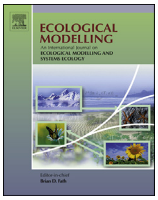
Ecological Modelling xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel



Influences of setting sizes and combination of green infrastructures on community's stormwater runoff reduction

Wen Liu, Weiping Chen *, Chi Peng

State Key Laboratory for Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

ARTICLE INFO

Article history:
Received 20 May 2014
Received in revised form 2 November 2014
Accepted 4 November 2014
Available online xxx

Keywords:
Green infrastructure
Setting size
Green area expanding
Concave green space
Storage pond
Porous brick pavement

ABSTRACT

Implementation of green infrastructures is an effective option for mitigating the impacts of increasing urbanization on stormwater runoff. In this study, we evaluated the runoff reduction effectiveness under various setting sizes of green infrastructures using a process-based stormwater runoff model. The model was validated with field data from a typical community in Beijing and proved to be accurate in estimating stormwater runoff under larger rain events. The pervious area percentage and soil hydraulic properties were key parameters influencing stormwater runoff. The four types of green infrastructures, including green area expanding, concave green space, storage pond and porous brick pavement were effective in reducing stormwater runoff, but single facility except the storage pond could not fully control runoff of 5-year recurrence storm. With integrated green infrastructures, runoff of 5-year recurrence storm could be 100% reduced by expanding the pervious area percentage to over 50%, or increase storage pond volume to over 1800 m^3, whereas a maximum runoff reduction of 95% could be achieved when the green land was reformed to concave with a depth of 4 cm, or 50% of the impervious area was replaced with porous brick pavement with a storage capacity of 8 mm. The combination of green infrastructures with proper setting sizes is necessary for optimal control of stormwater runoff management.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Urbanization is characterized by great land use and land cover alterations with an increase in impervious area, which impairs stormwater infiltration and significantly increases surface runoff during storm events, causing urban flooding, stream channel erosion and non-point pollution problems (Brabec, 2009; Hogan and Walbridge, 2007; Lee and Heaney, 2003; Paul and Meyer, 2001; Wissmar et al., 2004). Conventional methods of stormwater management sought to remove runoff from a site as quickly as possible and then store the stormwater at downstream facilities, including detention ponds, wet ponds and infiltration basins, to control the peak discharge (Gilroy and McCuen, 2009; Wang et al., 2014). While these approaches may control the downstream peak discharge rates, the issue of increased runoff volume remains (Holman-Dodds et al., 2003). Recent years, several innovated strategies such as green infrastructure, sustainable drainage system and water sensitive designs are popular as more sustainable solutions for stormwater management (USEPA, 2000; Lu et al., 2013). These approaches can solve the stormwater management problems by capturing and retaining rainwater, infiltrating runoff, and trapping and absorption of pollution through on-site and decentralized rainwater storage and infiltration facilities (Kloss, 2008).

Green infrastructures, also referred to as low impact development (LID) practices, are common technologies that manage stormwater at the source by restoring some of the natural hydrology functions in urbanized areas and create healthier urban environments. At the scale of a city or county, green infrastructure refers to interconnected network of green space that conserves natural systems and provides assorted benefits to human populations (Benedict and McMahon, 2006). At the scale of a neighborhood or site, green infrastructure is an approach to manage stormwater by infiltrating it in the ground using vegetation or porous surfaces, or by capturing it for later reuse. Many researches have studied the hydrological performance of green infrastructure practices on a laboratory, a pilot scale and in-situ full scale (Abbott and Comino-Mateos, 2003; Alfredo et al., 2010; Chapman and Horner, 2010; Dietz, 2007; Fassman and Blackbourn, 2010; Qin et al., 2013). Although the green infrastructure performance on reducing runoff volumes has been extensively investigated, few studies have attempted to compare the reduction effectiveness between integrated green infrastructure and single facilities (Liu et al., 2014).

---

* Corresponding author. Tel.: + 86 10 62843981; fax: +86 10 62918177.
E-mail addresses: wpchen@rcees.ac.cn (W. Liu), wpchen@rcees.ac.cn (W. Chen).

http://dx.doi.org/10.1016/j.ecolmodel.2014.11.007
0304-3800/© 2014 Elsevier B.V. All rights reserved.

