available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

New policies to deal with climate change and other drivers impacting on resilience to flooding in urban areas: the CORFU approach

Slobodan Djordjević[a,*], *David Butler*[a], *Philippe Gourbesville*[b], *Ole Mark*[c], *Erik Pasche*[d,1]

[a] *University of Exeter, North Park Road, Exeter EX4 4QF, United Kingdom*
[b] *University of Nice-Sophia Antipolis, 930 route des Colles, 06903 Sophia Antipolis Cedex, France*
[c] *DHI, Agern Allé 5, DK-2970 Hørsholm, Denmark*
[d] *Hamburg University of Technology, Denicke Strasse 22, D-21073 Hamburg, Germany*

ARTICLE INFO

Article history:
Received 14 March 2011
Received in revised form
9 May 2011
Accepted 10 May 2011
Published on line 16 June 2011

Keywords:
Urban flooding
Resilience
Collaborative research
Urban growth
Climate change

ABSTRACT

In the context of urban flood management, resilience is equal to resisting, recovering, reflecting and responding. The variety of causes of flooding and their consequences underpin the need for increased and internationally coordinated efforts to enhance technologies and policies for dealing with floods. This paper addresses this issue and presents some novel research ideas related to resilience to flooding in urban areas, which are under development within the EU FP7 project 'Collaborative research on flood resilience in urban areas' (CORFU). The approach adopted in this project aims to quantify the cost-effectiveness of resilience measures and integrative and adaptable flood management plans for different scenarios of relevant drivers: urban development, socio-economic trends and climate changes. It is believed that the way in which the different models are being put together, combined with the variability of conditions in case study areas in Asia and in Europe, will ultimately enable more scientifically sound policies for the management of the consequences of urban flooding.

1. Introduction

Resilience is a concept that is frequently used in various fields, including ecology, economics and engineering. Inevitably, different definitions have been offered. In the context of flood management, resilience can be defined as the capacity of a system, community or society, potentially exposed to hazards, to adapt by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures. This can simply be restated as: resilience is equal to resisting, recovering, reflecting and responding. The benefit of the above definition is that change and learning from the past are required to achieve resilience. The focus on adaptability provides a framework to develop and assess flood management strategies (Gersonius, 2008).

At the time of writing of this paper, within a course of only two weeks, major flood events took place in Australia, Brazil, Colombia, the Philippines and Sri Lanka. The short-term impacts included hundreds of casualties, many displaced people and enormous damage to property and infrastructure.

* *Corresponding author*. Tel.: +44 1392 722079.
E-mail addresses: S.Djordjevic@exeter.ac.uk (S. Djordjević), D.Butler@exeter.ac.uk (D. Butler), Philippe.Gourbesville@unice.fr (P. Gourbesville), Ole.Mark@dhigroup.com (O. Mark).
[1] Deceased.

1462-9011/$ – see front matter
doi:10.1016/j.envsci.2011.05.008

Subsequently, it will take years to get life back to normal in the affected areas, which will put huge pressure on national economies, cities, communities and individuals alike. Nevertheless, while these events were reported at the national level, they (with the exception of Australian floods) attracted relatively little attention in the global media, e.g. *The Economist* devoted only a small paragraph at the very end of its ''The world this week'' section, only after the news from daily politics (*The Economist*, 15 January 2011, p. 6).

On the other hand, the European Floods Directive requires Member States to assess if water courses and coast lines are at risk from flooding, to map the flood extents, the assets and humans at risk in these areas, and to take adequate and coordinated measures to reduce flood risk. This is by no means an easy task and significant investments and other efforts are being made by governments, experts and various stakeholders to establish flood risk management plans focused on prevention, protection and preparedness.

The variety of causes of flooding and their consequences underpin the need for increased and internationally coordinated efforts to enhance technologies and policies for dealing with floods. This paper aims to address this issue and to present some novel research ideas related to resilience to flooding in urban areas. The paper is structured as follows. Climate change and other drivers impacting on flood risks are discussed in Section 2. Section 3 contains an overview of selected recently completed and ongoing research projects in which the Authors have been involved or on which their current research builds upon. Various elements of resilient flood management strategies are discussed in Section 4. Section 5 outlines the approach that is under development within the EU Framework Programme 7 funded project CORFU – Collaborative research on flood resilience in urban areas (www.corfu7.eu). This interdisciplinary project involves seventeen partners from Asia and Europe; it started in 2010 and will finish in March 2014.

