Exposure to climate change hazards: A challenge in a risk analysis framework

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Introduction

Most part of quantitative climate change risk assessments developed at the urban and sub-urban scales rely on the availability of accurate information on potential climate change hazards. This information is usually derived from General Circulation Models that are regionalised by means of dynamic or statistical downscaling techniques.

On this basis, hazard information at the local level can be expressed through impact studies (pluvial, fluvial flood and flood derived by storm surge and sea level rise, UHI ..). This information, together with vulnerability estimates of the exposed assets, allows the quantification of the expected risks linked to specific climate change threats.

However, the underlying data needed to produce risk assessment of climatic events are not always available at the required spatial and temporal resolution neither at the required form. There is a clear need to integrate the vulnerability assessments with climate information into broader risk analysis frameworks in order to provide tools for the decision making process. The variable that does the nexus between climate information (hazard) and socio-technical and socio-ecological system analysis (vulnerability) into the risk assessment is the exposure component.

Under the WGII AR5 framework (IPCC, 2014) exposure remains a core component of risk and it characterizes the degree to which cities' population and assets could be directly affected by climate change-driven threats. The way in which the climate data are elaborated and the impact assessment is done (how the multi-model ensembles outputs are presented and used in impact studies) conditioned the exposure analysis.

The present work discusses some experiences related to how exposure is expressed according to different contexts or studies. To answer the specificity of each study several exposure indicators are defined and some combined exposure indices to hazards are presented.

Conceptual Framework

The vulnerability and risk in the context of climate change is built around the conceptual approach based on the IPCC AR5 (IPCC, 2014):

Risk = f(hazard, exposure, vulnerability)

Vulnerability = f (sensitivity, adaptive capacity)

It is possible to improve the risk management strategies going beyond the traditional economic cost-benefit analysis through the combination of hazard, exposure and vulnerability. That improvement can be done including societal, institutional and others dimensions of the vulnerability and spatial disaggregation.

Vulnerability and risk assessment methods range from global and national quantitative assessment to local-scale qualitative approaches.

For vulnerability and risk assessing a indicator-based approach can be used.

The Indicators, indices and probabilistic metrics need to be complemented with qualitative approaches (IPCC, 2012).

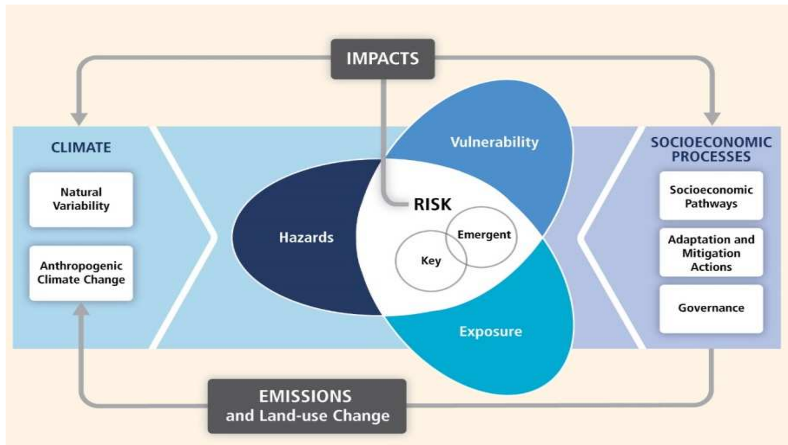
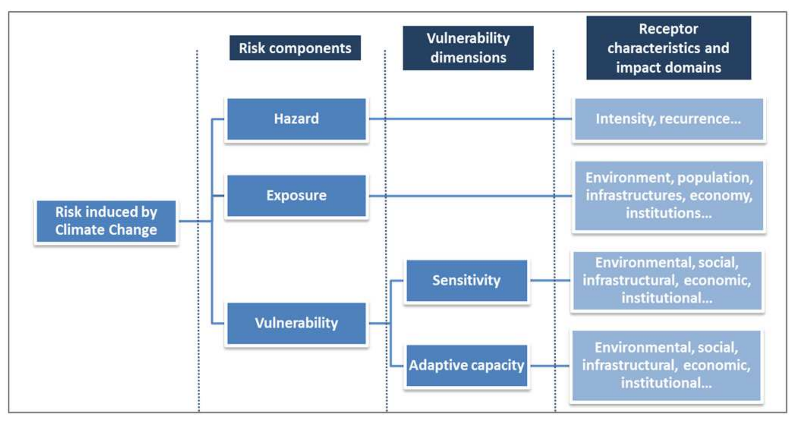


Figure 1. Risk Conceptual Framework (IPCC, 2014)



