem services during the twenty-first century by developing four global scenarios exploring plausible future changes in drivers, ecosystems, ecosystem services, and human well-being (http://www.millenniumassessment.org/en/Scenarios). Three of four detailed scenarios examined by the Scenarios Working Group suggest that significant changes in policies, institutions, and practices can mitigate some but not all of the negative consequences of growing pressures on ecosystems, but the changes required are substantial and are not currently under way.

Global Environment Outlook

The United Nations Environment Programme's third Global Environment Outlook (GEO). The Global Environment Outlook (GEO) project is the implementation of UNEP's mandate to keep the global environment under review. Initiated at the request of the UNEP Governing Council in 1995, GEO is both a process and a series of reports, analyzing environmental change, causes, impacts, and policy responses. The fourth Global Environmental Outlook (http://www.unep.org/geo/geo4/) provides alternative scenarios towards 2050 based on alternative policy priorities (Markets First; Policy First; Security First; Sustainability First).

World Business Council on Sustainable Development

The World Business Council on Sustainable Development (WBCSD; www.wbcsd.ch) has constructed a set of three scenarios to engage the business community in the debate on sustainable development. The focus here is on the scenario narratives, which span a broad spectrum of possible futures. For each of the narratives, the report presents a series of challenges to business and lessons to be drawn. The scenarios were developed in an open process involving representatives from 35 organizations.

World Water Vision

The World Water Vision (WWV) project was conducted by the World Water Council to increase awareness of an impending global water crisis. The WWV presents three global scenarios that focus on issues of water supply and demand in the coming decades, conflict over water resources, and water requirements for nature. The council recognized that the scenarios could illuminate water sutures and provide useful guidance to policy makers only if their scope extended beyond issues specific to water to include lifestyle choices, technology, demographics, and economics.

Regional and national scenario studies

There are a number of regional and national scenarios studies that also meet most of the criteria identified by Raskin (2005), however the timeframe of these studies is all for the coming 25-30 years.

Southern African Millennium Ecosystem Assessment (SAfMA)

SAfMA (http://www.millenniumassessment.org/en/SGA.Safma) is a formal assessment at the sub-global scale, with its own stakeholders and authorizing environment. The assessment was approached as an experiment with studies conducted through assessments at three spatial scales: the entire SADC region, two major river basins (the Gariep and Zambezi), and local communities (Gorongosa-Marromeu in Mozambique, Lesotho, Great Fish River basin, Richtersveld and Gauteng in South Africa). These areas include industrial production systems, urban, agricultural, livestock and forestry production areas, as well as natural vegetation and conservation systems. Assessments were conducted for the period 1960-2000 and two alternative scenarios projected to 2030.

Africa Environmental Outlook

The Africa Environment Outlook (AEO; http://www.grida.no/publications/other/aeo/?src=/aeo/) report provides a comprehensive and integrated analysis of Africa's environment. AEO contains a detailed assessment of the current state of the environment in the region, indicates discernible environmental trends and examines the complex interplay between natural events and the impacts of human actions on the environment. Against this background, the report analyses the effects of environmental change in terms of human vulnerability and security, presents a set of scenarios for Africa's future until 2032 and gives recommendations for concrete policy actions to steer the region, ultimately, towards the most favourable of those scenarios.

Aids in Africa

Aids in Africa: Three scenarios to 2025 (http://www-static.shell.com/static/responsible_energy/downloads/society/aidsinafrica.pdf) provides an in depth analysis of possible future development of HIV/Aids problems in Africa.

Mozambique Agenda 2025

Agenda 2025 was a consultation process towards developing a national vision of how Mozambique could develop over the coming decades. Four explorative scenarios are described, of which one scenario is chosen as the national vision. Most of the project the focused on identifying was to achieve this vision.

