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Review

Assessment of stormwater runoff management practices and governance under climate change and urbanization: An analysis of Bangkok, Hanoi and Tokyo

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ABSTRACT

As human history is changing on many fronts, it is appropriate for us to understand the different perspectives of major global challenges, of which, water is a major priority. The water resources in urban areas are either approaching or exceeding the limits of sustainable use at alarming rates. Groundwater table depletion and increasing flood events can be easily realized in rapidly developing urban areas. It is necessary to improve existing water management systems for high-quality water and reduced hydro-meteorological disasters, while preserving our natural/pristine environment in a sustainable manner. This can be achieved through optimal collection, infiltration and storage of stormwater. Stormwater runoff is rainfall that flows over the ground surface; large volumes of water are swiftly transported to local water bodies and can cause flooding, coastal erosion, and can carry many different pollutants that are found on paved surfaces. Sustainable stormwater management is desired, and the optimal capture measure is explored in the paper. This study provides commentary to assist policy makers and researchers in the field of stormwater management planning to understand the significance and role of remote sensing and GIS in designing optimal capture measures under the threat of future extreme events and climate change. Community attitudes, which are influenced by a range of factors, including knowledge of urban water problem, are also considered. In this paper, we present an assessment of stormwater runoff management practices to achieve urban water security. For this purpose, we explored different characteristics of stormwater runoff management policies and strategies adopted by Japan, Vietnam and Thailand. This study analyses the abilities of Japanese, Vietnamese and Thai stormwater runoff management policies and measures to manage water scarcity and achieve water resiliency. This paper presents an overview of stormwater runoff management to guide future optimal stormwater runoff measures and management policies within the governance structure. Additionally, the effects of different onsite facilities, including those for water harvesting, reuse, ponds and infiltration, are explored to establish adaptation strategies that restore water cycle and reduce climate change-induced flood and water scarcity on a catchment scale.

1. Background

The world's population has reached 7.2 billion, and more people live in cities than in rural areas (UNDESA, 2014). Water is a very critical natural resource for the world's fastest growing urban areas. Commercial, residential, and industrial users already place considerable demands on cities' water resources and supply, which often require water treatment (Bahri, 2012). The demand of water resources in urban areas is approaching the capacity of the water supply and, in many cases, the limits of sustainable water use are being exceeding (Hatt et al., 2004; Mitchell et al., 2003). In some cases, water scarcity is leading to conflict over water rights. In urban watersheds, competition with agriculture and industry is intensifying as cities expand in size and political influence (Bahri, 2012). With industrial and domestic water demand expected to double by 2050 (UNDP, 2006), competition among urban, peri-urban, and rural areas will likely worsen. A critical challenge to newly developed urban cities is design for resilience to the impact of climate change with regards to sustainable management of water resources. It is currently well accepted that the conventional urban water management approach is highly unsuited to addressing current and future sustainability issues (Ashley et al.,

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2005; Wong and Brown, 2008). The conventional approach to urban water systems around the world involves the use of a similar series of systems for drainage of stormwater, potable water and sewerage. As explained by Bahri (2012), the unsustainable nature of this approach is highlighted by the current ecosystem-related problems and degraded environment in urban areas due to changes in the hydrology of catchments and quality of runoff, leading to modified riparian ecosystems (Bahri, 2012). United Nations Agenda 21 (1992) stated that achieving sustainable urban water systems and protecting the quality and quantity of freshwater resources are key components of ecologically sustainable development. Because of climate change and the spread of urbanization, the negative impacts are intensifying, resulting in increasing runoff, pollutant loads and pressure on existing systems, with a significant economic cost required to augment conventional systems. Alternative approaches are required to develop sustainable water systems in urban environments, and Integrated Urban Water Management (IUWM) is one such approach, which views the water supply, drainage and sanitation as components of an integrated physical system within an organizational and natural landscape (Mitchell et al., 2007a, 2007b). It is an integrated system that seeks to reduce the inputs and outputs to decrease the inefficiencies of water resources that are associated with the traditional practices of urbanization (Hardy et al., 2005). Although this incorporation and diversification of urban water systems increase the complexity of urban water systems, they also provide more opportunities to attain sustainable water use and increase the overall water system resilience (Mitchell and Diaper, 2005; Mitchell et al., 2007b). The identified key components of the IUWM system are the methods and measures to capture and utilize urban stormwater. Fig. 1 defines stormwater as precipitation, such as rain or melting snow. In a natural environment, a small percentage of precipitation becomes surface runoff; however, as urbanization increases, the amount of surface runoff drastically increases. Surface runoff is created when pervious or impervious surfaces are saturated from precipitation or snow melt (Durrans, 2003). Pervious surface areas naturally absorb water to the saturation point, after which, rainwater becomes runoff and travels via gravity to the nearest stream. This point of saturation is dependent on the landscape, soil type, evapotranspiration and biodiversity of the area (Pierpont, 2008).