2. Drivers impacting on flood resilience

An emerging challenge facing the world is global warming, and thus climate change. The evidence for global warming is compelling, with records showing that the global-average surface air temperature has risen by around 0.6 °C since the beginning of the twentieth century, with about 0.4 °C of this warming occurring since the 1970s. 1998 was the warmest year on record, and 11 of the 12 years from 1995 to 2006 rank among the 12 warmest years (IPCC, 2007).

The key outcome of global climate model scenario studies is that the global average annual precipitation will rise, although changes will vary from region to region. The annual average precipitation is expected to increase over most of northern Europe, the Arctic, Canada, the northeastern United States, tropical and eastern Africa, the northern Pacific, and Antarctica, plus northern Asia and the Tibetan Plateau in winter. It decreases in most of the Mediterranean region, northern Africa, northern Sahara, Central America, the American southwest, the southern Andes, and southwestern Australia during winter. Rainfall *intensity* will increase in tropical and high-latitude regions that experience overall increases in precipitation (IPCC, 2007).

Of particular relevance to flooding, the expectation is that precipitation will be more variable and with greater extremes. Taking the United Kingdom as an example of northern Europe, the climate will become warmer, so that by the 2080s the average annual temperature is expected to have risen by between 2 °C and 3.5 °C. Temperature rises will lead to changes in precipitation patterns, although, little change is predicted in the annual amount of precipitation. Almost the whole of the UK is expected to be drier in the summer, with the greatest decreases in rainfall (up to 50%) in the south-east. Summer soil moisture is also reduced by 40% or more over much of England. Heavy winter rainfall will become more frequent, with intensities that are currently experienced around once every 2 years becoming between 5% and 20% heavier by the 2080s. Storm events in the summer will become more intense and more frequent. Sea level is predicted to rise everywhere, but more significantly in the south than the north (Hulme et al., 2002; Murphy et al., 2009).

The urban world is at a unique moment in time, especially in Asia. Three social, political, and financial movements are coming together in ways that will define future cities. The three movements are *urbanization*, *decentralization* and *domestic capital market development* (IBRD/WB, 2009). How a city is structured to manage its growth and vulnerabilities is critical. A city's access to domestic capital markets opens up opportunities to reduce its dependence on uncertain and/or politically motivated national government grants, subsidies, and allocations. Cities are implementing their identified priorities with capital improvement programs through a stream of dedicated resources.

Climate change will impact future city spatial patterns, growth, and development. The world's population is moving to cities; one-half of the global population is already urban. By 2030 at least 61 percent of the world's population will be living in cities (IBRD/WB, 2009). The figure for Europe is higher still: some 83% of the population – nearly 557 million – are expected to live in cities by 2050 (EC, 2010). Cities of the developing world will absorb 95% of all urban growth and will be home to almost 4 billion people, or 80% of the world's urban population (IBRD/WB, 2009). What was once dispersed rural poverty is now concentrated in urban informal and squatter settlements. More than one half of the world's slum population of 581 million is in Asia. By 2015, 12 of the largest 15 cities in the world will be in developing countries and 4 of those will be in Asia. The concentration of people in cities increases their opportunities as well as their vulnerabilities to natural hazards, civil strife, and climate change impacts.

The population's vulnerability increases not only from flooding due to more precipitation and storm surges, landslides, salt water intrusion and typhoons, but also from drought, earthquakes and other hazards. This is particularly the case where poor quality and ill-maintained infrastructure, low-quality building stock, and lower resilience of the high-density society come into play. For example, 8 out of the 10 most populous cities in the world, including Tokyo/Yokohama, Seoul/Incheon, Osaka/Kobe/Kyoto, Metro Manila and Jakarta in East Asia, face moderate to high earthquake hazards. Similarly, 8 out of 10 of the most populous cities are located on the coast and are vulnerable to storm surges and tsunami waves. Resilient cities need to develop plans with