SEVENTH FRAMEWORK PROGRAMME

HARVARD HUMANITARIAN INITIATIVE

Dec 09-10 2011

CLUVA

The 'Climate change and Urban Vulnerability in Africa' Project (http://www.cluva.eu/)

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Main objectives

The main objective is the assessment of the impacts of climate changes at urban scale in Africa in the next 40-90 years (2050-2100), by:

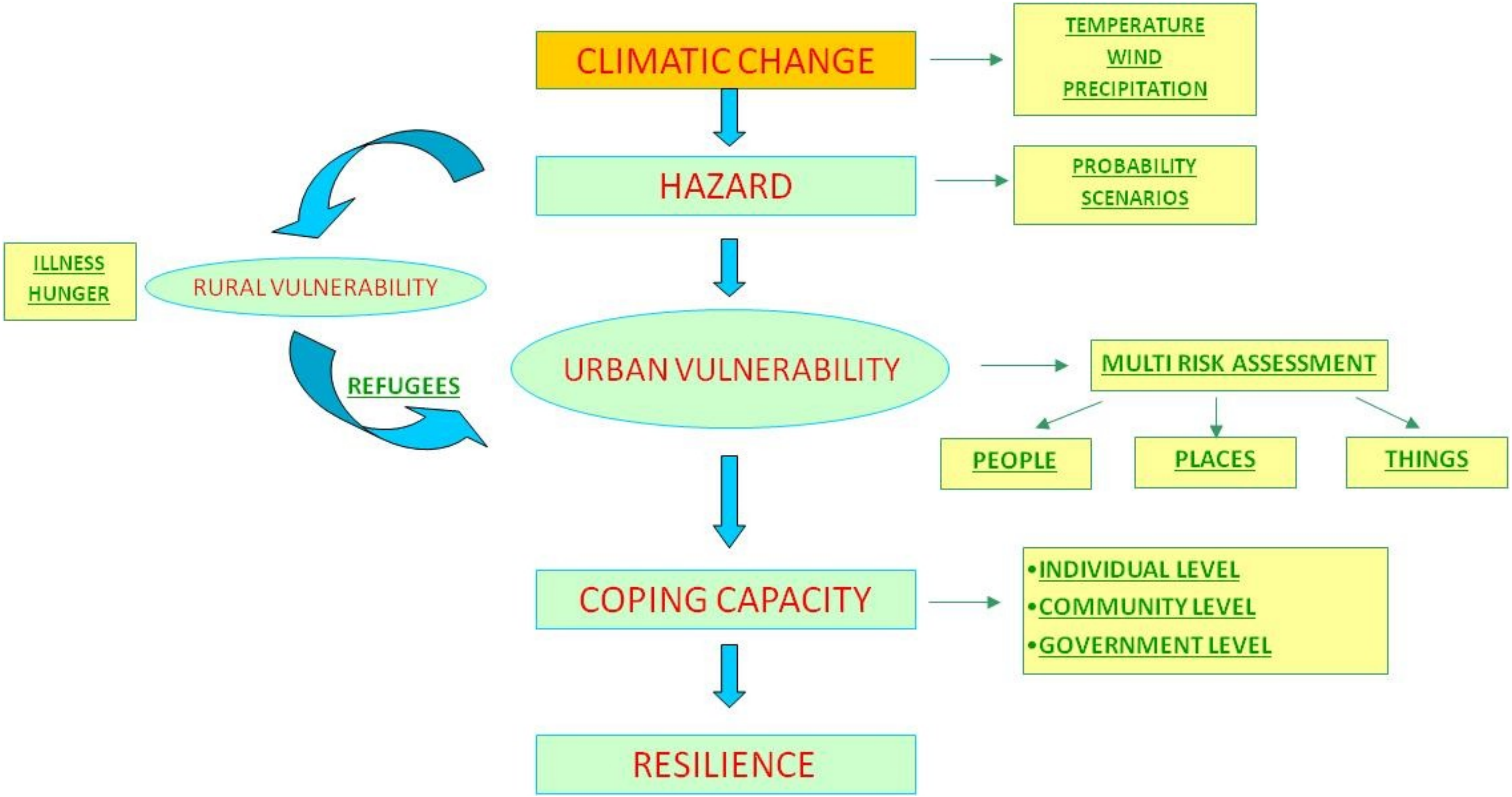
1. to downscale climate trends to evaluate threats (hazards) to cities: i.e., flood, drought, desertification, heat waves, sea level rise;

2. to develop methods and knowledge to quantitatively assess risks (i.e., employing probabilistic loss metrics) cascading from climate-change-induced hazards, considering vulnerability of urban built environment and lifelines, as well as social and economical vulnerability, in-town ecosystems and urban-rural interfaces vulnerability;

3. to get information to manage risks and to improve the coping capacity and the resilience of urban systems.

CLUVA is a 3-yr project (at the end of the first year) funded by the European Commission.

Conceptual Framework



Work Breakdown Structure

WP1 Climate change and natural hazard models

WP2 Vulnerability and risk assessment

WP3 Improving the resilience of urban systems to climate change

WP5 5 cities pilot studies

WP4 Research capacity building and dissemination
WP6 Coordination and Management

European partners and competencies

- **AMRA (Analysis and Monitoring of Environmental Risks) – Italy**
  Project Leader - Vulnerability and risk assessment
- **University of Copenhagen – Denmark**
  Governance and planning systems
- **University of Manchester – United Kingdom**
  Land use indicators
- **Technical University of Münich – Germany**
  Vulnerability and adaptation potential associated with urban ecosystems
- **CMCC (Euro-Mediterranean Centre for Climate Change) – Italy**
  Model projection of climate change
- **UFZ (Helmholtz Centre for Environmental Research) – Germany**
  Assessing social vulnerability
- **NIBR (Norwegian Institute for Urban and Regional research) – Norway**
  Innovative land use and governance strategies

African partners

- Gaston Berger University of Saint Louis – Senegal
- University of Yaounde – Cameroun
- Université de Ouagadougou – Burkina Faso
- Ardhi University – Tanzania
- Ethiopian Institute of Architecture, Building Construction and City Development – Ethiopia
- CSIR (Center for Scientific and Industrial Research) – South Africa

Model projection of climate change

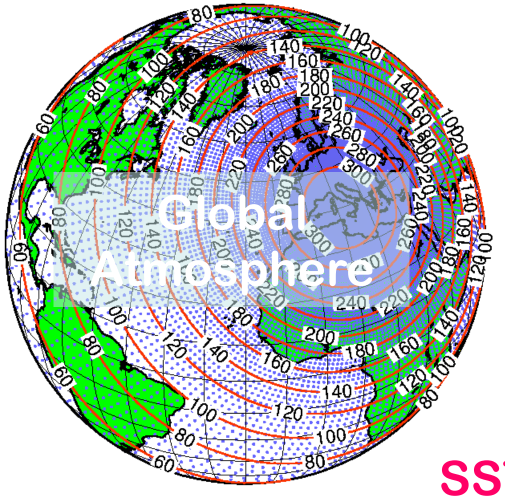
Aims:

- **to obtain scenarios of future climate from a set of 6 climate change scenarios from IPCC (AR4 and AR5), performed with global models (CMCC-MED and CCAM);**
- **to produce downscaled regional climate scenarios for selected African areas surrounding the 5 cities of interest (to follow), at high resolution (about 8 km), with regional models (COSMO-CLM and CCAM)**
- **to produce very high resolution projection (about 1-2 km) for the climate of the African test cities using specific and accurate statistical techniques.**

(The use of different climate models within a multi-model ensemble approach is very useful to describe the range of uncertainty associated with future climate change over the cities under consideration.)

