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Tipping points in adaptation to urban flooding under climate change and urban growth: The case of the Dhaka megacity

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ABSTRACT

Envisioning the future city as the outcome of planned development, several master and strategic plans for Dhaka were prepared. However, these plans, do not adequately address the well-known and combined effects of climate change and unplanned urbanization on urban flooding. Additionally, the spatial planning component is missing in adaptation planning, which broadly concentrates on the climate change. Long-term adaptation strategies should consider both the temporal and spatial extent of flooding. Uncertainties in climate change and urbanization will induce planning failure beyond the Adaptation Tipping Point for flooding exceeding the thresholds of the bio-physical system or the acceptable limits of societal preference. In this paper, a shift is proposed from the current planning practice of single-dimensional 'Predict and Act' towards a more resilience-based 'Monitor and Adapt' approach. It is prudent to visualize the effects of urbanization and climate change and translate them into strategies for improved adaptation based spatial planning. Here, Dhaka's exposure to floods under different climate change and urban (planned and unplanned) development scenarios is assessed based on acceptable thresholds obtained from plans (top-down defined) and stakeholders (bottom-up perspectives). The scale of effects of these two drivers on urban flooding is exhibited through the zone differentiated flooding extent. While apparently the effect of climate change on flooding is greater than that of unplanned urban developments, both play an important role in instigating tipping points and intensifying risks.

1. Introduction

Massive urbanization in the last few decades has converted many rural areas into urban areas and cities into mega and meta cities such as Dhaka. The numbers of megacities are growing in the developed as well as developing countries (Nicholls, 1995). This has brought about economic development and often improvement of quality of life. At the same time, urbanization along with climate change has compromised the social welfare of the inhabitants and management of sustainable environment (UNHSP, 2011; Discoli and Martini, 2012). Climate change enhances the frequency and intensity of hazards and then again, cities themselves trigger changes in the climate with increased energy consumption, burning of fossil fuel and economic activity (Roy, 2009).

Cities have grown either in a planned (regular) or in an unplanned (irregular) manner (Alnsour, 2016). Unplanned growth has been experienced in cities of Europe (Costa et al., 1991; Batty et al., 2003; Kaya and Curran, 2006), Africa (Ibrahim Mahmoud et al., 2016; Winsemius et al., 2016; Kithiia and Dowling, 2010) and USA (Graham et al., 2004)

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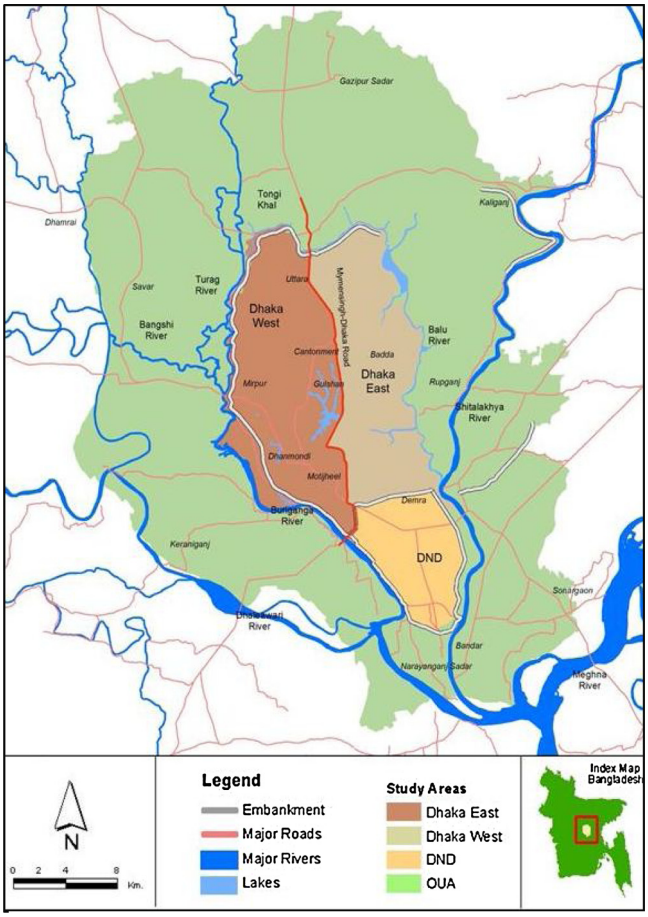

Fig. 1. Map of Greater Dhaka showing the four zones of the study area.

as well as in Asian cities such as Dhaka (Dewan, 2013; Ahmed and Bramley, 2015). In the past, cities in the present developed countries also experienced unplanned growth due to increased housing demand (Costa et al., 1991; Batty et al., 2003). Dense urban growth, inadequate drainage and increased high intensity rainfall events due to climate change have caused urban flooding, damage to life and property, and negative impacts on environment and health (Graham et al., 2004; Dewan, 2013). These impacts of flood vary across social strata, institutional setting, physical conditions and from one region to another (Walters, 2015).

