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Global policy analysis of low impact development for stormwater management in urban regions

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ABSTRACT

Population increase and migration from rural areas to urbanized regions have resulted in the formation of gray cities mainly comprised of impervious surfaces. High quantities of stormwater runoff containing pollutants from gray cities cause problems including inland flooding and water pollution. An innovative and evolving response to this global issue is the development of green cities that utilize low impact development (LID) and analogous initiatives. This paper aims to assess LID efforts and relevant governmental policies from a global perspective. It provides a vantage on major evolving LID technologies, where the best policies regarding planning, design, construction, and management are still not well known. The case studies of LID and relevant governmental policies around the world are presented to facilitate future quantitative and qualitative stormwater management in urban regions. This study found that the western and eastern regions around the globe have different driving forces and attitudes regarding implementing LID. These differences are reflected in the name of their LID-like initiatives with varying ramifications. The western regions, such as the United States, pay more attention to restoring water quality, whereas the eastern regions, such as China, prioritize flood prevention and rainwater harvesting. Levying stormwater fees and indirect subsidies by offering a discount are effective for promoting LID to some extent. This paper also provides an in-depth discussion in regard to the latest essence of LID technologies, which magnify their ability to manage stormwater while also providing societal, environmental, hydrological, and aesthetic benefits. Governments should encourage and support the development of green cities by using LID and analogous initiatives.

1. Introduction

Global changes including economic development, population growth and migration from rural areas to urbanized regions, and climate variation have resulted in the formation of more gray cities with higher flooding potential throughout the world. Gray cities are mainly comprised of impervious or sealed surfaces, with little regard to the ecological health and hydrologic characteristics of the area. Gray cities produce high quantities of stormwater runoff containing sediments, pathogens, metals, and chemical pollutants (Gasperi et al., 2009), resulting in the degradation of receiving water bodies. An innovative and evolving response to this global issue is the development of green cities, which are designed to restore the environmental and ecological damage. Green cities utilize low impact development (LID) and analogous initiatives to mimic pre-development hydrologic and ecological characteristics. Hence, LID is defined as a volume control approach, allowing developers to replicate predevelopment runoff patterns using micro-scale integrated management practices that capture and treat rainwater close to where it hits the ground in the beginning stage. In response to the need to address urban water reuse, water quality, and stormwater issues while considering not only water quality deterioration but also inland flooding and water depletion, LID can be used to develop a city with environmentally sustainable stormwater management.

In recent years, the management and treatment of stormwater runoff from urban areas has become a priority concern for those responsible for planning, design, construction, and maintenance of new urban infrastructure systems (Lucke and Dierkes, 2015). LID advocates for the management of rainwater runoff as close to its origin as possible, breaking away from conventional end-of-pipe approaches, and has therefore gained popularity among practitioners and public authorities (Sage et al., 2015). The LID approach is composed of site planning, hydrologic analysis, integrated management practices, erosion and sediment control, and public outreach programs (Prince George's County,

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1999). Examples of LID technologies include green roofs, permeable pavement, retention cells, treatment swales, and many others (see the Supplementary Materials in the Appendix). Currently, the concept of LID is mostly used in the United States (U.S.). Analogous concepts mainly include green infrastructure or green stormwater infrastructure (GSI) in the U.S., sustainable urban drainage systems (SuDS) in the U.K., decentralized stormwater management in Germany, and water sensitive urban design (WSUD) in Australia (Hoyer et al., 2011). LID and analogous initiatives are successfully tested tools for providing political, ecological or aesthetic, economical, and social benefits through natural solutions. LID and urban green spaces make aesthetic contributions to city life and provide people the opportunity to come in contact with nature (James et al., 2009). In Europe, green infrastructure refers to a more macroscopical concept focusing on the harmony of natural and semi-natural environments (European Commission, 2013). Green infrastructure is thus a strategically planned network of natural and semi-natural areas with environmentally and ecologically sound features designed and managed to deliver a wide range of sustainable services for communities. At present, an understanding of the multiple functions of LID is well developed; however, it is not well integrated into the policy, planning, design, and management of urban cities. In the past few years, only a few countries or regions have started formalizing relevant policies at different levels to promote LID. They are mainly the U.S., Europe (the United Kingdom and Germany), Australia (Australia and New Zealand), and Asia (Japan, China, Singapore, and Hong Kong).

This paper aims to assess LID efforts and review relevant governmental policies from a global perspective in those countries where LID technologies have been promoted by formal policies. It provides a vantage on evolving LID and analogous initiatives, where the best policies regarding planning, design, construction, and management are still not well known. The case studies of LID technologies and relevant governmental policies and regulations for areas around the world are presented to facilitate future quantitative and qualitative stormwater management in urban regions. This study may lead to answering the following questions: 1) how do LID policies vary from the eastern to western world? 2) how can LID technologies evolve to handle both quantitative and qualitative stormwater management issues? And 3) what type of economic instruments are most applicable for LID promotion? This sociotechnical analysis linking LID technologies with managerial policies may further support the shift from gray cities to green cities, which will preserve ecosystem services and ensure an environmentally sustainable future.

