Final Report

Urban Poverty & Climate Change in Dar es Salaam, Tanzania:

A Case Study

Prepared/contributed to by:

Pan-African START Secretariat
International START Secretariat
Tanzania Meteorological Agency
Ardhi University, Tanzania

March 10, 2011

Table of contents

List of Figures

List of Tables

List of Boxes

List of Photos

Average exchange rate between July 15, 2010 and December 15, 2010:

United States Dollar (US$) 1 = Tanzanian Shilling (Tsh) 1418.90

Acronyms & Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
AF	Adaptation Fund
CBO	Community-Based Organization
CCLM	Consortium for Small scale Modeling – ClimateLimited-areaModelling
CDM	Clean Development Mechanism
CDO	Community Development Organization
CIUP	City Infrastructural Upgrading Programme
CLACC	Capacity strengthening of Least developed countries for Adaptation to Climate Change
CTF	Clean Technology Fund
DAWASA	Dar es Salaam Water and Sewage Authority
DEM	Digital Elevation Model
DSM	Dar es Salaam
EIA	Environmental Impact Assessment
ENSO	El-Nino Southern Oscillation
FCPF	Forest Carbon Partnership Facility
FIP	Forest Investment Program
GCCA	Global Climate Change Alliance
GEEREF	Global Energy Efficiency and Renewable Energy Fund
GEF	Global Environment Fund
GHG	Greenhouse Gas
HIV	Human Immunodeficiency Virus
ICI	International Climate Initiative
IFPRI	International Food Policy Research Institute
IIED	International Institute for Environment and Development
ILO	International Labor Organization
IPCC	Intergovernmental Panel on Climate Change
IRA-UDSM	Institute of Resource Assessment – University of Dar es Salaam
ITCZ	Inter Tropical Convergence Zone
ITN	Insecticide Treated Net
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
KICAMP	Kinondoni Integrated Coastal Area Management Project
LDCF	Least Developed Countries Fund
LGDG	Local Government Development Grant
LGSP	Local Government Support Project
LLITN	Long-Lasting Insecticide Treated Net
MEVT	Ministry of Education and Vocational Training
MUM	Mfuko wa Usafi wa Mazingira
NAPA	National Adaptation Programme of Action
NEMA	National Environmental Management Act
NEMC	National Management Council
NGO	Non-Governmental Organization
NHIF	National Health Insurance Fund

NLFEP	National Lymphatic Filariasis Elimination Programme
NSSCP	Schistosomiasis and Soil-transmitted Helminthes Control Programme
NTD	Neglected Tropical Disease
PMI	President Malaria Initiative
PMORALG	Prime Minister's Office, Regional Administration & Local Government (also abbreviated TAMISEMI)
PRB	Population Reference Bureau
PRECIS	Providing Regional Climates for Impact Studies
REDD	Reducing Emissions through Deforestation and forest Degradation
SACOS	Saving and Credit Societies
SCCF	Special Climate Change Fund
SCF	Strategic Climate Fund
SPA	Strategic Priority on Adaptation
SUDP	Strategic Urban Development Plan
TAMISEMI	See PMORALG, above
THIS	Tanzania HIV/AIDS Indicator Survey
TMA	Tanzania Meteorological Agency
UCLAS	University College of Lands and Architectural Studies
UNAIDS	United Nations Programme on HIV/AIDS
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nation Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
UNV	United Nations Volunteers
URASU	Uchoraji na Ramani na Sanaa Shirikishi Dhidi ya Ukimwi
URT	United Republic of Tanzania
WBG	World Bank Group
WBI	World Bank Institute
WHO	World Health Organization
WMO	World Meteorological Organization
WWF	World Wildlife Fund

List of Local Terms

Daladalas	Minibuses and minivans
Masika	Long rains
Mtaa	Sub-ward
Vuli	Short rains

EXECUTIVE SUMMARY

This study seeks to understand key aspects of vulnerability of the urban poor in Dar es Salaam, Tanzania, how climate impacts upon this vulnerability, and to determine how forward-looking policies and programs can be developed that reduce the vulnerability of the poor, taking both current and expected future climate into account. Over 70 percent of the city's four million residents live in informal, unplanned settlements that lack adequate infrastructure and services, and over half of them survive on roughly a dollar per day. With a population growth rate of about 8 percent per year, Dar es Salaam is one of the fastest-growing cities in sub-Saharan Africa. City and municipal authorities face significant challenges with respect to providing new or even maintaining existing infrastructure and services.

Vulnerability to current climate

Detailed information on existing vulnerability to climate variability among poor residents of informal settlements was obtained through (i) review of existing literature, (ii) surveys involving over 500 households, (iii) community focus group discussions, and (iv) in-person visits with Government, non-government and community development organization officials. The surveys were implemented in high flood-risk areas, with a few not-at-risk areas included for the sake of comparison.

Vulnerability to climate variability is high in the informal settlements. Flooding is frequent, and is a result of both heavy or prolonged rainfall and a range of non-climatic factors such as overcrowding, dumping of sewage and solid waste into rivers and channels, and blockage of storm drains with garbage or illegal construction. Apart from damage to property, factors such as inadequate or absent supply of clean water, poor sanitation provisions, widespread use of pit latrines that overflow easily, and unhygienic practices render many residents of these settlements vulnerable to disease, particularly following flooding. Residents of these settlements are prone to malaria, lymphatic filariasis, cholera, dengue fever and diarrhea, among other diseases. Dar es Salaam experiences drought, too, which also tends to increase disease incidence, as clean water becomes scarcer. Drought also has adverse implications for electric power generation in the city, as hydropower is an important energy source. Floods, drought, and other climatic factors (humidity, high temperatures) have an impact on the livelihoods of the poor, many of whom are employed by the informal sector and are street vendors.

Analysis of climatic trends over the past four decades indicates rising maximum and minimum temperature trends in Dar es Salaam. Precipitation trends are less clear, and appear to indicate a declining number of rain days per year along with high variability. Rainfall intensity is expected to increase. Sea level rise would result in increased coastal degradation and higher storm surges, which would exacerbate flooding. Several of Dar es Salaam's major floods over the past three decades appear to be linked to El Nino events.

Impacts of climate change on Dar es Salaam's urban poor

A flood modeling exercise was undertaken using a digital elevation model and a hydrodynamic model to estimate how climate change is likely to alter flood spatial extent

over coming decades in Dar es Salaam's unplanned settlements. The maps included in this report show inundation corresponding to floods of differing return periods.

Reductions in annual mean rainfall in coming years could also lead to more droughts in parts of Tanzania, which would adversely affect food and water security and have profound indirect impacts, e.g., reduction in electricity provision for the city's poor, and increased disease incidence. Specific projections on drought for Dar es Salaam are not available, however.

Policies and programs with potential to increase resilience to climate change

The city's poor are currently unable to cope adequately with existing climatic variability, and rapid urban growth compounds the current situation. Climate change, including the increased variability of climate that it will bring, is likely to greatly aggravate vulnerability.

Against this backdrop, this study has identified examples of current policies and programs for the city that serve to both address current vulnerability and promote adaptation to climate change. Two programs, the Community Infrastructural Upgrading Program (CIUP) and the Strategic Urban Development Plan (SUDP), have both been targeting infrastructure improvements in poor areas of the city and seek to nurture community-based initiatives. Such initiatives need to be supported and expanded and, importantly, their benefits sustained.

Tanzania has ratified the United Nations Framework Convention on Climate Change, and has prepared a National Adaptation Programme of Action in which urgent adaptation needs have been identified. Adaptation projects have been initiated in Dar es Salaam in response to needs identified in the NAPA. These primarily focus on coastal area protection and afforestation/reforestation.

Reducing urban greenhouse gas emissions while generating local benefits

The study produced household surveys that inquired into fuel use among urban poor households. Charcoal, a woodfuel and cheaper than alternative sources, was the predominant source; Dar es Salaam consumes about 50 percent of the charcoal consumed by the country, with an estimated 94 percent of its households using charcoal, either on its own or in combination with other fuels. Its widespread use in congested, overcrowded neighborhoods that often have poor ventilation has adverse implications for the respiratory health of residents of these neighborhoods in addition to contributing greenhouse gas emissions. Programs that lead to increased use of alternative fuels (and less charcoal) would not only serve a global cause but would improve resident health and lower deforestation rates in the country. Regarding the latter, Tanzania is exploring options for participation in REDD programs.

Tanzania has engaged in a CDM project that involved gas flaring reduction at a waste dumpsite. Follow-up has been proposed to this project that, in addition to reducing greenhouse gas emissions, will involve city departments in efforts to create programs in waste recycling, distribution of compost and fertilizer, city greening, construction of embankments, and provisions for waste collection, storage and treatment. If funded, this

program will also comprise enforcement measures such as a “polluter pays” policy on industry and control of illegal dumping and unsanitary practices among community residents.

Looking forward

The first step towards helping the urban poor adapt to climate change in Dar es Salaam is to address areas that contribute to current vulnerability. This requires improving the quality of life of poor residents by providing them with basic services such as clean water, improved stormwater drainage, sanitation facilities, and better healthcare. Efforts made in this direction will reduce both current and expected future vulnerability to climatic variability and change.

At the city level, adaptation to climate change requires planning at longer-term timescales, particularly where it comes to physical investments that have long lifespans (many infrastructure investments are of this nature). For example, given indications that rainfall variability is increasing and rainfall may become heavier during individual episodes, stormwater drainage systems currently being constructed or repaired should be designed with added flexibility built in. The Dar es Salaam City Council and Municipal Council departments should bear in mind, when laying out infrastructure provisions for the informal settlements, that climatic trends and variability are changing, and will affect investments in the long term, both directly and indirectly.

A series of in-depth case studies should be conducted by research and policy communities in Dar es Salaam, in partnership with relevant regional and international actors, to examine municipal program needs given expected changes in climate for the city. Capacity building is needed at several levels, including in the city’s hydrometeorological departments, to improve forecasting and early warning abilities.

Education and training of poor communities on the links between inappropriate waste disposal practices and disease incidence, the benefits of switching to improved toilet facilities, and on hygiene and the need to boil drinking water, have immense potential in improving resident health in informal settlements in general, and particularly during times of flood and drought.

A relatively low-cost and yet potentially highly effective means of building resilience among the urban poor would be through enforcing oft-ignored laws and regulations that are already in place relating to waste disposal and illegal construction.

1 Introduction

1.1 Background to the Mayors Task Force case studies on climate change and urban poverty

This case study on climate change and urban poverty in Dar es Salaam is part of a multi-city effort that is rooted in the work program of the Mayors Task Force on Urban Poverty. The Task Force was established in January 2010 at the Global Dialogue for Mayors, at which mayors from Dar es Salaam, Jakarta, Mexico City and São Paolo, together with a global city network, decided upon the main elements of the Task Force's proposed work program. The World Bank Group is supporting the following elements of this work:

- Take stock of our understanding of the linkages between urban poverty and climate change;
- Identify good practice examples where shelter and services for the urban poor have been improved and have resulted in reducing the vulnerability to climate change and where carbon emissions have been reduced; and
- Propose policy and investment programs and municipal management improvements that benefit the urban poor and scale-up good practices.

In April 2010, the WBG and the Mayor's Task Force agreed to carry out four city case studies: Dar es Salaam, Jakarta, Mexico City and São Paulo. Given the close relationship between climate change adaptation and hazard management policies and programs, a strong focus of the case studies is examination of disaster risk management issues in the urban context.

The audience for this work includes mayors and city managers, national governments, donors, and practitioners in the fields of climate change, disaster risk management and urban development.

The case studies follow a common methodology drawing on the framework for Urban Risk Assessment (developed under a global study as part of the Task Force initiative), yet they will also have the flexibility to incorporate local contextual factors. Active participation of local experts and organizations is envisioned as an essential ingredient in the development of the case studies.

1.2 Climate change and cities: causes for concern

Cities are particularly vulnerable to the impacts of natural hazards due to their high concentration of people, infrastructure and economic assets. As many cities are located near the coast or along rivers and drainage lines, extreme climatic events such as windstorms and heavy rainfall can cause tidal surges and floods that have large impact on life and property. Climate change is likely to exacerbate risks. Sea level rise would result in larger storm surges (and flooding), coastal encroachment and salt-water intrusion. Increased climate variability would translate into possibly more frequent and/or severe storms, rain and drought.

Within cities, the impacts of climatic hazards are distributed unevenly among urban populations; generally speaking, lower-income communities tend to live in marginalized lands that face greater risk. Their capacity to respond is also lower; poorer residents tend to have less access to information, scant resources to withstand adverse impacts, and fewer safety nets. With little assurance that their homes and belongings will be safe in the case of evacuation, they can be reluctant leave them.

Apart from their vulnerability, the urban poor are important stakeholders for greenhouse gas (GHG) emission reduction strategies given that (i) they often suffer from the effects of poor air and water quality and will thus directly benefit from actions that improve local environmental quality; and (ii) as their living standards improve and as the city continues to grow, GHG emissions have the potential to rise markedly, even though they may be very low at present.

Many developing-country cities experience climatic hazards, yet most governments lack the financial and technical capacity to adequately address the risks. Understanding the factors that contribute to vulnerability to climatic and other risks, and the ways in which they can impede development at present and in the longrun, are essential in identifying lines of action for adaptation to climate change. This case study investigates how climatic factors feed into urban vulnerability in Dar es Salaam, Tanzania, and offers a preliminary identification of measures that can help reduce vulnerability to climate variability and change. Much follow on work will be needed, particularly involving a closer look at the water supply, sanitation and drainage, and health sectors.

1.3 Dar es Salaam: climatic hazards and urban poverty

Dar es Salaam is a city where urban poverty and climate variability – floods as well as drought - jointly create a situation of high vulnerability for the poor that affects crucial aspects of their lives, e.g., health, sanitation and access to clean water, and safety of housing and property.

Tanzania's largest city, with over 4 million inhabitants, Dar es Salaam is characterized by urban sprawl and expanding informal settlements, resulting from increasing population pressure, poor infrastructure and inadequate town planning. About 70 percent of the city's population lives in poor, unplanned settlements, of which 50 percent lives on an average income of about US$1 per day. Residents are usually too poor to pay for services or infrastructure, and health and environmental conditions are generally extremely poor.

Heavy rainfall frequently causes flooding in the city, particularly in unplanned settlements, which tend to be located in high-risk flood areas. Apart from the loss of property that floods often bring, and occasional loss of life, heavy rains pose widespread health risks for poor residents by causing pit latrines to overflow due to the high water table, and sewers and drains to overflow due to improper waste disposal practices. This creates breeding grounds for disease vectors and contaminates wells and springs so that

water is unsafe for household use. Malaria, lymphatic filariasis, and diarrhea are common in unplanned settlements, and other diseases are also found.

Tanzania – and Dar es Salaam – also experiences droughts; a particularly severe episode occurred in 2006. Drought affects the city's poor by reducing the availability of clean water, and causing food scarcity and higher food prices. This leads to disease and malnutrition. Also, the city's electricity generation is heavily dependent on hydropower, and electricity cuts during times of drought adversely affect the poor's wellbeing directly (domestic electricity use) and by affecting livelihood-generating activities.

An important projected aspect of climate change is an increase in climatic variability, which would result in more frequent and/or severe floods and droughts in the city. Given that the city's poor are unable to cope adequately with current variability, their situation is likely to worsen in the future, unless steps are taken to ensure that urban development and poverty reduction programs specifically take into account the prospect of changing climatic conditions. Infrastructure development programs and urban planning schemes, municipal services provision, and poverty reduction programs (including safety nets and health services) need to not only better integrate disaster risk management approaches, but also to consider that the trends are changing.

Average temperatures in Dar es Salaam have risen over the past few decades (mean maximum and mean minimum) and are projected to rise over coming years. Combined with heavier rainfall, this may raise humidity levels, with implications for health and environmental conditions in unplanned settlements.

Various initiatives have been taken over the past several decades to address the challenges posed to urban development in Dar es Salaam, but many of these have failed due to poor leadership, lack of a long-term approach, weak institutional capacity, absence of enforcement of laws and regulations, the very high rate of urban growth, and resource constraints.

This case study aims at providing an overview of the main issues, and is a first step towards identifying institutional constraints and good practice examples that can be built upon. It aims at providing policy recommendations and suggesting areas where detailed follow-up work is needed.

Seventy percent of Dar es Salaam's population lives in unplanned settlements, and over half of them live on an average income of $1 a day. These settlements lack adequate infrastructure and services, and are highly prone to adverse impacts of frequent flooding. Poor solid waste disposal and sanitation practices, combined with rainfall, result in contamination of water and spread of disease. Climate change will exacerbate these issues in the absence of sound, forward-looking planning measures.

1.4 Study methodology

Study Partners

This case study is a joint effort involving the following partners:

- *Institute of Resource Assessment, at University of Dar es Salaam*: background research and review of literature, interviews of households and institutional representatives, and on-site visits to flood-prone areas, report-writing
- *Ardhi University*: 2-dimensional flood modeling
- *Tanzania Meteorological Agency (TMA)*: provision of data on current climatic trends for Dar es Salaam, and projected future climate
- *International START Secretariat:* editing, coordination, report-writing
- *Support from Dar es Salaam City Council, consultation with NGOs and building on work from UNDP*
- *WBI:* guidance and feedback

Methodology

This case study was developed using the following 5 approaches:

Literature review

Preliminary research was done by examining available published information on Dar es Salaam's demographics, access to infrastructure and basic services, and climatic trends and projections. Gathering in-depth information on proposed policies and programs for the city, however, particularly those of relevance for the urban poor, proved very difficult. Obtaining meteorological data of high relevance to the study, e.g., in-depth analysis of rainfall intensity, was also difficult, suggesting capacity issues as well as resource and time constraints.

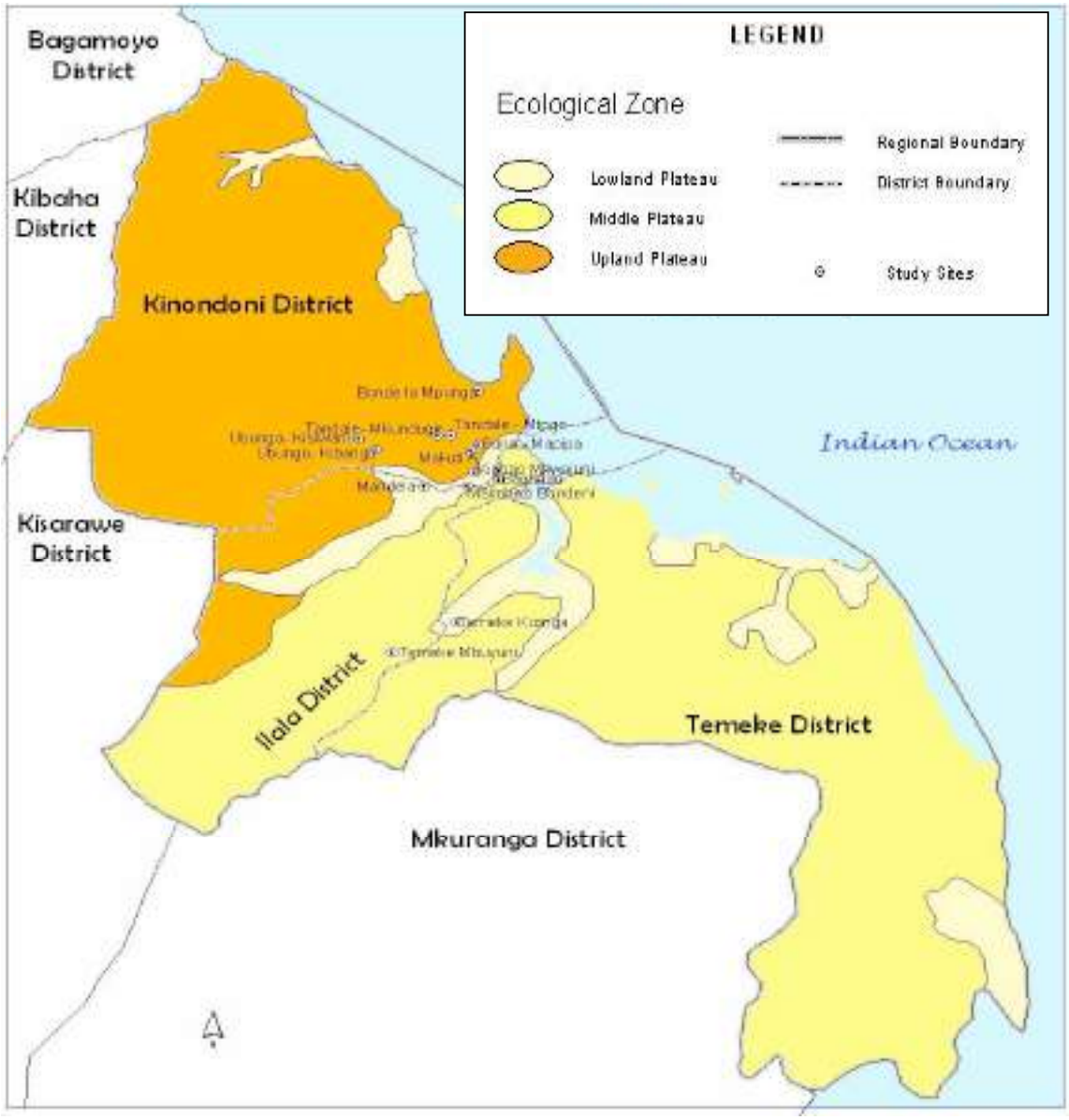
Household level socio-economic surveys

The surveys were designed to elicit information on populations living in flood-risk areas (see Annexes 1(a)-(e)) and contained questions on demographics; housing; household expenditure patterns; livelihoods; water sources, consumption and quality; disease prevalence; sanitation practices; energy use patterns; and knowledge and perceptions of climate risk and change. The study team supplemented the household interviews with on-site observations and inspection of surroundings, as well as focus group discussions with residents. Thirteen residential areas were studied, primarily in flood-prone areas (see Table 1). A total of 543 households were sampled.