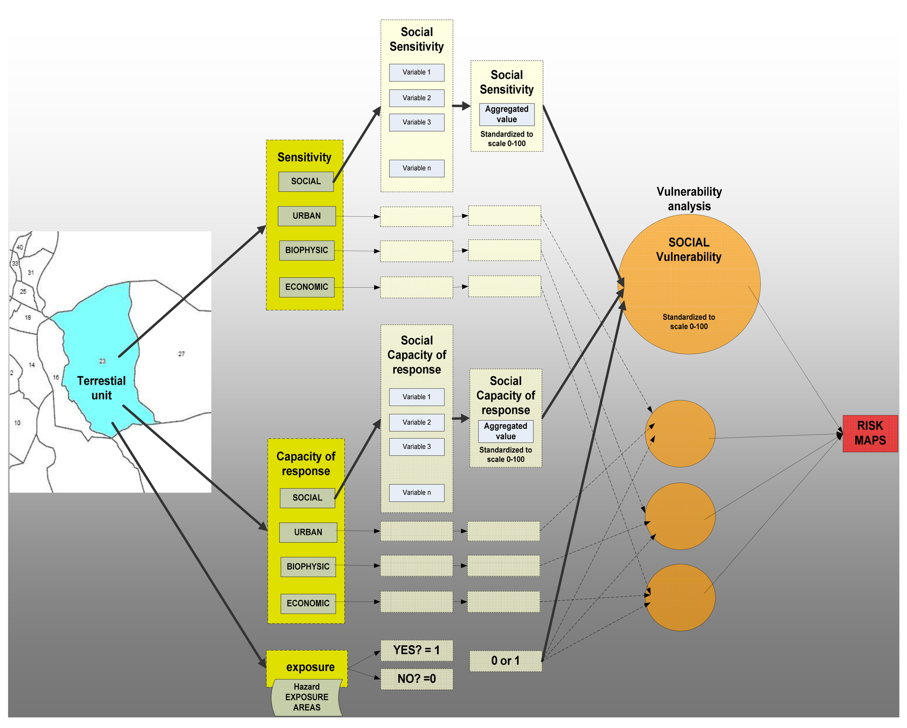


Figure 2. Risk components and the indicator-based approach (Tapia et al, 2015)

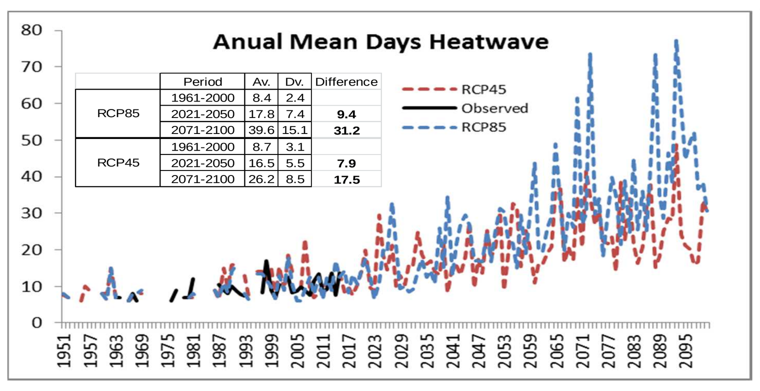


Figure 3. Heatwave index (Mendizabal et al, 2016)

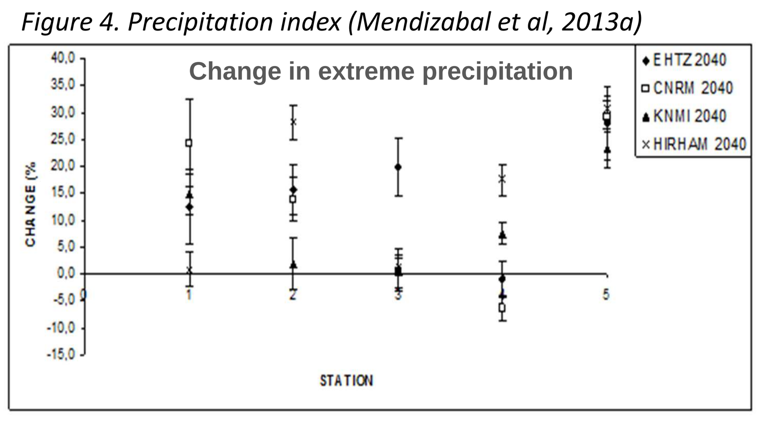


Figure 4. Precipitation index (Mendizabal et al, 2013a)

Figure 5. Flood maps (Mendizabal et al, 2013b)

