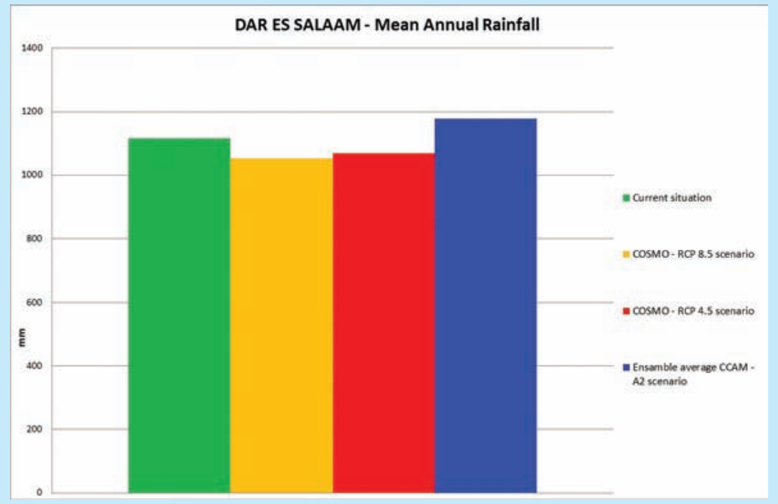
DAR ES SALAAM

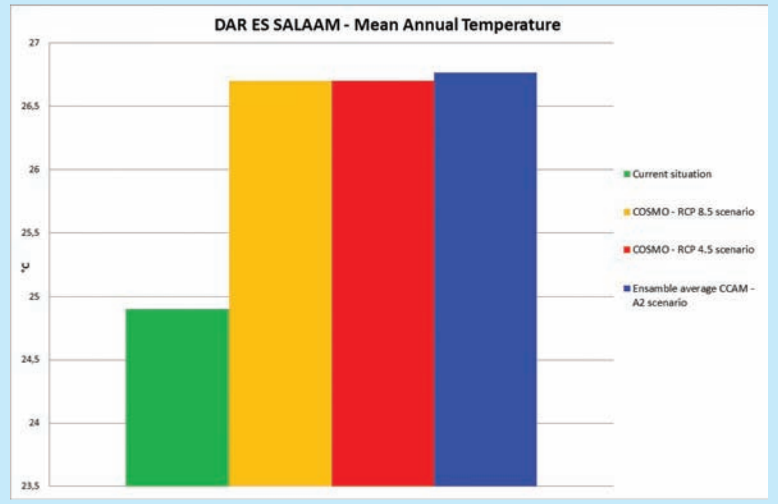
Tanzania

CLIMATE CHARACTERISTICS

The present day climate of Dar es Salaam is characterized by the strong seasonal rainfall cycle, with the “long rains” from March to May, and the “short rains” from November to January. These rainfall maxima are induced by meridional displacements of the Inter-tropical Convergence Zone. The city experiences peak temperatures during the austral summer from December to February, due to the peak in solar radiation.

The results of climate simulations for the period 2010-2050 suggest that:
- mean annual rainfall could slightly change;
- an increase of at least 1.5 °C in mean annual temperature is expected.



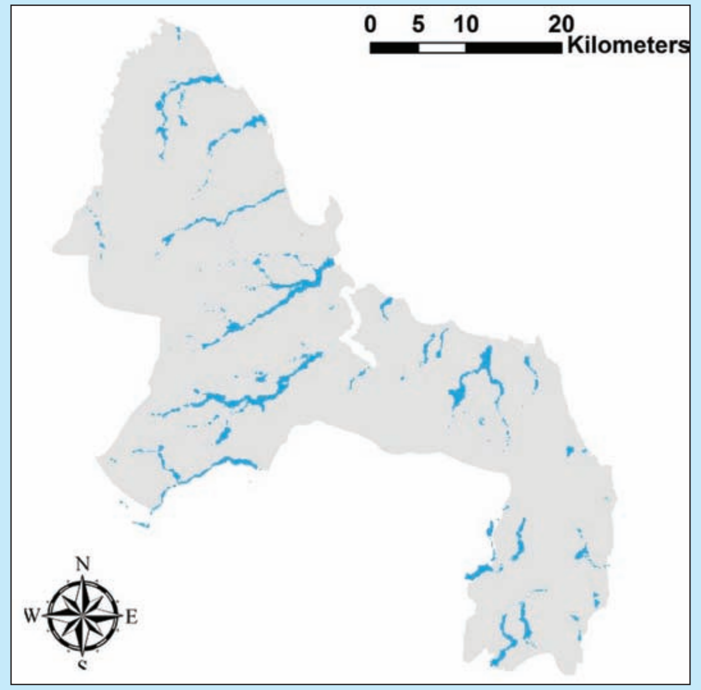


CLIMATE RELATED HAZARDS

Floods

The analysis of Extreme Rainfall Events, based on climate projections data until 2050, suggests that the intensity of Extreme Rainfall Events is expected to decrease, although an increase of the frequency is envisioned.