For the sake of comparison, a few households from adjacent not-at-risk areas were also interviewed. These included (i) Kibangu area in the Makuburi Ward, which is a raised hilly area adjacent to Ubungo Kisiwani, a floodprone area along the Ubungo River system, and (ii) Makuti A (hilly and non-floodprone), for the Suna study area (Suna is in the lowland in Msimbazi Valley and receives wastewater from the Ubungo and Msimbazi Rivers).

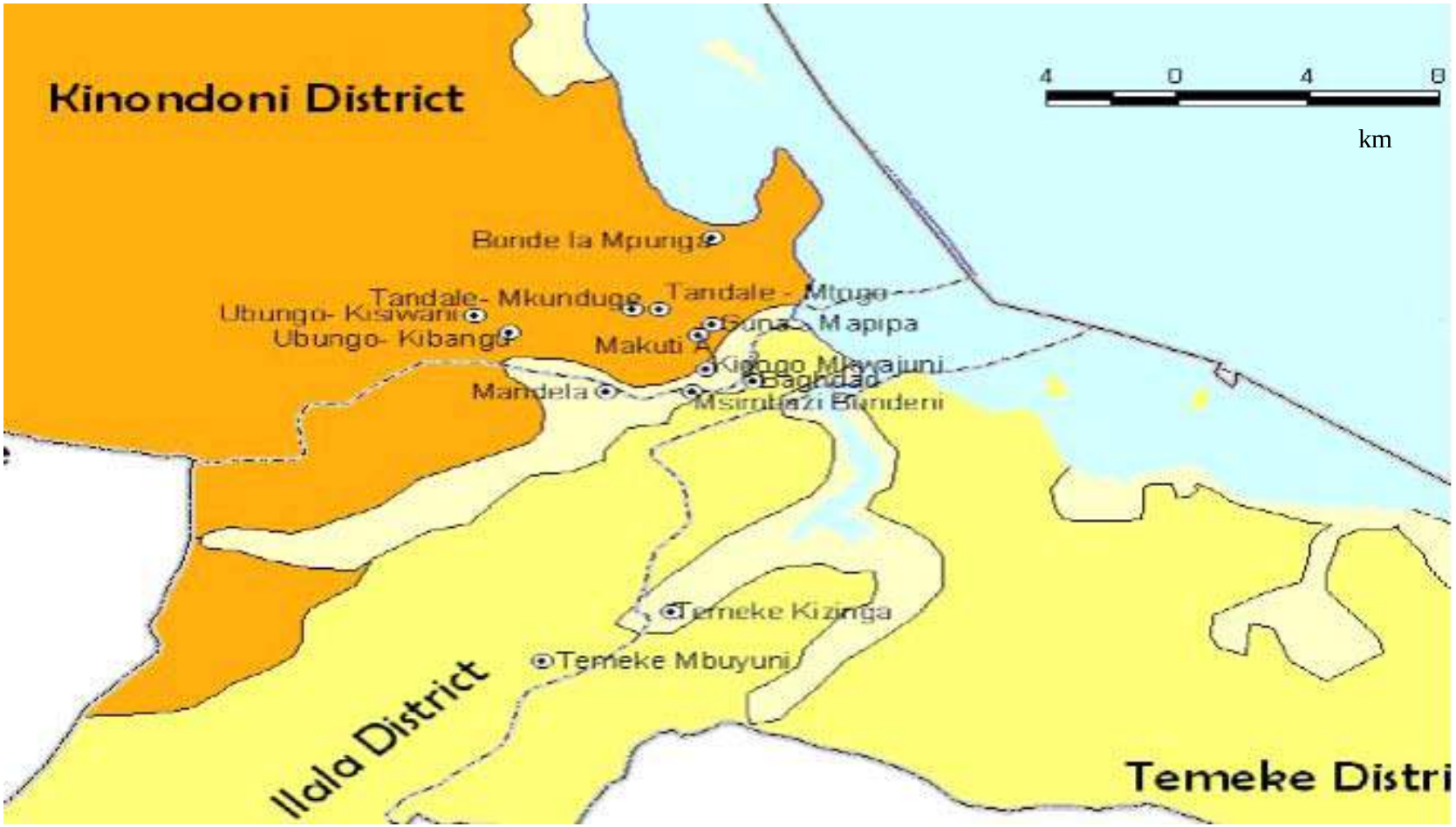
Figure 1(a) shows Dar es Salaam's districts and major topographical zones. Figure 1(b) is a closer look at this same map that shows the study areas.

Fig. 1(a): Map of Dar es Salaam municipal districts



Source: Institute of Resource Assessment Cartography Unit, Univ. of Dar es Salaam (2010)

Fig. 1(b): Map of Dar es Salaam case study areas



For each location, the area leader was asked to convene a meeting of individuals to share and discuss the information collected, analyze problems identified by households and other groups during the interviews, and jointly work out possible mitigation and adaptation measures.

All interviews and on-site visits were conducted by the study team based at the Institute of Resource Assessment at University of Dar es Salaam.

Table 1: Study areas covered by household surveys

No.	Study Area	District	River system	No. of households visited	Category: Flood risk /Control area
1	Suna (Magomeni Mapipa Jangwani Valley adjacent Muhimbili & Hannanasif)	Kinondoni	Ubungo-Ng'ombe	44	Flood risk
2	Msasani Bonde la Mpunga	Kinondoni	Sinza	41	Flood risk
3	Tandale Mtogole	Kinondoni	Ubungo-Ng'ombe	42	Flood risk
4	Tandale Mkunduge	Kinondoni	Ubungo-Ng'ombe	43	Flood risk
5	Ubungo Kisiwani	Kinondoni	Ubungo	41	Flood risk
6	Ubungo Kibangu	Kinondoni	Ubungo	42	Control area
7	Makuti A	Kinondoni	Ubungo	44	Control area
8	Mandela	Ilala	Msimbazi	43	Flood risk
9	Kigogo Mkwajuni	Ilala	Msimbazi and Ubungo-Kibangu	45	Flood risk
10	Ilala Quarters/Baghdad (near Yanga HQ)	Ilala	Msimbazi	34	Flood risk
11	Msimbazi Valley (Msimbazi Bondeni-down Msimbazi RC church mchicha valley)	Ilala	Msimbazi	35	Flood risk
12	Temeke Mbuyuni	Temeke	Kizinga	46	Flood risk
13	Temeke Kizinga	Temeke	Kizinga	43	Flood risk
Total				**543**	

Source: Survey Team, IRA, University of Dar es Salaam (2010)

Interviews with relevant institutional representatives

After gathering data and responses from residents living in floodprone areas, the study team conducted institutional visits to (i) learn about measures being taken by authorities to improve the situation for residents of floodprone areas, and (ii) compare their responses with views expressed by residents. The visits sought also to gather information on how authorities deal with other aspects of climatic variability, how they are planning to consider climate change impacts in the city, the barriers/obstacles they face, and any success stories and lessons learned in the process.

Municipal officials were interviewed from the Dar es Salaam City Council, including the City Drainage Engineer, the Waste Management Officer, and staff from the City Infrastructural Upgrading Programme (CIUP). Officials interviewed from the Municipal Councils included the CIUP coordinators, Community Development Officers, Environmental Management Officers, and Planning and Health Officers. Interviewees discussed ongoing and planned future CIUP efforts in solid waste management and carbon trade. Annex 2 provides information on the administrative structure of Dar es Salaam, i.e., how the City Council and Municipals relate to each other.

In addition to Government representatives, members of community-based organizations (CBOs) and non-government organizations (NGOs) were interviewed, as were members of the *Mtaa*[1] (sub-ward) administration, some of whom participated in the *Mtaa* level focus group discussions. Annex 3 provides a full list of people interviewed and their departmental/institutional affiliations.

Flood modeling exercise

A flood modeling exercise was undertaken by Ardhi University to map potential changes in rainfall regime and sea level rise on the flood extent and depth in the at-risk areas that were covered in the socio-economic surveys. A combined 1D-2D hydrodynamic model known as SOBEK was used (developed by Delft Hydraulics Software). The flood propagation model required spatial data (including a digital elevation model (DEM) and surface roughness estimates) and temporal data (such as initial water level, and downstream and upstream boundary conditions).

2 Geophysical and Climatic Background of Dar es Salaam

2.1 Geographical Location and Geophysical Characteristics

Dar es Salaam is located in the eastern part of the Tanzanian mainland at $6^{o}51'$S latitude and $39^{o}18'$E longitude. With an area of 1,350 km^2, it occupies 0.19 percent of the Tanzanian mainland, stretching about 100 km between the Mpiji River to the North and beyond the Mzinga River in the South. The Indian Ocean borders it to the East.

The beach and shoreline comprise sand dunes and tidal swamps. Coastal plains composed of limestone extend 10 km to the west of the city, 2-8 km to the north, and 5-8 km to the south. Inland, alluvial plains comprise a series of steep-sided U-shaped valleys. The upland plateau comprises the dissected Pugu Hills, 100-200 m in altitude. Dominated by limestones, sandy clays, coarse sands and mixed alluvial deposits, the soils of the Dar es Salaam region are not particularly fertile (Dongus, 2000).

The City is divided into three ecological zones, namely the upland zone comprising hilly areas to the west and north of the City, the middle plateau, and the lowlands, which include Msimbazi Valley, Jangwani, Mtoni, Africana and Ununio areas. Figure 1(a)

[1] *Mtaa* is the word for sub-ward; Dar es Salaam's administrative structure has four levels: city, municipality, ward and sub-ward.

displays the major zones. Natural vegetation mainly includes coastal palm groves, coastal shrubs, Miombo woodland, coastal swamps, and swampy mangrove trees and reeds. Prolonged human interference has reduced the diversity of woodland and scrub.

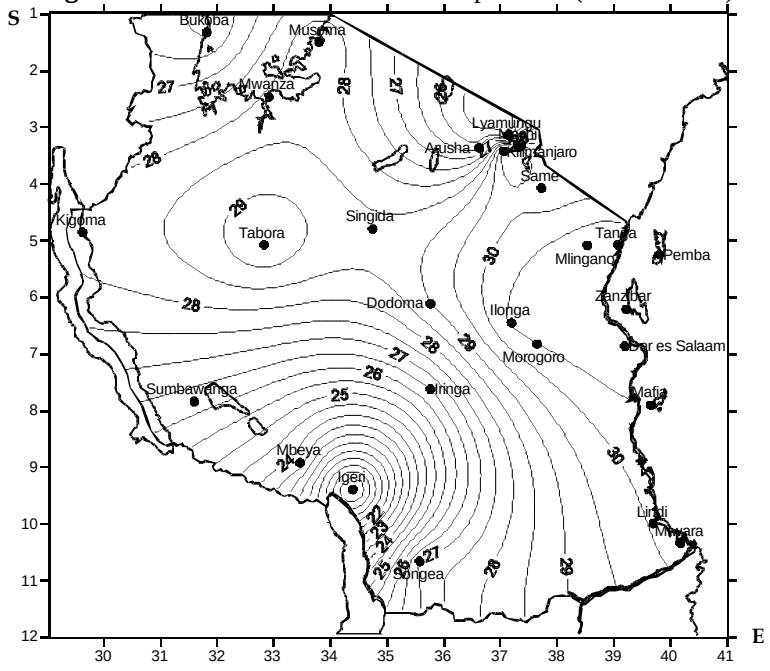
2.2 Climate

2.2.1 Climate overview

Dar es Salaam is a coastal city. It receives over 1,000 mm of rainfall per year and has a bimodal rainfall distribution, the two main rain seasons being the long rains and the short rains, associated with southward and northwards movements respectively of the Inter-Tropical Convergence Zone (ITCZ). The long rains season (*Masika*) occurs from mid March to end May, and the short rains (*Vuli*) from mid October to late December. Although June to September is typically a dry season for most parts of the country, coastal areas tend to receive a small amount of rainfall over this period. Rainfall in Tanzania is influenced by the southeast monsoon winds (May–September), the northeast monsoons (October–March), El-Nino Southern Oscillation (ENSO), tropical cyclones, easterly waves and the Congo air mass. Land and sea breezes along the Indian Ocean coast play a large role in modifying the spatial and temporal distribution of rainfall over coastal regions such as Dar es Salaam, Zanzibar, Pemba and Tanga.

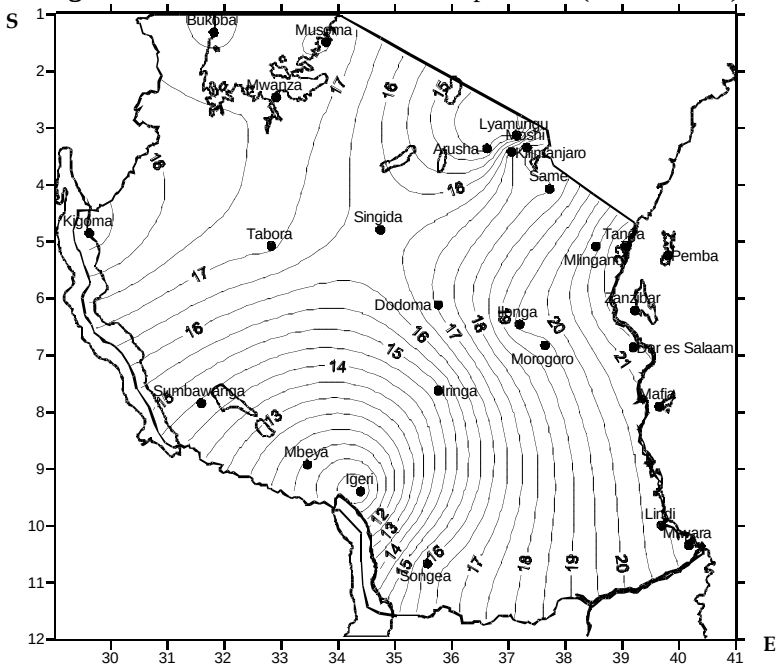
Dar es Salaam and Zanzibar have a mean annual maximum temperature of 30.8^{o}C (Figure 2), and a mean annual minimum temperature of 21.3^{o}C (Figure 3). The mean diurnal temperature range is 9.2^{o}C, which is smaller than in inland areas.

Figure 2: Mean annual maximum temperature (1971 – 2000)



Source: Matari et al. (2008)

Figure 3: Mean annual minimum temperature (1971 – 2000)

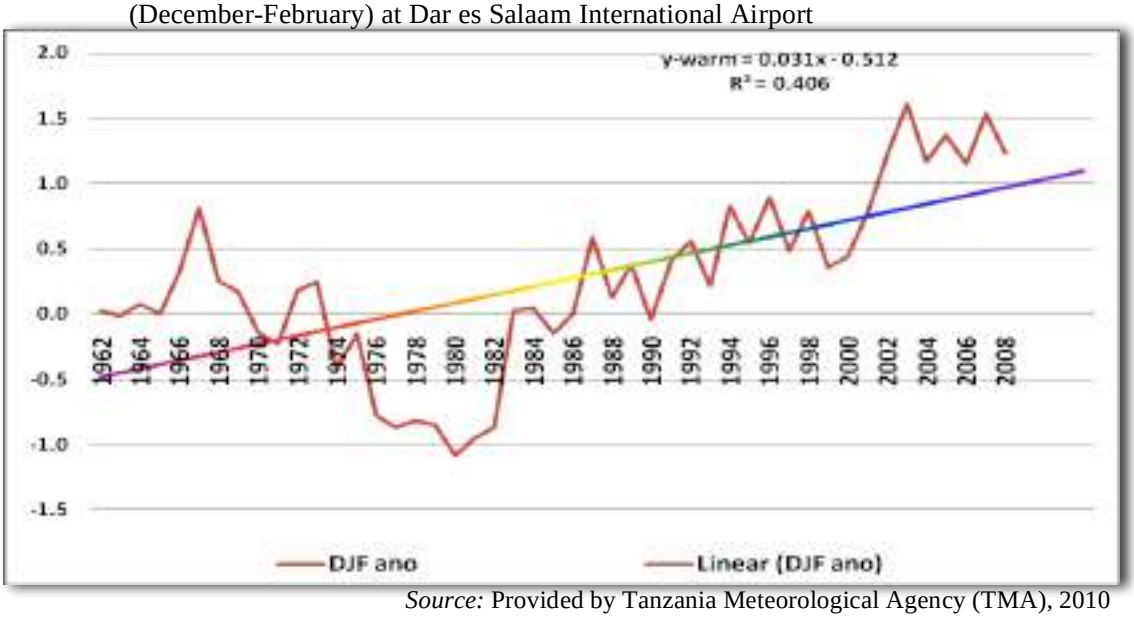


Source: Matari et al. (2008)

2.2.2 Temperature

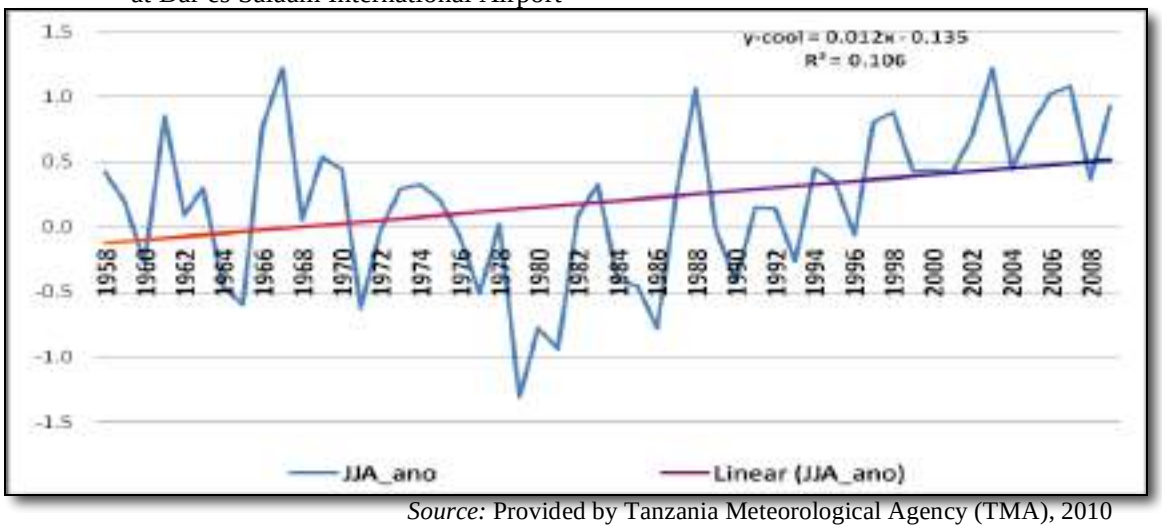
Analysis of both maximum (Figure 4) and minimum (Figure 5) temperatures at Dar es Salaam International Airport indicate significant positive trends over the past 4-5 decades.