Coupled atmosphere-ocean model or GCM

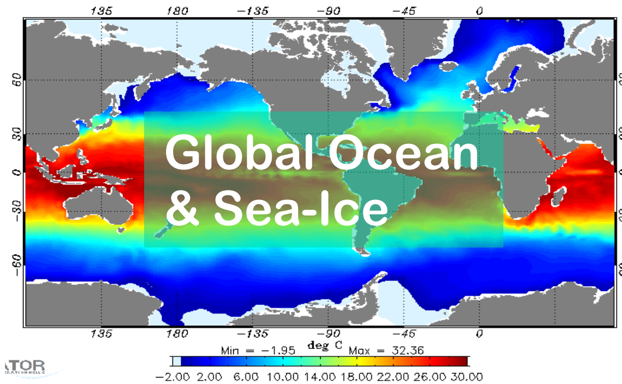
CMCC Centro Euro-Mediterraneo per i Cambiamenti Climatici



Heat Flux
Mass Flux
Momentum Flux

SST

SS vel.



ATMOSPHERE (dynamics, physics, prescribed gases and aerosols)

ECHAM5 T159 (~ 80Km) - L31

Roeckner et al. (2006)

COUPLER Oasis 3

Valcke et al. (2004)

OCEAN (dynamics and physics)
NEMO/ORCA2 (Barnier et al. 2006)

SEA-ICE: LIM (Timmermann et al. 2005)

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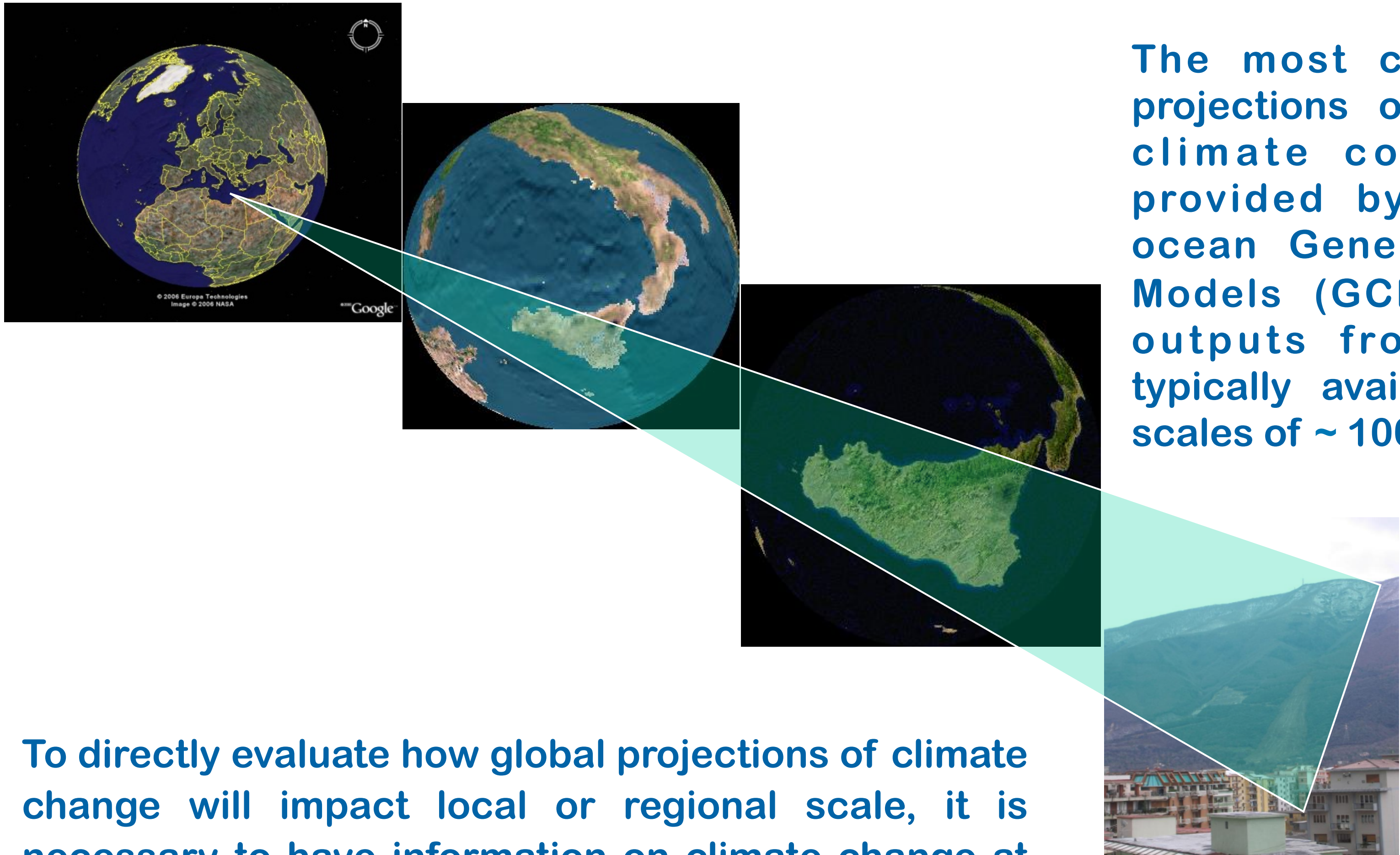
Global-to-local climate scenarios

CMCC
Centro Euro-Mediterraneo per i Cambiamenti Climatici

The most comprehensive projections of future global climate conditions are provided by atmosphere-ocean General Circulation Models (GCMs). However, outputs from GCMs are typically available at spatial scales of ~ 100 km.



To directly evaluate how global projections of climate change will impact local or regional scale, it is necessary to have information on climate change at spatial scales comparable to their scales.