However, assuming a business as usual scenario of population growth, runoff of rainwaters is expected to increase due to the decrease of the permeability of the urban environment.



Map of Topographic Wetness Index for Dar es Salaam (most susceptible areas to flooding phenomena based on a geomorphological criterion).

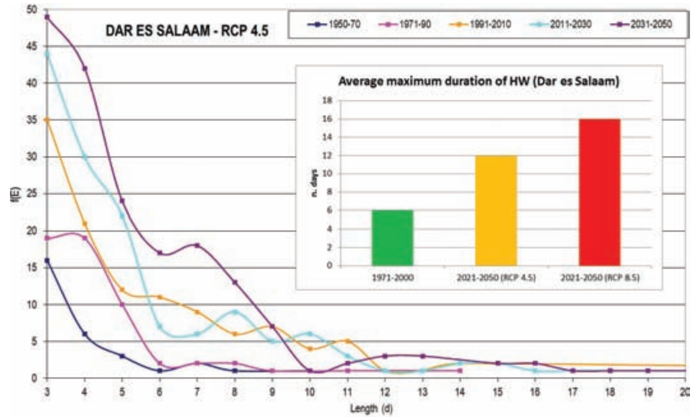
Drought

The analysis of the monthly average rainfall clearly shows that the current condition is extremely dry. Analysis based on climate projections reveals that this condition is expected to continue in the next 40 years.

Heat waves

Analysis of climate projections for Dar es Salaam reveals a strict correlation between heat wave duration and hot days number. The length of heat wave episodes shows a mean value increasing from 6 to 12(RCP4.5)-16(RCP8.5) days. The frequency distribution plot of hot days duration for four separate bi-decadal periods (see figure) shows the temporal change of heat wave characteristics. This distribution has become longer tailed with time. For example, the number of events with maximum length lasting 5 days could increase from 3 to 24 (33 for RCP8.5) over 100 years (from 1950-70 to 2030-2050).

The expected persistence of long-lived heat waves lasting approximately 1.5-2 weeks is clearly longer with respect to the climatological period (1961-1990). During 100 years, short lived but more intense waves are more than doubled in duration. It is evident the needs for the national health services to develop strategies for the mitigation of the heat wave effects, to enhance the resilience of the population, particularly the elder people.

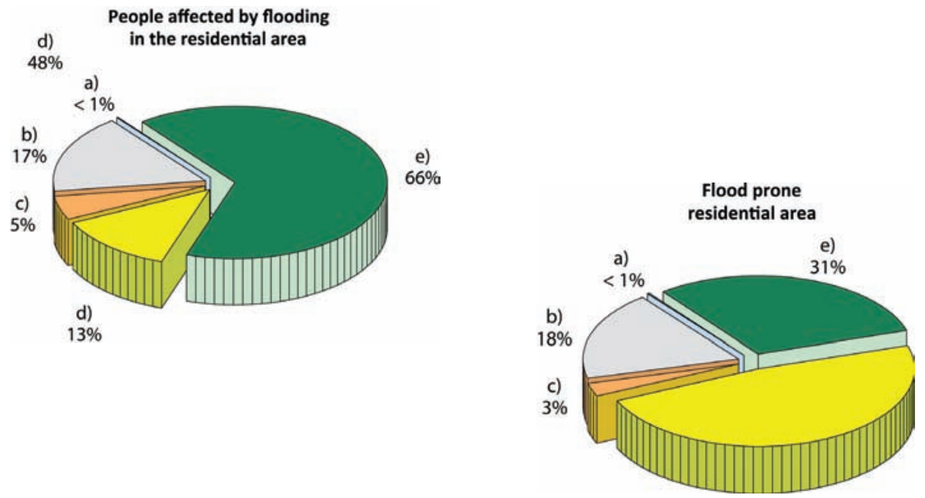


Average maximum duration of Heat Wave phenomena and frequency distribution plot of hot days duration for four separate bi-decadal periods.