Figure 4: Trend of mean maximum temperature anomalies during the warmest months (December-February) at Dar es Salaam International Airport



Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure 5: Trend of mean minimum temperature anomalies during the cool months (June-August) at Dar es Salaam International Airport



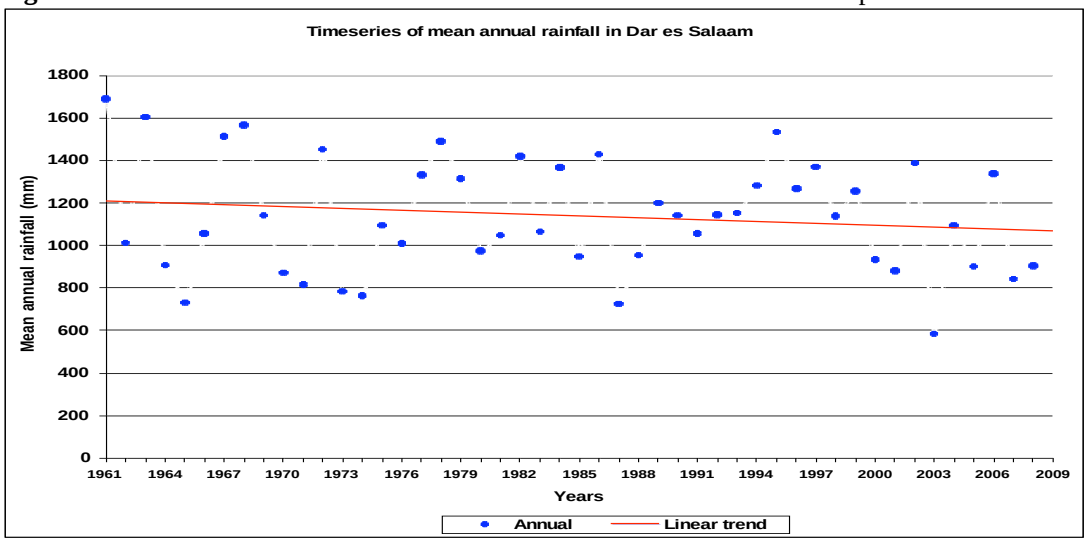
Source: Provided by Tanzania Meteorological Agency (TMA), 2010

2.2.3 Rainfall

Rainfall amount

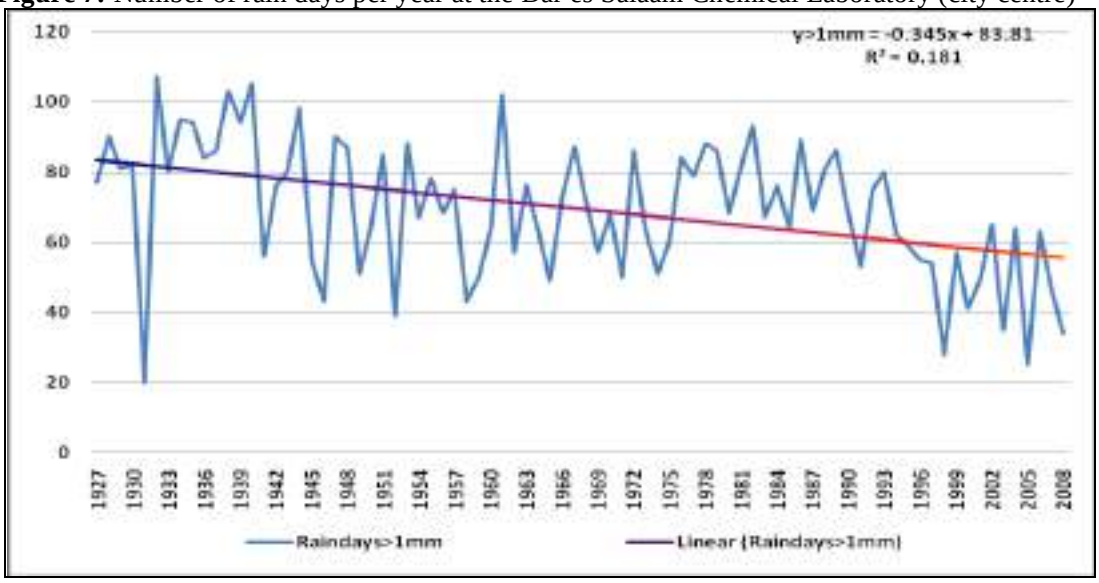
Figure 6 indicates that mean annual rainfall has declined in Dar es Salaam over the past five decades (as recorded at the Dar es Salaam Airport station). Figures 7 through 10 display the number of rain days for various locations in Dar es Salaam, and a declining trend may be seen at all four locations.

Figure 6: Trend of mean annual rainfall for Dar es Salaam International Airport station



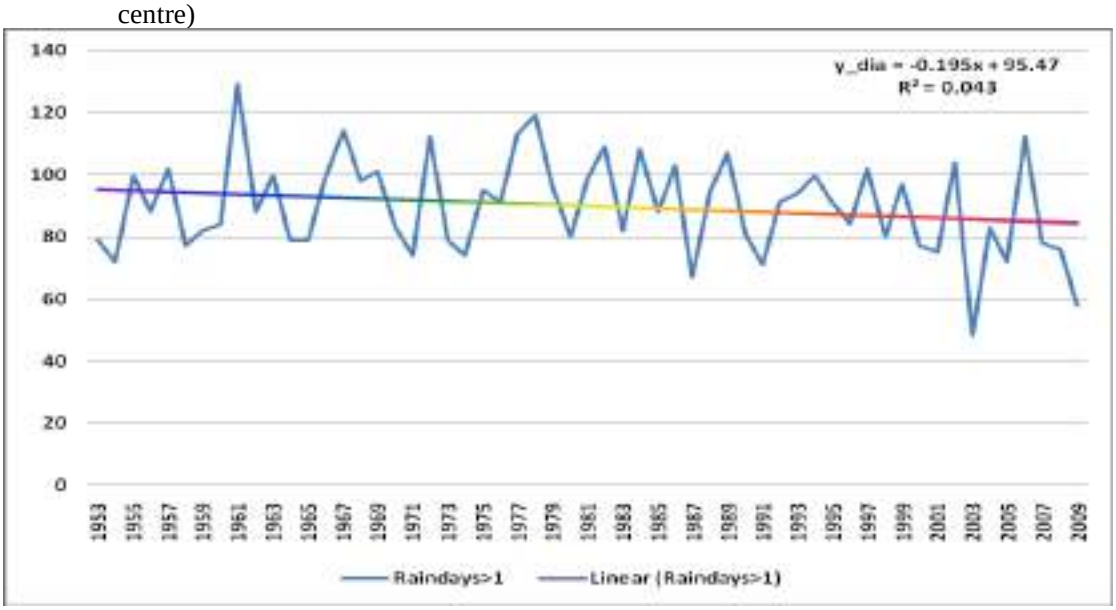
Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure 7: Number of rain days per year at the Dar es Salaam Chemical Laboratory (city centre)



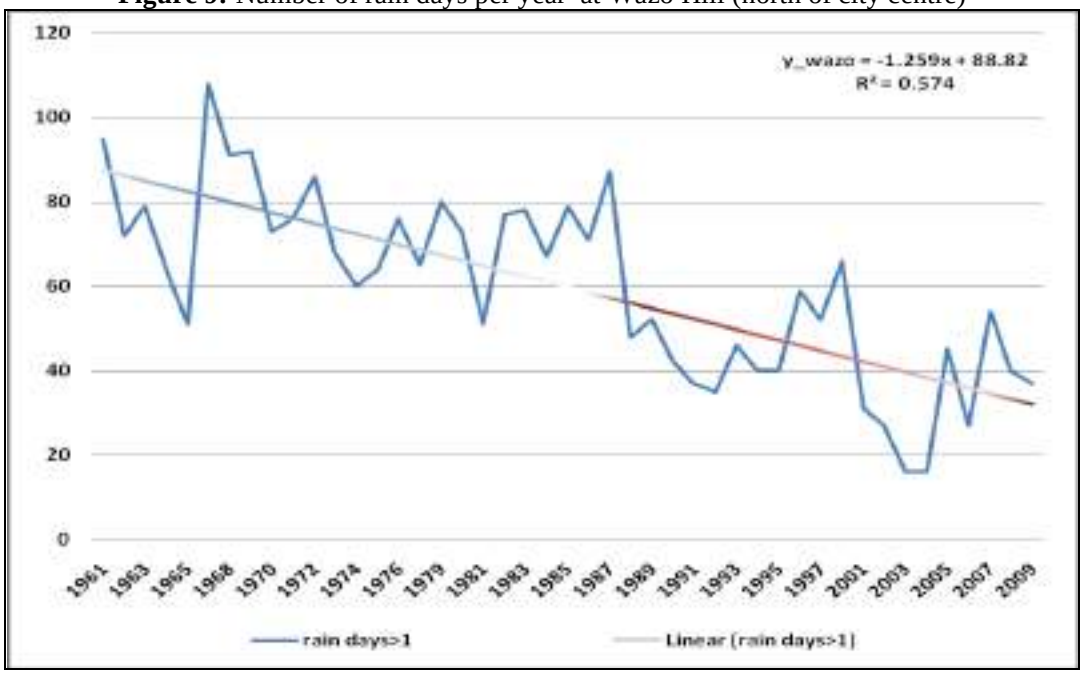
Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure 8: Number of rain days per year at the Dar es Salaam International Airport (south of city centre)



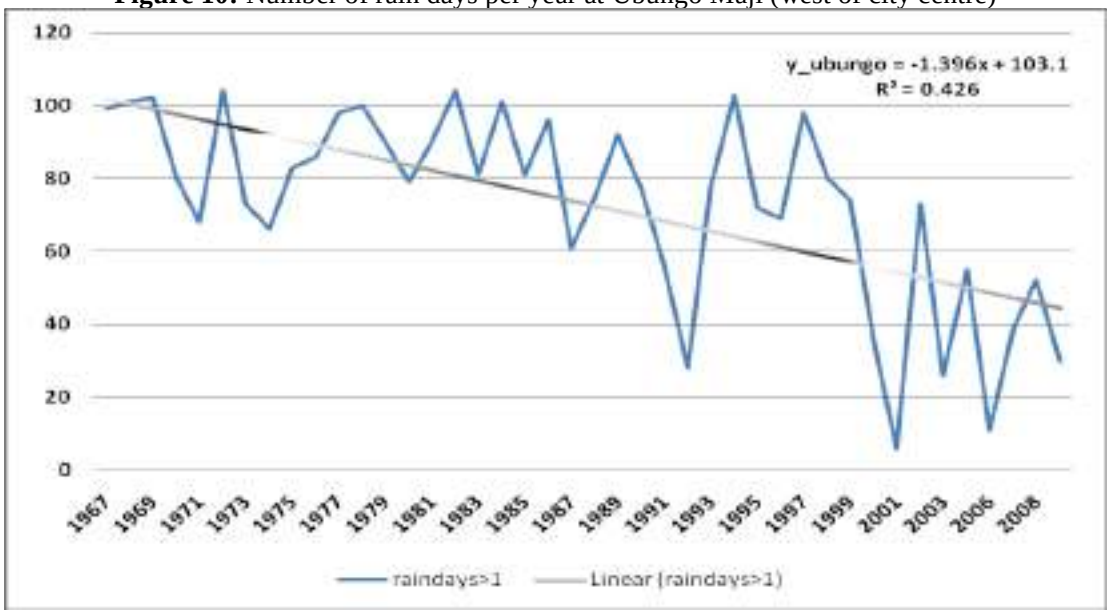
Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure 9: Number of rain days per year at Wazo Hill (north of city centre)



Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Figure 10: Number of rain days per year at Ubungo Maji (west of city centre)

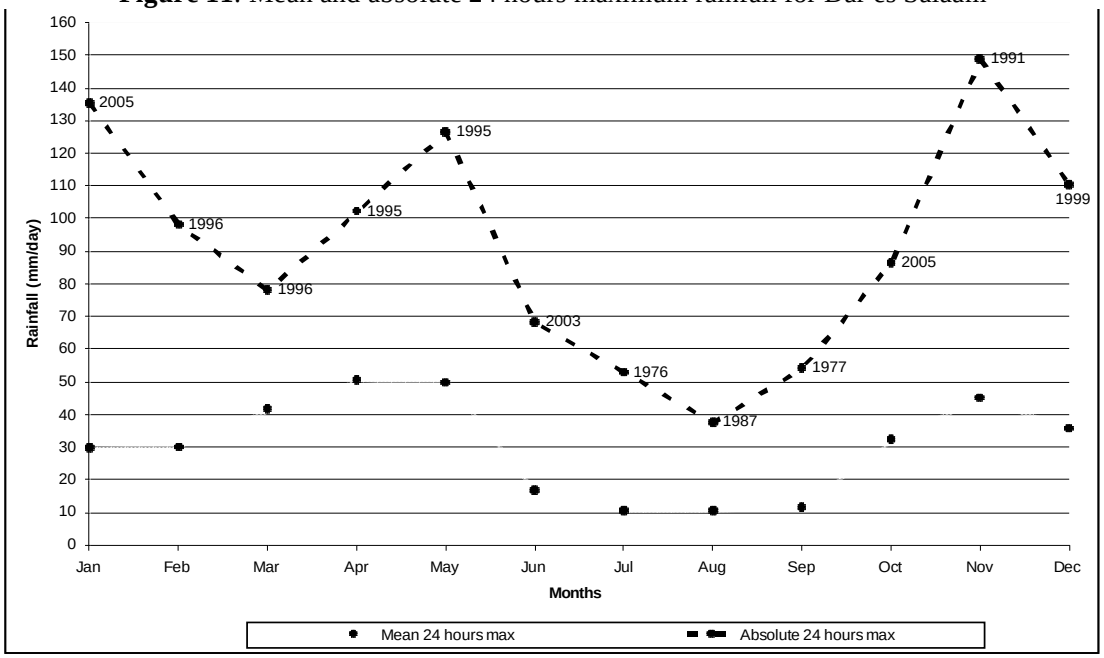


Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Rainfall intensity

Figure 11 shows mean and absolute 24-hour maximum rainfall for the period 1971–2009. Mean 24-hour maximum rainfall ranges from over 50 mm in April-May to 10mm for July-August. The absolute 24-hour maximum rainfall for the time period studied was recorded within the past decade.

Figure 11: Mean and absolute 24 hours maximum rainfall for Dar es Salaam



Source: Provided by Tanzania Meteorological Agency (TMA), 2010

Both rainfall amount and intensity are variables of concern from the point of view of flooding in Dar es Salaam. Intensity is likely to increase as climatic variability rises in coming years with the progression of climate change.

2.2.4 Flooding

A brief analysis of rainfall corresponding to recent significant floods experienced in Dar es Salaam is provided in Table 2. Many of these were associated with strong El Niño episodes. Thus improved forecasting of El Niño and improved public warning systems could play a role in reducing damages in the future.

Table 2: Information on significant floods in Dar es Salaam, 1983-2006

No.	Year	Months	Monthly rainfall			Remarks
			Longterm mean (mm)	Actual (mm)	Percentage of longterm mean	
1	1983	May	197.8	405.6	**205**	The rain was enhanced by El Niño.
2	1989	December	117.8	175.6	**149**	Tropical cyclone Albera was largely responsible for the heavy rain.
3	1995	May	197.8	374.2	**189**	There was continuous rainfall for at least two days during the March–May rain season.
4	1997	October	69.3	250.8	**361**	The rain was associated with a strong El Niño episode.
		November	125.9	152	**121**	
		December	117.8	231	**196**	
5	1998	January	76.3	107.3	**141**	The rain was associated with strong El Niño episode.
		February	54.9	123.7	**225**	
		March	138.1	155.2	**112**	
		April	254.2	319.9	**126**	
6	2002	April	254.2	569.4	**224**	The rain was enhanced by El Niño.
7	2006	November	125.9	240.9	**191**	The rain was enhanced by El Niño.
		December	117.8	230.4	**196**	

Source: Provided by Tanzania Meteorological Agency (TMA), 2010

A recent study by Watkiss et al. (2011) shows that currently 140,000 people in Dar es Salaam are below the elevation map's 10 m contour line, and over 30,000 are considered at risk. Measures to gauge and convey risk to the public in advance of flood events are thus of critical importance in helping people to prepare for them. The Tanzania Meteorological Agency undertakes these tasks, providing both near term (24 hour) and seasonal forecasts and warnings (see Box 1).

Box 1: Flood Early Warning Systems in Dar es Salaam

The Tanzania Meteorological Agency (TMA) issues flood warnings for Dar es Salaam. It provides warnings and advisories on extreme rainfall and flooding based on daily weather monitoring. Cloud evolution is monitored through observations and by using satellite pictures. The evolution and pathway of tropical cyclones along the Western Indian Ocean are also monitored on a real time basis

Warnings and advisories are disseminated to the public as needed, through various stakeholders such as the mass media and the disaster management department at the Prime Minister's Office. Flood warnings and advisories are given up to a day in advance (24 hour forecast) or at seasonal timescales (up to two months in advance).

Source: Provided by Tanzania Meteorological Agency (TMA), 2010

It should be stressed, however, that flooding in Dar es Salaam's unplanned settlements is also largely a function of inadequately maintained storm drains and poor waste disposal practices, and not just extreme rainfall. In fact, in the study team observed that some settlements in Msimbazi Valley tended to flood even in the absence of rainfall in the city

or upstream zones, due to clogging and structural interferences along the course of the Msimbazi River.

2.2.4 Droughts

From time to time, Tanzania[2] experiences prolonged droughts with severe socio-economic implications. The drought of 2006 damaged agricultural production, necessitated electricity cuts (and thus industrial production) and cut GDP growth by 1 percent (ClimateWorks Foundation et al., 2009). A number of diseases are related to drought in the country: malnutrition, trachoma, dysentery, cholera, and diarrhea (*ibid.*).

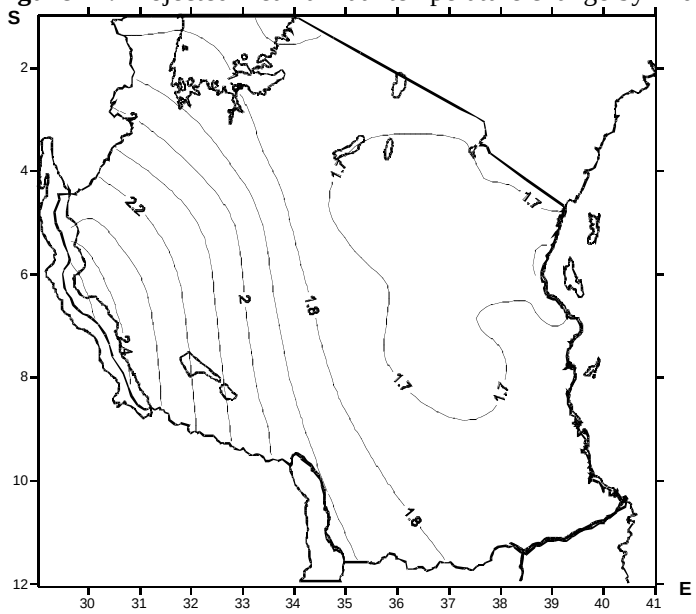
2.2.5 Climate change projections for Tanzania

Temperature

By 2100, mean annual temperature for Tanzania is expected to increase by 1.7°C over the northern coast, including areas around Dar es Salaam (Matari et al., 2008)[3], shown in Figure 12. Figure 13 shows CSAG's[4] analysis of projected change in monthly mean maximum temperature for Dar es Salaam by the 2050s. Depending on future rainfall regimes, these temperature increases could have wide-ranging effects, such as on urban agriculture (evapotranspiration, heat stress), disease incidence (direct effects of extreme heat on humans, as well as on disease vectors, e.g., by increasing humidity), hydropower generation (increased evaporation in reservoirs), household electricity requirements and a range of other factors of importance for the city's urban poor. Figure 13 indicates that temperature extremes will rise; Watkiss et al. (2011) looked at the projected increase in number of days exceeding 32°C in Dar es Salaam by 2050, and their results showed significantly increased exceedances, which would affect health as well as labor productivity in the city.

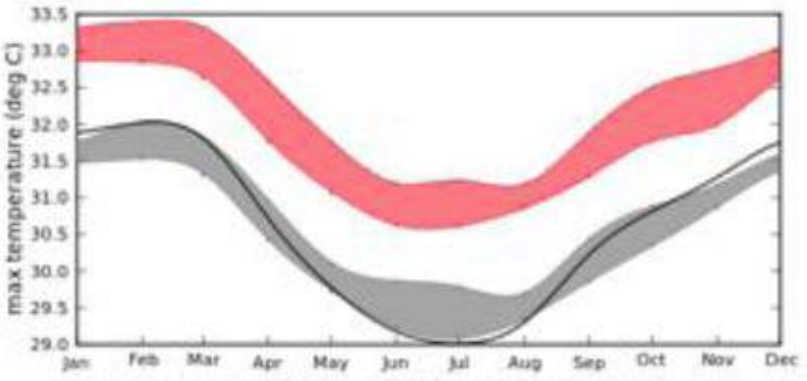
[2] It was not possible to obtain drought information for Dar es Salaam for this study.
[3] Matari et al. (2008) used the MAGICC/SCENGEN model to derive climate change projections for Tanzania for 2100, using five models and emissions scenario A1B.
[4] The analysis by CSAG (published in Watkiss et al., 2011) was conducted using CMIP3 Archive GCMs. Results are shown for the B1 emissions scenario.