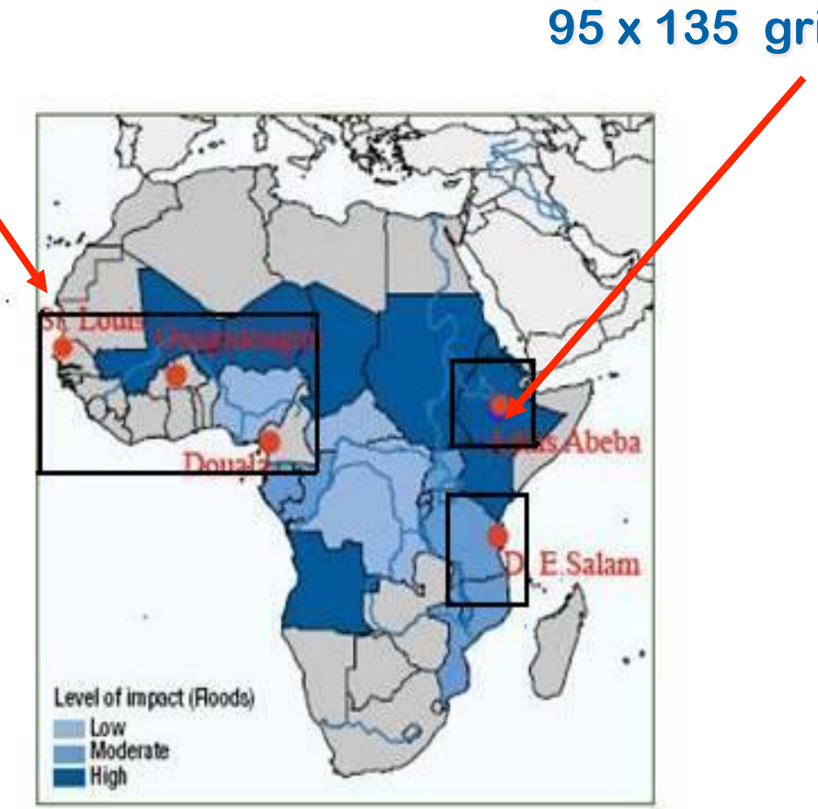
COSMO-CLM Regional models

Spatial Resolution : 8 *km*

Domain WEST:
(18 W -15.17 E; 3.3 – 16.8 N)
465 x 190 grid points

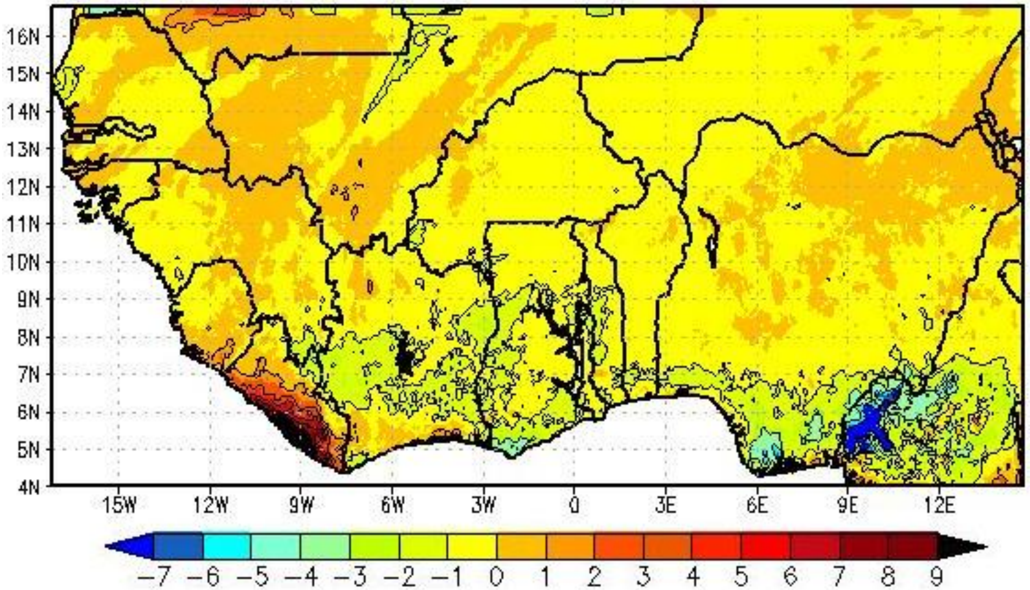
Domains EAST:
N (34.4 – 42.9 E; 6.1N – 12.5N)
120 x 90 grid points

S (34.5 – 41.3 E; 11.8S – 2.1S)
95 x 135 grid points



Precipitation variation (mm/month): future (2021-2050) minus past (1971-2000)

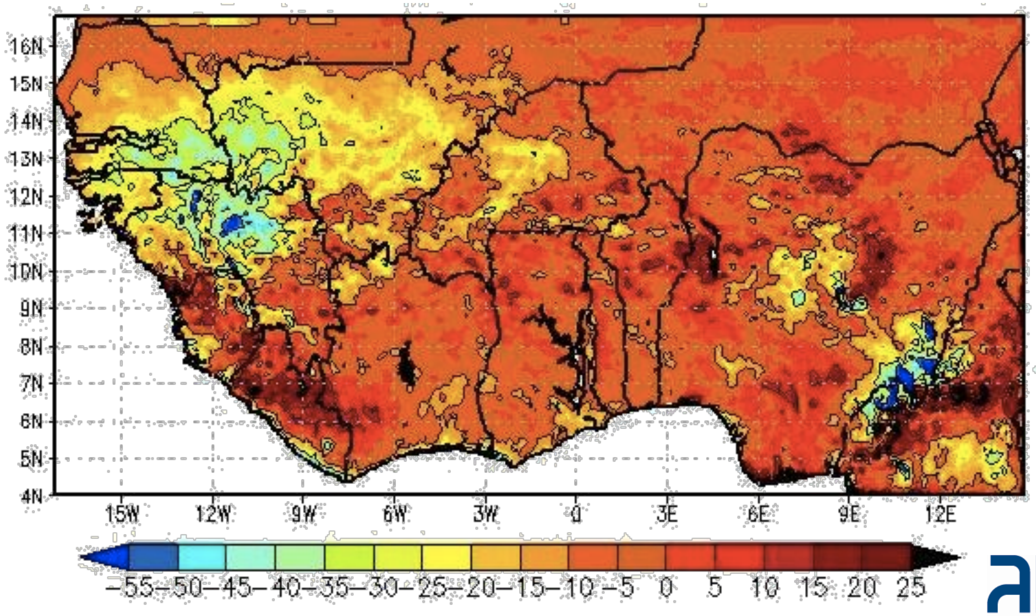
DJF



There is a big difference between winter and summer.

In winter, there is a slight decrease of precipitation, while in summer there is a general increase with some exceptions.

JJA



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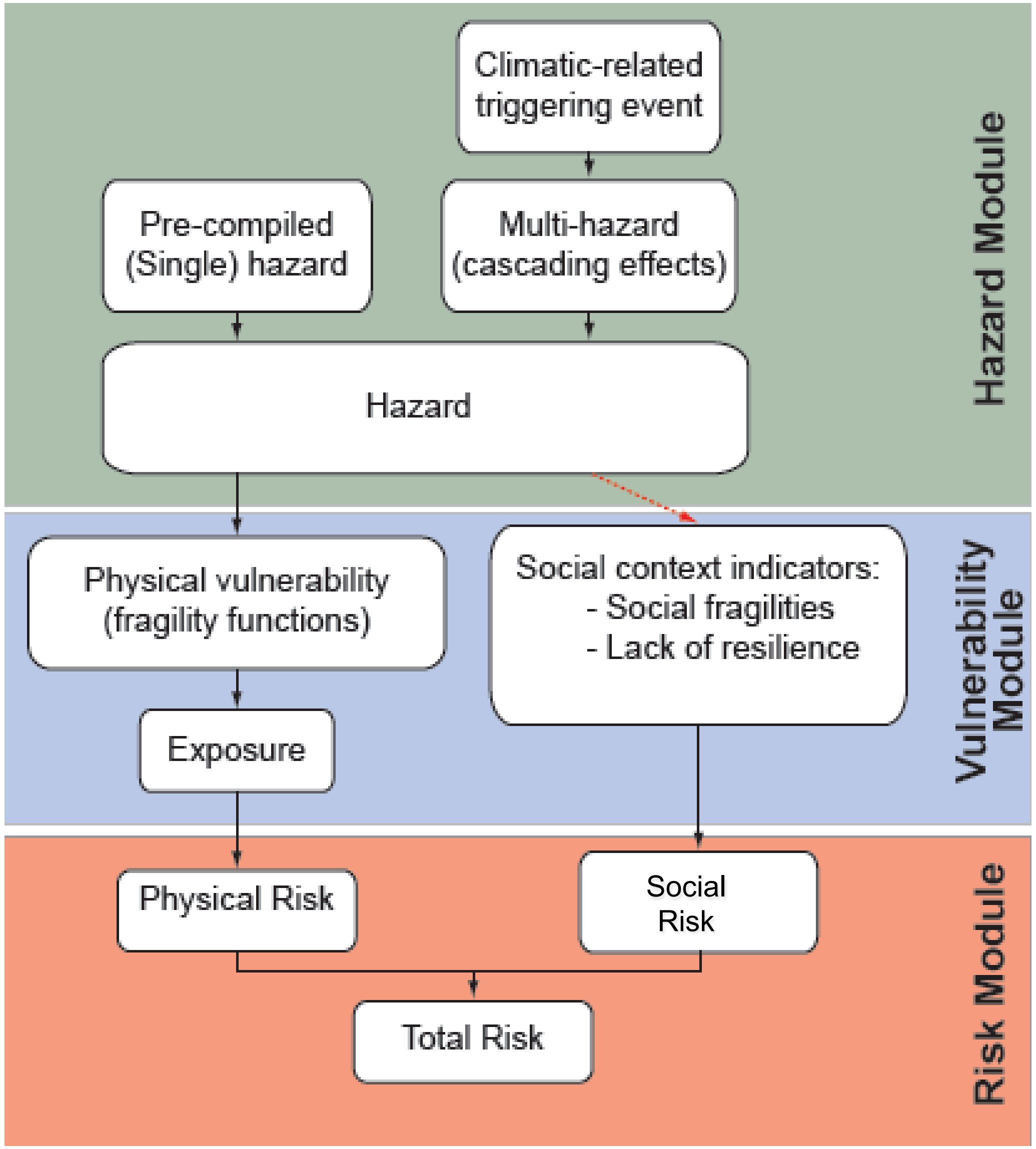


Multi-risk model

A multi-risk model, involving different hazards and vulnerabilities.