URBAN CHARACTERIZATION AND GREEN STRUCTURE MAPPING

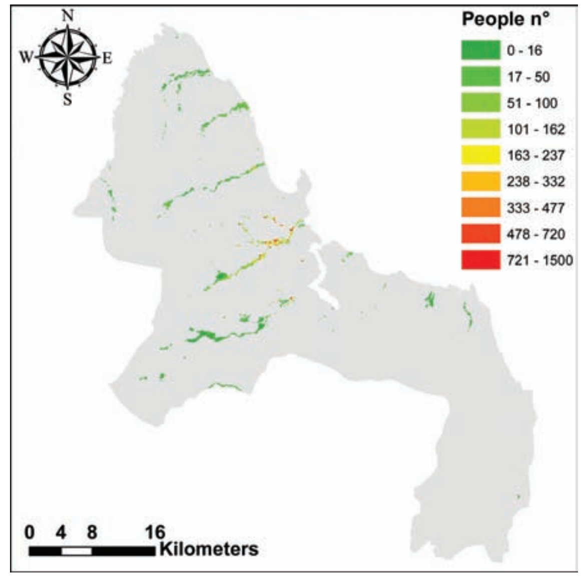
The 66% of the population in the flood prone residential area lives in residential type labeled as *mixed*. This residential type constitutes around 31% of the flood-prone residential buildings.

On the other hand, around half of the buildings identified as flood-prone belong to the scattered settlements category. Moreover, the inhabitants of the scattered settlements constitute around 13% of the total population affected by flooding.

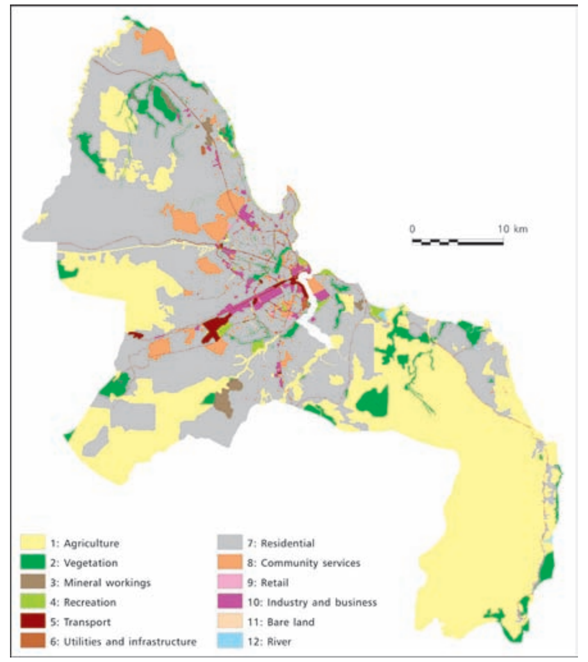


Losses of green structure from both the peri-urban (25-50km) and urban (<15km) zones are evident. The former has city-wide implications for provisioning services and future food security and the latter for human livelihoods, health and wellbeing, including local capacity for provisioning services in some of the poorest neighbourhoods.

Future scenario modelling under business as usual (i.e. continued low density development including flood prone areas) suggests that land associated with settlements could change from 47% to 53% of the study area between 2008 and 2025, an increase of 9769 ha. The expansion of settlements was estimated to be associated with a loss of 6,886 ha of farmland and 2,352 ha of green areas. The business as usual case suggests **a high concentration of settlements in flood prone areas by 2025**: 1,025 ha in areas classed as *riverine*.



The urban residential hot spots for flooding in Dar es Salaam.



Urban Morphology Types in Dar es Salaam.

