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Insights from socio-hydrology modelling on dealing with flood risk – Roles of collective memory, risk-taking attitude and trust

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SUMMARY

The risk coping culture of a community plays a major role in the development of urban floodplains. In this paper we analyse, in a conceptual way, the interplay of community risk coping culture, flooding damage and economic growth. We particularly focus on three aspects: (i) collective memory, i.e., the capacity of the community to keep risk awareness high; (ii) risk-taking attitude, i.e., the amount of risk the community is collectively willing to be exposed to; and (iii) trust of the community in risk reduction measures. To this end, we use a dynamic model that represents the feedback between the hydrological and social system components. Model results indicate that, on the one hand, by under perceiving the risk of flooding (because of short collective memory and too much trust in flood protection structures) in combination with a high risk-taking attitude, community development is severely limited because of high damages caused by flooding. On the other hand, overestimation of risk (long memory and lack of trust in flood protection structures) leads to lost economic opportunities and recession. There are many scenarios of favourable development resulting from a trade-off between collective memory and trust in risk reduction measures combined with a low to moderate risk-taking attitude. Interestingly, the model gives rise to situations in which the development of the community in the floodplain is path dependent, i.e., the history of flooding may lead to community growth or recession.

1. Introduction

1.1. Floodplains as human–water systems

People have lived close to rivers since the earliest times and this has been for very good reasons. Rivers have been the first transport corridors. The preferences for being close to the river extended into times when waterways were navigated and the economy developed along the rivers. Settlements close to rivers had very clear economic and military advantages. Controlling the rivers meant controlling the most important transport and communication routes. Floodplains along the rivers were also attractive because of the fertility of the land and the easy access to irrigation water. For a collection of all of these reasons, major cultures have developed along rivers such as, for example, those settled in Mesopotamia (Tigris and Euphrates), Egypt (Nile), Pakistan (Indus) and China (Yellow River). Even today, numerous societies live deeply connected to rivers and are dependent on them in many ways, such as in the Netherlands and in Bangladesh.

However, there is a dilemma. While floodplains have always been attractive settlement areas, living in the floodplains involves the risk of river flooding. On the one hand, from an economic perspective and for other benefits, it is advantageous to settle as close as possible to rivers. On the other hand, from the perspective of avoiding flood damage, it is advantageous to settle at a distance from the river that is safe from flooding. These competing objectives lead to a tradeoff situation in making flood coping decisions.

There are a number of ways communities have dealt with flooding. As technology advanced in history, structural measures have become increasingly important, such as building levees for flood protection and river training to increase the capacity of the river channels (Remo et al., 2012). More modern societies have a broader spectrum of flood risk management options, usually conceptualised as the flood risk management cycle consisting of four phases: mitigation, preparedness, response, and recovery (e.g., Thieken et al., 2007; Merz et al., 2010). While flood risk mitigation focuses on alleviating the frequency of floods and their damage, preparedness, response, and recovery aim to reduce vulnerability (Blöschl

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et al., 2013). The vulnerability perspective is broader and involves perception of citizens or communities, such as worry or fear (Slovic, 1987), social values (Slovic et al., 1979; Dake, 1991), and affects (Slovic et al., 2007).

The adoption of one flood risk management option or another has several implications, not only from the technical and economic, but also from the social and political viewpoint. People have shaped the river system in various ways through structural flood protection measures. River training and river straightening, increasing the conveyance of rivers and building levees will, locally, mitigate the flood risk, but further downstream the loss of retention areas may actually increase the flood risk (Di Baldassarre et al., 2009). Also, human activities in and near floodplains may involve land use changes that may affect flooding (Blöschl, 2007). Conversely, the river system and the nature of its floods will shape local society. Positive effects include additional economic and social opportunities (trade, agriculture, jobs) that would not exist further away from the river, but flood damage and the costs of construction and maintenance of flood defense systems will affect the economy. There are therefore feedbacks between riverine societies and fluvial processes (Di Baldassarre et al., 2013a,b). Over centuries, these feedbacks may lead to a co-evolution of people and rivers (Sivapalan et al., 2012).