Figure 12: Projected mean annual temperature change by 2100



Source: (Matari et al., 2008)

Figure 13: Projections of monthly mean maximum temperature for Dar es Salaam, 2046-2065 Scenario B1



(1961-2000) (2046-2065)

The black line represents the multi-model median. The grey envelope represents the envelope of climate model projections for 20th century period. The red envelope represents the future period (2046-2065).

Source: Watkiss et al. (2011)

Rainfall

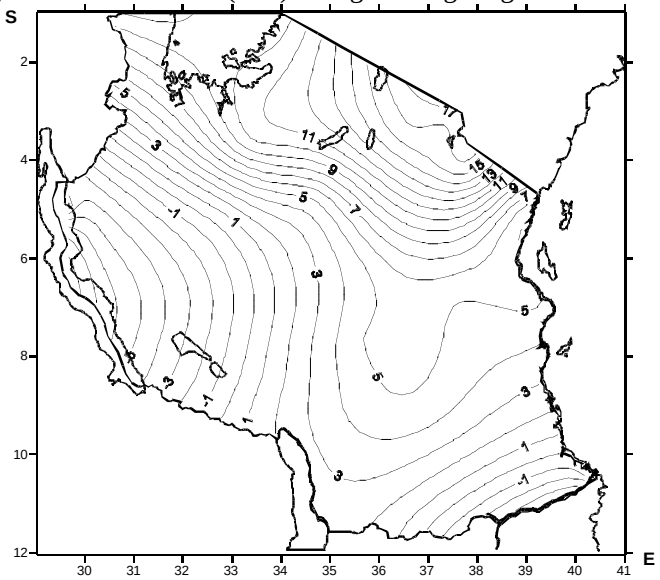
According to Matari et al. (2008), mean rainfall is projected to increase during the long-rain season over coastal areas, including Dar es Salaam, by up to 6 percent by 2100 (Figure 14). These results are also supported by two regional climate models[5], which

[5] The two regional climate models used include (i) PRECIS (Providing Regional Climates for Impact Studies), developed by UK Met Office, and (ii) CCLM (COSMO-CLM; COnsortium for Small scale MOdeling – ClimateLimited-areaModelling), maintained and developed by the COSMO Consortium.

indicate a slight increase in rainfall over the entire northern coast of Tanzania, including the Dar es Salaam region. According to Watkiss et al. (2011), however, it is unclear whether rainfall in Tanzania will increase or decrease with climate change, with some models projecting that precipitation may increase in the late summer, with some signs of drying in early summer. Figure 15 shows monthly precipitation projections to the 2050s for a B1 scenario.

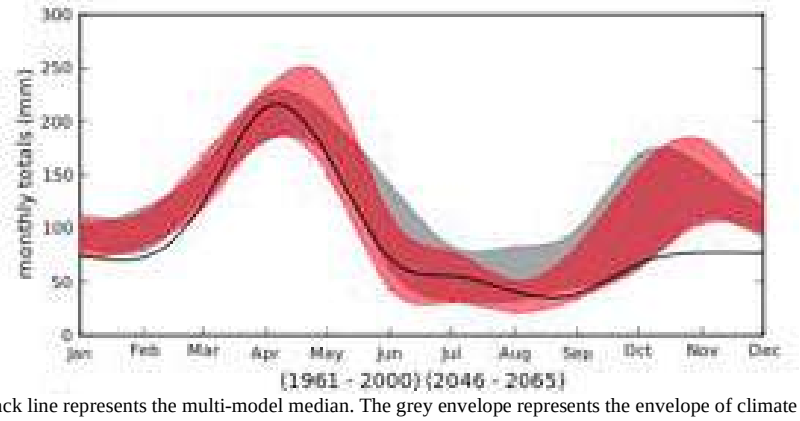
If annual rainfall does increase over coming years, the current observed declining trend in number of rainy days for Dar es Salaam over the past several decades (refer to Figures 7-10), should it continue into the future, indicates a potentially grim situation from the perspective of severe flooding in the city, as it suggests that rainfall intensity is rising. Increase in rainfall intensity is in agreement with general expectations that variability is increasing with climate change, and that both droughts and floods are likely to increase in magnitude and frequency.

Figure 14: Projected mean rainfall (mm) change during long rains season (March – May)



Source: (Matari et al., 2008)

Figure 15: Projections of monthly precipitation for Dar es Salaam, 2046-2065 Scenario B1



The black line represents the multi-model median. The grey envelope represents the envelope of climate model projections for 20th century period. The red envelope represents the future period (2046-2065).

Source: Watkiss et al. (2011)

Climate variability and extreme events

According to Watkiss et al. (2011), projections vary widely for Tanzania on extreme events; El Nino has been seen to have a large impact on inter-annual variability (with heavier rainfall associated with strong El Nino events), but it is not clear how climate change will affect the frequency and magnitude of El Niño events and thus their impact on Tanzania. However, Shongwe et al. (2009 in: Watkiss et al., 2011), upon examination of long-term trends, state that the intensity and frequency of extreme heavy rainfall may increase in the wet seasons, which would imply greater flood risk.

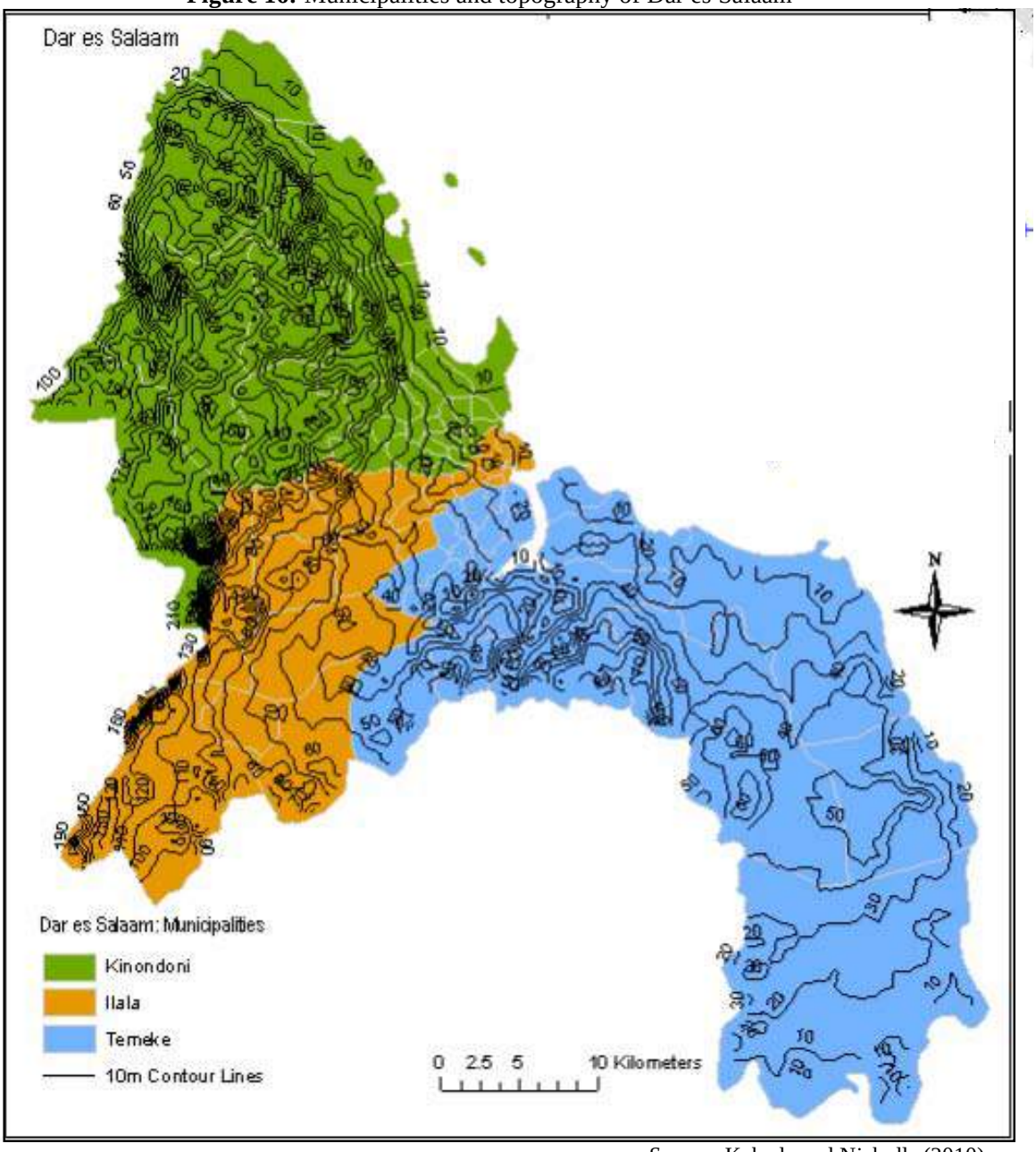
Impact on drought is uncertain (Watkiss et al., 2011) with some models predicting intensification with climate change and others a reduction in severity.

Sea level rise

Kebede and Nicholls (2010) have analyzed Dar es Salaam's vulnerability to sea level rise. They estimate that at present 8 percent of the city currently lies in a low elevation zone below the 10 m contour line (see Figure 16), inhabited by over 143,000 people, with associated economic assets estimated (in 2005) at US$168 million. Of these, over 30,000 people and US$35 million of assets are located in the 1 in 100 year floodplain. In the *absence* of climate change induced sea level rise, 60,000 people and US$219 million in assets are expected to be exposed to a 1 in 100 year flood by 2030. The results of their analysis, using various population growth rates and climate change scenarios, are summarized in Table 3, and reveal that the magnitude of socio-economic changes (rapid population growth, urbanization, spatial population distribution and associated economic growth) may be of greater import than sea-level rise in terms of overall increased exposure of population and assets to coastal flooding in Dar es Salaam (explanation of methodology for calculation of population and assets at risk is given in Annexes 4a and 4b). Figure 17 shows projected exposure of Dar es Salaam's population by municipality to a 1 in 100 year flood, in the absence of adaptation measures.

It is worth noting that mean sea level tide gauge measurements at Zanzibar (over 1984-2004) and Dar es Salaam (1986-1991) show a slight *declining* trend. Kebede and Nicholls (2010) caution, however, that records of short duration (<50 years), can be subject to bias due to interannual-to-decadal water level variability. However, if it is true that sea levels off the Tanzania coast are stable or falling, expected future rises will be slightly smaller than global mean changes (*ibid.*).

Figure 16: Municipalities and topography of Dar es Salaam



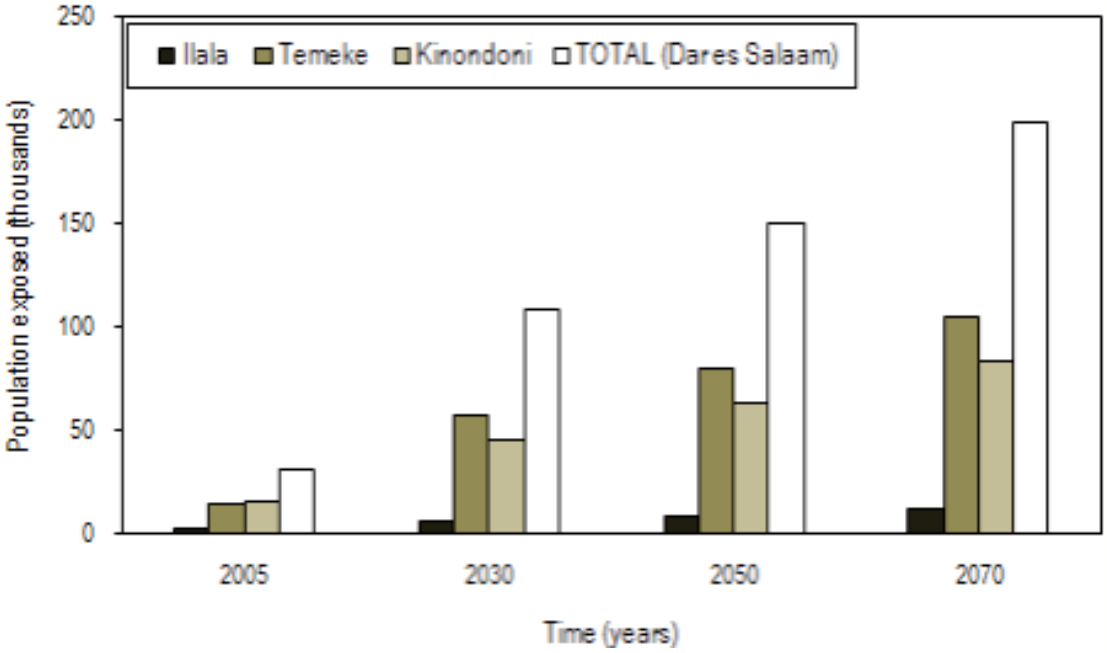
Source: Kebede and Nicholls (2010)

Table 3 Population and assets exposed to the 1 in 100 year return period extreme water levels in Dar es Salaam under the ranges of sea level rise scenarios

Year	Extreme Water Levels (m)	Population Exposed (thousands)			Assets Exposed (in US$ millions)		
		Population Growth Distribution Scenarios			Population Growth Distribution Scenarios		
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
No climate-induced SLR Scenario							
2005	3.06	30.1	30.1	30.1	35.4	35.4	35.4
2030	3.02	105.7	59.6	29.7	388.1	218.8	34.9
2050	2.99	140.6	79.1	28.7	1996.8	1123.3	33.7
2070	2.96	182.4	102.7	28.5	8434.4	4748.7	33.5
B1 low-range SLR Scenario							
2005	3.08	30.4	30.4	30.4	35.8	35.8	35.8
2030	3.07	106.8	60.8	30.3	392.4	223.1	35.6
2050	3.08	147.3	83.9	30.4	2092.4	1192.3	35.8
2070	3.09	193.1	110.5	30.7	8929.5	5112.0	36.1
A1B med-range SLR Scenario							
2005	3.09	30.7	30.7	30.7	36.1	36.1	36.1
2030	3.13	108.0	62.3	31.1	396.7	228.8	36.5
2050	3.19	150.2	87.7	31.8	2132.9	1245.7	37.4
2070	3.26	198.9	116.4	32.3	9197.7	5380.6	38.0
A1FI high-range SLR Scenario							
2005	3.12	31.1	31.1	31.1	36.5	36.5	36.5
2030	3.23	110.0	64.3	32.0	404.1	236.0	37.7
2050	3.38	155.7	91.5	33.2	2212.2	1299.9	39.0
2070	3.58	208.8	122.0	34.6	9658.0	5643.7	40.6
Rahmstorf SLR Scenario							
2005	3.11	31.0	31.0	31.0	36.5	36.5	36.5
2030	3.21	109.7	63.9	31.9	402.8	234.8	37.5
2050	3.37	155.5	91.3	33.1	2208.9	1297.1	39.0
2070	3.62	212.6	126.1	35.0	9831.1	5832.3	41.2

Note: The population growth scenarios used are: (i) Scenario 1: assuming uniform population growth per district weighted by 2005 population distribution (high scenario); (ii) Scenario 2: assuming uniform population growth per ward weighted by 2005 population distribution (medium scenario); and (iii) Scenario 3: a 'no population growth' scenario, assuming the population in all the city districts is kept to 2005 levels (low scenario).
Costs are provided in 2005 US$ and are not discounted.

Figure 17: Exposed population in Dar es Salaam in 2005, 2030, 2050 and 2070 to a 1 in 100 year flood event under the A1B mid-range SLR scenario, no adaptation



Source: Watkiss et al. (2011)

2.2.6 Implications of climate change for Dar es Salaam

As discussed in greater detail in Section 3, a large proportion of Dar es Salaam's population lives in informal, unplanned settlements and the majority of these residents are poor. Vulnerability to current climate conditions is high, and is a function of socio-economic factors (high population and overcrowding, poverty, malnutrition, exposure to disease), lack of adequate infrastructure and municipal services (e.g., waste removal, provision of clean water, access to working sanitation and drainage systems), poor hygienic practices, and climate variability (heavy rainfall, drought). Heavy rainfall frequently causes flooding in the settlements, and, among other problems, contributes to increased disease incidence. Drought, too, is associated with increased disease incidence in limiting the availability of clean water.

Given the city's current 'adaptation deficit'[6] and poor integration of disaster risk management approaches in urban planning, climate change is likely to exacerbate vulnerability over coming decades, particularly taken in conjunction with urban population growth and the increasing concentration of economic assets. Although future rainfall patterns are uncertain, variability is likely to increase and intensification of heavy rainfall is expected. Thus flooding may become an increasingly severe issue, particularly taken together with socio-economic projections, unless adaptation measures are implemented. Increases in mean temperature, combined with fewer rainy days per year, could also prolong the length of dry seasons or intensify droughts. Recent extreme

[6] I.e., its inability to cope adequately with existing conditions.

climatic events (e.g., the droughts of 2006 and 2008/2009, and the floods of 2009/2010) severely impacted sectors such as transport, energy and health, with adverse socio-economic implications.

Projected changes in climate will have significant impacts on Tanzania's rain-fed agriculture and food production (Matari et al., 2008; Mwandosya et al., 1999), and could thus impact on urban agriculture in Dar es Salaam, a means of livelihood and subsistence for the city's poor. Warming will shorten the growing season and, together with reduced rainfall, reduce water availability (Paavola, 2003).

Coastal degradation and salt-water intrusion are major problems for Dar es Salaam's coastal areas today, and under projected climate change and possible sea level rise, coastal ecosystems would be highly threatened (Watkiss et al., 2011), affecting the livelihoods and ecosystems services of coastal communities. Residents of coastal wetlands that have incurred saltwater intrusion (such as Suna, Mtoni Azimio, Msasani Bonde la Mpunga) informed the study team that they frequently need to repair their houses as salt-water intrusion is corroding the foundations and cement bricks are being eaten away.

In all, climate change will exacerbate problems experienced by Dar es Salaam's urban poor in areas such as health, living conditions, livelihoods and economic security. Urban development and poverty reduction policies and programs for the city need to be adjusted to not only better integrate disaster risk management approaches but to take a long-term perspective that takes climate change into account. At the same time, existing policies and regulations that can reduce the vulnerability of the poor need to be better enforced.

3 Dimensions of Urban Poverty in Dar es Salaam

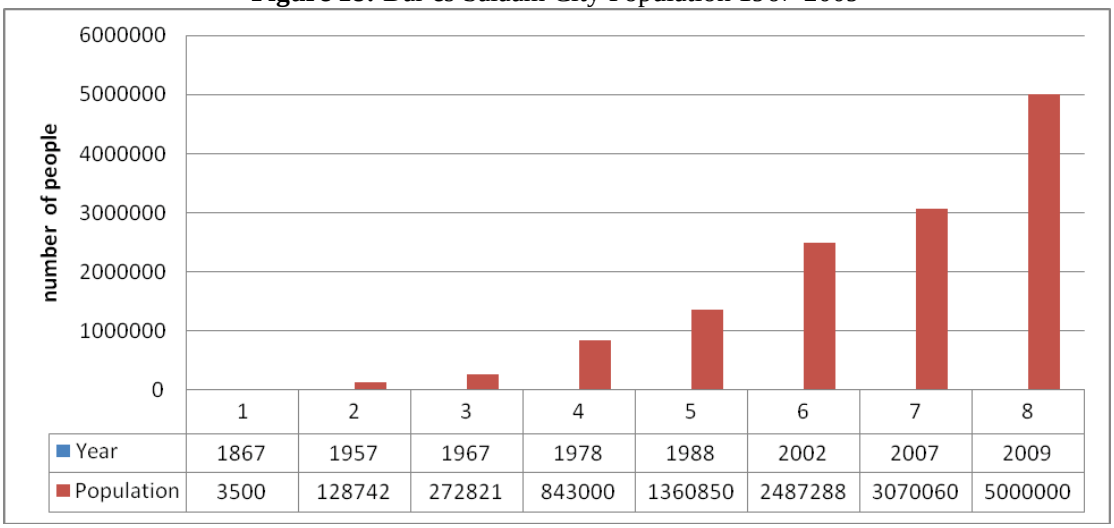
3.1 Overview: Population, poverty and settlement patterns

Size and growth

Dar es Salaam has a population of about 5 million (see Figure 18) that could reach up to 8 million by 2020 if present trends continue (Casmiri, 2009; DSM City Council, 2010). The city's population has been growing at the rapid rate of about 8 percent per annum (World Bank, 2002), a result of high in-migration from other areas and a birth rate of about 4.5 percent per annum. With population densities reaching 1,500 persons/hectare (on average, approximately 150 persons/hectare), it has a population about seven times the size of the next most populated city, Mwanza, and continues to attract the most migrants.