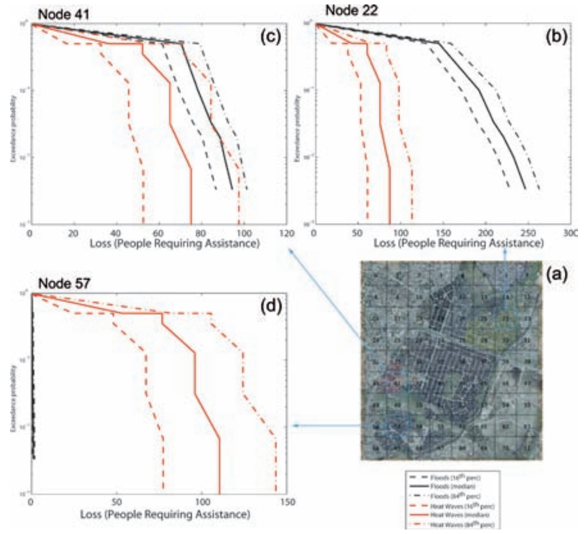
FINDINGS ON SOCIAL VULNERABILITY ASSESSMENT

Findings on social vulnerability for the communities of Bonde la Mpunga and Magomeni Suna for Dar es Salaam have been grouped according to four main vulnerability dimensions:

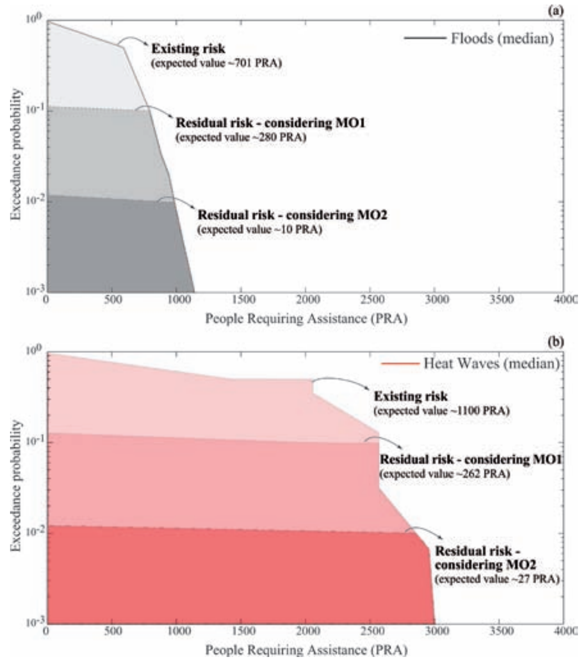
Asset vulnerability	
Bonde la Mpunga	– 41% of the households have 5+ members, mean household size is 4.22 – 50% of the households have 2 to 3 young dependants below 18 years – About 60% of the households are primary school leavers – Small business is the main source of income – Income levels range from less than TSHS 100,00 to TShs 8,000,000 per month. Average income is TShs 490,000 per month – Fungus, schistomiasis and typhoid, cholera are common diseases
Magomeni Suna	– 43% of the households have 5+ members, mean household size is 3.91 – 45% of the households have 1 to 2 young dependants below 18 years – 13% of the households have 1 to 2 elder persons above 65 – About 40% of households are primary school leavers – Small business is the main source of income. Other income sources include urban agriculture, fishing and casual labouring – Income levels range from less than TShs 100,00 to TShs 1,500,000. Only 11% of the households have income above TShs 500,000 per month. Average income is TShs 490,000 per month – Malaria, diarrhea and fungal infections are common diseases
Physical vulnerability	
Bonde la Mpunga	– Pit latrine is used by 66.7 % of the households – Haphazard disposal of solid wastes on open spaces and drainage channels – Only Few trees dispersed at individual households – Multiple sources of energy for households-charcoal, kerosene, electricity, wood, gas – Water sources-public/private water tapes and bore holes – 46 % of houses not accessible by car – Insufficient and poor quality storm water drainage channels – Only 36% of the households have formal title ownership of the land and properties
Magomeni Suna	– Pit latrine is used by 83.33 percent of the households – Haphazard disposal of solid wastes on open spaces, drainage channels and along river valleys – Only Few trees dispersed at individual households – 61% of the households depends on charcoal as source of energy of cooking – Households access water from public and private water tapes – 55% of houses not accessible by car – Insufficient and un-maintained storm water drainage channels – Only 2% of the households have formal title ownership of the land and properties – Lack of community facilities including education and health
Institutional vulnerability	
Bonde la Mpunga	– Local institutions at grass root level such as NGOs CBOs, are involved in cleaning storm water drains, solid waste collection and provisioning of health and education services – Sub ward government and Ten Cell Units mobilize community for environmental cleanness, construction and maintenance of storm water drains – Little support from Municipal and City Authorities in adaptation to flood hazards
Magomeni Suna	– Informal and non state institutions more active in supporting the community to adapt to flood hazards – Formal institutions intervene only during emergency/disaster events – Residents lack trust to the warning information provided by the formal institutions – Little confidence in political support to adapt to flood hazards
Attitudinal vulnerability	
Bonde la Mpunga	– Long duration of residence up to 82 years – Household perception that floods are created by the rich people – Only 51% of the households have social networks – More than 80% of the networks are informal – Family related networks more dormant – Households are aware of the flood hazards – More individual initiatives in coping to floods
Magomeni Suna	– Different perceptions: flood is a God given-nothing can be done, water is afraid of people – Only 50% of the households have social networks – Kin related networks more dormant, others include gender, friendship and livelihood related networks – Households are aware of the flood hazards but have no option

