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Review

Lessons from flood early warning systems

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ABSTRACT

Success stories from the developed and developing world show that EWS are a useful tool to save lives, prevent damage and enhance the resilience of a society. Despite the substantial technical progress, from an operational point of view, major challenges remain to achieve the potential benefits of EWS, in particular in communicating risk information and early warnings to emergency services and the population at-risk and consequently trigger response actions.

Case studies from Europe (Belgium) and Africa (Egypt, Mali) demonstrate the actual use of EWS for flood emergency response. Recommendations are consequently provided to better trigger a response from stakeholders at all levels and across sectors (authorities and at-risk population) and to realise benefits that go beyond flood risk reduction, but also address climate change adaptation.

1. Introduction

The development and implementation of Early Warning Systems (EWS) for natural hazards has repeatedly been cited as an area in disaster risk reduction where substantial progress has been made over the last decade (Hallegatte, 2012; UNISDR, 2015). Success stories from the developed and developing world show that EWS are a useful tool to save lives, prevent damage and enhance the resilience of a society (UNEP, 2012; Golnaraghi, 2012; Baudoin et al., 2014; UNISDR, 2015). The following developments have driven the increasing deployment of EWS: (1) international commitment to develop EWS in the 2005 UN Hyogo Framework for Action, renewed in the 2015 Sendai Framework for Disaster Risk Reduction (United Nations, 2015); (2) major technological advances including better forecasting techniques such as radar nowcasting, ensemble numerical weather forecasting and the growing availability of high-resolution satellite data (Alfieri et al., 2012; UNEP, 2012; UNISDR, 2015); (3) improved technology for communication and sharing of information, including mobile phones, internet and social media (Webster, 2013; UNISDR, 2015); (4) recent studies illustrating that early warning systems can have significant benefits exceeding their costs (Teisberg and Weiher, 2009; Rogers and Tsirkunov, 2010; World Bank, 2011; Bouwer et al., 2014,); (5) growing focus on the benefits that EWS can provide for climate change adaptation, in addition to disaster risk reduction (Hallegatte et al., 2012; Borga et al., 2011; UNISDR, 2015; Zommers and Singh, 2014; WMO, 2015).

Despite the substantial technical progress, from an operational point of view, major challenges remain to achieving the potential benefits, in particular in communicating risk information and early warnings to emergency services and the population at-risk, and consequently trigger response actions. Many authors (e.g. Maskrey, 1997; UN, 2006; Hellmuth, 2007; Zommers and Singh, 2014; Baudoin et al., 2014; UNEP, 2012; UNISDR, 2015) state that the potential benefits of scientifically sound forecasting systems will not materialise if a warning is not understood, is not useable or does not result in emergence response action.

While some success stories of EWS are documented from developing and developed countries (e.g., Golnaraghi, 2012; UNEP, 2012; Baudoin et al., 2014; UNISDR, 2015), publications that systematically analyse the effectiveness of the whole EWS process are rare (e.g., Cools et al., 2012; Schelfaut et al., 2012; Demeritt et al., 2013). Emphasising that an effective early warning system needs to span all components from hazard detection through to community response, UNISDR (2009) defines an early warning system as "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss". EWS are commonly agreed to consist of four components: (1) risk knowledge, (2) monitoring, forecasting and warning, (3) communication of an early warning, and (4) response capability (UN, 2006).

The majority of scientific publications on water-related EWS address the first two components. For example, Borga et al. (2011)

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and Alfieri et al. (2012) elaborate on the effectiveness of European flood EWS. Others address EWS in developing countries, e.g., Webster (2013) and Hossain et al. (2014) for flooding of the Ganges in Pakistan and Bangladesh, Cools et al. (2012) for flash floods in Egypt, Zwarts (2013) for Mali. Alfieri et al. (2013) elaborate on the Global Flood Awareness System (GloFAS). Some authors elaborate on the social science aspects of EWS (components 3 and 4). For example, Mayhorn and Collins Mc Laughlin, (2014) and Demeritt (2014) target best practices and challenges for the communication of flood risk and flood alerts. Opportunities for community participation and the integration of local knowledge in flood EWS are described elsewhere, e.g. Gautam (2013) and Baudoin et al. (2014).