2. LID in America

As more attention had been paid to the non-point source pollution control in the U.S., the water quality act issued in 1987 began to require the national pollution discharge elimination system (NPDES) permits for stormwater discharge. The NPDES stormwater program, in place since 1990, regulates discharge from municipal separate storm sewer systems (MS4s), construction activities, industrial activities, and those designated due to water quality impacts (US EPA, 2016a). The federal government authorized most states to implement the stormwater NPDES permitting (US EPA, 2016b) and developed the water quality scorecard to help local governments identify opportunities to remove barriers and provide incentives for improved water quality protection. The NPDES permit requirements are thus the primary driving force for local stormwater codes. This type of regulation aimed at water quality improvement was a leap forward and laid the framework for stormwater management in the U.S. for many years. Meanwhile, the best management practices (BMPs) to prevent or reduce the water pollution were proposed for stormwater management. However, many traditional stormwater BMPs, such as detention ponds and retention basins, generally addressed only peak flows and limited water quality and were not cost-effective (Prince George's County, 1999).

In the early 1990s, the idea and techniques of LID were pioneered in Maryland State and gained extensive attention in the U.S., Canada, and some other countries. LID represents a significant advancement in stormwater management. Nowadays, this approach focuses on source control and combines a hydrological functional site design with pollution prevention measures to compensate for land development impacts on hydrology and water quality (Prince George's County, 1999). Very recently, an analysis of the LID implementation in 23 U.S. cities indicated that rainwater harvesting for stormwater reuse as an alternative water source can reduce stormwater runoff volume up to 20% in semiarid regions (less in regions receiving greater rainfall amounts) based on a long-term simulation (Steffen et al., 2013). Furthermore, as LID approaches were proven to effectively reduce sewer overflows by diverting stormwater from the sewer system, a multi-department intent encouraging the use of LID was initiated in 2007 in order to promote the benefits of using green infrastructure (GI) in protecting drinking water supplies, mitigating sewer overflows, and reducing stormwater pollution (US EPA, 2007). Federal clean water act programs require local governments to overhaul stormwater management strategies to protect and improve surface-water quality (US NRC, 2008). Following this movement, many state and local governments gained interest in LID technologies, recognizing the ecological, hydrological, economic, and societal benefits of using them. In 2008, the “Green Infrastructure Municipal Handbook” was released to provide local governments with a step-by-step guide to implementing LID in their communities (Bitting and Kloss, 2008). While there is interest in the multiple benefits of LID in the U.S., LID technologies have recently gained attention specifically in relation to stormwater management in terms of both flood control and water quality management simultaneously with an integrated approach between the conventional drainage system and the LID technology (Fig. 1) (more LID technology hubs can be seen in the Appendix). After the incipient development of LID technologies on the east coast of the U.S., the LID strategy has grown more popular in western North America, especially in Seattle (Washington), Portland (Oregon), Vancouver (Canada), Chicago (Midwest), and on the east coast in Massachusetts since the early 2000s (Eason, 2003). For example, in response to flooding and water quality concerns related to stormwater, the New York City (NYC) Green Infrastructure Plan (Fig. 2) emerged in 2010 to promote urban green space, low impact development, and retention and reuse of stormwater (Bloomberg 2010).

Unlike other ways of coping with the threat of flooding such as buying flood insurance to reduce the possible impact (Pasterick, 1998), using LID can address the underlying flooding problem to some extent, leading to the management of stormwater in a safe and sustainable

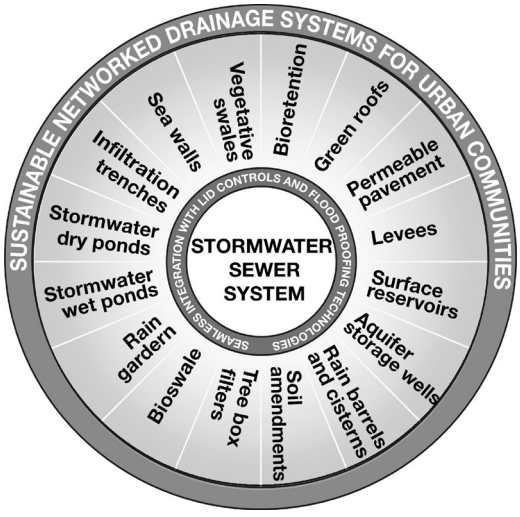

Fig. 1. A modern technology hub for multi-scale stormwater management in coastal or inland urban environments.