The multi-hazard concept may refer to:

- the fact that different sources of hazard might threaten the same exposed elements (with or without temporal coincidence);
- one hazardous event can trigger other hazardous events (cascade effects);

The multi-vulnerability perspective may refer to:

- a variety of exposed sensitive targets (e.g. population, infrastructure, cultural heritage, etc.);
- time-dependent vulnerabilities, in which the vulnerability of a specific class of exposed elements may change with time as consequence of different factors (as, for example, the occurrence of other hazardous events)

From climate change to urban-scale (community-scale) hazards

Considered hazards:

Floods

Droughts

Desertification

Urban Heat Waves

Sea Level Rise

Test cities:

Douala, Cameroun

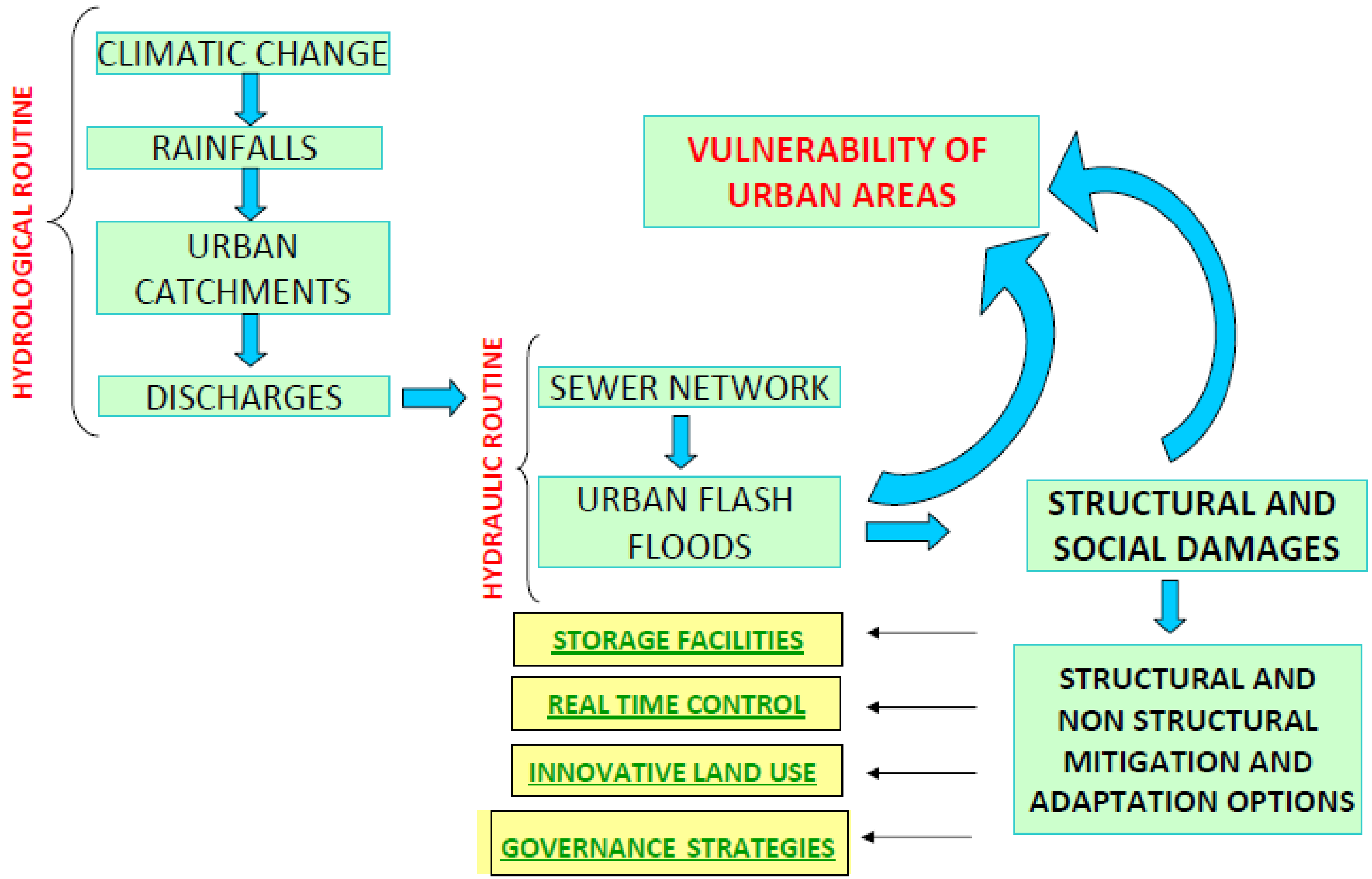
Saint Louis, Senegal

Ouagadougou, Burkina Faso

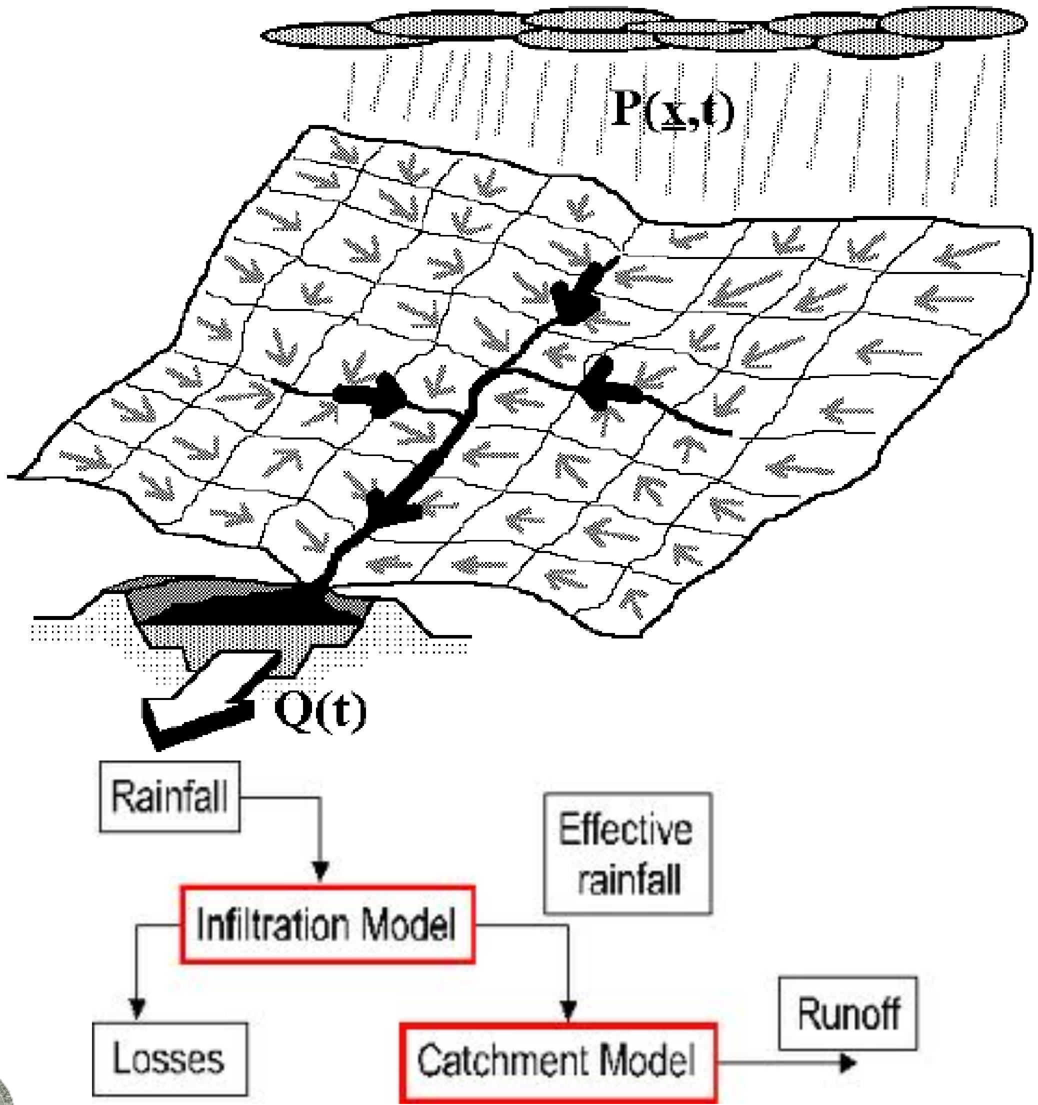
Addis Ababa, Ethiopia

Dar Es Salaam, Tanzania

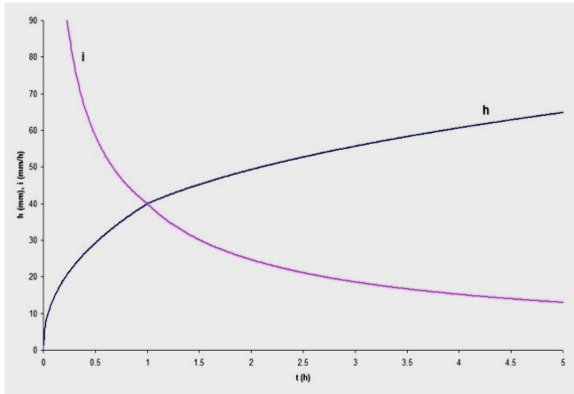