Annex IX: Zonation

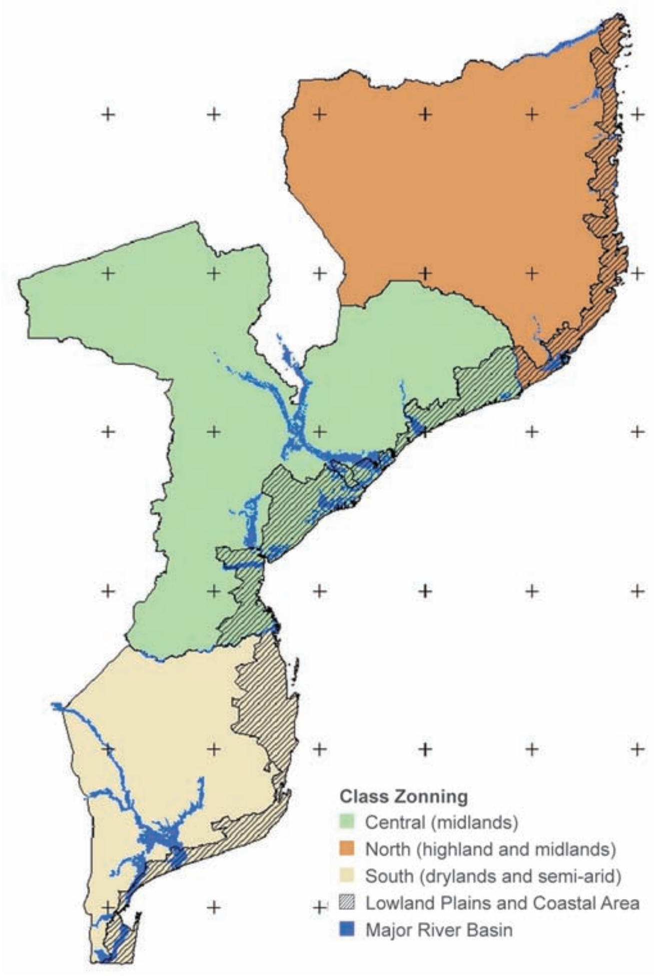
The lowland Plains and Coastal: This class occupies the Indian Ocean coast of Mozambique and the transitional zones between the planalto and coastal areas with less than 200m above sea level. The food system in this area is characterized by combination of fishing, crop production and livestock rearing (in some areas), and high population density. Rainfall is described as good in most years. Bimodal rainfall is observed in most years, drought occurrence is reported in some years. Some locations where there is overlap with river basin suffer flood hazard in better-than-average good year.

Major River Basin: This class occupies the lower elevation of the river valleys of major rivers in the country including the Zambezi-Chire river basin, Lugenda river basin, Lurio river basin, Buzi-Save river basins, and the Limpopo river basin. This area is characterised by good soil fertility, good irrigation potential, suitability for horticultural and food crops, fishing is also important. This is exposed to risks of periodic flooding with the possibility of crop and property damages.

The North (highland and midlands): This class is characterised by high altitude often more than 200m above sea level (MASL); it enjoys better-than-average rainfall distribution, and is suitable for most crops; incidence of crop failure is minimal (drought conditions in extreme years) This area is found in the north region of the country. These include Planato de Maravia, Planalto de Lichinga, and Planalto Mozambicano.

The Central (midlands): Is the medium altitude region of the central part of Mozambique, includes lowlands < 200m, mid altitude areas 200-500m, and sub and planaltic zones 500-1000m a.s.l covering Manica and Sofala provinces. Rainfall ranges in general from 800-1200mm (wet semi-arid and sub-humid climates).

The South (drylands and semi-arid): This area is mainly located in the southern part of the country with rainfall less than 600 mm per year. Rain-fed crop production is susceptible to climatic variability, prone to periods of moisture stress for vigorous plant growth and development, irrigation potential exists but is unlikely to be optimally utilised given the prevailing family sector investment levels and technical capacity. This food system is suitable for large-scale livestock production. Employment income is substantial in this food system particularly remittance income from South Africa. The food system is defined as production-deficit in most years. These areas are mainly found in Maputo, Gaza, part of Inhambane.



Annex X: List of donors activities, projects, programmes and financing in the environment sector