In the urban environment, due to the impervious surfaces that cover the natural environment, the hydrological processes of surface water runoff become more unnatural, causing damage to infrastructure and contamination of water by pollutants (Ragab et al., 2003). The need for stormwater runoff management capture and transportation systems developed as a result of human experiences with various challenges due to destructive floods.

The sustainable stormwater runoff management target is to understand the changes in the urban landscape, in which the addition of vegetation is not widely observed, with the aim of devising approaches to limit certain undesirable effects and to take advantage of the new opportunities (Huang et al., 2007). A sustainable stormwater system is not a system to address runoff problems and avoid unwanted contaminants in the water, but rather, it is a system to increase the potential usability of water resources in society (Sundberg et al., 2004). Stormwater capture and drainage may be considered not only as systems to divert undesired water from urban areas but also as valuable elements for landscaping the surroundings of buildings and roads (Boller, 2004). In general, to control surface runoff, flood control agencies have constructed large centralized facilities, such as culverts, detention basins and sometimes re-engineered natural hydrologic features, including the paving of city river channels to quickly convey runoff to receiving water bodies. These large-scale facilities are required to handle the massive amounts of runoff generated by the largest storm events, as it would be impractical to handle this runoff on a decentralized parcel-by-parcel basis with small-scale infiltration devices. The current trend is toward a more overall integrated approach to manage stormwater runoff as an integrated system of preventive and control practices to accomplish stormwater management goals. The first principle is to minimize the generation of runoff and pollutants through a variety of techniques, and the second principle is to manage runoff and its pollutants to minimize their impacts on humans and the environment in a cost effective manner (EPA, 2007). The utilization of remote sensing and GIS technology in stormwater management is constantly evolving, and commonly used GIS technologies are utilized to help decision-makers to determine the most efficient ways to manage stormwater, including the selection of capture measures based on criteria, and the evaluation of methods to capture urban runoff (Wilson et al., 2000). However, as explained by Wang et al. (2004), even in the most technically complex analysis, it is always necessary for the human element to select appropriate criteria and make other subjective decisions. There will frequently be decisions made in stormwater management that reflect the economic, political, social, and aesthetic components that may not always be easily incorporated into a GIS analyses and modelling system. Important aspects of community attitudes are also considered in this study, as these attitudes are influenced by a

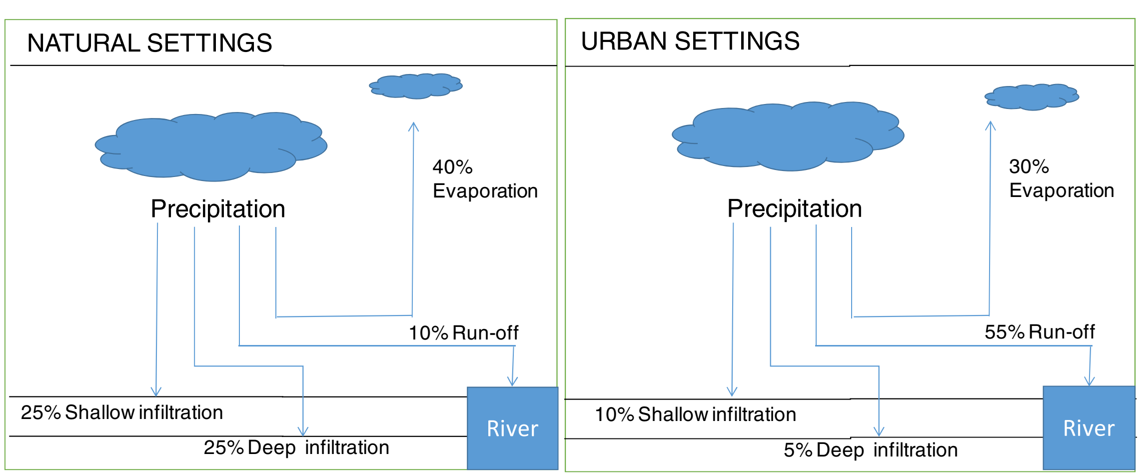

Fig. 1. Comparison of absorption and surface runoff between a natural and an urban environment.