Incoming people move to Dar es Salaam in search of income-generating opportunities, education, and other subsidized or free public goods and services. Increasing levels of poverty, population growth and the lack of a sustainable housing policy, however, mean that much of this urban growth is often absorbed into informal settlements.

Figure 18: Dar es Salaam City Population 1967-2009



Source: Casmiri (2009) and DSM City Council (2010)

The rise and expansion of informal settlements

An estimated 70 percent of Dar es Salaam's population lives in poor, unplanned settlements (World Bank, 2002). Residents are usually too poor to pay for services or infrastructure and authorities too resource-constrained to maintain these; thus, health and environmental conditions are generally extremely poor.

Tanzania's policy towards informal settlements in Dar es Salaam has varied over past decades (discussed in World Bank, 2002). In the 1960s, slum clearance was the main approach; slum sites were cleared and buildings with high construction standards were erected on cleared sites (implemented through the National Housing Corporation). This proved unsustainable, however, and was abandoned by the end of the 60s due to high economic and social costs, and having contributed little to the net housing stock.

In the 1970s and 1980s, the government's approach changed, and squatter area upgrading projects and service provision (supported by the World Bank) formed the national strategy for managing the growth of informal settlements. After World Bank funding for these projects ceased, however, the Government of Tanzania was unable to continue financing them, and subsequent years saw the growth and emergence of new unplanned settlements as well as deterioration of previously installed infrastructure, due to lack of maintenance (World Bank, 2002).

Poverty

About half the residents of Dar es Salaam's informal settlements live on an average income of US$1 per day (World Bank, 2002) and in constrained circumstances. Many are migrants from other parts of Tanzania in search of better opportunities; studies by Simler (2006) show that poverty rates for the country are lowest in Dar es Salaam, Arusha and Kilimanjaro. In a survey of three unplanned settlements, 79 percent of respondents were born outside the city, and 46 percent considered themselves poor or very poor (World

Bank, 2002). IFPRI (2006) also shows that child malnutrition tends to be lower in urban areas than rural ones (although absolute numbers of malnourished children is large in urban areas due to the higher population density). Life expectancy in Dar es Salaam's informal settlements is low, between 44-46 years, and infant mortality is high at about 97 deaths per 1000 live births (World Bank, 2002).

Access to clean water and sanitation are major problems for Dar es Salaam's poor, and, as discussed in more detail later in this Report, contribute to widespread illness, including cholera, malaria, lymphatic filariasis, and diarrhea, particularly during flood episodes, which could be more severe or frequent in future due to climate change.

Up to about 75 percent of the residents of Dar es Salaam's informal housing settlements are unemployed or under-employed (World Bank, 2002), with the main source of income for the latter group being through informal activities and micro-enterprise. Employment in Dar es Salaam as a whole declined from 64 percent to 42 percent between 1992 and 2000, and self-employment rose from 29 percent to 43 percent. Poverty for those in self-employment rose from 29 percent to 38 percent over the same period (*ibid.*).

The primary cooking fuel for the residents of informal communities is charcoal – the cheapest and most easily available option. Congested housing in these settlements, however, could mean that negative health effects of charcoal burning could be significant, particularly in poorly-ventilated areas, where respiratory illnesses are common. Alternative fuel and energy sources are available but currently too expensive for the poor to afford. Efforts to subsidize these for the poor would result in health benefits in urban settlements as well as global benefits in terms of greenhouse gas emissions reductions.

3.2 Urban infrastructure

The public and private sector have been unable to keep pace with population growth in the city. As a result, urban development is hindered by low management capacity and inadequate institutional arrangements, and demand for infrastructure and urban services is not being met (World Bank, 2002), least of all in informal settlements, with adverse implications for urban poverty.

3.2.1 Roads

The city's road network totals about 1,950 km in length, of which 1120 km (less than 60 percent) is paved, and is inadequate to satisfy its population density, spatial expansion and transportation needs. Dar es Salaam hosts about 52 percent of Tanzania's vehicles, and has a traffic density growth rate of over 6.3 percent per year (JICA, 1995; Kanyama et al., 2004). Roads generally do not have walkways or bicycle-ways, resulting in non-segregation of traffic.

Most people depend on public transportation, particularly *daladalas* – variously sized minibuses and minivans – though these are skewed in favor of the more affluent, as they

tend to focus on the most profitable lines (Olvera et al., 2002). The public transport system suffers from congestion and delays, poor vehicle condition and excessive gaseous emissions, an increasing number of road accidents, bus fares that are insufficient to cover operating costs, poor customer services, and uncomfortable traveling conditions.

Rapid urbanization is a leading cause for the poor state of the city's public transportation. As population continues to increase and urban sprawl expands, more people travel to and from urban centers, often over longer distances. The limited capacity of existing transport infrastructure is stretched to the limit, resulting in poor social, economic and environmental performance (Kanyama et al., 2004). The situation is particularly limiting for Dar es Salaam's poorest residents in unplanned wards; Howe and Bryceson (2000) found that almost 81 percent of unplanned residential areas in Dar es Salaam have poor access to public transportation, especially buses.

Climatic factors greatly exacerbate existing constraints to roads and transportation in Dar es Salaam. Although most roads are poorly maintained and have poor surface conditions, these "can even become impossible during the rainy season, when the increasing number and depth of holes can completely block vehicles" (Olvera et al., 2002: 88). Daily trips on foot can also become much more difficult during rains, when people are cut off from their neighborhoods if bridges or roads collapse (*ibid.*). Access problems are particularly serious in squatter settlements, where, most often, access roads were not planned from the start (*ibid.*) Increases in rainfall intensity, which are expected to occur with climate change, provide additional imperative for the need to address transportation issues.

3.2.2 Drainage

Poor drainage is a major contributor to flooding episodes in the city's unplanned settlements and to disease, environmental degradation, and degradation of roads and pavements. The city has a total of about 1100 km of open lined ditches and 600 km of piped stormwater drainage, but lack of regular maintenance, illegal construction of additional structures, and residents' practice of dumping refuse into the drains has led to deterioration of drain function. In informal settlements, alleyways are often too narrow to enable waste collection trucks to enter; thus, waste disposal is a major problem and it is often dumped into ditches and drains, or alongside drainage channels, obstructing flow.

The existing drainage system fails to serve the needs of the poor given current rainfall conditions; the prospect of an increase in rainfall intensity with climate change in coming decades makes a pressing case for the need to not only rehabilitate and maintain existing city drainage infrastructure and enforce laws that prohibit dumping solid waste into drains, but plan improvements and expansion with greater flexibility built into the design (i.e., ability to handle larger volumes of stormwater).

3.2.3 Physical access to services

Access to services such as schools and health facilities are also constrained in informal settlements, in large part due to physical issues associated with poor road access and

quality. Olvera et al. (2002) state that the "unequal access to transportation networks is all the more critical in that it is combined with a more or less pronounced lack of services" in various areas (p.89), with the poor road connections in unplanned settlements being the cause of greater distances to main schools and health services. They state:

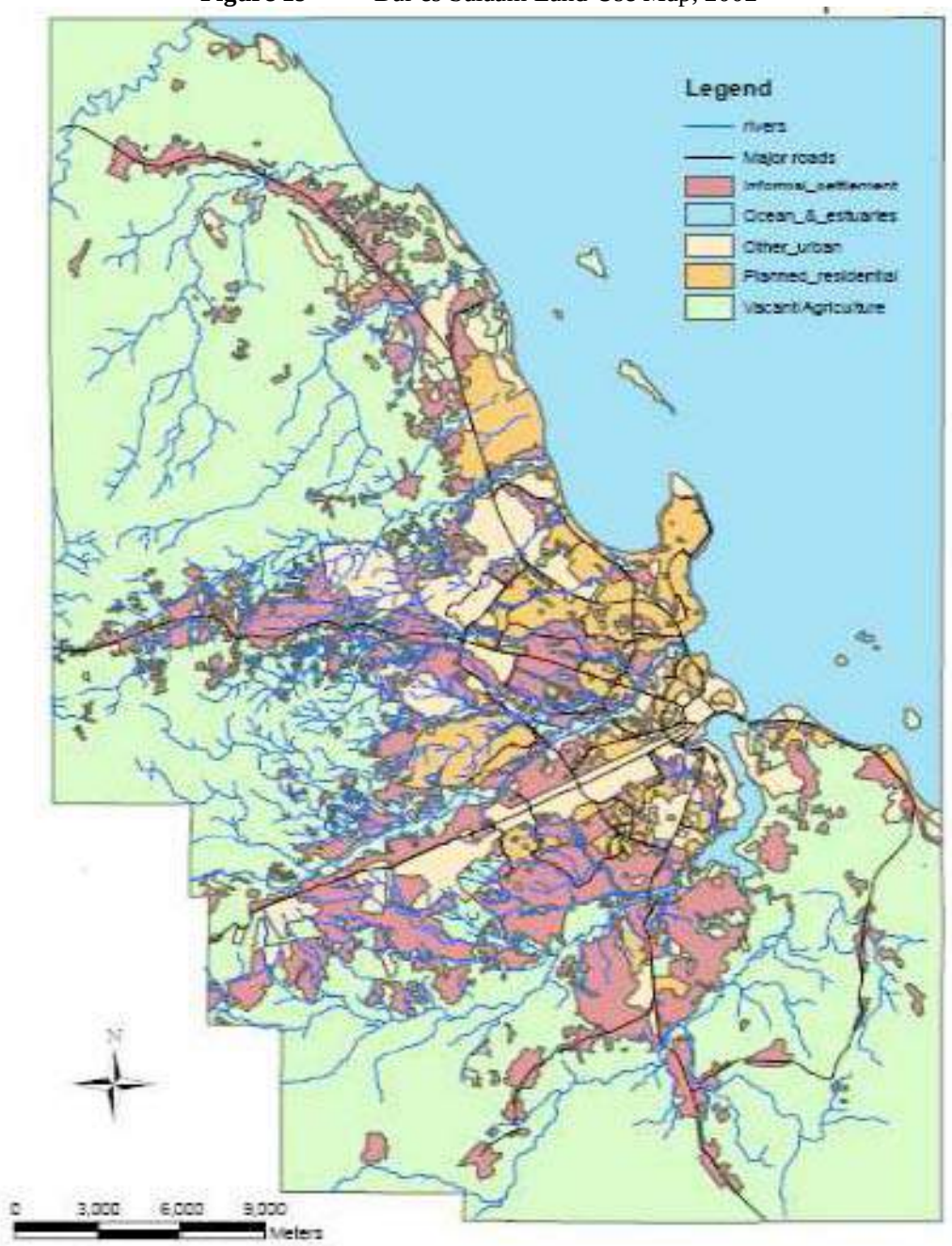
- The availability and cost of public transport weighs heavily on essential fields such as health and education in that they tend to reduce access to those services;
- Often, poor households (the vast majority) must limit their trips outside the neighborhood to the most indispensable activities;
- Both public and private primary and secondary schools are at a greater distance from unplanned settlements than from affluent neighborhoods;
- Above and beyond the difficulty of transportation, particularly for schoolchildren, the simple cost of trips increases the overall cost of schooling and may constitute one of the factors resulting in the premature exit from school for children in poor families.
- Transportation difficulties further reduce the possibilities of finding an accessible job;
- Health services such as public/private clinic/hospitals are closer in proximity to affluent neighborhoods than to squatter settlements. The cost and inconvenience of traveling to these areas, in compliance with the high cost of health care, greatly deters the poor population from using and benefiting from hospital services;

3.2.4 Housing

Dar es Salaam has three municipalities: Temeke, Ilala and Kinondoni (as shown in Fig. 1(a)). The largest concentration of poor unplanned settlements is in Kinondini; these are overcrowded and lack basic infrastructure services. Most of the city's unplanned settlements are located along the Kilwa, Morogoro, Nelson Mandela and Pugu roads (Howe and Bryceson, 2000). Briggs and Mwamfupe (2000) state that development of the city's informal settlements was driven by hydrological characteristics and the available public transportation system, and Sietchiping (2005) shows that informal growth patterns tend to emerge along riverbanks, steep slopes, dumping grounds, abandoned or unexploited plots, along transportation networks, near industrial and market areas, and in low-lying areas or wetlands. Figure 19 displays the location of Dar es Salaam's informal settlements (in year 2002).

Although formal procedures apply for plot acquisition in Dar es Salaam's planned urban areas, illegal housing is common in unplanned areas. This results in insecurity of land use, which can play a major role in the vulnerability of residents. Dar es Salaam's open spaces (public and private lands) are widely used for urban agriculture, for example, but agreements between owners and users are sometimes nonexistent or informal.

Figure 19 Dar es Salaam Land Use Map, 2002



Source: Vincent (2009)

Housing construction often occurs in areas that have been identified as hazardous lands, despite the fact that the Dar es Salaam City Master Plan of 1979 prohibits this. Some residents settle in former quarry areas, which are often also waterlogged areas, or build houses close to waste stabilization ponds that are not managed well. Such residents are highly exposed to illness associated with and standing wastewater and water that accumulates during rainfall-induced flooding.

Several agencies are engaged in housing issues in Dar es Salaam, The housing industry is, in fact, a major source of employment and catalyst for economic development in the city. The private sector is involved in housing construction, and the Government plays a role in housing and residential development directly as well as through its parastatal agencies (National Housing Corporation, involved in constructing shelter for rental) and Pension Funds (the Parastatal Pension Fund and National Social Security Fund have invested in major real estate developments in Dar es Salaam).

3.2.5 Water supply

The primary source of Dar es Salaam's water supply is the Ruvu River, from where about 262 million liters are extracted each day. An additional 6 million liters per day are extracted from the Kizinga River. After being treated at several water plants, the water is transmitted through pipes to various parts of the city. Unfortunately, a large volume of water is lost en route due to poor infrastructure (e.g., broken pipes) and unauthorized use. Broken pipes also serve as entry points for bacteria, which may result in disease.

Regular water supply is often not provided to unplanned settlements, and many farmers depend on water from wells or directly from rivers (however, rivers and streams are often contaminated with untreated waste that is dumped directly into them by households and industry). In the early 2000s, only 98,000 of the city's residents had access to piped water, and, with 60 percent lost through leakages, and another 13 percent through unauthorized use and illegal taps, only 26 percent of the water was billed (Greenhill and Wekiya, 2004) and only16 percent actually paid for (WaterAid, 2008). Water quality and reliability was poor, especially in low-income areas, and was frequently purchased at exorbitant prices from vendors, kiosks and neighbors.

In a study of 45 of Dar es Salaam's wards, containing 84 percent of the city's population, the percentage of informal residents without access to improved drinking water ranged from 37.8 percent to 90 percent, with a mean of 71.8 percent (Penrose et al., 2010). This also means that for residents engaged in urban agriculture, most are only able to cultivate during the rainy seasons.

Unpredictable water supply situations have led poorer residents to try to adapt to the situation by diversifying sources and reducing consumption. The considerable cost of a piped water connection continues to pose an obstacle for poorer households (see Box 2).

Box 2 Experiences of women of Dar es Salaam's unplanned settlements in obtaining water

Mary, a social worker who came from Kilimanjaro region 10 years ago, has to get her water from a well 500 m from her home. Each bucket she carries back costs her 30 Tanzanian shillings (US 3 cents per bucket). "Getting water now is so much more difficult than before. Then we used to have piped water coming to the house. We used to pay 8,000 shillings a month for it. Then it stopped coming," she says. She thinks the pipe infrastructure broke down and was never repaired. Like many others, she buys her water from someone who has dug a well with no checks on the quality of the water she and others are using.

Anna, who came to Dar es Salaam nearly two years ago with her husband and children after they could no longer scrape a living growing and selling vegetables in Tabora, western Tanzania, can at best only afford five buckets of water a day. With a husband unable to work and in poor health and the family of five living in one tiny room with no electricity, Anna struggles to keep the family afloat. Five buckets of water at a total cost of 15 US cents a day for drinking, washing and cooking in a country where millions of people are living on less than one dollar a day is a significant amount of money.

Source: Taken from Pandya (2009: 10)

Existing constraints to clean water supply for the residents of Dar es Salaam's unplanned settlements will become an increasingly severe issue given both increased climatic variability (with the possibility of more or longer drought periods) and the projected growth of the city's population over coming decades. At present the city's water demand is already far outstripping its water treatment capability. Existing treatment capacity is 282,000 m^3 per day; water demand in 2007 was 412,000 m^3 per day. Demand is projected to rise to 964,000 m^3 per day by 2032, and the planned future design capacity of the system is for 960,000 m^3 per day, using current sources as well as deep groundwater to be extracted from the Kimbii and Mpera wellfields (DAWASA, 2008b). Given immense resource constraints at present, substantial support is likely to be needed by city authorities to meet this design goal.

Pandya (2009) states that work is expected to commence shortly on the drilling of 20 deep wells that can produce 260,000 m^3 a day, and the lower Ruvu treatment plan will be expanded to increase output by nearly 90,000 m^3 a day. Additionally, the Norwegian Embassy is funding a US$6 million research project on the long-term sustainability of deep-water aquifer tapping, including the effects of climate change.

3.2.6 Sanitation systems

Sanitation and garbage disposal is an immense problem in informal settlements, in terms of sewage infrastructure, household provisions, and behavioral practices.

The sanitation system found most commonly in informal settlements is pit latrines. In Penrose et al's (2010) study of 45 of Dar es Salaam's wards, they found that the percentage of informal residents lacking improved sanitation ranged from 71.7 percent to 97.3 percent, with a mean of 92.4 percent. In heavy rains the pit latrines tend to fill up, and human excreta overflows into settlement areas. Some residents empty their pit latrines when it rains by discharging the waste into the rainwater, but due to the high

water table and poor drainage system, this polluted water can remain undrained in the settlement for a long period of time. As discussed in later sections, this is a major factor in disease prevalence in these settlements. Heavier rainfall, as might be experienced in Dar es Salaam with climate change, will exacerbate this situation.

To sum up, the city's planning agencies have been unable to keep apace with the rapid expansion of the city, largely fuelled by migrant growth. Most of the city's population lives in unplanned settlements – many in abject poverty – which are characterized by substandard infrastructure and lack of basic municipal and other services. These communities face transportation constraints, insecure housing, problems in accessing clean water, unhygienic sanitation provisions, and lack of awareness on hygienic sanitary practices. Climatic factors, e.g., heavy rainfall, work in conjunction with this situation to impose additional hardship and increase disease incidence.

3.3 Socio-economic issues

3.3.1 Health

Disease prevalence

According to WHO (2008), food and waterborne diseases such as diarrhea, cholera, hepatitis A, and typhoid fever, as well as vector-borne diseases – mainly malaria, dengue fever and schistosomiasis – are widespread in Dar es Salaam. Many of these diseases indicate poor environmental conditions, and it is important to note that climate change – in altering humidity and rainfall – could increase the spread of both vector- and water-borne disease.

Data from hospitals and health centers

The case study team determined disease prevalence for Dar es Salaam's three municipalities by reviewing the monthly health statistics of hospital and dispensary registers. Diseases were ranked according to number of cases, with the top 10 shown in Table 4.