Donor	Project title	Implementing agency	Contact person: Donor	Contact person: "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
1. GENERAL ENVIRONMENT																
1.1 On going financing																
1.1.1 National																
Danida/DDC	Mainstreaming of drought & desertification issues into local level devpmnt policies, strategies & plans	UNDP/MICOA	"DDC: Verity Nyagah"	"UNDP: Pedro Simpson "	$	90,000	90,000	grant	07/2003	06/2008	2003-2008		Provinces & Districts	90 000 $ for 2008	x	
FAO/ Netherlands	Decentral. legal support/capac. build. to promote sustain. dev./ good gov. at local level	CFJJ	NL: Celia Jordão	"FAO: Samiro Magane"	$	3,292,012	3,292,012	grant	02/2005	02/2005	2005-2009	Chris Tanner	national		x	
AECI	Institutional strengthening of DPCAA Cabo Delgado	MICOA/DPCAA Cabo Delgado			€	575,000	793,500	grant	06/2005	06/2005	2005-2008		Cabo Delgado			
Danida	Institutional strengthening of MICOA	MICOA	"Danida: Farida Saifodine"	Nat. Dir. DPE: E. Nhachungue	DKK	30,000,000	5,330,490	grant	11/2005	11/2005	2006-2010	Tom Durang	national, Map., Mani., Namp.		x	
Danida	Natural resources management	Provincial Gov. in Sofala	"Danida: Farida Saifodine"	Direct. DPCAA - Sof.	DKK	23,800,000	4,228,855	grant	11/2005	11/2005	2006-2010	Gaia Allison	Sofala		x	x
Danida	Urban environmental management	Municipalities	"Danida: Farida Saifodine"	Dir. CDS ZU: L. Cumbeza	$	5,330,490	5,330,490	grant	11/2005	11/2005	2006-2010	Johan Boerekamp	7 cities - North Moz.		x	x
Danida	Coastal development	Provincial Gov.	"Danida: Farida Saifodine"	DPCAA Inhamb. & Gaza; CDS ZC	DKK	21,200,000	3,766,879	grant	11/2005	11/2005	2006-2010		Inhambane, Gaza		x	x
Sweden	Technologias de processamento dos recursos naturais para o desenvolv. sustentável	SAREC/UEM			$	1,200,000	1,200,000				2006-2009					
FAO/Norway	National forest programme facility	MINAGRI/ DINATEF	"Norway: Øystein Botillen"		$	100,000	100,000	grant		08/2007	2007-2008		national			
Ireland via UNEP	Poverty environmental initiative phase II	"UNDP/UNEP/ MICOA"	"UNEP Nairobi: L. Sorensen "	"MICOA: E. Nhachungue"	$	2,428,000	2,428,000	grant	07/2008	08/2008	2008-2010	Evaristo Baquete, Baiba Gaile	national, Cabo Delgado, Gaza, Zambezia	includes 3 studies	x	x
AFD	Study on natural capital and sustainable growth in Mozambique	MICOA	AFD: Bruno Leclerc	"MICOA: E. Nhachungue"	€	150,000	207,000	grant		05/2008	2008-2009		national		x	x
France	Capacity building of FUNAB	FUNAB	"France: Odette Rodrigues"	"FUNAB: C. Seventine"	$	50,739	50,739	grant	07/2008	07/2008	2008-2009		national		x	x
UNEP	Africa Environment Information Network	UNEP, MICOA	"UNEP: Chris Ambala"	"MICOA: E. Nhachungue"	$	200,000	200,000	grant			2008-2011		national	80 000 $ per year	x	
DFID	Technical Support to the Ministry of Energy on Biofuels	Ministry of Energy	"DFID: Emidio De Oliveira"		$	671,121	671,121	grant	10/2008	10/2008	2008-2011		national		x	