MULTI RISK ASSESSMENT AND DECISION-MAKING IN DAR ES SALAAM

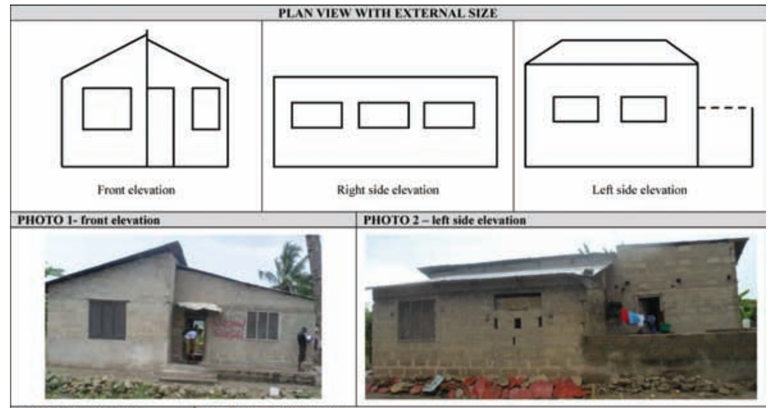
An example of application of the proposed multi-risk analysis tool has been performed in a pilot area in Dar es Salaam, Tanzania, that covers the areas occupied by the subwards of Suna, Magomeni Idrisa, Dosi, Hanna Nassif, Kigogo Mbuyani, Mtambani, Mwnyimkuu, Mzimuni Idrisa, Mzimuni Makumbusho, and Mzimuni Mtambani.
The hazards considered in this exercise are floods and heat waves, which are climate-related hazards resulting from intrinsic processes of cascading effects from atmospheric conditions. The main effort in this case has been oriented towards the harmonization of the data, analyses and results. A comparative example in which the resulting risk curves for floods and heat waves are compared at different nodes of the analysis domain has been performed (see figure on the right).
Beyond the direct comparative analysis, decision-makers can use the multi-risk results also to evaluate the effects of different risk management options (RMO). In fact, considering the results of the multi-risk analysis, if one or more risks are judged to be unacceptable and they are to be reduced through risk management options, both the expected values of risk and the risk curves can be used to estimate the effectiveness of the RMOs. Building a levee, for example, is one option (among many other) for managing the flood risk and it is the example that we use here for the illustration.
This figure on the left shows the risk curves derived from the assessment of the three different decisions for the risk of floods and heat waves (figure on the left). The decisions considered are "do nothing" and other two different RMOs. The "existing risk" curve corresponds with the "do nothing" option, and the other two curves represent the residual risk after acting specific mitigation options. After assessing a set of MOs, a set of data composed by the cost of implementing the MO, the residual risk, and the reduced (or mitigated) risk is available to help the decision-maker. For example, the decision-maker can use this information to perform cost/benefit analyses and to decide where and how to operate more effectively considering the available resources.



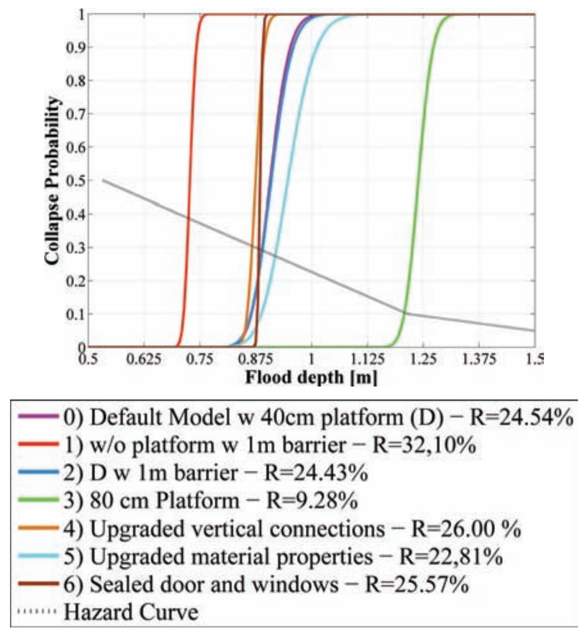
Comparative plot of the Flood and Heat wave risk curves (exceedance probabilities and annual losses): (a) grid domain for the analysis; (b) risk curves in the node No. 22 (X=7 - Y=3); (c) risk curves in the node No. 41 (X=2 - Y=6); (d) risk curves in the node No. 57 (X=2 - Y=8). For details, see the text.