Through many studies the effect of urbanization on flooding has been demonstrated for cities (Young, 2013; Pathirana et al., 2014; Muis et al., 2015; Veerbeek, 2017) in developing countries including Dhaka (Dewan and Yamaguchi, 2008; Gain and Hoque, 2013; Onishi et al., 2013; Dasgupta et al., 2015). In a recent study (Dasgupta et al., 2015), the impacts of climate change and urban growth (planned) were assessed using hydrodynamic models covering the central part and the Dhaka-Narayanaganj-Demra (DND) areas of Greater Dhaka (see Fig. 1). Also, there were studies which by applying land use models specifically looked at the urban growth trend of Dhaka into the future (Corner et al., 2013; Ahmed and Bramley, 2015). Apart from these studies, several plans in the form of master and strategic plans for Dhaka have been prepared. However, these studies and plans, did not adequately address the well-known and cumulative effects of climate change and unplanned growth on urban flooding. Additionaly adaptation plans for Dhaka concentrate broadly on the issues of climate change, in which the spatial planning component is missing.

An important aspect of urban development plans and adaptation plans is to develop short and long term strategies considering the effects of climate change and urban growth on flooding. Since the emergence of climate change as a threat, adaptation and mitigation have become vital parts of policies, plans and programs on urban flood management (Djordjević et al., 2011). This paper shows that stemming from the dynamics of the climatic and non-climatic drivers (i.e. land use change), Adaptation Tipping Points (Kwadijk et al., 2010) will occur in the biophysical system from urban flooding. Adaptation Tipping Points (ATPs) are the thresholds or specific boundary conditions where ecological, technical, economic, spatial or societal acceptable limits are exceeded (Haasnoot et al., 2011). The ATP concept was found useful in the Netherlands, USA, Vietnam and Bangladesh for formulating water management strategies under climate change including the Bangladesh Delta Plan 2100 (BDP2100).

As such the main research question is to see how by taking into account the combined effects of planned and unplanned urban growth along with climate change can support the assessment of ATPs due to urban flooding. In the same line of thinking as the BDP2100 i.e. resilient adaptation based planning, this research additionally explores the differential impacts of unplanned development with climate change on flooding. Resilience based adaptation means such a system which can recover and sustain under the impacts of e.g. climate change and continuous urbanization (Walker et al., 2013). As Dhaka is in its transition of becoming a meta city by 2020 (exceeding 20 million population), unplanned development is taking place beside the planned development. The unplanned growth together with the climate change impacts is likely to enhance urban flooding and compromise urban resilience as it may (over)stretch social adaptive capacity. The uncertainties in climate change and land use development are likely to create a mismatch with the actual changes and cause plans to fail (Walker et al., 2013). Rigid plans based on a single scenario cannot address the existing uncertainties with urban development and climate change. Therefore, adoption of a resilience based approach in the vulnerability assessment and planning process can help to deal with the impacts and improve the planning process.

It is therefore time to rethink the current planning process and shift from a single dimensional 'Predict and Act' approach towards a multi-dimensional resilience based 'Monitor and Adapt' approach (Walker, 2011) to deal with climate change in an urbanized world. Predict and Act refers to an approach where a fixed plan is prepared based on predicted scenarios (Walker et al., 2013). Resilience based approach is much more dynamic, a flexible plan is prepared so that the system adapts with the continuously monitored change (Walker et al., 2013). The assessment of ATPs gives a platform to consult with the stakeholders and set the standards for acceptable changes. On the basis of community consultations and by reviewing the existing plans, the thresholds were obtained for the assessment of ATPs. Cities growing in an unplanned manner are likely to reach ATPs at a different space if compared to planned growth and will therefore require alternative strategies, as shown in this paper. For this reason, spatially explicit planned and unplanned urban growth scenarios with climate change scenarios were applied in the flood models. Contrary to previous studies, this paper also compares the scale of effects of climate change with the consequences of urbanization on flooding and its implications on spatial planning and flood adaptation in future.

2. Case study area and methodology

2.1. Case study area

Based on the existing setup of the flood management structures and administrative boundaries of Greater Dhaka can be divided into four zones: Dhaka East, Dhaka West, Dhaka-Narayanganj-Demra (DND) and the Outer Urban Area (OUA) (Fig. 1). For example-Dhaka West is fully protected from River floods by the western embankment and the flood proofed Mymensingh-Dhaka road (Fig. 1). Dhaka east is partially protected with the road in one side and wetlands in the other side. The DND is fully protected from the River with circular road cum