Donor	Project title	Implementing agency	Contact person: Donor	Contact person: "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
1. GENERAL ENVIRONMENT																
1.1.2 regional																
UNEP	Cap. building progr. for the integration & institutionaliz. of envir. managt into nat. pov. reduc. progr. & related activities	UNEP, MICOA	"UNEP: Esther Mwangi"	"MICOA: Dambuza Chissano "	$	"Total region: 338 000 Total Moz.: na "	"Total region: 338 000 Total Moz.: na "	grant			2004-2008		national	Moz., Rwanda, Tanz. & Uganda	x	
UNEP (GEF), Norway	Addressing land-based activities in the western Indian Ocean	UNEP in coop. with various national institutions	"UNEP: Peter Scheren"		$	"Total region: 11 000 000 Total Moz.: na "	"Total region: 11 000 000 Total Moz.: na "	grant			2005-2009		national, local	8 countries	x	
UNEP (GEF)	Sustain. manag. of Inland wetlands in Southern Africa: a livelihoods & ecosystem approach	UNEP	Mohamed Sessay		$	"Total region: 970 000 Total Moz.: na "	"Total region: 970 000 Total Moz.: na "	grant			2005-2009		national	Southern Africa	x	
UNIDO (GEF)	Reduction of environmental impact from coastal tourism	UNIDO	UNIDO: Chika Ukwe		$	"Total region: Total Moz.: 626 400"	"Total region: Total Moz.: 626 400"	grant			2008-2010		national	8 countries		
1.2 Pipeline of financing																
1.2.1 national																
WB	Supporting the policy dialogue on natural resources, environment and climate change	WB/MICOA with the support of the env WG focal point	"WB Pretoria: JC Carret "	"MICOA DCI: Telma Manjate"	$	"Total region: 200 000 Total Moz.: 50 000"	"Total region: 200 000 Total Moz.: 50 000"	grant	Sep-08		2008-2010		national	non lending technical assistance	x	x
Danida	Urban environmental management	Municipalities	"Danida: Farida Saifodine"		DKK			grant			2008-2011	Johan Boerekamp	13 cities	Austria & Switz. cofinancing		
FAO/Japan	Prevention and disposal of obsolete pesticides in Moz phase 2009-2010	MICOA/DNGA and MINAG/ DNSA			$	1,000,000	1,000,000	grant			2009-2010		national	focus on provincial level		
UNEP/UNIDO/ Others	Consumo e produção sustentável na cidade de Maputo	MICOA/CNPML	"UNEP Nairobi: L. Sorensen "											10 years program		
1.2.2 regional																
UNDP (GEF)	Agulhas & Somali current-marine ecosyst-9 countries	UNDP/MICOA			$	Total region: 12 200 000 Total Moz.:	"Total region: 12 200 000 Total Moz.: "	grant			2008-2013		national			
WB (IDA)	Lake Niassa development project		"WB : Frauke Jungbluth"											Mozambique, Malawi, Tanzanie		

Annex X: List of donors activities, projects, programmes and financing in the environment sector

Donor	Project title	Implementing agency	Contact person: Donor	Contact person: "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
2. CLIMATE CHANGE & ADAPT.																
2.1 Ongoing financing																
2.1.1 national																
GTZ	Strengthening of disaster risk management systems	ARGE IP/INGC	"GTZ: Peter Luhmann"	Wolfgang Stiebens	€	2,850,000	3,933,000	grant			2007-2009		national			
UNDP (GEF)	Coping with drought and climate change	MICOA (DNGA), Gaza Province	UNDP: Michel Matera	MICOA: Iracema Maiopue	$	1,889,840	1,889,840	grant			2007-2011		Guija District Gaza Prov.	Danida indirect funding		
"Delivery as One UN Joint Program"	Strengthening disaster risk reduction and emergency preparedness	UNDP/UN-HABITAT UNICEF/FAO/ WFP IOM/WHO/ UNFPA	"UNDP: Michel Matera"		$	10,000,000	10,000,000	grant	05/2008		2008-2010		national, provincial and local			x
"Spanish MDG Achievement Fund UN Joint Program "	Environmental mainstreaming and adaptation to climate change	"FAO/UNEP/ UNDP UN-HABITAT/ WFP UNIDO MICOA/MINAG/ DPE Gaza"	"UNDP: Isabel Kreisler "		$	7,000,000	7,000,000	grant	03/2008	xxx-07	2008-2011		Limpopo basin & Chicualacuala district - Gaza			x
Danida/GTZ/ UNDP	Impact of climate change on disaster risk and adaptation	INGC	"Danida: F. Saifodin GTZ: W. Stiebens UNDP: M. Matera"	"INGC: Barbara Van Logchem"	$	496,668	496,668	grant	05/2008		2008		national		x	x
Finland/WB	Estudo de viabilidade : plantacoes florestais e sequestro de carbono	Prodeza / INDUFOR	"WB : D. Behr Finland: M.Pekkola"	"Induf.: M. Camargo Prod.: A. Zacarias"	€	53,950	74,451	grant	08/2008	08/2008	2008-2009		Zambézia	53 950 € from Prodeza	x	
2.1.2 regional																
Finland/Spain/ Sweden	Regional clean development mechanism capacity building project for Sub-Saharan Africa - phase 1	"UNDP-UNEP MICOA/ MINERG/ MINAG"		"UNDP: Lolita Hilario"	$	"Total region: 1 530 000 Total Moz.: 72 991"	"Total region: 1 530 000 Total Moz.: 72 992"	grant			2007-2009		national	Ethiop., Kenya, Maurit., Moz., Tanz., Zamb.	x	x
UNEP (GEF), GTZ	Integrating vulnerability & adaptation to CC into sustain. develop. policy planning & implement. in East & Southern Africa	African Centre for Technology Studies (ACTS) , MICOA	UNEP: Lisa Leclerc	"ACTS: W. Stiebens MICOA: T. Manjate"	$	"Total region: 800 000 Total Moz.: na"	"Total region: 800 000 Total Moz.: na"	grant			2007-2010		national	Eastern and Southern Africa	x	
Finland/IUCN	Climate change & developm.: recognizing the role of forest & water resources in cc adaptation	IUCN	Finland: M. Pekkola	"IUCN: Marta Monjane"	€	"Total region: 2 000 000 Total Moz.: 272 548 "	"Total region: 2 760 000 Total Moz.: 376 116"	grant	12/2007	04/2008	2008-2010		national: Gaza, Inhambane, Sofala	3 countries: Moz., Tanzanie, Zambie	x	x

