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Developing the evidence base for mainstreaming adaptation of stormwater systems to climate change

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ABSTRACT

In a context of high uncertainty about hydro-climatic variables, the development of updated methods for climate impact and adaptation assessment is as important, if not more important than the provision of improved climate change data. In this paper, we introduce a hybrid method to facilitate mainstreaming adaptation of stormwater systems to climate change: i.e., the Mainstreaming method. The Mainstreaming method starts with an analysis of adaptation tipping points (ATPs), which is effect-based. These are points of reference where the magnitude of climate change is such that acceptable technical, environmental, societal or economic standards may be compromised. It extends the ATP analysis to include aspects from a bottom-up approach. The extension concerns the analysis of adaptation opportunities in the stormwater system. The results from both analyses are then used in combination to identify and exploit Adaptation Mainstreaming Moments (AMMs). Use of this method will enhance the understanding of the adaptive potential of stormwater systems. We have applied the proposed hybrid method to the management of flood risk for an urban stormwater system in Dordrecht (the Netherlands). The main finding of this case study is that the application of the Mainstreaming method helps to increase the no-/low-regret character of adaptation for several reasons: it focuses the attention on the most urgent effects of climate change; it is expected to lead to potential cost reductions, since adaptation options can be integrated into infrastructure and building design at an early stage instead of being applied separately; it will lead to the development of area-specific responses, which could not have been developed on a higher scale level; it makes it possible to take account of local values and sensibilities, which contributes to increased public and political support for the adaptive strategies.

1. Introduction

It is common to consider adapting stormwater systems to climate change by adding simple uplifts to rainfall intensities and then assessing whether or not the existing system can cope or not (e.g., Defra, 2010; Semadeni-Davies et al., 2008). This is the Predict-Then-Adapt method which begins by considering the changing climate system (drivers) and the consequent pressures (e.g., increased runoff), state (e.g., system performance) to predict the impacts (e.g., flooding and

Abbreviations: ATP, adaptation tipping point; AMM, adaptation mainstreaming moment; CSO, combined sewer overflow; IDF, intensity–duration–frequency for rainfall; LAA, learning and action alliance.

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pollution). Responses then need to be formulated to deal with the pressures and impacts in a way that maintains expected levels of performance. This method has been classified as cause-based after its reasoning (Jones and Preston, 2011). The main problem with it is the reliance on estimated climate change scenarios that are expected to provide some precision as regards forecasts of climate change. However, despite past and current scientific advances in climate modelling, there remain large uncertainties about the direction, rate and magnitude of climate change. Uncertainty associated with climate modelling arises from model errors, internal variability and emissions scenario uncertainty (Cox and Stephenson, 2007). Whilst climate science can potentially reduce the uncertainty from model errors and, to some extent, also from internal variability, this uncertainty reduction will be a gradual and lengthy process. Nevertheless there will always be some irreducible uncertainty related to future emissions. Additionally, there is uncertainty about how global climate changes will influence changes in hydrological processes especially at urban drainage catchment scale (Willems et al., 2012). These climate change uncertainties will limit the usefulness of the Predict-Then-Adapt method for adaptation-related decision making for stormwater systems. Critiquing Predict-Then-Adapt, Dessai et al. (2008) conclude that the development of adaptive strategies should not be based solely on climate model predictions and adaptation, as a consequence, should not be limited by the lack of precision in forecasts.

Rather, the full range of possibilities for climate change needs to be addressed in adaptation-related decision making for stormwater systems. Recently a range of methods for decision making under uncertainty has been developed that do not rely on precise forecasts. These methods generally, though not always, align with the effect-based approach (Lempert et al., 2004). Effect-based approaches can be undertaken virtually independently of climate change scenarios, and in particular of probabilities of climate change. They start by specifying an outcome (i.e., expected performance) used to define acceptability thresholds to manage the impacts, and then assess the likelihood of attaining or exceeding this outcome as a result of changing drivers. An example of this is the exploratory modelling-based method for robust adaptation decision making (Lempert et al., 2003). This uses computer modelling to develop a large ensemble of future scenarios, where each scenario represents one possible set of boundary conditions as well as one possible choice among many alternative adaptive strategies. It aims to identify adaptive strategies that are robust under a wide range of future scenarios.

In addition to this exploratory modelling-based method, the adaptation tipping point (ATP) method (Kwadijk et al., 2011) is also used within the effect-based approach. The ATP method is aimed at assessing whether, and for how long, the performance of the existing system will continue to be acceptable under different climate conditions. It uses the concept of ATPs, which are reached if the magnitude of climate change is such that acceptable technical, environmental, societal or economic standards may be compromised (Haasnoot et al., 2009). The main advantage of the ATP method is that it is relatively simple to use in practice when compared with, for example, the exploratory modelling-based method. It is also simpler in concept and illustration when engaging with decision makers or other stakeholders.

Equally as important as the approach to the cause and effect chain (i.e., cause-based and effect-based) is the approach to spatial scale. The main orientations in terms of spatial scales are: top-down and bottom-up (Jones and Preston, 2011). The top-down approach considers the outputs of global climate models, which are downscaled to regional climate models to serve as input to hydrological models to assess impacts (Parry and Carter, 1998). Adaptive strategies are then developed based on the likely physical impacts of climate change on the system of interest. However, as a consequence, such an approach tends to neglect the wider contexts—including spatial planning, economic priorities, technical regulation, cultural preferences, risk psychology, etc.—in which adaptation has to take place (Dessai et al., 2009). As many of these characteristics tend to be location-specific, there is currently an increasing recognition of bottom-up approaches to the development of adaptive strategies. The bottom-up approach commences at the local scale, assessing the existing system to determine whether it is feasible to increase its ability to deal with climate change, including the variability (Jones and Boer, 2005). It also takes account of climate model predictions for the assessment of robust adaptation requirements through scenario-based approaches (e.g., Evans et al., 2004). This approach is based on the recognition that adaptation is better conceived as a socio-economic process rather than as a set of stand-alone adjustments, taking a more dynamic view of adaptation by combining climate change with socio-economic drivers (Jones and Preston, 2011). This concept has also been referred to as 'adaptation mainstreaming' (Huq and Reid, 2004).

Adaptation to climate change (at any spatial or temporal scale) is usually assumed to require additional financial capacity to better deal with more severe climatic conditions and to enhance climate change resilience. Here, resilience is defined in relation to the flooding system as the ability of the system to continue to function as expected in the face of change. The implementation of adaptive strategies at city or neighbourhood level is generally constrained by a lack of insight into the costs and benefits of adaptation (e.g., IPCC, 2007). This makes it difficult for decision makers to compare alternative options for adapting the stormwater system to climate change and to consider potential trade-offs. In the Western world in particular a steep increase in the proportion of capital investments in urban regeneration and renewal is anticipated in the coming decades (Zevenbergen et al., 2008). Hence, there are huge opportunities to exploit these urban dynamics to better adapt the infrastructure and building stock of Western cities to climate change and reduce adaptation costs.

The objective of this paper is to introduce a hybrid method (based on existing methods) for climate impact and adaptation assessment to facilitate mainstreaming adaptation of stormwater systems to climate change: i.e., the Mainstreaming method. The Mainstreaming method starts with an analysis of ATPs, which is effect-based, and extends this to include aspects from the bottom-up approach. The extension concerns the analysis of adaptation opportunities in the stormwater system. The results from both analyses are then used in combination to identify and exploit Adaptation