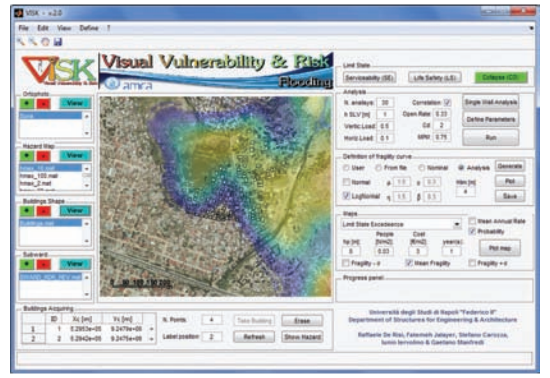
Risk curves representing the existing risk and the residual risk considering different mitigation options. (a) Example for the flood risk. (b) Example for the heat waves risk.



GPS COORDINATES	See bottom of page for details		
No. of stories	1	Height of storey	2.60m *(up to ceiling level)*
Presence of mezzanine (mansard)		Yes:	No: ✓
Geometric size			
L (plan length)	9.030m	W (plan width)	10.80m
Wall material	Cement blocks		
Wall thickness	0.125m		
Presence of cross connection in the corners		Yes: ✓	No:
Presence of buttress		Yes:	No: ✓
Presence of plaster		Yes: - *half wall, about 1.10m of glazed plaster, at front elevation*	No: ✓
Presence of water-proof paint		Yes:	No:
If wall material is wood and mud	Are wooden piles anchored in foundations?	Yes:	No:
	Are the wooden horizontal piles connected and continuous over the perimeter?	Yes:	No:
Roof typology	Flat:	Pitch:	One side:
			Two side: ✓
	Structural material (a)	Corrugated Iron Sheets	
	Presence of roof beams	Yes: ✓	If yes, material (b): *Wood/Softwood timber, untreated*
		No:	
	Presence of drainage or drip	Yes:	No: ✓
	Presence of roof coverage	Yes: ✓	If yes, material (c): *Corrugated Iron Sheets, Gauge 30*
		No:	
	Use of water proof materials	Yes:	If yes, material:
		No: ✓	
Presence of foundation	No: / Yes: ✓	If Yes:	
		Construction material:	* Plain concrete
		Elevation from ground:	
Presence of lintel beam	*-half beam (over doors and windows)*	Yes: ✓ (200mm thick)	No:
Functionality of doors and windows (in impeding/delaying the water entrance)	Quality of doors:	Good:	Bad: ✓
	Quality of the windows:	Good:	Bad: ✓
Minimum height of the window above the floor	1.15m		
Window dimensions	L (plan length) 1.15	H (height)	1.20
Height of the door above the floor	** 0.40m		
Door dimensions	L (plan length) 0.90	H (height)	2.15
Presence of barrier in front of the door	Yes: ✓ / No:	If Yes:	
		Elevation from ground	0.40m



The fragility curve can be read as: *the building is going to collapse with 50% probability due to a flood height of around 0.88m and it is going to collapse with 100% probability* due to a flood height of around 1m.*
The annual risk of collapse (fragility integrated with hazard) is shown as a percentage next to the legend. The risk can be interpreted as following: *There is around 24.5% probability that the building is going to collapse in a one year time frame.*
* The 100% probability is based on the working assumptions made.