Donor	Project title	Implementing agency	Contact person Donor	Contact person "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
2.1 Ongoing financing																
2.1.2 regional (continued)																
"DFID/ Netherlands/ Switzerland"	Study on the economics of adaptation to climate change	WB	WB: Margulis		$	"Total region: 8 000 000 Total Moz.: 800 000 "	"Total region: 8 000 000 Total Moz.: 800 000 "	grant		04/2008	2008-2009		national	"6 countries G8 study"		x
DFID	RCCP - Regional climate change programme for southern Africa	One World	"DFID: Andrew Mac Lean"	"DFID Pretoria: Pinky Pheeloane"	$	"Total region: 9 800 000 Total Moz.: "	"Total region: 9 800 000 Total. Moz.: "	grant			2008-2011		national	Southern Africa		x
UN-Habitat Global Programme (funded by Norway)	Cities in climate change initiative, sustainable urban development network (Sud-Net)	UN-Habitat Urban Envir. Section	"Norway: Øystein Botillen"	"UN-Habitat: Jaime Comiche"	$	"Total region: 4 400 000 Total Moz.: na"	"Total region: 4 400 000 Total Moz.: na "	grant		04/2008	2008-2011		Maputo	"Kampala, Sorsogon, Esmeraldas, Maputo"	x	x
2.2 Pipeline of financing																
2.2.1 national																
JICA	Research on coastal integrated management system	MICOA	JICA: Ono Kenta	MICOA: T. Manjate	$	150,000	150,000	grant					national		x	
JICA	Reducing impact of climate change (coastal erosion) in Beira city	MICOA	JICA: Ono Kenta	MICOA: T. Manjate	$	5,000,000	5,000,000	grant					Sofala		x	
JICA	Climate change adaptation (equipment provision for water supply and flood management)	MICOA/INGC/ DNA	JICA: Ono Kenta		$	9,000,000	9,000,000	grant					Maputo & Gaza Provinces		x	
	Creation of a common fund for disaster risk management	INGC / CTGC														
"UNDP/Denmark/ Norway"	"INGC Climate Change Project Phase II - Adaptation to CC in Moz."	INGC	"Danida: F. Saifodin UNDP: M. Matera Norway: "	INGC: Barbara Van Logchem				grant			2009		national			
2.2.2 regional																
WB	Malawi and Mozambique: economic vulnerability and disaster risk assessment	WB						grant		04/2009	2008-2009		national	Mozambique, Malawi		x
UNDP/Japan	Africa Adaptation Program - Supporting integrated and comprehensive approaches to CC adaptation	MICOA, INGC, MINEC, Finanças	UNDP: Isabel Kreisler		$	"Total region: 92 200 000 Total Moz.: TBD"	"Total region: 92 200 000 Total Moz.: TBD"	grant								

Annex X: List of donors activities, projects, programmes and financing in the environment sector

