Coping with urban floods: a special decision-support system to improve resilience

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Abstract

In a context of over-urbanisation and global warming, urban floods have increased in intensity and probability. Cities have to adapt themselves to climate change by developing new urban strategies to better integrate flood risk and urban development. After the attacks of 11 September 2001, Hurricane Katrina in 2005, the major accident of Fukushima in 2011, scientists, managers and politicians have been focusing on the concept of resilience as a new paradigm for implementing integrated risk management plans. In policy, economics, urban planning, architecture and scientific research, the aim is to make urban systems simultaneously less vulnerable and more resilient to climate-related disasters, while addressing the long-term challenges of sustainability and quality of life. This concept is referring to the ability of a system to keep its own variables despite disturbances. Nevertheless, despite the increasing use of this concept, very few concrete actions have been made, probably because cities are too complex systems to modify. The objective of this research is therefore to (re)working on the operationalization of resilience by defining new objectives and actions. To do this, this study is building up a tool facilitating understanding of this notion, and especially its integration into management and planning policies, at the crossroads of urban, technical and social resilience. We are developing a decision-support system with our partner: Avignon city council (France), to measure current resilience. By designing resilience indicators, we are helping Avignon to increase knowledge on its territory, to understand resilience and to build a strategy to improve urban capacities to face to floods. Preliminary results show precisely the components accentuating or diminishing resilience.

Keywords: Urban resilience, flood risk, climate change, urban indicators

1 Introduction

Ubiquitous in political speeches, international organizations and planning policies, the concept of urban resilience spreads in the academic field as well as the operational field in the late 2000s. If, historically speaking, the concept of resilience appeared in physics to describe the return to a previous state of an element, it was the field of psychiatry that served to popularize the term. For the psychiatrist Boris Cyrulnik, resilience is a capacity to take back a development despite trauma. It is understood as the ability to withstand a shock, both in resisting and adapting, in order to restore acceptable functioning (Cyrulnik, 2004). Adapting to the ecological field (Holling, 1973), resilience is defined as the capacity of a system to absorb disturbances and to recover after a major disruption and to restart an activity on the territory. The concept emphasizes the idea that disturbance - or shock - is not (or not anymore) necessarily negative, but is fully

involved into the creation of a new model by supporting the idea of innovation, learning, rebound and change. Resilience refers to capacity as well as absorptive and recovery capacity (Serre, 2016), to a learning ability (Vale and Campanella, 2005; Zevenbergen, 2016), or adaptability capacity (Barroca *et al.*, 2013). Resilience term always refers to a return to an acceptable equilibrium, whether pre-shock or new one (Dauphiné and Provitolo, 2004). Therefore, the concept of resilience refers to a technical, urban, social, architectural, economic and political innovation which allows a questioning of our risk management systems. This injunction to innovation adapts perfectly to the urban, economic, political, social and ecological complexity of the contemporary and urban world.

However, despite the significant increase of the use of the term resilience (Meerow *et al.*, 2016) in urban practices, concrete advances still have to be made. The goal of this research is therefore to facilitate the understanding of this concept, and especially its integration in management and

planning policies, at the crossroads of urban, technical and social resilience.

## 2   Increase urban resilience: a collaboration between research and urban services

Concrete work on resilience cannot be envisaged without a specific study area. The current research project is established in the Provence-Alpes-Côte d'Azur Region (France, PACA), and more precisely in Avignon for physical and hydraulic reasons (Rhône-Durance river confluence). Subject to severe and recurring floods, the city of Avignon is extremely vulnerable to this hazard. Thus, a need for a spatial decision-support system to integrate the concept of resilience into practice seems crucial. It is set up in partnership with Avignon urban and technical services. Indeed, if the city is already equipped with communication and protection tools, the concept of resilience is, as previously established, still very little integrated. A decision support tool for integrating this notion into urban practices would be extremely innovative and useful for a flood-prone community. This collaboration enriches the theoretical work of research by further integrating it with the social, urban, architectural, political and economic needs of the community. It is thus a work on the border between the practical - professional application and the theoretical research. Researchers and practitioners will increase the understanding of urban risk in all "*its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environmen*t" (UN General Assembly, 2015) and resilience capacities and capabilities.