Please cite this article in press as: Liu, W., et al., Influences of setting sizes and combination of green infrastructures on community's stormwater runoff reduction. Ecol. Model. (2014), http://dx.doi.org/10.1016/j.ecolmodel.2014.11.007

Further, factors that influence the effectiveness of green infrastructure have not been conclusively determined (Gilroy and McCuen, 2009). Brander et al. (2004) and Holman-Dodds et al. (2003) showed that the effectiveness of infiltration techniques in reducing runoff were dependent on soil and storm event type. Some researches indicated that the LID performance on runoff reductions generally were more effective for small storms (Damodaram et al., 2010; Holman-Dodds et al., 2003; Hood et al., 2007; Lee et al., 2012; Qin et al., 2013; Schneider and McCuen, 2006; Williams and Wise, 2006). Guo and Cheng (2008) showed that the distribution of the pervious area and the impervious area influences the effectiveness of LID measures. Gilroy and McCuen (2009) showed that the effectiveness of LID practices in a micro-watershed was influenced by the spatial location and the storage volume of cisterns and bioretention pits. The storage volume is positively correlated with percent reduction in the peak discharge rate and total runoff volume. However, few references have showed the flood mitigation mechanism of other green infrastructure facilities (Gao et al., 2013), and examined how the internal factors (i.e., setting sizes) of green infrastructure affect the reduction effectiveness.

To achieve desired levels of practice performance control with minimal investment, it is necessary to study the impacts of setting sizes and combination effects of green infrastructures on stormwater runoff reduction. As stormwater runoff generation is affected by many factors and hydrological processes, proper model with validated data is necessary for optimal design of community to minimize its impacts on urban water environments.

In this research, we studied the effects of various setting sizes of green infrastructures on stormwater runoff using a process-based stormwater runoff model, which was intentionally developed to simulate the runoff reduction functions of green infrastructures. A typical community in Beijing was used for the case study. Field data were collected for model validation. Sensitivity analysis of model parameters was conducted to quantify the impacts of different factors on stormwater runoff generation in the community. Runoff reduction effectiveness under various setting sizes of green infrastructures was studied. An optimal combination of green infrastructures was designed and proposed to implement in the community.

2. Materials and methods

2.1. Field experiments

Field experiments were conducted in the Wangchunyuan residential community, which is located at the north of Chaoyang district, Beijing (40°02′36″N, 116°24′54″E). The region is classified as a typical monsoon-influenced humid continental climate. The multi-annual average rainfall is about 585 mm and the annual mean temperature is 13.1 °C. The catchment area of the northern outlet of the community is 29,500 m^2 and the pervious area percentage accounts for 30.2%. The rainfall and stormwater runoff flows were measured by adding an ISCO 674 tipping bucket rain gauge (Teledyne ISCO, NB, USA) and an ISCO 750 area velocity module to the ISCO 6712 automatic sampler at the northern outlet from July to September in 2013. The instrument measures rainfall, average velocity and depth of flow every 5 min. Stormwater runoff levels were determined by differential pressure, the average velocities were measured using ultrasonic sound waves and the Doppler effects. Data were logged at 5-min intervals and flow rates were calculated using the Flowlink software version 5.1 (Teledyne ISCO, NB, USA).

2.2. Model description

A process-based stormwater runoff model was developed to evaluate the stormwater runoff reduction effects of green infrastructures, which was based on the water mass balance and the processes of urban hydrological cycle. In the model, the urban underlying surfaces are divided into three types of surfaces, namely impervious surfaces, pervious surfaces and water bodies. In a rain event, the rainfall would be routed through interception, evaporation, infiltration and depression processes of the hydrological cycle dependent on the nature of surfaces and dynamic factors to produce the surface runoff. The interception process of vegetation canopy is calculated by the Rutter model (Rutter et al., 1975; Wang et al., 2008). The estimation of potential evaporation is using the Hargreaves–Samani formula. The soil infiltration is calculated by the Green–Ampt equation. The water routing through each surface is calculated independently and then summed up to obtain the total stormwater runoff. Impacts of

Table 1
The parameters used for the default simulation of runoff generation.

Parameters	Values	Units	Sources
Community's characters			
Percentage of impervious areas	69.8	%	Based on local investigation
Percentage of pervious areas	30.2	%	Based on local investigation
Meteorological conditions			
Maximum daily temperature	31	°C	Beijing meteorological data
Minimum daily temperature	22	°C	Beijing meteorological data
Average daily temperature	26.5	°C	Beijing meteorological data
Soil properties			
Saturated hydraulic conductivity	0.144	mm/min	Xie et al., 1998
Wetting front suction	69.696	mm	Fu et al., 2002
Saturated water content	40.627	%	Xie et al., 1998
Initial water content	26.279	%	Xie et al., 1998
Vegetation characters			
Leaf area index	3.85	–	Su and Xie 2003
Extinction coefficient	0.3	–	Wang et al., 2008
Special leaf storage	0.2	mm	Wang et al., 2008
Runoff yield parameters			
Depression of impervious area	3	mm	Xu, 1998
Depression of pervious area	4	mm	Lei et al., 2010

Please cite this article in press as: Liu, W., et al., Influences of setting sizes and combination of green infrastructures on community's stormwater runoff reduction. Ecol. Model. (2014), http://dx.doi.org/10.1016/j.ecolmodel.2014.11.007

Download English Version:

https://daneshyari.com/en/article/6296425

Download Persian Version:

https://daneshyari.com/article/6296425

Daneshyari.com