Donor	Project title	Implementing agency	Contact person: Donor	Contact person: "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
3. CONSERVATION																
3.1 On going financing																
AFD	Development of the Quirimbas national park	Mitur/DNAC and PN Quirimbas	"AFD: Karen Colin de Verdière"	"DNAC: F. Pariela PNQ: J. Diaz"	€	3,500,000	4,830,000	grant	06/2004	12/2003	2005-2009		Cabo Delgado		x	x
AFD (french GEF)	Development of the Quirimbas national park	Mitur/DNAC and PN Quirimbas	"AFD: Karen Colin de Verdière"	"DNAC: F. Pariela PNQ: J. Diaz"	€	700,000	966,000	grant	06/2004	03/2004	2005-2009		Cabo Delgado		x	x
KfW/PPF	Transfrontier Conservation Area - Limpopo National Park - Phase II	MITUR/ Peace Parks Foundation (PPF)	KfW: Ralph Kadel	MITUR/DNAC: Bartolomeo Soto	€	5,800,000	8,004,000	grant	05/2005	05/2005	2005-2009		Gaza Province		x	
GTZ	Sustainable Forest Management and Conservation 2006-2008	GTZ/Mitur/ DNAC-MINAG/ DNTF			€	1,400,000	1,932,000	grant	09/2006	12/2005	2006-2008		Gaza Province			
WB (IDA)	TFCA TDP (transfrontier conserv. areas, tourism development project)	Mitur/DNAC	WB: Aniceto Bila		SDR	15,000,000	20,000,000	credit	04/2006	12/2005	2006-2011					
WB (GEF)	TFCA TDP (transfrontier conserv. areas, tourism development project)	Mitur/DNAC	WB: Aniceto Bila		$	10,000,000	10,000,000	grant	05/2006	12/2005	2006-2013					
WB (PHRD)	TFCA TDP (transfrontier conserv. areas, tourism development project)	Mitur/DNAC	WB: Aniceto Bila		$	3,700,000	3,700,000	grant	06/2006	12/2005	2006-2013					
AFD	Development of the Limpopo national park	Mitur/DNAC and PN Limpopo	"AFD: Karen Colin de Verdière"	"DNAC: F. Pariela PNL: B. Chande"	€	11,000,000	15,180,000	grant	04/2007	11/2006	2007-2011		Gaza		x	x
AFD/KfW/WWF	Preparation of a trust fund for conservation areas	Mitur/DNAC	AFD: Bruno Leclerc	WWF: Helena Motta	$	172,000	172,000	grant			2007-2009			"AFD: 84 000 KfW: 42 000 WWF: 46 000"	x	x
Italy	Sustainable livelihoods & nat. res. manag. in protect. & multiple use Areas	IUCN Italy/ MITUR	"Italy: Mario Angaroni"	"IUCN: Marta Monjane"	€	2,768,108	3,819,989	grant	11/2006	07/2003	2007-2010		Gaza Province		x	
3.2 Pipeline of financing																
Italy	Community manag. & conservation of nat. Res. in Gilé and Pebane Districts	"DPT Zambezia COSV"	"Italy: Mario Angaroni"	"COVE: Ettore Cerchia"	€	890,881	1,229,416	grant			2008-2011		Zambezia		x	x
AFD (french GEF)	Support to Gile reserve	Mitur/DNAC/IGF	"AFD: Karen Colin de Verdière"	IGF	€	1,000,000	1,380,000	grant			2009-2012				x	x
FAO/WB (GEF)	Payment for ecossystem services to support forest conservation & sustainable livelihoods	MINAG/MITUR	"FAO: Samiro Magane"		$	5,151,000	5,151,000	grant			2009-2014					
UNDP (GEF)/ Others	Strenghtening management effectiveness of protected area system in Mozambique	Mitur/DNAC	"UNDP: Fabiana Isser"		$	19,800,000	19,800,000	grant			2009-2014		national			x
KfW/PPF	Transfrontier Conservation Area - Limpopo National Park - Phase III	MITUR/ Peace Parks Foundation (PPF)	"KfW: Ralph Kadel"	MITUR/DNAC: Bartolomeo Soto	€	10,000,000	13,800,000	grant			2009-2012		Gaza			
GTZ	Sustainable Forest Management and Conservation		"GTZ: Wipke Thies"		€	2,500,000	3,450,000	grant								