Table 4. Diseases prevalent in Dar Es Salaam City, by municipality

Kinondoni 2006-Sept 2010		Ilala (2006-2009)		Temeke 2007 – Sept. 2010	
Above 5	*Under 5*	*Above 5*	*Under5*	*Above 5*	*Under 5*
Malaria	Malaria	Malaria	Malaria	Malaria	Malaria
Acute respiratory infection	Acute respiratory infection	Acute respiratory infection	Pneumonia	Urinary tract infection	Acute respiratory infection
Skin infections	Skin-Infection	Diarrhea	Gastroenteritis	Acute respiratory infection	Diarrhea
Anemia	Anemia	Nutritional Disorders	Acute respiratory infection	Pneumonia	Urinary tract infection

Diarrhea	Pneumonia	Pneumonia	Ski Infections	Diarrhea	Pneumonia
Urinary tract infection	Diarrhea	Urinary tract infection	Urinary tract infection	Skin infections	Skin Infection
Pneumonia	Protein energy malnutrition	Skin Infection	Anemia	Intestinal Worms	Ear Infection
Non-infectious gastro	Eye Infections	Skin infection, non-fungal	Worms	Anemia	Eye Infection
Skin infection, non fungal	Skin infection, non fungal	Tuberculosis	Minor Surgery	Ear Infection	Dysentery
Intestinal Worms	Nutritional deficiencies	Anemia	Diarrhea		

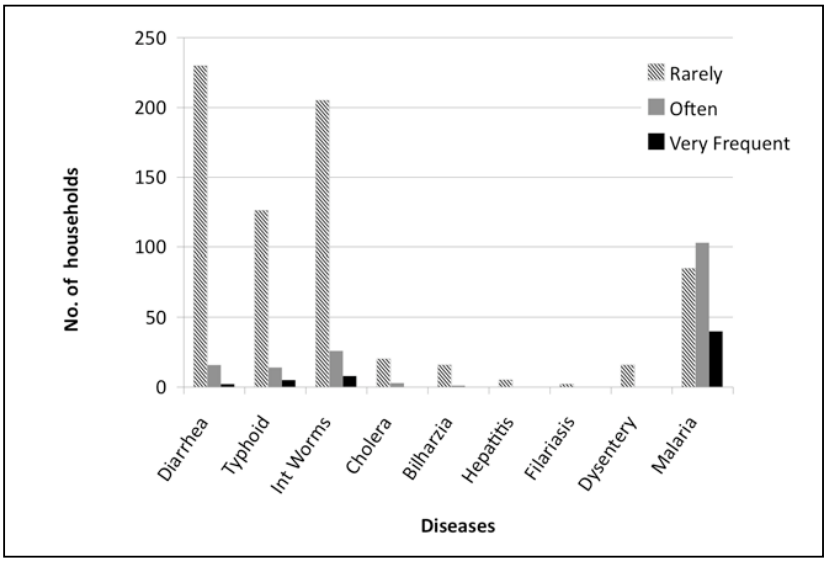
Source: Hospital and Health Centers, MTUHA Registers (researched in 2010 by IRA)

Table 4 shows that water borne disease, vector borne disease and parasites, infections, and malnutrition abound. Malaria is common – a vector-borne disease that is exacerbated by standing water conditions. Acute respiratory infection is also prevalent, reflecting poor housing conditions and improper ventilation. The high incidence of diarrhea, intestinal worms and gastroenteritis are indications of poor sanitation conditions and contamination of food and soil with human excrement. Poor personal hygiene is also evident from the fact that water-washed diseases (e.g., infectious skin and eye diseases) are rampant, as are fecal-oral diseases such as diarrhea and dysentery.

Data from household surveys

The University of Dar es Salaam study team included questions on health in the household questionnaires implemented in unplanned settlements. Residents were asked to rank diseases suffered in the household within the previous two weeks. As shown in Figure 20, more households suffered malaria “very frequently” than any other ailment, and diarrhea, typhoid and intestinal worms were also found to be common, indicating poor environmental conditions.

Figure 20: Illnesses and diseases suffered by residents in households within 2 two weeks prior to the survey implemented in October 2010 (n=543)



Source: University of Dar es Salaam, Case Study Team (2010)

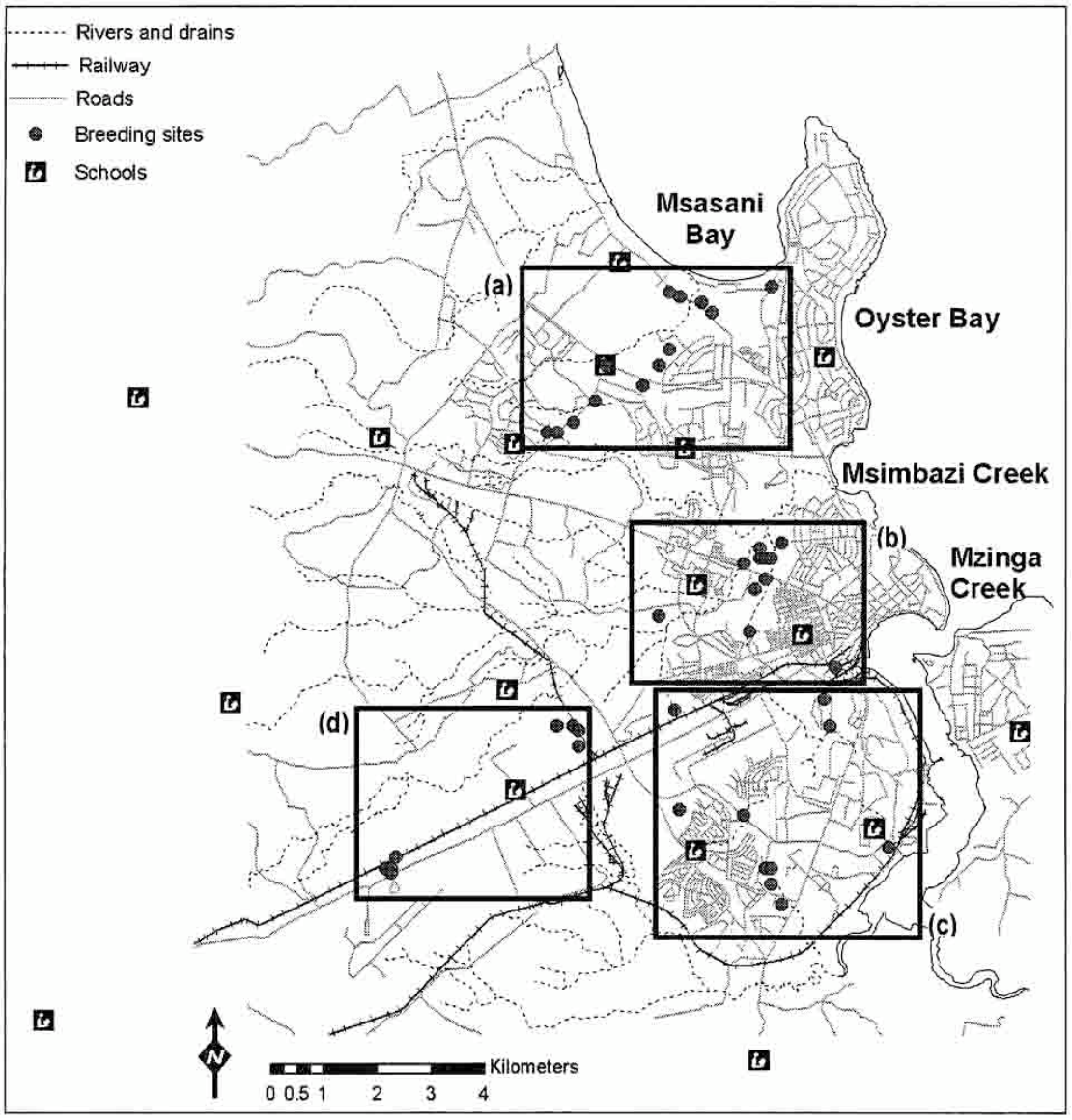
Malaria

Global malaria mapping ranks Tanzania a very high malaria endemicity area (as defined by WHO) with 10 percent of its urban and rural population at risk, the most vulnerable groups being pregnant women and children under 5 years of age (WMO, 2010). According to health services professionals, malaria is Dar es Salaam's foremost health problem for both adults and children (Tanner et al., 1991). Despite marked seasonality in mosquito densities, which usually peak with the rain season, malaria transmission is intense and recurrent, which could be explained by the fact that malaria-transmitting mosquitoes are reported to be rampant throughout the year in Dar es Salaam, due to frequent accumulation of water in residential environments. Figure 21 shows an urban malaria risk map for Dar es Salaam based on studies conducted by de Castro et al. (2004).

The mosquitoes *Anopheles gambiae* and *Anopheles funestus* are the main vectors, with an estimated 200–300 infective bites per person per year, mostly in waterlogged urban and rural areas of Tanzania (Smith et al., 1993). Life-threatening malaria is reported to occur largely in children, commonly those under a year old (Schellenberg et al., 1999). According to a study conducted by De Castro et al. (2004), 2-10 percent of school children living in urban Dar es Salaam are infected with malaria. Anemia, largely caused by malaria (Menendez et al., 2000), is also common in adults and children.

The Government's efforts to control malaria are discussed later in this Section.

Figure 21 Urban malaria risk map for Dar es Salaam, Tanzania



Source: De Castro *et al* (2004)

Cholera

Penrose et al. (2010) analyzed urban environmental data and the burden of cholera in Dar es Salaam and found that cholera incidence was most closely associated with informal housing, population density, and the income level of informal residents. Figure 22 shows cholera-prone areas in Dar es Salaam.

The household surveys documented only one case of cholera. The University of Dar es Salaam team had difficulty in obtaining data on trends in diseases epidemics such as cholera from the health facilities. They found, however, that Ilala Municipality reported

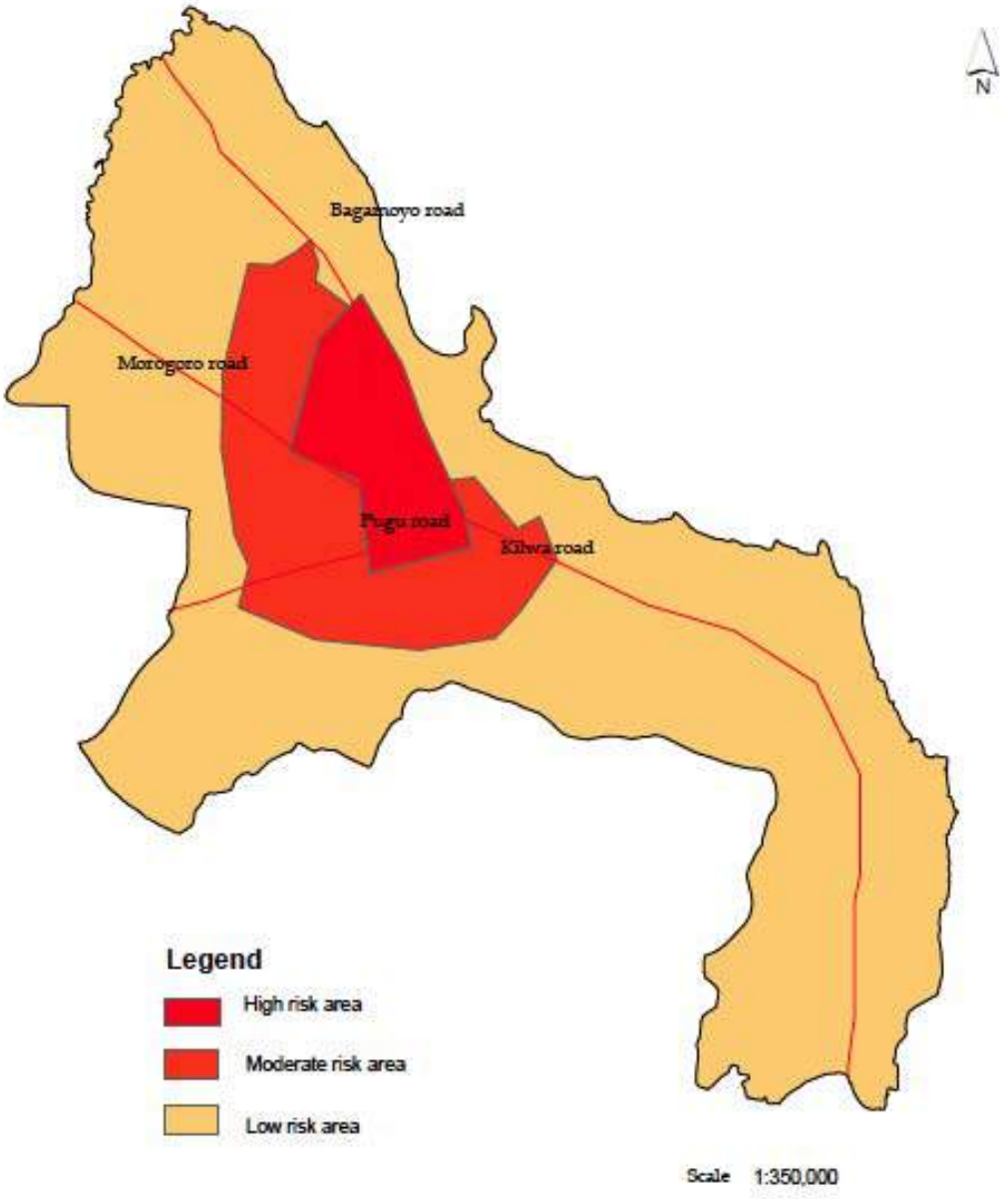
158 cases of cholera in 2009 (6 below and 152 above 5 years of age), all of which were fatal. Temeke Municipality was reported to be leading in cholera epidemics in Dar es Salaam. PRB (2007) report that since the first major cholera epidemic was reported in southern Tanzania in 1977, it has spread to most regions of the country and has remained endemic and a chronic problem in Dar es Salaam ever since. Between 1 January and 31 December 2006, a total of 14,297 cases, including 254 deaths (1.8 percent case fatality rate) were reported from 16 regions of Tanzania's 21 regions. Dar es Salaam represented 62.7 percent of the total cases and 101 deaths (39.8 percent of total deaths; WHO, 2008).

Dengue fever

Dengue fever is a tropical disease transmitted by four types of arthropod-borne viruses through a bite from an infected *Aedes aegypti* (rarely *Aedes albopictus*) mosquito species. The geographic spread of the infection is similar to that of malaria, although unlike malaria, which is also found in remote rural areas, dengue infections most often occur in the urban areas of tropical nations (Tomashek, 2009). Tourist facilities in Dar es Salaam (e.g., hotels, lodges) receive many visitors from tropical countries where the disease is prevalent. Tomashek reports of transmission of the dengue virus through exposure to dengue-infected blood, organs, or other tissues from blood transfusions; solid organ or bone marrow transplants; needle stick injuries; and mucous membrane contact with dengue-infected blood. Poor disposal of hospital waste, including syringes, could be a possible route of transmission of dengue; private health facilities have mushroomed over the city and hospital waste is mixed with other type of waste (industrial, domestic etc), with potentially serious consequences for waste scavengers, who usually work bare-footed and sort through waste with bare hands.

Climate change is likely to affect dengue fever outbreaks by creating increased breeding environments for mosquitoes, similar to the way it will affect malaria incidence. Dengue fever alerts have been generated from time to time in Dar es Salaam in recent years but the disease has generally been contained to a few cases.

Fig. 22 Areas in Dar es Salaam prone to cholera incidence



Source: Ardhi University (2010)

Other diseases

Lymphatic filariasis (elephantiasis) is another mosquito-related tropical disease found in Dar es Salaam (Castro et al., 2010); up to 30 percent of the city's population is estimated to host elephantiasis worms (Health Focus, 2006). Although a massive network of drains (~1130 km) was designed to prevent stagnant water from accumulating and consequently

providing a suitable breeding ground for mosquitoes, a study by Castro et al. (2010) found evidence that these drains are among the most common mosquito larvae habitats. Drains cannot serve their function due to blockage and degradation caused by illegal construction and improper solid waste disposal procedures by residents.

Dysentery and typhoid occur frequently in Dar es Salaam; in 2009, Ilele Municipality reported 58 cases of dysentery and 227 of typhoid. Diarrhea takes a large toll; WHO (2007) estimates that there are over 56,000 annual deaths in Tanzania due to diarrhea resulting from polluted water and poor hygiene. Rift Valley Fever outbreaks occur occasionally near borders with other countries, and Dar es Salaam's dwellers have been frequently warned about this illness.

Other notable health concerns in the city include the prevalence of HIV and drug abuse. According to the Tanzania HIV/AIDS Indicator Survey (THIS) conducted in 2003-2004, the prevalence of HIV in DSM was 10.9 percent – higher than the national percentage of 7 percent (Lorenz et al, 2005), with 12.2 percent of the women testing positive, and 9.4 percent of men. A widely neglected issue in this context adult mortality from AIDS is the increasing number of HIV/AIDS orphans, of whom there are nearly 2 million in the country (UNAIDS/WHO, 2004).

To sum up, residents of Dar es Salaam's informal settlements suffer frequently from a range of diseases and ailments that climatic factors have direct or indirect influence over, and include water-borne, vector-borne, and parasitic illnesses. These commonly include malaria, dengue fever, lymphatic filariasis, typhoid, diarrhea and various other bacterial infections. Humidity levels and ponding caused by rainfall can create breeding sites for vectors. Poor hygienic practices, cramped living conditions, and lack of clean water are also major factors.

Climate change, in increasing climate variability and thereby possibly giving rise to heavier rainfall as well as longer or more frequent drought, could further restrict the poor's access to clean water, and thus lends an added dimension of urgency to address these basic needs.

National efforts in disease prevention

Tanzania is involved in many programs for the elimination of communicable diseases such as malaria, schistosomiasis, filariasis, oncocerciasis and soil helminthes. Also, in recognition of the role of climate in the propagation of many local diseases, and of the fact that climate change may exacerbate this, Tanzania has established a multi-sectoral committee to work on issues of health and climate change. The committee is working on early warning mechanisms for diseases whose spread has climatic dimensions, such as malaria, cholera, Rift Valley fever and dengue fever. Rapid response teams are also being trained and equipped to handle cases of these diseases.

Schistosomiasis and soil-transmitted helminthes

The Schistosomiasis and Soil-transmitted Helminthes Control Programme (NSSCP) is a school health program that has been implemented in the country since 2004 and involves screening pupils for about 15 diseases annually. Depending on prevalence rates, they are treated on a mass or selective basis. Schistosomiasis, soil helminthes and river blindness are covered by the WHO Neglected Tropical Diseases (NTDs) Control Programme, which in Tanzania is implemented by the Ministry of Health and Social Welfare in collaboration with city and municipal authorities. In schools, it is implemented in collaboration with the Ministry of Education and Vocational Training (MEVT).

Medicine for combating filariasis is distributed free of charge to adults (Health Focus, 2006). With donor support, the Government of Tanzania started a National Lymphatic Filariasis Elimination Programme (NLFEP) in 2000, with massive campaigns in coastal areas. Dar es Salaam became involved in the programme at a later stage (in 2006). Donor funding for the programme ended in 2006 but was sustained through the government and respective districts and municipalities until July 2010, after which the agreement with districts/municipals and the National Institute of Medical Research to supply medicines ended.

Programs urgently need to focus on reducing unsanitary conditions in poor residential areas. Also, de-worming programs need to be implemented for both children as well as adults.

Malaria control

The tri-fold objectives of Tanzania's malaria control program are to reduce vector longevity, vector density and human-vector contact. The WHO-recommended strategy being employed is universal coverage with long-lasting insecticide treated nets (LLITNs), which are being distributed free of charge to all residents in rural and urban areas, targeting the poor in particular. The nets reduce the lifespan of female mosquitoes as well as their contact with humans. The LLITNs are designed to remain effective for at least three years, obviating the need for other insecticide treatments. In large households, two or more members are required to share a net.

Initially sold for a highly subsidized fee, the nets are now distributed free of charge. Groups at greatest risk – young children and pregnant women – are given priority, and are usually allocated nets when they attend antenatal, postnatal and immunization clinics. These malaria eradication efforts are largely funded by the USA President Malaria Initiative (PMI) and UNICEF.

Mass media campaigns – TV, newspapers and leaflets – are helping with mass distribution, in informing the public that the nets are free of charge, and in demonstrating how they should be used.

During the household surveys conducted for this study, residents that responded that they had a family member who suffered from malaria within the previous two weeks were

asked about strategies used to combat malaria. Only 10 percent reported using a mosquito net for prevention purposes. The responses mostly focused on recovery, i.e., seventy-two percent said they usually go to hospital after falling ill, and 8 percent said they buy medicine when they fall ill. Data from other studies in malaria eradication in high mosquito and malaria incidence areas (in Ifakara-Kilombero Wetlands and Ramsar Site area) show, for children aged under 5 years, that 13 percent of children sleep under a recently treated net, 54 four percent sleep use a net, and 37 percent use nets that were treated at some point in time (Ifakara Health Institute). Data on urban use of mosquito nets in Tanzania is shown in Table 5.