Over the last decade, methods based on indicators occurred in the field of risk, and more precisely to measure vulnerability of territories and populations at risks (Cutter *et al.,* 2008*)*. A vulnerability indicator can be defined as a tool able to provide data about susceptibility, fragility, vulnerability, adaptability and resilience of a system (Birkmann, 2006). To concretise the notion of resilience on the territory, three indicators have been therefore co-created thanks to this research with Avignon GIS service to measure pre-existing resilience. These three indicators are:

- An urban resilience indicator (Cutter *et al.*, 2010; Serre, 2016);
- A technical resilience indicator of (Serre, 2011; Serre, 2018; Lhomme et al., 2013);
- An indicator of a social resilience indicator (Cutter *et al*., 2010; Rufat *et al*., 2015).
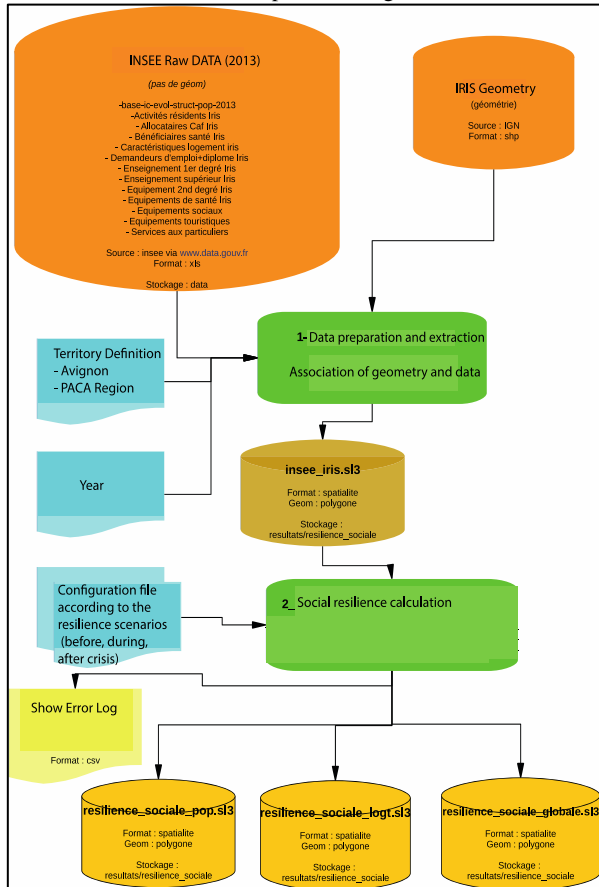
We used variables in order to study both inherent vulnerabilities and inherent resilience of a society and its territory (Figure 1). It is established here that these variables indicate a *potential* of resilience (Serre and Heinzlef, 2018) in order to revive a social, economic, urban, and systemic activity after a shock. The variables of each indicator were based on an analysis of the scientific literature in order to identify the different social (age of the population, level of education, knowledge of risk, etc.), urban (urban structure, economic dynamics, state of structures, etc.) and technical

components of the territory. The scientific consensus that resilience is multidisciplinary has led to the selection of data including the social, economic, institutional, infrastructure and community structure (Cutter *et al.*, 2008).

