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Profiling urban vulnerabilities to climate change: An indicator-based vulnerability assessment for European cities

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ABSTRACT

Governing climate change in cities entails a good understanding of urban vulnerabilities. This research presents an Indicator-based Vulnerability Assessment for 571 European cities. Basing on panel data from Urban Audit database and a set of newly developed indicators, we assessed urban vulnerabilities for the following *impact chains*: (i) heatwaves on human health; (ii) drought on water planning, and; (iii) flooding (sub-divided into pluvial, fluvial and coastal) on the socio-economic tissue and the urban fabric. Results shed light on the key challenges that specific groups of European cities face in order to better deal with the expected impacts of climate change. This knowledge is a necessary step to advance in the understanding of urban risks to climate change and the development of effective EU policies for urban adaptation.

1. Introduction

Cities shelter more than half of world's population. In the EU, over 75% of the population already lives within urban areas, and it is expected that this proportion will grow up to 82% by mid-century (UN-Habitat, 2011). Inevitably, a large concentration of population, assets and economic activities, frequently achieved through rapid urbanisation in previous decades, implies more risks linked to the various impacts of climate change (EEA, 2012; IPCC, 2014).

Understanding these trends is crucial to avert the potential damages and to minimise the impact of cities themselves on the global environment. But cities are not simple objects to analyse. Urban areas are characterised by the interactions between a number of sub-systems, such as the built environment, the infrastructures, the social, natural and production systems, etc. (Liu et al., 2007; Turner et al., 2003b). These complex relations pose enormous challenges for adaptation planning at the city level (IPCC, 2014). From a climate risk management perspective (Thomalla et al., 2006), the links and interactions among the urban sub-systems, and between them and the hazardous climatic events that might trigger disasters, are deemed to shape the susceptibility of cities to harm and their capacity to resist and recover from such events (Cardona, 2005; Cutter et al., 2010; IPCC, 2012).

According to the IPCC Fifth Assessment Report of 2014 (AR5), *vulnerability* is one of the three core components determining climate-driven risks, the other two being *hazard* and *exposure* (IPCC, 2014). In AR5 vulnerability is defined as "the propensity or predisposition to be adversely affected", encompassing "a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014, Glossary). Therefore, albeit some earlier studies consider vulnerability as a function of sensitivity, adaptive capacity *and* exposure (Brooks, 2003; Füssel, 2007; Polsky et al., 2007; Turner et al., 2003a), in this work we follow the more recent IPCC interpretation that only recognises two core dimensions of vulnerability, namely *sensitivity* and *adaptive or coping capacity*. Sensitivity can be defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli", and Adaptive capacity as "a system's ability to adjust to climate change (including climate

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variability and extremes), to moderate potential damage, to take advantage of opportunities or to cope with consequences" (IPCC, 2001).

Indicator-based Vulnerability Assessments (IBVAs) typically aim at the characterisation of those processes shaping vulnerability within specific domains of the system under analysis. Frequently, these aspects are initially assessed separately and then combined as aggregated synthetic vulnerability "indices" or "scores" (Adger, 2006; Birkmann et al., 2013; Füssel, 2010; Hinkel, 2011). At the urban level, IBVAs typically focus on: (i) specific cities or sub-urban areas that are characterised against a pre-defined set of climate hazards (Carter et al., 2014; Depietri et al., 2013; El-Zein and Tonmoy, 2015; Frazier et al., 2014; Jiao and Moinuddin, 2015; Johnson et al., 2012; Jun et al., 2013; Lissner et al., 2012), or; (ii) the potential receptors of climate impacts, including specific communities and social groups (Maldonado and Moreno-Sánchez, 2014; Mitchell and Borchard, 2014), or sub-systems of the built environment like the infrastructures or other components (Friedrich and Kretzinger, 2012).

A number of previous works have explored vulnerabilities to climate change in Europe. Many studies done at national or regional scales adopted a broad characterisation of climate vulnerabilities, including aspects related to the expected severity of impacts, the level of adaptation in place and the capacity to cope with the impacts, thus combining in different ways features related to hazard, exposure, sensitivity and adaptive capacity under the vulnerability umbrella (Dunford et al., 2013; Lung et al., 2013; Metzger and Schröter, 2006; see e.g. Schauser et al., 2010). In contrast, studies conducted at the urban and sub-urban levels in Europe tend to be more specific. These works generally adopt a narrower definition of vulnerability and focus on one specific climate threat, like heat stress (Dugord et al., 2014; Wolf and McGregor, 2013), or – pluvial, fluvial or coastal – flooding (Balica et al., 2012; Kaźmierczak and Cavan, 2011; Koks et al., 2015; Tapsell et al., 2002). To our current knowledge no study has systematically assessed vulnerabilities to droughts at the city/sub-city levels in Europe.