For example: flood risk assessment and risk management strategies design



Flood hazard analysis (1)



Rainfall probability curve

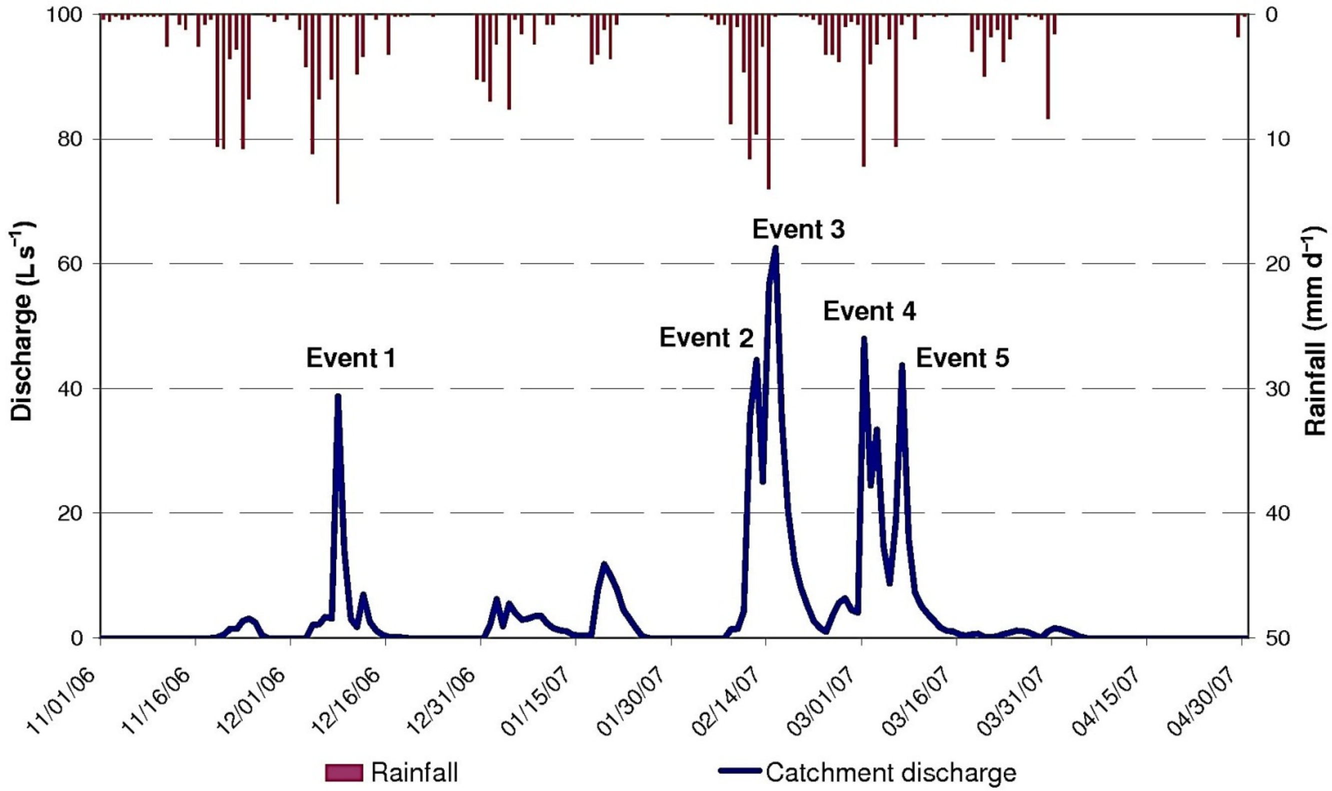


$$h_{\delta,T} = \mu_{\delta} K_T$$

- h : rainfall height
- δ : duration
- T : return period

Gumbel, Weibull, Pearson, TCEV, …

Flood hazard analysis (2)

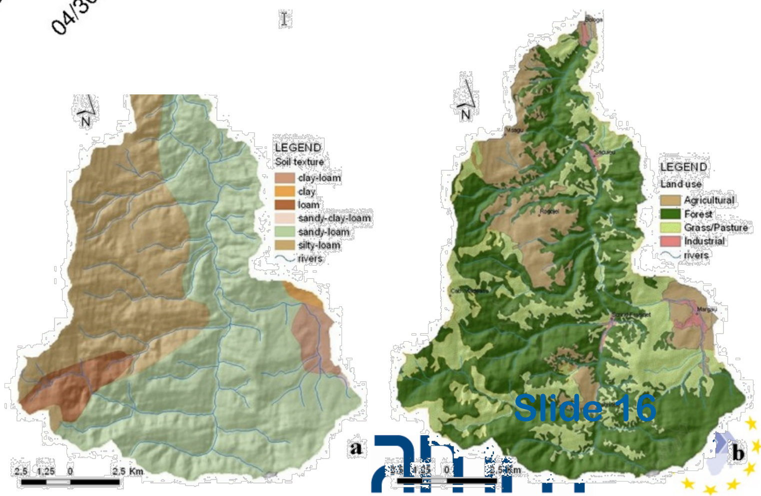


Rainfall - Runoff catchment based model:

- Rational formula
- Curve Number
- SWMM
- ....

Natural/urban drainage basin features:

- Topographic (area, length of main channel, slope)
- Geological and pedological
- Land use

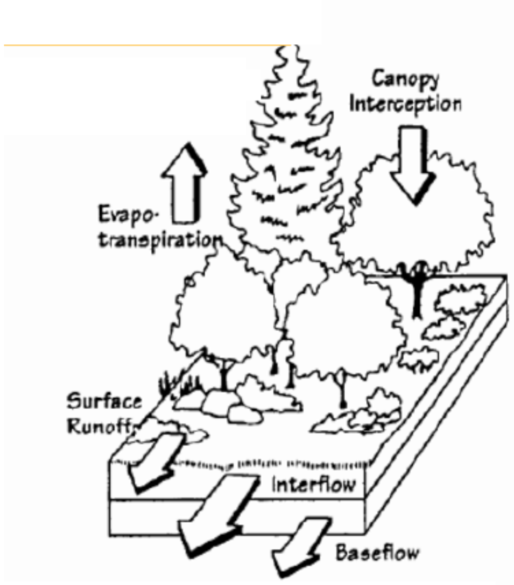


Flood hazard: issues related to urbanization

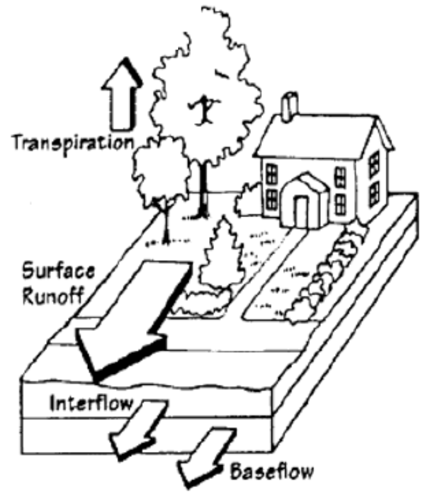
- Reduced evapotranspiration
- Less infiltration of storm water in the subsoil
- Reduced times of concentration of catchments
- Increased flood discharges and volumes
- Increased soil erosion and sediment transport
- Increased loading of pollutants in sediments
- Increased landslides

