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Combining hazard, exposure and social vulnerability to provide lessons for flood risk management

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ABSTRACT

Flood risk assessments provide inputs for the evaluation of flood risk management (FRM) strategies. Traditionally, such risk assessments provide estimates of loss of life and economic damage. However, the effect of policy measures aimed at reducing risk also depends on the capacity of households to adapt and respond to floods, which in turn largely depends on their social vulnerability. This study shows how a joint assessment of hazard, exposure and social vulnerability provides valuable information for the evaluation of FRM strategies. The adopted methodology uses data on hazard and exposure combined with a social vulnerability index. The relevance of this state-of-the-art approach taken is exemplified in a case-study of Rotterdam, the Netherlands. The results show that not only a substantial share of the population can be defined as socially vulnerable, but also that the population is very heterogeneous, which is often ignored in traditional flood risk management studies. It is concluded that FRM measures, such as individual mitigation, evacuation or flood insurance coverage should not be applied homogenously across large areas, but instead should be tailored to local characteristics based on the socioeconomic characteristics of individual households and neighborhoods.

1. Introduction

Flood risk is generally defined as the function of hazard – the probability of a flood event; exposure – the population and value of assets subject to flooding; and vulnerability – the capacity of a society to deal with the event (Kron, 2005; IPCC, 2012). While the understanding of hazard and exposure has greatly improved over the years, knowledge of vulnerability remains one of the biggest hurdles in flood risk assessment to date (Mechler et al., 2014; Mechler and Bouwer, 2014; Visser et al., 2014). Traditionally, studies assessing flood risk and the feasibility of flood risk management (FRM) policies include the physical vulnerability of structures and goods as an indicator of flood risk (e.g. Filatova, 2014; Jongman et al., 2014a). Although this captures the susceptibility of properties to a certain flood hazard, it does not include the vulnerability of their inhabitants. The capacity of households to adapt and respond to hazards is equally important for the assessment of hazard impacts and the successful implementation of policy measures aimed at reducing risk, such as stimuli for individual risk mitigation, evacuation plans, as well as insurance coverage for natural disaster risk. This capacity to adapt and respond is largely a function of

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a household's socio-demographic status that is related to their social vulnerability (Cutter et al, 2003; Smith et al., 2006). As such, the social characteristics of households living in areas exposed to flooding can be considered an important factor in determining the feasibility of FRM policies.

However, flood risk assessments that provide inputs to the evaluation of FRM policies often do not evaluate social vulnerability. More specifically, traditional flood risk assessments either assess damage based on physical vulnerability (e.g. Jongman et al., 2012; Koks et al., 2014), or assess the risk to life by assuming a homogeneous vulnerability of the entire population (e.g. Jonkman et al., 2003). Such studies mostly estimate damage or fatality losses as a function of water depth, thereby neglecting the social dimensions of risk and spatial variation in those dimensions. On the other hand, comprehensive social vulnerability studies have produced valuable information on the different parameters that determine a vulnerable population, while not linking this specifically to risk management. Previous social vulnerability studies have varied from spatial assessments, assessing patterns of social vulnerability in a region (e.g. Wu et al., 2002; Wood et al., 2010; Felsenstein and Lichter, 2014; Zhou et al., 2014), to assessments which are more focused on the identification of socioeconomic characteristics that can explain the social vulnerability of a population (Cutter et al, 2003; Fekete, 2009). This study shows how a joint assessment of hazard, exposure and social vulnerability provides valuable information for the evaluation of FRM strategies, such as risk mitigation policies and flood insurance coverage.

The goal of this paper is twofold. First, we develop a state-of-the-art approach to assess flood risk of households within an area, which allows for a joint assessment of flood hazard, exposure and social vulnerability. Second, a case-study in the Netherlands shows how this methodology can provide lessons for FRM. The innovative contribution of this paper to the current literature is twofold. First, the detailed analysis of socio-demographic characteristics on the household level provides new methodological insights into the assessment of social vulnerability and its combination with hazard and exposure. Second, an application of the derived social indicators to an evaluation of FRM practices provides guidance to both policymakers and practitioners for developing risk management and risk reduction policies.

2. Data and methods

The methods and data used in this study are described in the following subsections. The methodology is applied to the greater Rotterdam area, which is a densely populated area in the western part of the Netherlands. Due to its location around the delta of the river Rhine, it consists of both protected and unprotected areas (see Fig. 1), which makes it a potential hazardous area for flooding. In addition, exposure to flooding is high because of its dense population and the location of the largest port of Europe. Table 1 provides an overview of the data which is used in this study.

2.1. *Flood hazard zones*

This study makes a distinction between multiple hazards zones. First, both embanked areas and unembanked areas (the outer dike areas) are identified. Embanked areas are considered being less prone to flooding but the effects can be substantial, because these areas are generally low lying and densely populated. In other words, flooding in these areas has a low-probability but a potentially high impact. Unembanked

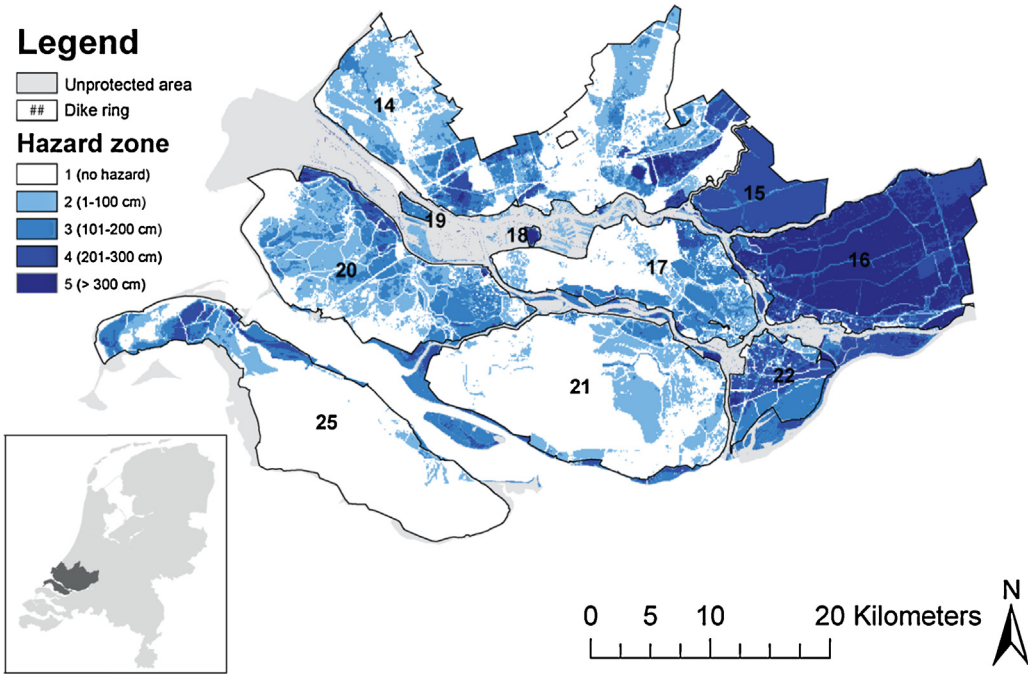

Fig. 1 – Five distinctive flood hazard zones for the greater Rotterdam area in the current situation. *Note*: the numbers in the map represent different dike-ring areas.