This paper assesses and compares the effectiveness of the whole EWS process – that is all four components described above – for three flood EWS, coming from Europe and Africa. The flood EWS used in the region of Flanders, Belgium (Europe) is used as a state-of-the-art example from Europe. The EWS for flash flood warning in Egypt (Red Sea Mountains) and Inner Niger Delta (Mali) are from the developing world. The Egypt case demonstrates the challenges and solutions in an area where flood risk knowledge is limited and the lead time small (a few hours). In the case of the Inner Niger Delta in Mali, risk knowledge is substantial and the lead time is several months. While the Egyptian EWS is designed to be used by the authorities, the Mali EWS is for the local communities. Based on the comparison of the effectiveness of the whole EWS process, this paper identifies lessons learned on the use of EWS and provides recommendations on how to increase the effectiveness of the EWS process. While the technical aspects of the EWS are briefly compared in this paper, this paper particularly addresses the last component of the EWS process—response capability. Recommendations are hence intended to firstly better trigger a response from stakeholders at all levels and across sectors (authorities and at-risk population) and secondly to realize benefits that go beyond flood risk reduction, but also address climate change adaptation.

2. Comparative analysis of floods EWS in case studies in Africa and Europe

2.1. Description of the case studies

The three case studies presented in this paper offer the opportunity to discuss differences in the effectiveness of EWS in the diverse institutional and socio-economic contexts of Belgium, Egypt and Mali (Fig. 1). The flood early warning system for the region of Flanders (Belgium) is built following the major damages of the flood of the Demer River in 1998. Floods are the most widespread natural hazard in Belgium. In the 1998 Demer River flood, people were warned by speaker phone by police and firemen. A pilot EWS for the Demer river became operational in 2003. In 2007, the EWS was extended to the whole territory of Flanders. The EWS is also systematically evaluated and upgraded (Schelfaut et al., 2012; CIW, 2013). Flood hazard and risk maps are available from the website waterinfo.be.

The EWS in Egypt and Mali are more recent (operational since 2010 and 2013 respectively) and have been developed under conditions of data scarcity and limited local institutional capacity. In Egypt, the EWS aimed to reduce the number of casualties and damage to infrastructure from flash floods, while also capturing floodwater (Cools et al., 2012). Flash floods in arid mountainous regions are destructive natural disasters. A flash flood can be generated instantly during or shortly after a rainfall event, especially when high-intensity rain falls on steep hill slopes with shallow, impermeable soils, exposed rocks and lack of vegetation (Lin, 1999; Wheather, 2002). In the period 1979–2010, 9 flash floods occurred in the Egyptian case study following rainfall events of 10–20 mm (Cools et al., 2012).

In Mali, floods in the Inner Niger Delta are beneficial for the local economy and livelihoods. Fish catches, rice yields and grazing potential are directly related to the intensity of floods (Zwarts et al., 2005). A weak flood is detrimental on the large-scale for the Inner Niger Delta, as the region is then suffering from drought. The annual flood cycle in the Inner Delta is described by Zwarts et al. (2005): During and after the rainy season (June–October), large areas of the Inner Niger Delta are inundated. In the dry season, the water level in the Inner Niger Delta is less than 50 cm. The time and height of the annual peak flood varies, between 336 cm (in 1984) and 625 cm (in 1957). Lower-intensity floods inundate the floodplain for four months only (October–February), while high-intensity floods lead to inundation for 8 months (September–April). The maximum area that is flooded each year varies from 5000 km^2 to 20,000 km^2 depending on the flood intensity (Liersch et al., 2013).

2.2. Risk knowledge: rainfall and flood forecasting

The methods used for rainfall and flood forecasting in the case studies, in addition to the provided lead time, is shown in Table 1.

Fig. 1. Case studies from Europe (Belgium) and Africa (Egypt and Mali).