Catchment water balance

Pre Urbanization

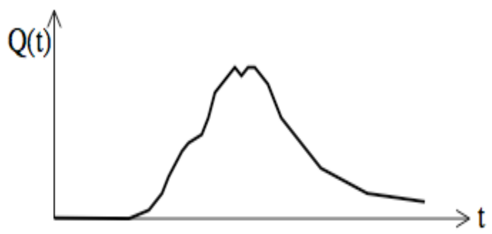


Post Urbanization

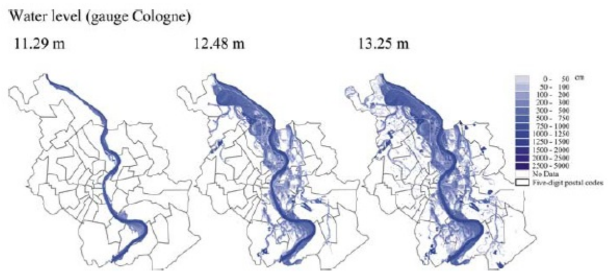


Flood hazard: hydraulic analysis

Peak discharge (T) → **Urban sewer network / Hydrographic network** → **Inundated areas**



- Soil topography (DEM)
- Natural or artificial drainage networks features
- Urban infrastructures (buildings, roads, …)



Water height
Water velocity
Duration of inundation

Another example of climate-induced hazard: Droughts (1)

Drought originates from a deficiency of precipitation over an extended period of time, usually some months or years.

SPI: Standard Precipitation Index

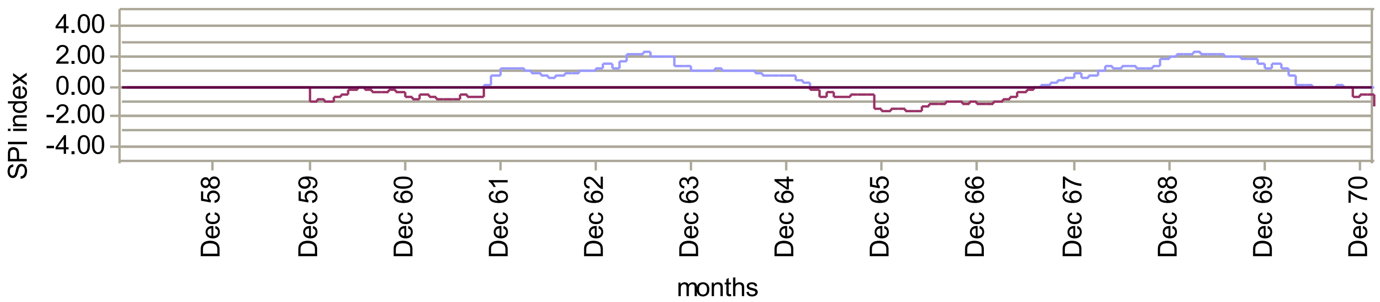
SPI was designed to quantify the precipitation deficit for multiple time scales (3-6-12-24-48 months).

SPI calculation is based on the long-term rainfall record for a desired period, fitted to a probability distribution (Gamma distribution), which is then transformed into a normal distribution, so that mean SPI for the location and desired period is zero. Positive SPI values are greater than median precipitation, and negative values less than median precipitation.

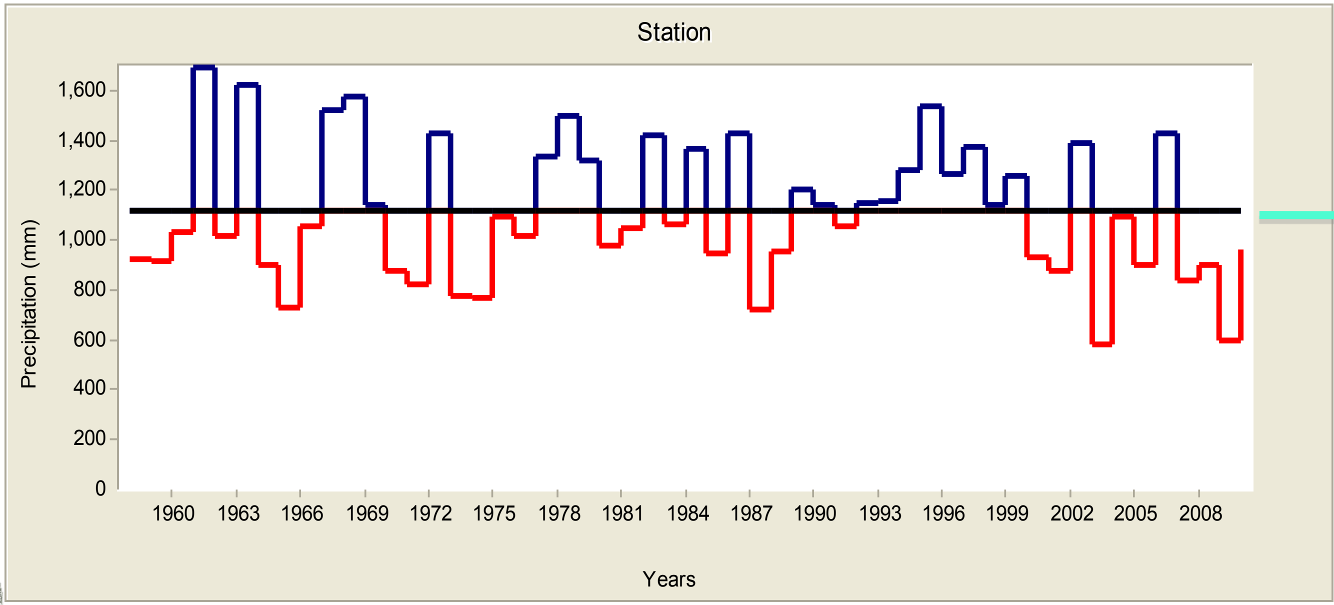
Data sets of precipitation also allowed the analysis of historic droughts by the Method of Run. This method considers a threshold below which an event can be described as "drought".