1.2. Flood risk coping culture

The way people deal with floods, and therefore the feedbacks involved, are ultimately controlled by the risk coping culture of a particular society (Pfister, 2011; Shrubsole, 2001). "Risk culture" (Moore, 1964; Douglas and Wildavsky, 1982; Thompson et al., 1990;Rohr, 2007, among others) is a very broad concept used to better understand how different communities live and cope with risk. Risk coping cultures differ depending on a number of social, economic, political and technical aspects and their reciprocal interactions (Handmer, 2001; Baana and Klijnb, 2004). These cultures can be considered as prototypes of responses to risk, which underline different views about the risk and its management, but also about nature and society. This paper analyses flood risk coping culture, with focus on the community dynamics. Thus, we investigate the community's behaviour – as a whole – in coping with flood risk and do not address the individual response of citizens, which, indeed, might deviate from the community dynamic or even drive it (see, e.g., the different theoretical frameworks in Slovic et al., 1979; Slovic, 2000; Douglas and Wildavsky, 1982; Beck, 1992; Johnson and Covello, 1987; Jasanoff, 1998; Strydom, 2002). In particular, we focus on three main components that contribute in shaping flood risk culture: collective memory, risk-taking attitude and trust. Although these three factors do not by themselves comprehensively explain the complex process of building up a flood risk culture, we identify them as the leading characteristics of this process.

Occurrence of floods tends to increase peoples' recognition that their property is in an area that is potentially at risk of flooding (Burningham et al., 2008), both at the scales of individuals and communities (November et al., 2009), which is one of the main reasons why flood coping actions are taken. Floods people have experienced personally may be much more relevant for driving risk coping behaviour than information on historic floods (Tversky and Kahneman, 1973; Pagneux et al., 2011). In particular, the emotional and affective processes involved (including fear and powerlessness) as well as the tangible and intangible losses may be more important than the cognitive assessments of those risks (Loewenstein et al., 2001; Terpstra, 2011). Hazards interact with psychological, social, institutional, and cultural processes in ways that may result into the amplification of the risk perception and of the social response to the risk (Kasperson et al., 1988; Jasanoff, 1998). Frequent events ensure that the perception of risk remains high (Bradford, 2012) and, conversely, long periods without floods will serve to diminish awareness (Burn, 1999). The memory of floods tends to be short, i.e., people tend to forget quickly (Pfister, 2011). The capacity of the community to keep awareness high is referred to as *collective memory*. Collective memory is intended here as the opposite of forgetfulness, i.e., the time scale at which awareness is lost, and is one major aspect that influences how people live and choose to cope with flood risks at the community scale.

Another attitude that is relevant both at the scales of individuals and communities is the *risk-taking attitude*, i.e., the amount of risk a community is collectively willing to expose themselves to. Cameron and Shah (2012) showed how risk preferences have important implications for economic development. For example, these preferences may affect decisions on building constraints which in their own turn influence urban and industrial development, especially in areas characterised by scarce land availability. They also noted that risk aversion is influenced by subjective beliefs of the probability of a disaster to occur (also see Kahneman and Tversky, 1979; Tversky and Kahneman, 1992 for a theoretical discussion of risk-taking/risk-aversion attitudes). Risk preferences at the community level are very crucial for decisions about flood risk mitigation. For example, a community might be aware of the risk but decide to settle close to the river due to a number of different reasons among which the trade-offs between high safety standards and economic growth (Kahn, 2005; de Moel et al., 2011), and, more in general, between public and private benefits (Beatley, 1989; Beatley, 1999; Burby, 1998; Gregory, 2002). The risk-taking behaviour itself is related to a number of cultural factors as well as experience of personal threat to life (Ben-Zur and Zeidner, 2009).

One other aspect of risk coping culture is the *trust* in risk reduction measures, which plays a central role for risk management in present societies (Slovic, 1993). A review of Wachinger et al. (2013) suggests that personal experience of a natural hazard and trust, or lack of trust, in authorities and experts have the most substantial impact on risk perception. A higher level of trust in flood protection measures tends to reduce citizens' perceptions of flood likelihood, which may hamper their flood preparedness intentions (Terpstra, 2011). Trust also lessens the amount of dread evoked by flood risk, which in turn impedes flood preparedness intentions. For instance, trust in flood protection works is one of the causes of the so called "levee effect" (White, 1945; Burton and Cutter, 2008; Di Baldassarre et al., 2009; Ludy and Kondolf, 2012) and it may increase the feeling of safety, favour a delegation of responsibility to the authorities in charge of building and monitoring the structural devices, and, in this way, encourages the neglect of personal engagement in risk mitigation actions (Scolobig et al., 2012). However, there are also studies that conclude that higher level of trust may lead to more effective preventive actions (Samaddar et al., 2012).

1.3. Research question

Given that collective memory, risk-taking attitude and trust are important controls on how communities deal with flood risk, and therefore are fundamental characteristics of the risk coping culture of communities, it would be of interest to understand their influence on floodplain community development in clearly defined settings. The aim of this paper is to gain insight into the effect of these factors on the evolution of flood risk management measures and the economic development of communities at the time scales of centuries. We analyse a hypothetical setting of a city at a river where a community evolves, making choices between flood management options on the floodplain. The analyses are based on an extension of the socio-hydrology model of Di Baldassarre et al. (2013b) that represents the most important feedbacks between