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Impacts of climate and land use changes on flood risk management for the Schijn River, Belgium

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ABSTRACT

Flooding is the most common natural disaster in Europe. Modern flood risk management relies not only infrastructure development but also on governmental and non-governmental actors applying legal, economic and communicative water management instruments. Within the European Union (EU), flood management closely relies on policy set at the EU and national levels. It is now recognized that a sound understanding of climate change is required in addition to current management by taking into account land use change and socio-political context, as climate and land use changes have major impacts on hydrological responses.

This paper investigates the hydrological behavior due to urbanization under current and future climate scenarios of high summer and high winter rainfall for 20 sub-catchments of the Schijn River, located in the Flanders region near Antwerp, Belgium. As urbanization increases and existing rainfall-runoff models neglecting the specific behavior of urban runoff, a hydrological model was developed based on a basic reservoir concept and applied to the existing rainfall-runoff model (PDM) flow to examine the specific urban contribution. Results revealed that peak flow for urban runoff and the total peak flow (i.e. rural and urban runoff) were significantly higher (i.e. ranges from 200% to 500%) than the existing rainfall-runoff model (PDM) flows, because of faster and more peaked urban runoff response. The impact of climate change on current and future conditions was also assessed by estimating peak flows with respect to return periods from the flood frequency curve. The predicted peak flow of high summer future climate scenario was significantly higher (i.e. ranges from 200% to 250%) than that of the current climatic condition for this region. Furthermore, hourly peak flow and daily volume ratios of 100-year return period for the highest, lowest and average impervious area were projected for the time horizon of the year 2100. It is concluded that climate change impacts contribute the most in producing peak flow in coming years, while increased urbanization takes the second place for both hourly and daily values. Results on urbanization effect and climate change impact assessment are useful to the water managers for spatial planning, emergency planning and insurance industry.

1. Introduction

Flooding is the greatest economic natural disaster in Europe (Guha-Sapir et al., 2013) via damage and property and infrastructure, as well as physical injury and loss of life. As discussed below, EU flood policies took their roots in more than 100 major floods which occurred in the years 2000–2005 in Europe, among those, 9 floods were classified as extreme (Barredo, 2007). Major flood events resulted in 155 casualties and economic losses of more than €35 billion (Barredo, 2007). Material damage by floods in Europe in 2002 is estimated to be higher than in any previous year (Barredo, 2007). Damages caused by extreme floods have increased more than double in the last 50 years (Munich Re, 2005). (Feyen et al., 2009) estimated that economic losses caused by flooding in the EU are €6.5 billion per year, while the estimated annual damage is projected to rise to at least twice this amount by the end of this century. In May and June 2013, an extreme flood hits Central Europe in the Elbe and Danube River catchments and caused the highest water levels ever recorded (ICPDR, 2014). Subsequently, these floods highlighted the challenges related to Flood Risk Management (FRM) and fuelled the necessity for effective action programmes driven by policy in Europe. FRM is defined as a process of 'holistic and continuous societal analysis, assessment and mitigation of flood risk'

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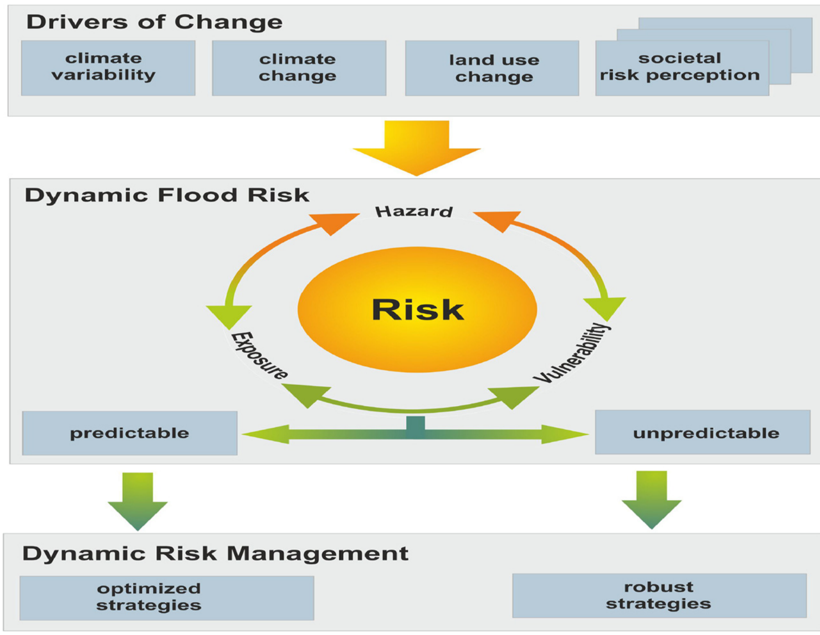

Fig. 1. Drivers of changes in flood risk, dynamic risk and dynamic flood risk management.
Source: (Merz et al., 2014).