Another example of climate-induced hazard: Droughts (2)

SPI trend (24 months) in Dar Es Salaam (Dec. 1958 – Dec 1970)



Method of run (Dar Es Salaam, 1958 – 2010)



Mean annual rainfall 1114.7 mm

Another example of climate-induced hazard: Desertification (1)

It is a phenomenon that develops over long periods and can be defined as a trend

Various factors affecting desertification are climatic data (temperature, precipitation, wind, humidity), geomorphology, geology, vegetation, land use, management…

Initially the climatic and bioclimatic conditions have been analyzed on subcontinental scale by using indices as:

- **De Martonne's aridity index** $\frac{P}{10+T}$
- **Lang's factor** $\frac{\mathrm{P}}{\mathrm{T}}$
- **Emberger's factor** $Q = \frac{P}{(M^2 - m^2)} \cdot 100$

P: mean annual rainfall

T: mean annual temperature

M: hottest month's maximum temperature

m: coolest month's minimum temperature

Another example of climate-induced hazard: Desertification (2)

ARIDITY INDEX AI

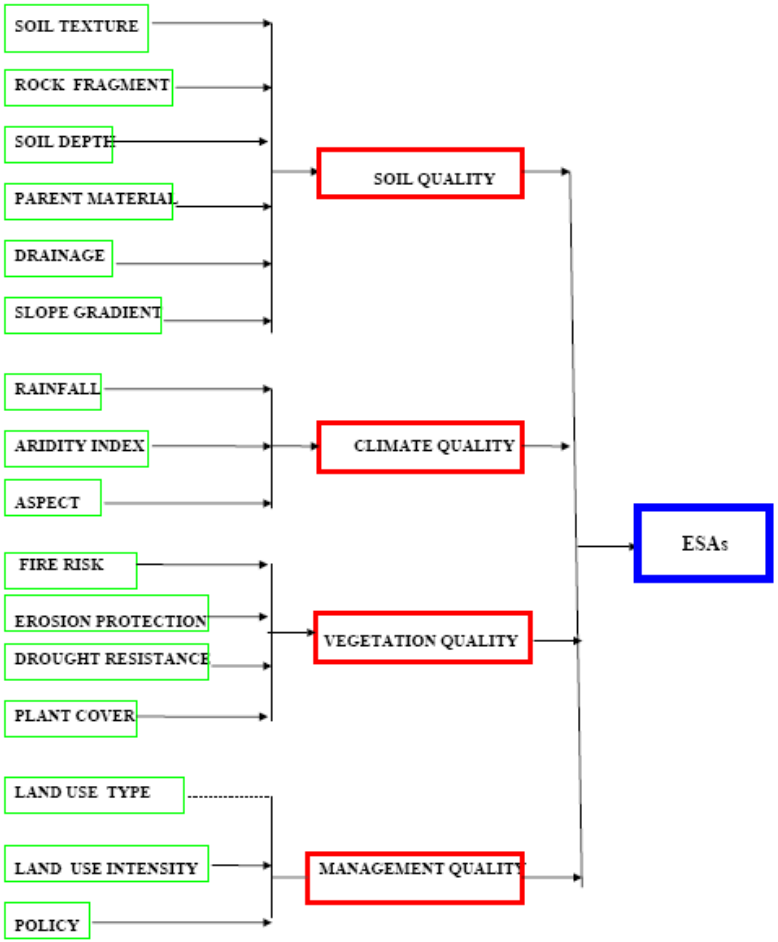
AI = P/ETP where P is mean annual rainfall and ETP is potential evapotranspiration taking into account mean monthly temperature and latitude of the place.

By means of aridity index can be defined four arid zones: hyper-arid (AI less then 0.03), arid (AI index between 0.03 and 0.2), semi-arid (AI index between 0.2 and 0.5) , sub-humid (AI index between 0.5 and 0.7) and humid zone (AI more then 0.7).

	Ouagadougou		Saint Louis		Douala		Addis Ababa		Dar Es Salaam	
T	28.66		25.5		26.57		16.77		26.14	
P	664		283.3		3629.26		584.54		1097	
Lang	23.18	arid	11	arid	136	humid	34.8	arid	42	subhumid
De Martonne	17.18	semiarid	8	arid	99	humid	21.84	subhumid	30.4	humid
Emberger	48.8	semiarid	38.4	arid	861	humid	121	subhumid	85.97	subhumid
IA	0.54	subhumid	0.27	semiarid	3.0	humid	0.81	humid	1.07	humid

Another example of climate-induced hazard: Desertification (3)

The Environmentally Sensitive Areas (ESAs) to desertification can be analysed with reference to various parameters such as landforms, soil, geology, vegetation, climate, and human action.



$$ESAI = (SQI * CQI * VQI * MQI)^{1/4}$$

Parameters used for definition and mapping of the ESAs

Type	Subtype	Range of ESAI
Critical	C3	>1.53
«	C2	1.42-1.53
«	C1	1.38-1.41
Fragile	F3	1.33-1.37
«	F2	1.27-1.32
«	F1	1.23-1.26
Potential	P	1.17-1.22
Non affected	N	<1.17

Another example of climate-induced hazard: Heat Waves (1)

Heat waves are a result of the interaction between atmospheric, oceanic and land surface processes that produce high air temperatures frequently accompanied by humid conditions.
These extreme weather conditions can last days or weeks and may have adverse health consequences for the affected population.

The World Meteorological Organization and the World Health Organization have not yet issued a standard definition of heat wave.

Problem: lack of suitable time series for the meteorological variables likely to be involved, at least in almost all developing countries.

Another example of climate-induced hazard: Heat Waves (2)

Generally, the definition is based on the indicators overcoming of some threshold values, identified by the highest values observed in time series data, considering the relation between heat wave and the climatic specific conditions.

Threshold (after EuroHeat Project and based on the data availability): daily T_{max} over the 90th percentile of the monthly distribution for at least 3 days.

The 90th percentile has been evaluated over a climatic base period (1961-1990)

Vulnerabilities

Physical - Vulnerability of urban structures and lifelines

Environmental - Vulnerability of agriculture
Environmental fragility (e.g., groundwaters, land)

Social - The specific social inequality of people in the context of a disaster
… in broad terms, how susceptible people are to a hazard

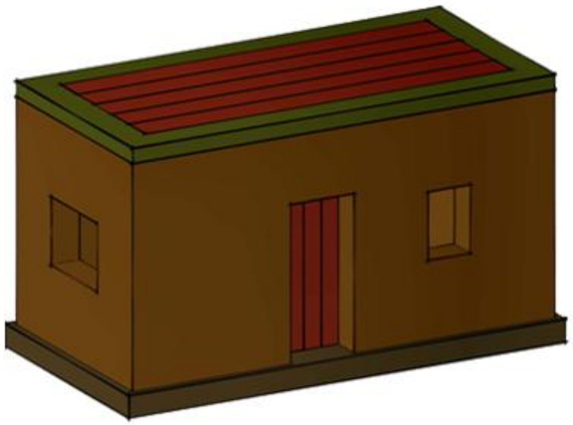
Economic - Vulnerability of different economic sectors

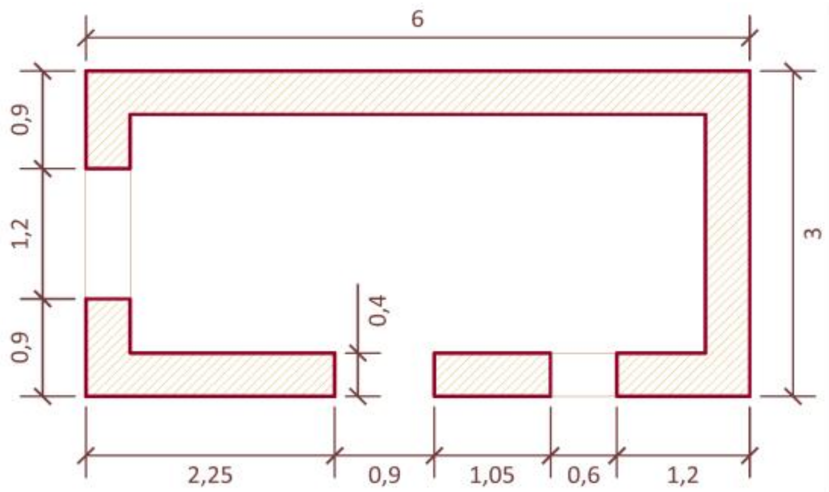
Institutional - Effectiveness and failure of organized structures and institutions