Figure 1: Resilience indicators
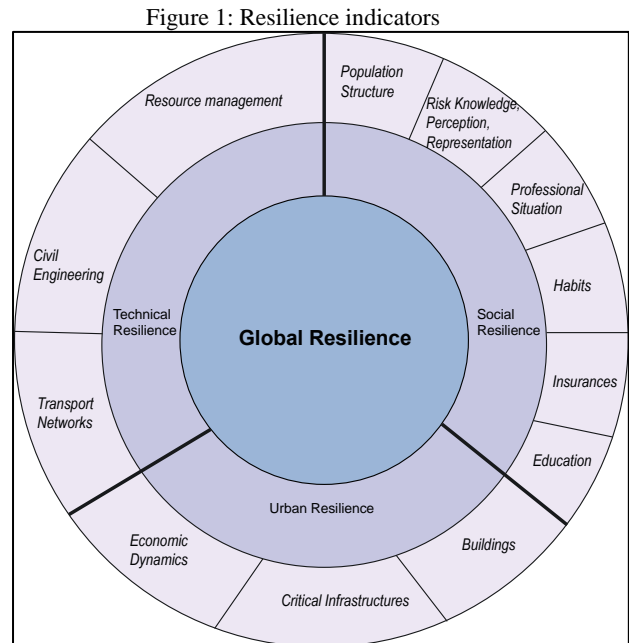
Then, each variable is placed on a positive or negative curve of resilience. This definition of the parameters corresponds to a unique form of deviation (Holand *et al*., 2011) for each variable, thus making it possible to vary the overall value of the resilience per indicator. In order to create a generic tool that can be used by different actors, all the indicators are built using national data in Open Data (INSEE, SIREN) and Open Source. The resiliency calculation for each variable and indicator is built using a Data Management Engine (ETL), the Feature Manipulation Engine (Figure 2), used by the GIS service of French cities. Maps and analyses are done on QGIS.

Figure 2: Extract from social resilience calculation on the Feature Manipulation Engine tool

recover from it. The city has been able to acquire new knowledge about the urban social structure and can see a new way to improve its crisis management strategy, for example. Figure 5 highlights the percentage of people between 25 and 39 years old for a scenario post-crisis. This young population is a characteristic of resilience in many aspects: young people will be more resilient during crisis, because better understand policies' orders, could leave if necessarily, and help people. After crisis, they will be able to restart an economic activity for instance. As each indicator (urban, technical and social) is independent of each other, it is more obvious for politicians and managers to work on variables with low levels of resilience and to identify areas to be redeveloped and / or reintegrated in urban dynamism. Since indexes and variables have their own resilience calculation, it is also possible to change spatial scales and urban structures. It is thus envisaged to test the indicators on different territories, whether in La Rochelle (France) or Mons (Belgium). In the end, the tool will have to make it possible to analyse the urban projects envisaged on the territories and thus analyse their contribution to the improvement of local resilience and to the scale of the city.

Figure 3: Social Resilience-Scenario During Crisis – Avignon's scale
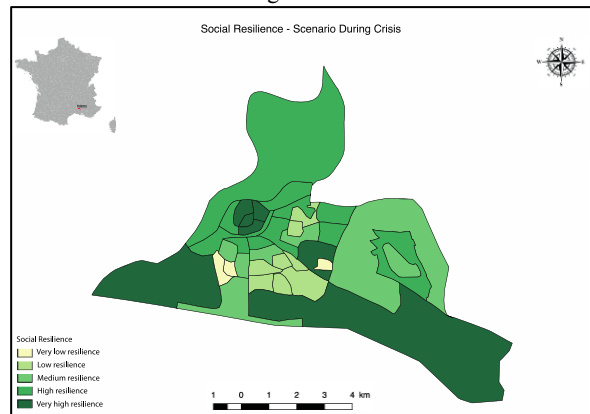

The spatial scale of analysis is local and is explained by the desire to work with local actors in order to answer their problems of management facing the risk of flooding. Thus, urban projects at the neighbourhood levels will be analysed in terms of their contribution to the intrinsic resilience of a larger area. This scale of neighbourhood or urban project, so far poorly explored (Balsells *et al*., 2015) allows acting directly on the territory, to innovate, to experiment and to test new practices (Barroca and Serre, 2013) directly with the managers. As a result, the main scale of study chosen to assess urban resilience is as accurate as possible, ie at the IRIS scale. This scale is located between the 200 x 200m grid (INSEE) and the District Council. Each computation is therefore multi-scalar but also multi-temporal. Indeed, the resilience to risks must be imagined according to a multi-temporal paradigm, to act before the crisis, ie to anticipate (urban planning); and to recover from the event (to rebuild, to restore an activity, to adapt; (Barroca *et al*., 2013)).