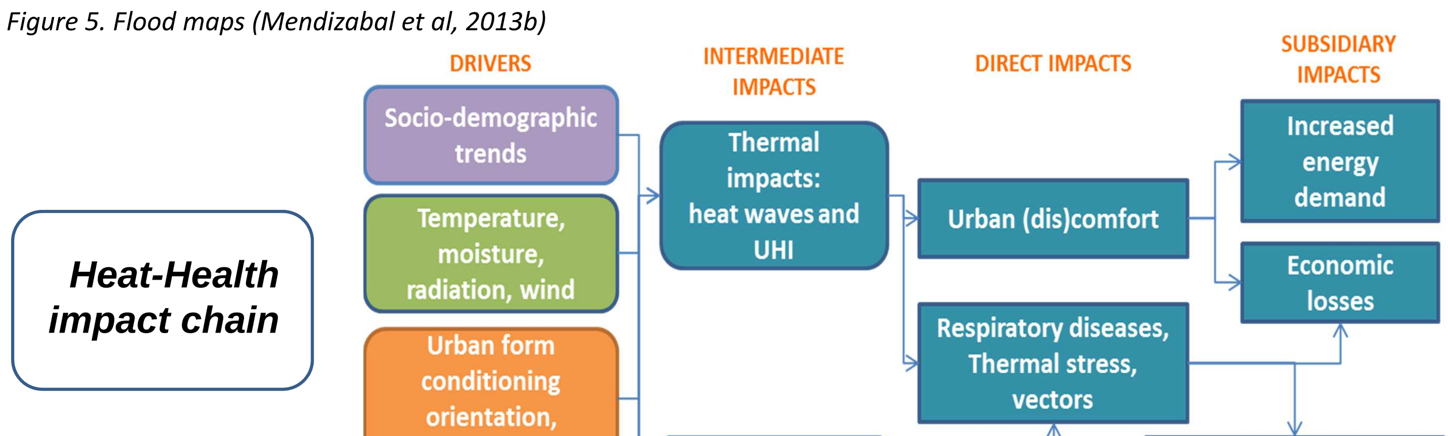


Figure 6. Heat-health mpact chain

The **exposure indicator** need to be defined for each impact chain which is defined considering the hazard and the domain or potential element at risk (e.g. environment, population, infrastructures, economy, institutions).

Some examples of impact chains are: heat waves (hazard) on human health (domain); floods (pluvial, fluvial and coastal) on socio-economic tissue and urban fabric (domain), etc.

The following exposure indicators (see table 1) are proposed for different impact analysis (e.g. flood, sea level rise, heat …):

Measuring the exposure

The **exposure** is the link between hazard and vulnerability. It is calculated differently on depending the type of hazard information we have.

The type of hazard information can be:

- Based on a new generation of **General Circulation Models (**GCMs) made available by the Climate Model Intercomparison Project (CMIP5). Expressed as changes under different scenarios (RCP2.6, RCP4.5, RCP8.5), comparing the reference period (e.g.1961-1990) with a projected period (e.g. 2071-2100) we can have several indicators: Drought Severity Index (for drought); number, duration and maximum temperatures reached (for heat waves) (Figure 3); or change in heavy precipitation (for flood) (Figure 4) among others.
- Based on **impact modeling**, which are forced with climate projections. Expressed as changes under different scenarios (RCP2.6, RCP4.5, RCP8.5), comparing the reference period (e.g.1961-1990) with a projected period (e.g. 2071-2100) we can have several indicators: fluvial flood map (Figure 6), pluvial flood map, UHI map etc.

Table 1. exposure indicators

HAZARD	DOMAIN	EXPOSURE INDICATOR
Coastal flooding	Socio-economic tissue	Percentage of economic activities in each unit of analysis (e.g. neighbourhood) potentially exposed to storm surges and sea level rise flooding (with a specific return period, commonly used, 50 years return period).
Coastal flooding	Urban fabric	Percentage of urban surface in each unit of analysis (e.g. neighbourhood) potentially exposed to storm surges and sea level rise flooding (with a specific return period, commonly used, 50 years return period).
Fluvial flooding	Socio-economic tissue	Percentage of economic activities in each unit of analysis (e.g. neighbourhood) potentially exposed to river flooding (with a specific return period, commonly used, 50 years return period).
Fluvial flooding	Urban fabric	Percentage of urban surface in each unit of analysis (e.g. neighbourhood) potentially exposed to river flooding (with a specific return period, commonly used, 100 years return period).
Heatwave	Health	Percentage of population in the unit of analysis (e.g. neighbourhood) compared with the whole analysed area (e.g. city)
Drought	Socio-economic tissue	Percentage of economic activities in each unit of analysis (e.g. neighbourhood): all companies
Drought	Water planning	Percentage of population in the unit of analysis (e.g. neighbourhood) compared with the whole analysed area (e.g. city)

Conclusions

The exposure indicators will be different depending on the kind of hazard information we have. An example, if we have a UHI map then we can see the areas with highest temperatures and calculate the exposed population. However, if we only have the number of heatwaves in the summer and the temperature involved for all the city (one data for all the city), the exposed population is all.

Therefore, for the exposure analysis some assumption need to be made:

- In case the information has not a good resolution for the unit of analysis, an assumption is that the population is evenly distributed over the unit analysis area.
- For some hazards there is not internal variability within the unit of analysis and therefore the whole area is considered equally affected for the hazard. This happens when we work with hazard information that comes from climate projections and there is no impact modeling (this occurs in case of droughts and heat waves).

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