GENERAL PRESENTATION

Dar es Salaam is the largest city in Tanzania with an estimated population of 3.4 million inhabitants. It is one of the ten fastest growing cities worldwide, with an estimation of 4.5 million in 2020.
Dar es Salaam covers almost 1,400 km². The region is headed by the Regional Commissioner while the city is managed by the City Council. The area is divided into three autonomous municipal councils: Kinondoni, Ilala and Temeke. Each council is subdivided into 11 divisions, segmented into 73 wards. Sub-wards (Mtaa) are the lowest administrative level.
Compared to other Tanzanian regions, Dar es Salaam hosts the highest (65.1%) percentage of individuals in their working age (15-64 years). Urban unemployment however, continues to persist due to the differential between annual migration rate (10%) and the annual economic growth (4%). The literacy rate has increased steadily over the last decades with Kiswahili being the most dominant language.

List of contributors (text and photos)
Edoardo BUCCHIGNANI, Paolo CAPUANO, Francesco DE PAOLA, Raffaele DE RISI, Kibassa DEUSDEDIT, Angela DI RUOCCO, François ENGELBRECHT, Alex GARCIA-ARISTIZABAL, Maurizio GIUGNI, Lise HERSLUND, Fatemeh JALAYER, Nathalie JEAN-BAPTISTE, Regina JOHN, Patrik KARLSSON NYED, Gabriel KASSENGA, Wilbard KOMBE, Klara KWEKA MSALE, Alphonce KYESSI, Sarah LINDLEY, Elinorata MBUYA, Riziki SHEMDOE, Ingo SIMONIS, Maria Elena TOPA, Guido UHINGA

DAR ES SALAAM
Tanzania

SPECIFIC RECOMMENDATIONS

Recommendations to decrease structural vulnerability in Dar es Salaam

Structural Material: Cement blocks; Self weight (γ): 14 to 18 KN/m3; Elastic modulus (E): 1.2 GPa; Compression strength (f_c): 1 to 3 MPa; Shear strength (f_v): 0.03 to 1 MPa; Flexural strength (f_t): 0.2 to 1.5 MPa;
Loading: Hydrodynamic, hydrostatic and debris impact;
Restraint: The wall panel is assumed to be fixed at the base and hinged at the two vertical sides.
As-is configuration: Vulnerability of the structure to collapse is represented by the fragility curves (probability of collapse vs. flood height). The fragility curve for the default (*as-is*) configuration is plotted as case 0 (purple). The *as-is* building is assumed not to have sufficiently water-tight doors and windows. Moreover, it is assumed that it has a raised foundation of 40cm. Another possible and much less favorable *as- is* condition is a structure without raised platform having a barrier constructed in front of the door (case 1, red, R=32%).
Effective mitigation strategies: The following low-cost mitigation strategies lead to an improvement (although often non-sufficient) in the structural performance:
1. Increase the height of foundation to 80 cm (case 3, green, annual risk of collapse= 9.2%)
2. Protect the walls from direct contact with water (case 5, cyan, annual risk of collapse = 22.8%)

Ineffective mitigation strategies:
1. Improving the wall connections (case 4, light brown, annual risk of collapse= 26%)
2. Sealing the doors and windows (case 6, brown, annual risk of collapse = 25.6%). Note that this strategy improves the building in terms of life safety condition but subjects it to hydrostatic loads and thereby renders it more vulnerable to collapse.

The map of multi-dimensional vulnerability to flooding in Dar es Salaam at the level of the subward administrative unit. The map is a combination of 16 indicators selected and weighted by stakeholders. The four minor maps depict a sample of individual vulnerability indicators, each representing a distinct dimension; a) Population density, b) Age, c) Participatory decision-making, and d) Level of Social Network. The minor maps reveal that also other parts of the city may be vulnerable to flooding, but with respect to only one or a few individual vulnerability indicators. The light-blue areas in the main map are indications of where flooding is more likely to occur (according to a hydrological model using a topographical wetness index). High-risk areas are where subwards highly vulnerable to flooding (red borders) are coinciding with areas more likely to become flooded.

Specific recommendations for Dar es Salaam

- Mainstream climate change adaptation, water management, reducing vulnerability etc. into main city plans like the master plan, sector plans.
- Identify and include important stakeholders across sectors and levels in a continuous process towards a broad adaptation effort to increase awareness raising and competences and coordination.
- Initiate 'integrated local projects' in the most vulnerable areas (and resettled areas) that combine urban service upgrading, livelihood projects with local land use management and regulation.
- Adopt urban development strategies aiming at avoiding a large increasing of surface impermeability, and consequently of floods' intensity, caused by large settlement expansion at the expense of mainly agricultural land and other vegetated areas. This can be obtained by increasing current settlements' density in a well-balanced manner in order not to have negative impacts on living conditions.