Donor	Project title	Implementing agency	Contact person Donor	Contact person "Implem. ag."	Curr.	Amount in currency	"Amount in dollars 1€ = 1,38$"	Type of funds	Date of signat.	Date of approv	Duration	TA*	Location	Comments	"Valid. by the donor"	"Proj. doc. avail."
4- Ongoing fundings to NGOs																
EU	Regional scaling up benefits for rural areas population	Africa Wildlife Foundation			€	"Total region: 2 499 999 Total Moz.: "	"Total region: 3 449 999 Total Moz.: "	grant	12/2004		2004-2009			4 countries: Moz., Bots., Zambie, Zimba.		
EU	Segurança posse terra e desenv. sustent Sul Sofala	HILFSWERK AUSTRIA	EU: Ana Monge		€	662,020	913,588	grant	12/2005		2005-2010		Sofala			
EU	Programa trienal para assegurar a posse terra e RN	NOVIB	EU: Ana Monge		€	1,500,000	2,070,000	grant	12/2005		2005-2008		Zambézia			
EU	Farmer club for forests - promoting sustain. NRM	ADPP	EU: Ana Monge		€	298,976	412,587	grant	03/2007		2007-2009		Quirimbas Park			
"DFID, Netherlands, Danish Embassy, SIDA, SDC"	Community Land Use Fund (iTC)	KPMG - Fund Manager	"DFID: Emidio De Oliveira"	"KPMG: Joachim Langa "	$	7,000,000	7,000,000	grant	11/2005	11/2005	2005-2010		Gaza, Manica, Cabo Degado		x	
Italy	Improv. of the socio-eco. cond. of the poorest rural pop. in Marracuene district	"CESVI (Italy) FNP (Forum para a Natureza em Perigo)"	"Italy: Mario Angaroni"	"CESVI: Leone Tarabusi"	€	836,326	1,154,130	grant		02/2007	2008-2010		Maputo Province, Marracuene		x	
Italy	Socio-eco. develop. through sustainable tourism in Inhambane Province	DPT Inhambane/ CELIM & LVIA (Italy)	"Italy: Mario Angaroni"	Celim: Luca Chionni LVI: Katia Ferrari	€	1,264,408	1,744,883	grant		07/2007	2008-2010		Inhambane		x	
ALL - Completed financing																
WB (IDA)	Coastal zone	Micoa			SDR	4,200,000	5,600,000	credit	10/1999	01/2000	2001-2007		north			
WB (GEF)	Coastal zone	Micoa			$	4,100,000	4,100,000	grant	10/1999	01/2000	2001-2007		north			
UNDP	Adaptation Programme of Action (NAPA)	MICOA			$	200,000	200,000	grant		06/2003	2003-2007					
FAO	Support for community forestry and wildlife management	MINAGRI/ DINATEF			$	900,722	900,722	grant	08/2003	08/2003	2003-2007		national			
EU	"Miombo Comunity Land Use Carbon Manag-N'hambita"	University of Edinburg	EU: Ana Monge		€	1,587,232	2,190,380	grant	07/2003		2003-2008		Sof.-Gorong. Buffer zone	climate related		
Italy	National/provincial forestry inventories in the context of PISA/PIDA - Integrated Progr. for Agricult. Dev.	MINAG			€	2,500,000	3,125,000	grant	04/2002	07/2002	2004-2007		national	In ODAMOZ - PIDA - AID 7271		
FAO/Japan	Prevention and Disposal of Obsolete Pesticides in Moz phase 2005-2008	MICOA/DNGA and MINAG/ DNSA			$	2,552,870	2,552,870	grant	02/2005		2005-2008		national	next phase: 2009-10 under preparation		
FAO	Support to the Development of a Territorial Planning Policy and New Legislation - Phase II	MICOA/ DINAPOT			$	129,200	129,200	grant	06/2005	06/2005	2005-2007		national			
France	Environmental awareness	Rádio Moçambique			€	31,000	38,750	grant	09/2006	09/2006	2006-2007		Inhambane			
FAO/Netherlands	FAO-NETHERLAND Partnership programme - FNPP Forestry	Central Gov. (MPD & MITUR) and Gaza Gov			$	100,000	100,000	grant			2006-2007		Gaza			

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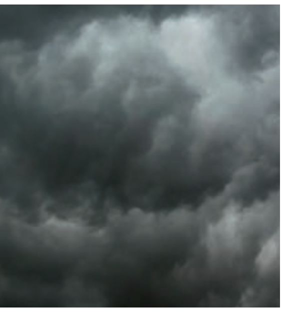

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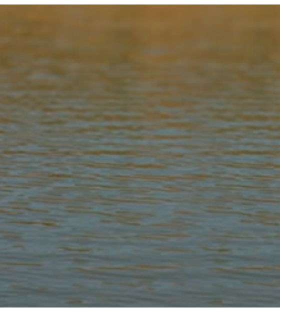

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