Table 5: Household Ownership of Mosquito Nets in Tanzania

Background characteristics	Any type of mosquito net			Ever-treated mosquito nets			Insecticide treated mosquito nets (ITNs)			Number of households investigated
	% with 1 net	% with > 1 net	Average nets per household	% with 1 net	% with > 1 net	Average nets per household	% with 1 net	% with > 1 net	Average nets per household	
Urban	76.6	47.2	1.6	72.3	42.1	1.5	59.2	41.6	1.1	2,106
Rural	48.9	26.5	0.9	44.8	23.3	0.8	32.6	14.6	0.6	6,391
Mainland general	55.6	30.7	1.1	50.8	27.0	0.9	38.3	17.9	0.7	8,269
Mainland urban	78.5	46.6	1.6	72.0	44.4	1.5	58.8	30.9	1.1	2,041
Mainland Rural	48.1	25.5	0.9	43.8	22.3	0.8	31.6	13.6	0.5	6,228
Dar es Salaam	**89.2**	**54.1**	**1.9**	**81.2**	**46.9**	**1.7**	**70.0**	**36.6**	**1.3**	**693**
Other Urban areas	74.1	43.5	1.5	68.2	39.1	1.4	54.2	28.6	1.0	1,448
Zanzibar	81.4	65.3	2.2	80.6	64.2	2.2	71.9	53.1	1.7	228

- An ever-treated net is a pretreated net or a non-pretreated that has subsequently been soaked with insecticide at any time.
- An insecticide-treated net (ITN) is 1) a factory-treated net that does not require any further treatment or 2) a pretreated net obtained within the past 12 months, or 3) a net that has been soaked with insecticide within the past 12 months.

Source: URT (2008:135) Tanzania HIV/AIDS Malaria Indicator Survey

From Table 5, it may be seen that although Dar es Salaam is ahead of other areas in the country, household usage of mosquito nets (treated or untreated) is low; while average household size is 4.2 people, the average number of nets per household is 1.3-2. These statistics reveal the limitations of relying on a single methodology, i.e., distribution of mosquito nets. An approach with multiple, integrated efforts is needed that includes improvements in environmental sanitation and eradication of vector borne diseases.

Factors contributing to spread of communicable disease

The following factors were observed by the study team during on-site visits and reported by residents during the survey to contribute to the spread of communicable diseases:

- *High groundwater table:* This causes many latrines and septic tanks to flood, allowing human excreta to enter streams, rivers and wells that are used for many domestic, food vending and other activities (gardening, washing utensils in restaurant/food vending sites, washing marketed fruits and vegetables, etc). This brings cholera bacteria (*Vibrio cholerae*) in contact with hands, or it may be ingested. The filling rate for disposal facilities of excreta and sullage is high. It is too costly for residents to have these emptied on a frequent basis using tankers. Also, tanker access to the facilities is problematic due to congestion of housing structures and narrow alleys.
- *Unsanitary practices/behavior* contribute to illness, e.g., poor hand washing before eating, after defecation or touching waste.
- *Poor latrine design:* Many of the latrines are not ventilated or covered, allowing fly breeding and the spread of disease pathogens. The majority of poorer urban dwellers have not adopted the ventilated, improved latrines that were promoted since the 1980-1990s under urban sewerage and sanitation programs that included demonstration of various low cost ventilated latrines as well as a loan scheme for their construction by trained masons. Other observations by the study team were (i) in cases where ventilated pipes for latrines and septic tanks were installed, the open tip usually had a wire mesh missing that is required for trapping flies, and (ii) covers for the latrine holes, that prevent flies from entering and breeding or escaping, were not always in place.
- *Crude disposal of solid and liquid waste*: Even where communities have participated in upgrading programs such as SUDP and CIUP, unsanitary practices continue. This is true even in cases where communities participated fully and contributed financially to the initiatives. This could indicate the need to empower local level structures, i.e., *Mtaa* environmental and other committees and their legal structures (e.g., Ward Tribunals) and grant such structures more authority in dealing with local level environmental matters.

3.3.2 Subsistence and livelihoods

Overview from literature

About 95 percent of the city's population depends on activities in the informal sector for its livelihood; involvement in the informal sector is, in fact, a survival strategy for the unemployed, low wage earners, and women without sufficient skills to secure well-paid jobs (Dongus, 2000). Residents' activities are diverse and include mining (sand, gravel stones,

limestone, salt extraction), urban agriculture (vegetables, cassava, legumes, sweet potatoes, cashewnuts, coconuts) and fishing. Recreation and tourism occur mostly along the Indian Ocean beach areas. Other informal activities include petty trade, vending of cooked and uncooked food items, vending of used clothes and other industrial produced goods; providing services in the transport sector and other activities that are characteristic of the informal economy in third world countries (Kinabo, 2003; Casmiri, 2009). Urban agriculture, also an informal sector activity, is chosen by a large number of residents, because it can offer employment, income and food security for the urban farmers and their families (Dongus, 2000). It can be seen that many of these activities – urban agriculture, food vending, tourism – are vulnerable to the impacts of adverse climate, and climate change may pose risks to the livelihoods of these groups (for example if droughts or storms intensify).

The Household Budget Survey of 2000/01 shows that wages and other income from employment provide 41 percent of total household income in Dar es Salaam, while income from self-employment represents almost 30 percent. Over one-third of households in Dar es Salaam depend on a single type of income source (URT 2002), indicting that a significant proportion of households experience constraints to household income. This situation is aggravated by a decline in government and parastatal employment and a rise in the self-employment. The survey indicated that income earnings from self-employment were usually less than those from employment in the public sector. It also revealed that the absolute number of people who are poor is increasing in Dar es Salaam, partly due to high population growth, and that income and expenditure gaps are increasing between low and high-income earning groups.

Unemployment was estimated at 46.5 percent in Dar es Salaam in 2002, while it was 25.5 percent in other urban and 18 percent in rural areas (URT, 2004).

Insights from household survey results

The surveys implemented by the Case Study Team of over 500 households in informal settlements showed that more than 57 percent of respondents were self-employed and were engaged in similar activities. Only 16 percent had regular employment (see Table 6).

Table 6: Occupational Status of Respondents

Occupation	Male	Female	**Total**	%
Employed	35	52	87	16
Self employed	89	219	308	57
Dependant	13	113	126	23
Retired officer	17	5	22	4
Total	154	389	543	100

Source: University of Dar es Salaam, Case Study Team (2010)

Of those who were self-employed, 67 percent were engaged in business (petty trade); 9 percent in activities requiring technical skills (car mechanics, carpentry, masonry, plumbing); 4 percent in agriculture; and 4 percent in professional jobs such as medical doctor, nurse, teacher, clerk, security guard and hairdresser. Fishing was also cited as an occupation.

The study team found that some of the respondents' income-earning activities are being undertaken in hazardous areas, such as contaminated environments. These include

contaminated rivers that not only contain sewage and items that may prick (nails, needles), but also chemical waste from industries and informal sector activities. Other residents had created bathing facilities that earn them a small income, but these swimming/bathing facilities are not disinfected, nor are they inspected by health officers (see Photo 4, pg. 63).

The activities of the 56 entrepreneurs that were interviewed are shown in Table 7.

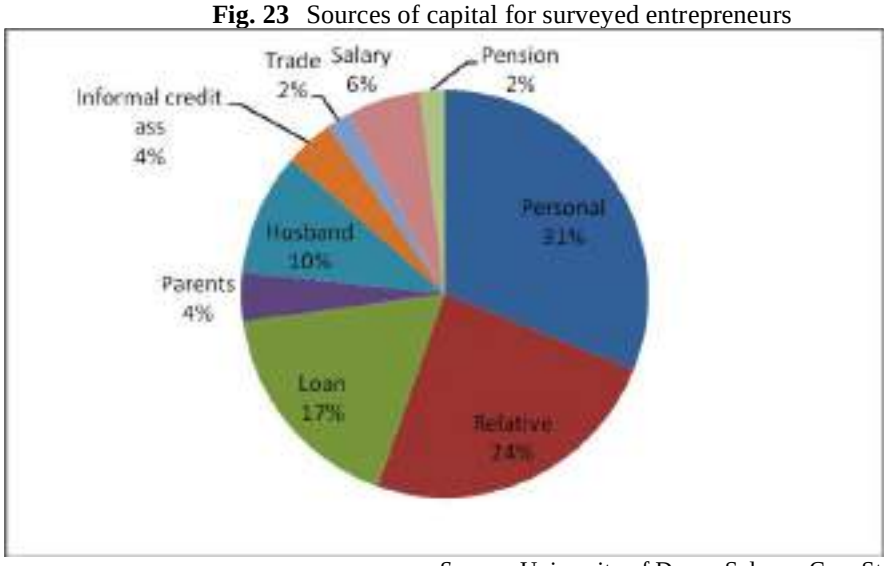
Table 7: Activities of the 56 Entrepreneurs

Income-generating activities	Frequency	%
Swift market (*genge* trade green, raw food, fruit, seed varieties)	15	26.8
Food vendor/tea room/soft drinks	14	25.3
Cleaner, house to house	3	5.4
Trade construction material	3	5.4
Tailoring activities	3	5.4
Shoe maker and sales of shoe items	3	5.4
Waste recycling	2	3.6
Meat Butcher	2	3.6
Charcoal vendor	2	3.6
Selling industrial *khanga* wear	2	3.6
Vending fodder to livestock keepers	2	3.6
Milling machine	1	1.8
Vending water	1	1.8
Hair salon	1	1.8
Mobile phone spare parts	1	1.8
Vending cigarettes, juices, groundnuts and candy	1	1.8
Total	56	100

Source: University of Dar es Salaam, Case Study Team (2010)

The main source of capital for these entrepreneurs was seen to vary, but, as can be seen in Figure 23, “personal source” of capital predominated, followed by “relative”, “loan facility” and “partner” (husband) as important sources. Other sources include savings from salary, informal credit associations, parents, pension and savings from petty trade undertaken in the past.

Fig. 23 Sources of capital for surveyed entrepreneurs



Source: University of Dar es Salaam, Case Study Team (2010)

Entrepreneurs were asked about problems they face in their business. The top ten are shown in Table 8, and some of these are climate related, such as disease, dust and environmental degradation. Shortages in water availability, which may be exacerbated with possible drought intensification in future, can result in low electricity generation and inability for vendors to use equipment such as fridges and electric stoves.

Table 8: Problems Commonly Faced by Entrepreneurs in Dar es Salaam's Informal Settlements

Problem	Rank
Low income of customers	1
Low capital	2
Few customers	3
Poor work equipment (fridges, stoves)	4
High prices of input items	5
Diseases	6
Customers do not make timely payment	7
Dust	8
Filthy environments, flies	9
Disruption by city authorities	10

Source: University of Dar es Salaam, Case Study Team (2010)

The low incomes of customers can result in delayed payment, which in turn affects the financial status of the vendors/traders and their ability to run a profitable business. Low capital inhibits the purchase of useful equipment such as refrigeration or deep freezers to store decomposable items. Other problems mentioned included rainfall, poor roads, high taxes charged by city authorities, and lack of proper venues for entrepreneurial activities. Lack of transport and disturbances caused by city authorities (who attempt to curtail activities that may contribute to filthy environments) are institutional problems that need to be addressed.

The link between climate and income for residents of informal settlements

The study team asked self-employed residents about how climate change might affect their business. The following ten effects were mentioned, in order of decreasing importance:

1. Dampness and spoilage of goods
2. Increased dust
3. Shortage of customers
4. Muddy, poor, or impassable roads
5. Increased flies
6. Smelly, decomposing garbage
7. Lack of goods as access becomes difficult
8. Increased prices of items
9. Poor health of traders
10. Spoiled furniture for those trading wood

Most if not all of these problems are already being faced to some degree by residents. Climate change was seen as having real potential to exacerbate challenges that are already being experienced. More of the problems identified appeared to be associated with rainfall than the dry season. The dry season can lead to increased income for vendors, as prices tend to rise due to drought-induced scarcity of items. However, street businesses are adversely affected by electricity cuts and rising costs of inputs.

3.3.3 Access to basic services

Education system

The city's main education system comprises pre-primary, primary, secondary and tertiary levels. Pre-primary services were provided by the government in the past but are now mostly privately owned. By 2004, Dar es Salaam had about 149 government schools and 74 private schools. The socio-economic profile for the city (2004) shows that school enrolment is much higher in primary schools than pre-primary, since primary education is mandatory. The pupil to classroom ratio in Dar es Salaam is very high, averaging about 124 pupils for each classroom, and the pupil to desk ratio is 6 (each desk serves six pupils). The high pupil to teacher ratio also means that many students do not have much access to the teacher.

The Government covers all tuition costs for government nursery schools and primary schools. In government secondary schools, the tuition costs are shared by the Government and parents. Many students receive government loans for college education, particularly university. Some pay tuition costs on their own.

Access to health services

Most Dar es Salaam dwellers with formal employment avail of medical services through insurance, mainly the National Health Insurance Fund (NHIF). By 2004, the NHIF medical care services covered over 1.2 million beneficiaries through a network of over 3,500 accredited public/private health facilities, with the majority of NHIF members living within an average of 10km from these facilities. Apart from the NIHF, there are private health insurance schemes operating in Dar es Salaam, notably MEDEX and AAR. The range of benefits offered is more or less similar to those of NHIF.

Most residents prefer government hospitals and health centers due to their lower fees. However, of Dar es Salaam's total of 22 hospitals (in 2004), only 4 were owned by the

government; similarly, and only 5 of its 25 health centers were owned by government. The number of hospitals is insufficient for the city's population. In 2004, Dar es Salaam's population to physician ratio was 18,637 (18,637 persons per physician). The poor quality of health services is also reflected in the long queues to see doctors, the congestion in hospital wards, and poor facilities in general (URT, 2004).

Social capital

Dar es Salaam's dwellers build their social network through their neighborhood as well as cooperative networks. The city's many cooperatives include: housing cooperatives, industrial cooperatives, saving and credit societies (SACOS), fisheries cooperative societies and service providers. These facilitate the provision of social and economic services that accomplish the city's efforts in improving living standards on the city dwellers. By 2001, the municipality of Kinondoni had about 134 cooperative societies. Other networks facilitating social capital are civil organizations within the city, which are mainly community-based organizations, non-government organizations, and economic development fund groups. These all seek to improve residents' living standards (URT, 2004).

3.3.4 Emerging issues

The city of Dar es Salaam has urbanized rapidly in recent decades, largely due to high in-migration from rural areas and nearby towns. However, the process has not brought about sustainable urbanization, as manifested in poor socio-economic and environmental conditions (URT, 2004). The city's growth has, to a large extent, favored the rich at the expense of the poor. Rent and land have become scarce resources, obtained at high prices, and sometimes involving payment of middlemen as chief bargainers. No effective measures are being taken to monitor and reduce these challenges.

The city has also experienced a sharp decline in employment provision by government and parastatal agencies, partly due to privatization. The city's ever-expanding urban sprawl is characterized by low-rise structures and a low-density built environment, and infrastructure provision to newly-built areas as well as maintenance of services in old, inner city areas is placing an increasing financial burden on the public sector (Kanyama et al., 2004).

Much of Dar es Salaam's poor are relegated to informal settlement areas. Areas such as these, with inadequate infrastructure, suffer from disease and livelihoods insecurity and are highly vulnerable to the impacts of adverse climatic conditions. Inadequate social services and lack of gainful opportunities also provide breeding grounds for violence, alcoholism, drug abuse, commercial sex, mugging and banditry in these settlements (URT, 2004). Urban ghettos and stigmatized neighborhoods can result. Urban violence borne of social inequality creates insecurity and erodes the social fabric, threatening the foundations of democratic institutions.

Against this backdrop of vulnerability for Dar es Salaam's poor, who lack basic infrastructure and services, climate change and variability lend an added dimension of adversity. Little effort has been made thus far to establish coping mechanisms that serve marginal communities living in flood-prone areas.

4 The Urban Poverty – Climate Change Nexus in Dar es Salaam

4.1 Vulnerability of the poor to climatic hazards

Dar es Salaam is already highly vulnerable to climatic variability, which is expected to increase as climate continues to change. The aspect of most frequent concern to Dar es Salaam currently is heavy rainfall. In combination with poor drainage, illegal construction and other infrastructure problems, heavy rainfall results in flooding that causes major losses and disruptions. For the multitudes of the city's population living in informal settlements, poor sanitation provisions and practices contribute to an additional threat: disease. Diseases commonly occurring in these congested, unsanitary settlements during flood periods include malaria, cholera, dysentery and diarrhea. Some other factors that contribute to flooding in these settlements include flat topography, lack of stormwater drainage systems, blockage of natural drainage systems, building in hazardous areas, and unregulated housing and infrastructure development. Livelihoods activities are also adversely affected by both heavy rainfall and by drought.

4.1.1 Flood risk

The following areas in Dar es Salaam are existing flood-prone sites where, in the absence of remedial measures, climate change is expected to exacerbate vulnerability:

(i) Msasani bonde la Mpunga

Covering an area of 60 ha (mixed residential, commercial & institutional), two main stormwater channels pass through the areas and plays an important role in the city's drainage system. The Master Plan of 1979 designated this area as hazard-prone land, yet development continues due to factors such as proximity to the new American Embassy, presence of a private hospital and large shopping malls, residences of former senior government officials, and the presence of hotels and private offices that provide employment.

Drainage channels are blocked by refuse throughout the year as well as by structures that hinder the flow of wastewater, causing houses to be flooded by unhygienic, sewage-based wastewater in houses (Kiwasila, 2010). Tandale Mtogole, Mkunduge, Ubungo Kisiwani and Msasani Valley – sites covered by this case study – all face these issues. In all flood-prone areas in slums, people have developed short and long-term solutions, which may not be viable in preventing diseases. Some of the temporary methods (cited by CLACC, 2009) include removing mattresses and other belongings and stowing them in the ceiling board area, and children being put to sleep on tabletops or roofs in the case of high floodwaters. Longer-term solutions included setting up barriers or constructing solid concrete walls around the house, with the entrance to the house being via a flight of steps or stones. This ad-hoc approach, however, often exacerbates flooding in surrounding areas.

This settlement has been the focus of a case study on integration of disaster risk management in urban planning, as part of the AURAN project (phases I and II), discussed further in Box 4.

(ii) Msimbazi Valley

The valley covers a wide area across both the Ilala and Kinondoni Municipalities. It is known to flood even during the absence of rainfall in Dar es Salaam, since the Msimbazi River, as it flows through Ilala and Kinondoni on its way to the sea, routinely encounters clogged drains

and structural interferences along its course. Msimbazi valley, in Kinondoni, and settlements in Kinondoni Municipality in general, are the fastest-growing settlements in the city despite their location in flood-prone areas. The influx of people in the Msimbazi valley has been accelerated by factors such as easy access to unregulated farming and building plots, proximity to the city centre, low levels of awareness, poor enforcement of regulations concerning land use, and availability of low-cost housing. These valley areas continue to be populated, exposing residents to life-threatening floods and flood-related health problems.

(iii) Jangwani

This is an informal settlement area in the vicinity of Morogoro Road, on the way to the city centre from Magomeni. It is a low-lying area that suffers flooding during the rainy season nearly every year. The Msimbazi River passes through this valley, and is joined by the Ubungo River which flows across Tandale Mkunduge and Mtogole. (While crossing Tandale, the Ubungo River is christened Ng'omber River, literary meaning 'Cow Dung Carrying River[7].) The two rivers turn the Jangwani Suna area (study site) into a peninsula, increasing the risk to dwellers that are at the mouth of the river. Due to its susceptibility to environmental threats, the area was declared 'not residential' by the former Minister for Lands and Human Settlement Development. However, it is at present highly inhabited, with a mixture of mud, wattle and modern housing constructed adjacent to the filthy sewage-based wetland area of Msimbazi River.

Disposing of sewage off-plot through a piping system connecting to open drains or the river valley is a common practice in Dar es Salaam city and in Jangwani-Suna area in particular. Solid waste is used in the area to reduce the impact of floods; it is collected by CBOs and the *Mtaa* pays lorry owners to haul it to the valley, where unemployed youths then pile it up. In this attempt to keep floodwaters at bay, however, they create muddy conditions and amass decomposing matter that provides breeding grounds for culex mosquitoes (vectors of filariasis).

(iv) City Centre

This is the most flooded area in the city. The problem is exacerbated by poor infiltration and outdated and mal-functioning sewerage and storm water drainage systems.

(v) Mikocheni B

Ponding water is common along the main road and in courtyards due to lack of space for construction of stormwater drainage systems. The natural stormwater drainage system has been blocked by haphazard construction, including of heavy cement block houses and multi-storied buildings. These have blocked underground channels that used to direct the water flow to Msasani and into the Indian Ocean. The water flow now tends to back up and flood houses and feeder roads for months.

[7] Low-income people in Tandale Mtogole and Mkunduge do keep livestock (cows, goats, sheep) under zero grazing and do sell milk for income. However, much of the dung is disposed of into Ubungo river and flows across Jangwani valley Suna residential area into the Indian Ocean, Filthy water containing animal dung, debris, human excrement from latrines, floating solid waste is a characteristic feature of the part of Ubungo River which is Ng'ombe. Dark chemical ridden waters is a characteristic of the Msimbazi River crossing Jangwani area as the river is illegally used by some industries in Ilala Municipality mostly in disposing off plot industrial liquid waste water.