(Schanze, 2006; Merz et al., 2010). It aims at managing the whole flooding system to reduce flood risks and providing environmental, social and economic benefits both for present and future (Sayers et al., 2014). In this case, accurate and updated data is necessary for decision-making and that's why the implementation of FRM strategies is quite challenging for practitioners, policy makers and researchers.

1.1. Dominating drivers of change for flood risk

The DPSIR model (EEA, 1999) is widely used to conceptualize environmental changes which set risk management rules. In this context, socio-economic developments are the driving forces (D), leading to environmental pressures (P) such as, increasing temperature and precipitation, which themselves lead to changes in environmental state (S) such as, inundation and flood, impact (I) refers to the effects on the environment of the pressures that are exercised on the system such as damage of property, ecosystem and loss of life, and response (R) consists of the actions taken to improve the status of the system by the society or policy makers such as strict rules for construction, maintaining natural floodplain etc. Some potential drivers of change are identified by (Merz et al., 2014) in Fig. 1.

Land use changes such as shifts from forestry to agriculture, from pasture to arable land, from rain fed to irrigated agriculture or from agricultural use to urbanized areas act as drivers for changes (EEA, 2016). Climate change impacts are increasingly considered in flood management along with other drivers such as, land cover changes and increasing water demand (Quevauviller, 2011).

In this respect, Global Climate Models (GCM) and Regional Climate Models (RCM) have shown that the magnitude and frequency of high precipitation extremes are likely to increase for Northern Europe and for Central and Southern Europe in winter (Dankers and Feyen, 2008; IPCC, 2013). For 2071–2100, projected precipitation extremes highlight an increase in Northern Europe, especially during winter (Kundzewicz et al., 2013) leading to increased flooding across most of North, Central and Eastern Europe (Lehner et al., 2006). Decreased flooding is projected for some parts of Central and Southern Europe (Dankers and Feyen, 2008). Alfieri et al., (2015) report that floods with return periods of 100 years are projected to increase double in frequency within 3 decades.

1.2. EU flood policy

At the European Union (EU) level, the water policy is governed by the Water Framework Directive (WFD), which aims to achieve good status for all waters in Europe (European Commission, 2000). The 2015 objectives have only been partly achieved in the 1st River Basin Management Plan (RBMP, 2009–2015) and are being now pursued in the 2nd RBMP (2015–2021). Flooding was not explicitly addressed in the WFD, nor climate change or its impacts. RBMPs represent the water management instrument and implementation of the WFD in all EU Member States. While climate change was not considered in the first cycle of RBMP (2009–2015), it has gradually been introduced in the policy discussions. In particular, climate impact has been discussed from 2009 onward through Common Implementation Strategy (CIS), composed of policy makers, experts from the Member States and of the European Commission (CIS, 2009) and recommended to integrate this dimension into the second (2015–2021) and third (2021–2027) cycles of RBMP (European Commission, 2013) to meet WFD goals under future projected climatic conditions. This approach is a kind of climate-proofing of the water policy (Quevauviller, 2014).

Recognizing the continued risks of flooding, specifically after the most devastating flood event in Central Europe in August 2002 and at the request of the EU Member States, the EC proposed the Flood Directive (FD) to set rules for the risk assessment and management of flooding (European Commission, 2007) in Europe. Complementing the WFD, the FD aims at reducing the adverse consequences of floods to human health, the environment and economic activity, taking into account the future changes in the risk of flooding as a result of climate change. Three steps are described in the EU Flood directive - preliminary flood risk assessment, flood hazard and risk map and FRM planning (Fig. 2).

As flood risk is not constant over time, flood risk maps and plans need to be revised every 6 years (De Moel et al., 2009) corresponding to the RBMP cycle. The principal information on flood and FRM at EU level is based on the reporting under the FD, which contains the Flood Hazard and Risk Maps and the draft of FRMPs i.e. flood-related action programs have to be embedded into the second RBMP (European Commission, 2015a). So the preliminary flood risk assessment would ideally consider climate change impacts and urbanization, that would