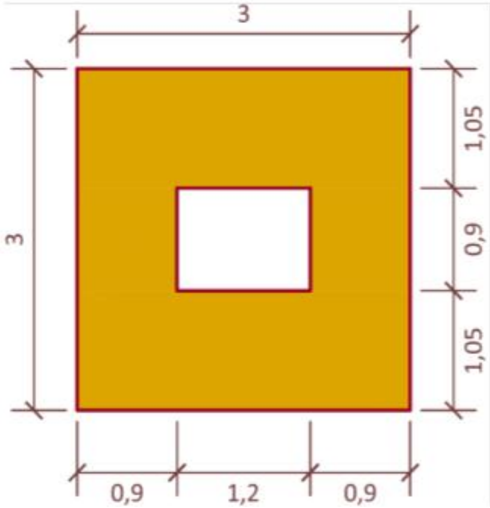
Birkmann, United Nations University

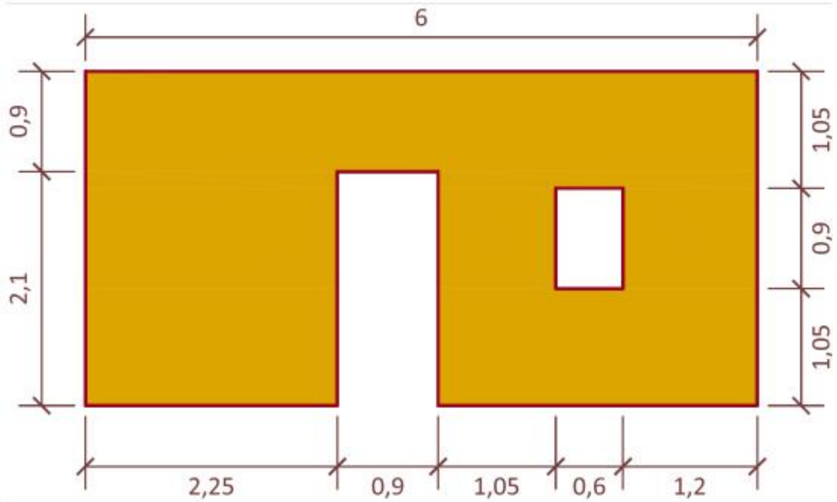
The system entails an informal settlements consisted of different groups of buildings vulnerable to floods

Example of vulnerability: informal settlements subjected to floods.









Example of quantitative (probabilistic) risk assessment allowing to compare (and rank) different risks.

For each hazard a set of potentially damaging scenarios can be selected, relating them to certain probability levels.

For these scenarios which assets are exposed to the hazardous events can be assessed and what the effects are.

Direct monetary losses due to inundation could then be estimated by superimposing inundation patterns with the land use cover.

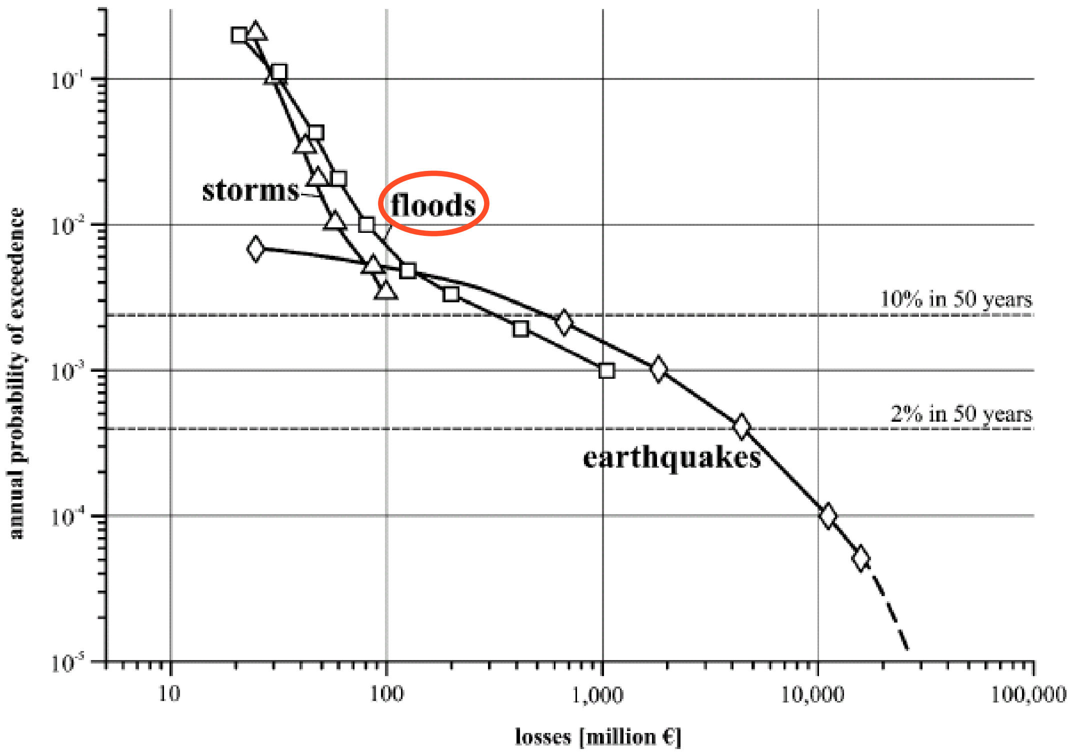


Figure 8. Risk curves of the hazards due to windstorms, floods and earthquakes for the city of Cologne for losses concerning buildings and contents in the sectors private housing, commerce and industry (reference year: 2000).

Grunthal et al, Natural Hazards, 2006

- **Examples of social fragility indicators (S_F):**

Social fragility indicator (S_F)	**Measure (example)**
Slums-squatter neighbour-hoods	Slum-squatter neighbour-hoods area/Total area
Mortality rate	Number of deaths each 10,000 inhabitants
Delinquency rate	Number of crimes each 100,000 inhabitants
Social disparity index	Index between 0 and 1
Population density	Inhabitants/Km^2 of build area

Social vulnerability

- **Examples of lack of resilience indicators (S_R):**

lack of resilience indicator (S_R)	**Measure (example)**
Hospital beds	Number of hospital beds each 1,000 inhabitants
Health human resources	Health human resources each 1,000 inhabitants
Public space	Public space area/Total area
Rescue and firemen man-power	Number of units each 10000 inhabitants
Development level	quantification index

Developing innovative land use and governance strategies for urban development to reduce the vulnerability of African cities and improve coping capacity and resilience towards climate change

- Investigating the extent to which disaster risk reduction and climate change adaptation are integrated into existing urban planning and governance systems, aiming to provide recommendations on how to improve the integration

- Developing a set of land use indicators to identify high risk areas and vulnerable communities (topography and soil; land uses; morphology and structure of built environment; infrastructures; green structure, including urban-rural interface; formal and informal housing; business and mixed areas)

- Developing a coherent and integrated urban planning approach with substantial participation from local stakeholders (government, private sector, Non Governmental Organizations and civil society)

Case-studies and climate-induced hazards

City	Flood	Drought	S.l.r.	Desertif.	H. Waves
Ouagadougou	x	x		x	x
Saint Louis	x	x	x	x	x
Douala	x		x		x
Dar Es Salaam	x	x	x		x
Addis Abeba	x	x			x

Case-studies and planned tasks

SAINT LOUIS: Identification of the relevant climate core variables as well as value added statistics; Floods, Sea level rise, Droughts, Desertification, Heat waves; Governance and Urban planning; Informal settlements; Indicators of high risk areas and vulnerability.

OUAGADOUGOU: Identification of the relevant climate core variables as well as value added statistics; Floods, Droughts, Desertification, Heat waves; Social vulnerability indicators; UMT and ecosystems services.

DOUALA: Identification of the relevant climate core variables as well as value added statistics ; Floods, Sea level rise, Heat waves .

ADDIS ABEBA: Identification of the relevant climate core variables as well as value added statistics; Floods, Droughts, Desertification, Heat waves; Social vulnerability indicators; Informal settlements and road network vulnerability (maybe also earthquakes); UMT analysis and ecosystems service; Governance and Urban planning activities.

DAR ES SALAAM: Identification of the relevant climate core variables as well as value added statistics; Floods, Sea level rise, Droughts, Heat waves; Informal settlements and road network; UMT analysis and ecosystems services; Multi Risk test case application; Indicators of high risk areas and vulnerability; Social vulnerability indicators; Governance and Urban Planning Activities

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