(vi) Kunduchi and Bahari Beach

These areas are susceptible to the effects of sea level rise, storm surges and coastal erosion. Kunduchi beach and Bahari beach in Dar es Salaam have been eroded to the point that heavy investments had to be made to sustain them as beach areas. At Kunduchi, the headwater waves have advanced about 200 m in the past 50 years, as a result of which a mosque, five residential houses, and a historic fish market constructed in 1970s were washed away or destroyed (CLACC, 2009). Africana Hotel, constructed in 1967, is no longer operating due to damages. Sea walls have been constructed, stones placed and trees planted at several sites along the beach. These areas are particularly vulnerable to further coastal degradation, sea level rise and storm surge intensification as may occur with climate change.

(vii) Ocean Road Beach Area

Ocean Road has been eroded, threatening the sustainability of the road itself and of the State House. A sea wall has been constructed and barriers have been erected to deter cars from reaching the beach and loosening the sandy beach soils, which may accelerate beach erosion.

(viii) Vingunguti, Mtambani and Mnyamani

As Msimbazi River passes through these areas, it is prone to floods. These areas were formerly used largely for rice faming and now accommodate the city's Waste Stabilization Ponds, which receive wastewater from industries and residential areas. In order to reduce flood risk in the area, the World Bank funded the construction of a major storm and wastewater drainage channel that disposes of water into the Msimbazi River, and Plan International has provided boreholes to reduce the incidence of water-related disease. However, local practices of disposing of solid waste into drainage channels; constructing houses and industrial premises on the Msimbazi River valleys; and moving earth and constructing concrete walls without constructing underground passages to allow for seepage of water, have thwarted such remedial efforts. Flooding from river and rainwater into houses is a common problem, and tends to instigate conflict among residents (Kiwasila, 2010). Households living in valleys reported that they experience floods every year during the rainy season, with impacts including displacement and property damage. However, these residents return after the floods have receded – possibly due to lack of alternative options – and continue to dump solid waste and engage in activities that contribute towards exacerbation of flooding. Floods also influence the prevalence of cholera epidemics and typhoid.

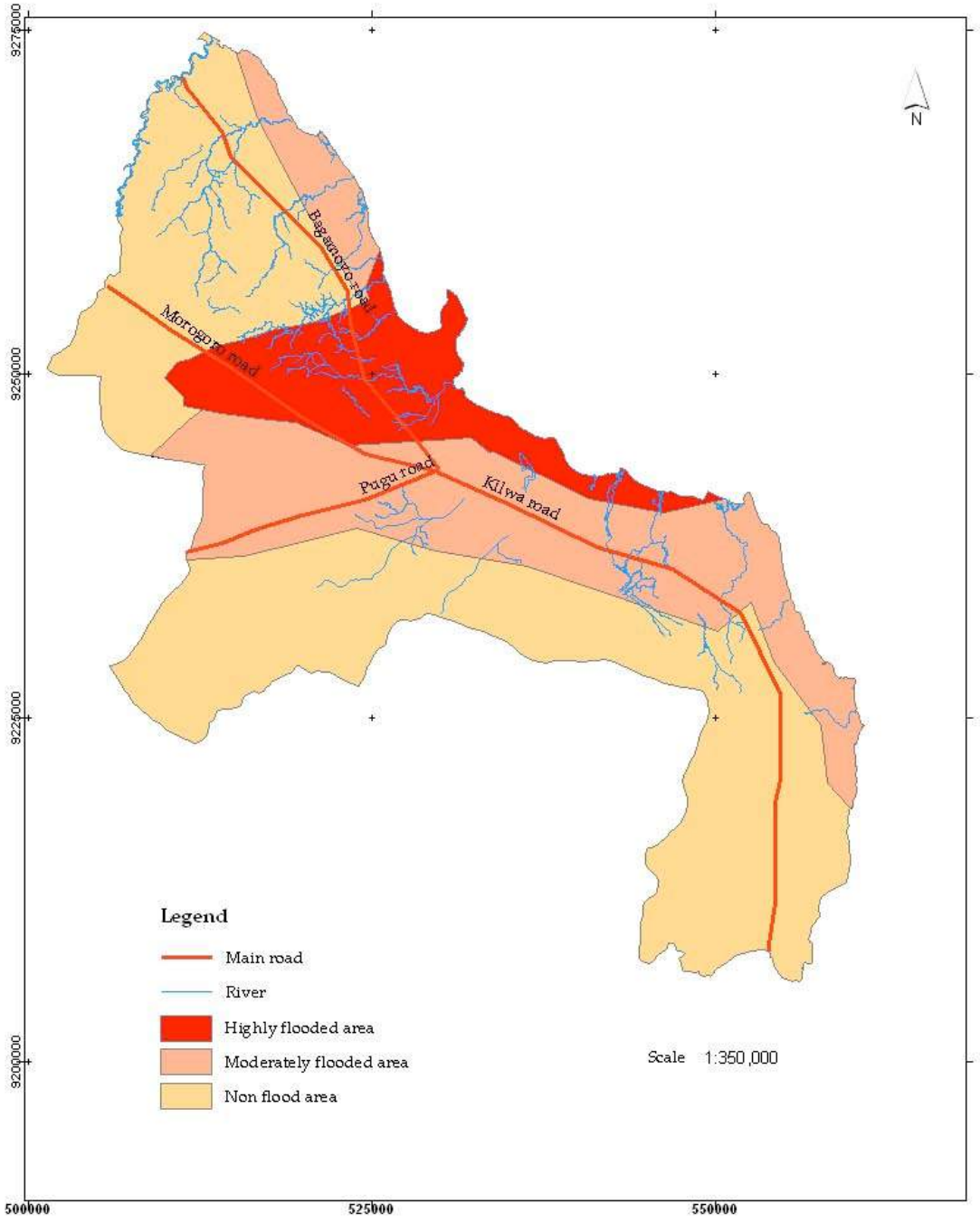
(ix) Temeke River Kizinga areas

The area along Kizinga River in Temeke Municipality is a largely unplanned settlement in a moderately floodprone area with a large population that is self-employed in the informal sector. Outdoor vending activities are common. Many residents use unclean water sources and do not boil their drinking water, and about 95 percent use pit latrines (which tend to overflow easily in floods) for disposal of excreta. The lowland area along Kizinga River floods during the rain season, and this fact combined with unhygienic practices has resulted in Mbagala Kizinga becoming a leader in cholera episodes in the city. Other diseases often found in this locality include malaria, bilharzia, typhoid and dysentery.

As the area is low-lying, residents frequently use solid waste during times of flooding to cover gullies and prevent water from ponding around their houses. It is common in the area to find a road full of piled-up solid waste, including plastics, coconut husks and wooden waste from carpentry shops, as a way of reducing the impact of floods and water-ponding along feeder roads and around houses. This practice, combined with inadequate stormwater drainage and clogging of existing drains, results in the creation of unsanitary areas that provide breeding sites for mosquitoes.

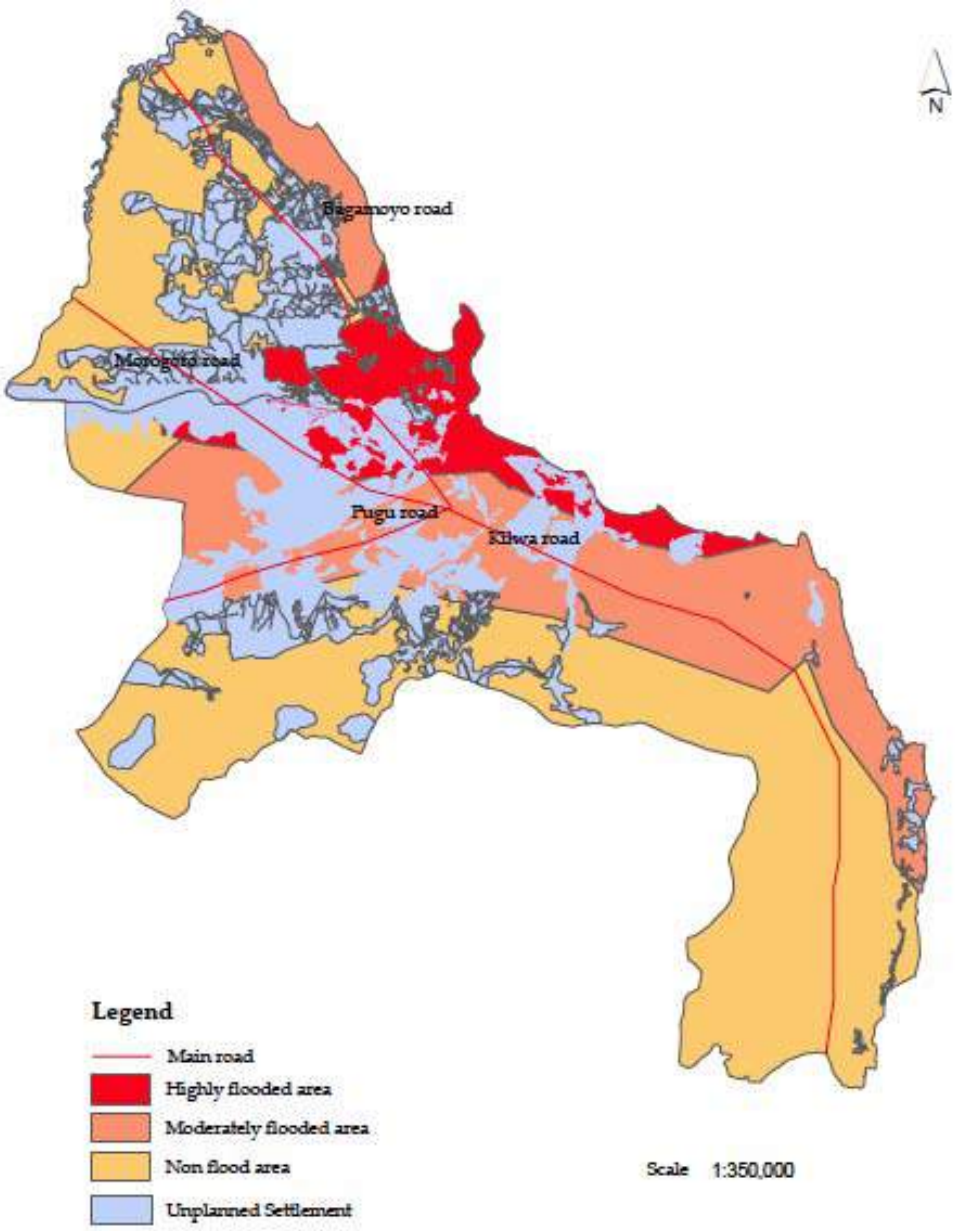
Figure 24 shows floodprone areas for Dar es Salaam. Figure 25 shows flood hazard zones overlain on urban poor (unplanned) settlements.

Figure 24: Flood hazard zone map for Dar es Salaam



Source: Ardhi University, 2010

Figure 25: Flood hazard zone map overlain on urban poor settlements



Source: Ardhi University, 2010

4.1.2 Drought risk

Tanzania[8] occasionally experiences prolonged droughts that can have severe socio-economic implications; the drought of 2006 damaged agricultural production, necessitated electricity cuts (and thus drops in industrial production) and cut GDP growth by 1 percent (ClimateWorks Foundation et al., 2009). A number of diseases are related to drought in the country: malnutrition, trachoma, dysentery, cholera, and diarrhea. Although increased drought has been projected for Tanzania's central regions (ClimateWorks Foundation, 2009), the impact of climate change on drought is uncertain for Tanzania in general (Watkiss et al., 2011), with some models predicting intensification and others reduction in severity. Prolonged droughts affect hydropower generation and result in electricity shortages and rationing in the city, as was the case in the drought of 2006.

Reduced water becomes a major issue for Dar es Salaam's poorer residents, causing disruption of social services and adversely affecting nutrition, subsistence, and livelihoods – particularly small-scale industries such as food vending, which require the use of freezers and refrigerators.

Drought was perceived as a risk posed by climate change to the community by 13 percent of the respondents interviewed by the study team (see Section 4.2, Figure 27).

4.1.3 Diseases

Sanitation provision in Dar es Salaam is grossly deficient; most people living in unplanned settlements do not have access to hygienic toilets and thus large amounts of fecal waste are discharged to the environment without adequate treatment. A high water table means that during heavy rainfall, flooding is quick to occur and waste-ridden muddy water remains undrained in settlements for a long period of time. Stormwater drains are frequently blocked by crude dumping of solid waste. Contaminated stagnant water is a common breeding site for mosquitoes, leading to high malaria incidence in settlements, and to other water borne diseases such as cholera, dysentery and diarrhea. Photos 1–6 below illustrate these conditions.

Photo 1 Stagnant water in an informal settlement

Photo 2 Crude dumping of solid waste

[8] It was not possible to obtain drought information for Dar es Salaam for this study.

Photo 3 Waste-dumping along storm-water drains

Photo 4 Contaminated swimming facility (paid)

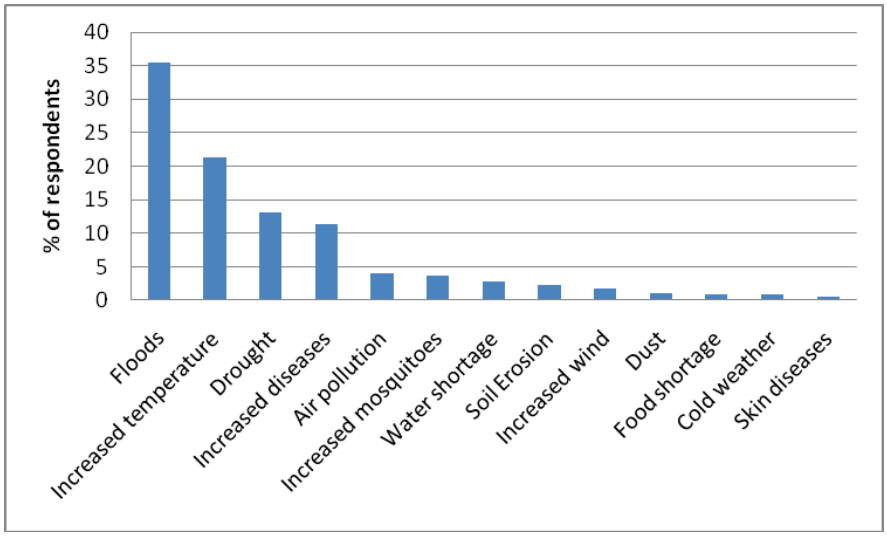
Source: Meshack et al. (2006)

4.2 Household identification of risk

Household identification of risks posed by climate change

When the study team inquired into household perception of risk associated with climate change, 35 percent identified floods as the topmost problem (see Figure 26). Increased temperatures, droughts and diseases also ranked high.

Figure 26: Community identification of risks associated with climate change



Source: University of Dar es Salaam, Case Study Team (2010)

Identification of risks generally faced by residents of unplanned settlements

When the study team asked residents of informal settlements about problems they face in general, many problems were found to be either directly or indirectly climate-related and have the potential to be largely ameliorated through appropriate policies and programs, thus reducing vulnerability to future climate threats. The results are shown in Table 9.

Table 9: Major problems faced by communities in the study area

Ranked Problems	Climate related?	No. of respondents who identified this threat	% of respondents
Floods	Yes	109	25.7
Diseases	Yes	97	22.9
Heat/Increased temperature	Yes	33	7.8
Mosquitoes	Yes	25	5.9
Theft		25	5.9
Shortage of water	Yes	19	4.5
Environmental pollution	Yes	17	4.0
Bad smell in the area	Yes	16	3.8
Crude garbage disposal		15	3.5
Drought	Yes	13	3.1
Dirty unsafe water	Yes	11	2.6
Off-plot sludge disposal	Yes	10	2.4
Noise		7	1.7
Poor infrastructure		7	1.7
Poor social services		5	1.2
Lack of roads		4	0.9
Mud	Yes	4	0.9
Hunger	Yes	3	0.7
Increased flies	Yes	2	0.5
Dust	Yes	1	0.2
Inflation		1	0.2
Total households		**424**	**100.0**

Source: University of Dar es Salaam, Case Study Team (2010)

Floods and diseases were identified as significant problems by over a fifth of the respondents interviewed. Other problems that rainfall and humidity can have significant impact on include mosquito presence, pollution and strong odors in the neighborhood, unsafe drinking water, mud, and flies. High temperatures, too, were identified as a problem and can increase decomposition rates and heat stress, while drought affects water quantity and quality, dust levels, and hunger.

As climate continues to change, increased rainfall variability, resulting in heavier and/or more frequent flooding, as well as the possibility of higher temperatures and more frequent drought, would greatly exacerbate the existing vulnerabilities identified. City and community measures to reduce existing vulnerability are crucial in building resilience towards future climatic changes.

4.3 Projected impacts of climate change in Dar es Salaam

A range of possible impacts of climate change could aggravate the vulnerability of Dar es Salaam's urban poor. Climate change is likely to increase rainfall intensity in Dar es Salaam and thus worsen flooding. A rise in sea level would exacerbate ongoing coastal erosion and degradation. Coastal storms could become more intense and be accompanied by greater storm surges than at present, placing coastal communities at greater risk. Increased temperature could raise humidity levels in rainy seasons, with adverse implications in terms of pest and

disease incidence. Prolonged drought would affect water and electricity, with adverse implications for health, agriculture, agribusiness, and small business enterprise in the city.

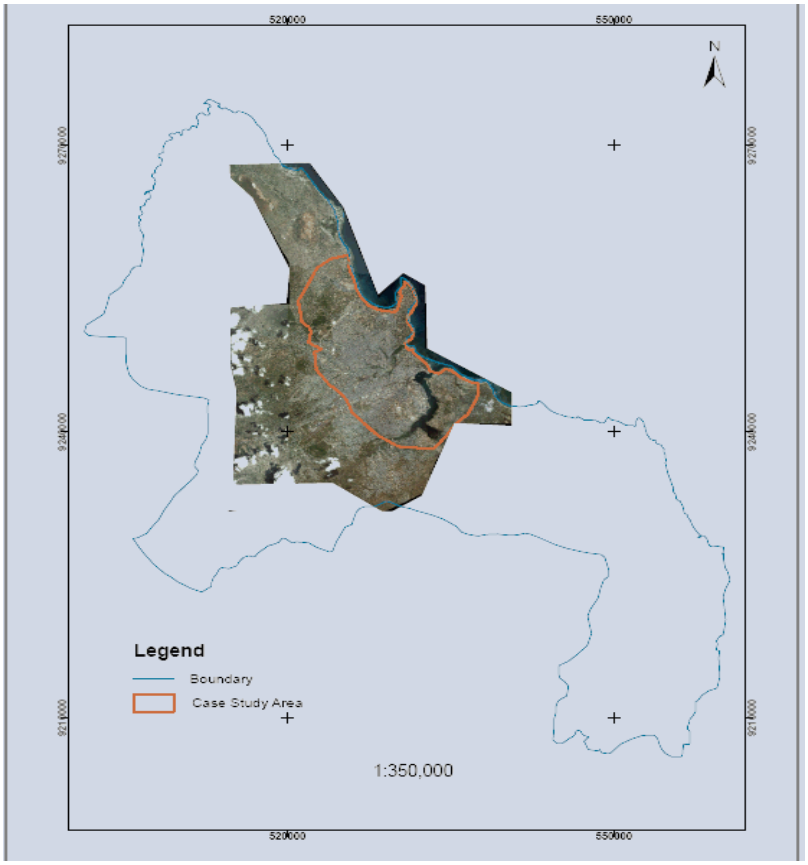
4.3.1 Flood modeling

Ardhi University undertook a flood modeling exercise that would provide an indication of the effects of climate change on flooding in Dar es Salaam by mapping potential changes in rainfall regime and sea level rise on the flood extent and depth in at-risk areas that were covered in the socio-economic surveys implemented by the University of Dar es Salaam. A combined 1D-2D hydrodynamic model known as SOBEK was used (developed by Delft Hydraulics Software). This flood propagation model required spatial data (including a digital elevation model and surface roughness estimates) and temporal data (such as initial water level, and downstream and upstream boundary conditions).

Figure 27 shows a map of Dar es Salaam with case study area outlined that was used for the modeling. Figures 28 (a), (b) and (c) show flood extents for floods with a 5, 10, and 50 year return period, using varying rainfall magnitudes taking sea level rise into account (kept constant across the maps).

Detailed information on the digital elevation model used, and flood model parameters, schematization, calibration and scenarios, is available in Annex 5.

Figure 27 Dar es Salaam showing a case study involved in modelling



Source: Ardhi University (2011)