3   Results

Preliminary results, based on the social (Figure 3) and urban resilience indicator (Figure 4), make possible to analyse the social structure of Avignon according to the capacity of the populations and urban structure to support the event and to

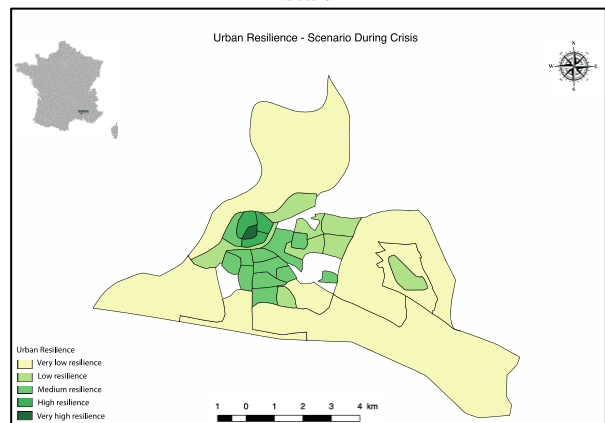Figure 4: Urban Resilience-Scenario During Crisis-Avignon's scale
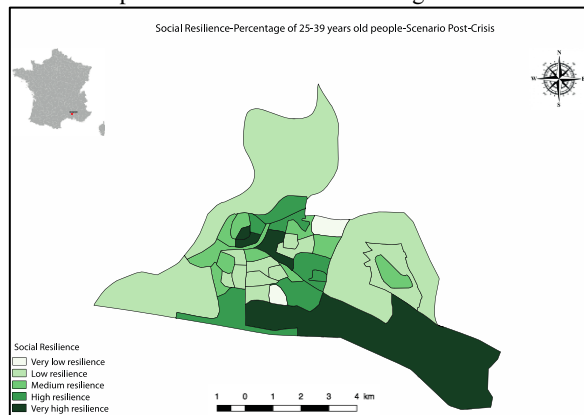

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Figure 5: Social Resilience-Percentage of 25-39 years old
People-Scenario Post-Crisis – Avignon's scale

4   Discussion

While the concept of resilience still remains vague and imprecise in many aspects (Balsells et al., 2015), the international work of various researchers and risk managers succeeds in allowing us perceiving characteristics that a territory must develop or acquire to be resilient and to face to risks. The concept of resilience provides interesting answers to take into account complex and multi-scale systems such as the city and its technical networks.

This particular research emphasizes the capacities of preparation, resistance and adaptation, capacities that are declined according to different temporalities of a flood. This research thus is developing an analysis adapted to multi-temporal forms of a crisis, also at several spatial scales. Moreover, this work develops an operational research with territorial managers integrating the concept of resilience into public policies. We analysed organisational resilience highlighting urban factors able to increase or decrease resilience. The application of this resilience strategy to specific territories demonstrates its feasibility and usefulness in so-called risk territories. In addition, the research-practice partnership underlines the growing need for territories and communities to acquire tools in order to better understand the concept of resilience, and especially to apply it practically to their territories, habits, populations, operating modes, knowledge, perspectives. For example, the city of Avignon already uses the new social resilience database in order to study the urban well-being and quality of life at a local scale. With these new data, public policies are planning to create a decision support tool to influence urban renewal projects to analyse the quality of social and urban life. A request has already been made by the Head of the technical services of the city of Avignon to the GIS service to create a demographic and social atlas on the community, thanks to the new data provided by the research work.

Combining these results should be interesting to understand globally urban resilience and build a strategy to increase urban capacities to face to floods. To validate the presented approach, other territories will be investigated like Cannes in PACA Region and Rotterdam due to their flood risk levels.

This would emphasize the generic aspect of the tool, while nuancing indicators and variables.

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