Even if some of these contributions based on the same geographical context and focused on the same climate threats, comparability of results is undermined by the variety of choices made with respect to the conceptualization of the vulnerability and risk constructs, the implementation of a range of analytical methods, and the diversity of indicators used. This prevents these works to be used by local city planners and policy makers in general as a means to understand how each city compares to others in terms of specific vulnerabilities to climate change threats.

This study presents an IBVA for European cities developed under a consistent definition of vulnerability and a stable analytical method based on similar assumptions and comparable indicators. We develop a fixed vulnerability concept linked a generic climate change impact model, with a focus on adaptation planning (Fig. 1). In our model the vulnerability component is explained by non-climatic, mainly controllable socio-economic drivers. Under this interpretation vulnerability contributes to the construction of climate change risks to the same extent as the non-climatic locational drivers (i.e. exposure) and the underlying climatic hazards.

Basing on this generic model, the vulnerable systems are then characterised within a number of combinations of climate stressors and potential receptors that we refer to as *impact chains*. These include (i) heatwaves on human health; (ii) droughts on water planning, and; (iii) floods (subdivided into coastal, fluvial and pluvial) on the socio-economic tissue and the urban fabric. The procedure for selecting these impact chains is provided in Section 2.2.

The relevant vulnerability dimensions under each impact chain have been characterised by means of a comprehensive set of indicators covering both biophysical and socio-economic factors. Indicators have been collected or derived from relevant sources or otherwise produced basing on Big Data methods. Eventually, vulnerability scores summarising the vulnerabilities of 571 European cities to the considered climate threats are produced.

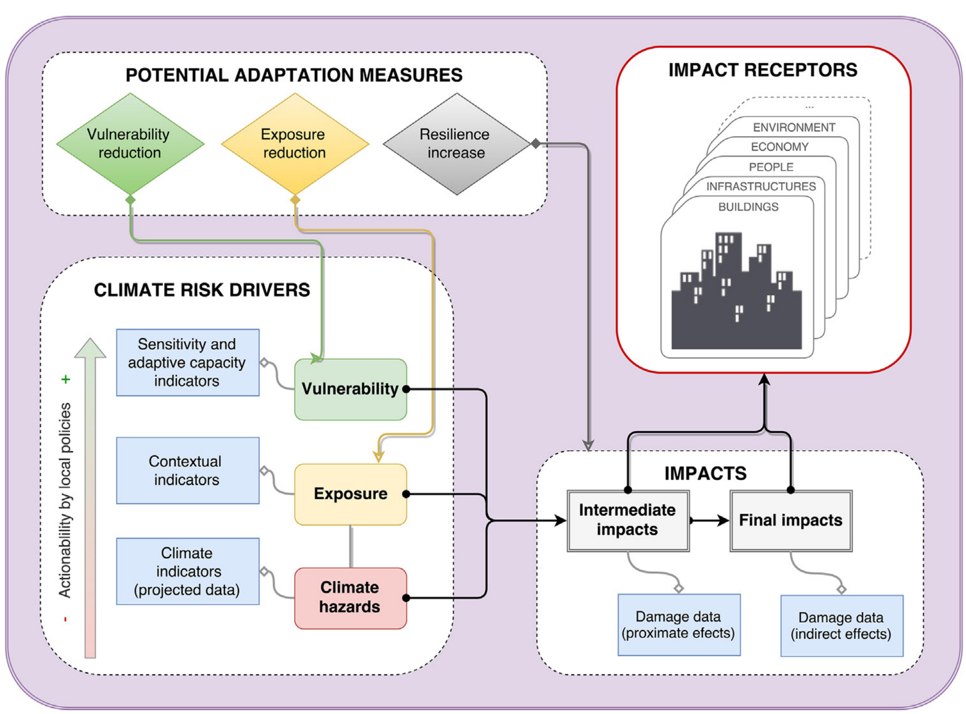

Fig. 1. A generic conceptual model representing the causal structure of vulnerability and risk under climate change.