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Flood Mitigation Considering Low Impact Development in an Urbanized Watershed

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Abstract: This study assessed the performance of LID practices (rainwater harvesting and permeable pavements) as retrofitting technologies on flood mitigation in an urbanized watershed using a flooding inundation model (Flo-2D). Rainwater harvesting is applied on 55% of the roofs. Permeable pavements are applied on 50% of parking lots, piazzas and non-busy roads. There was about 4% reduction in inundated area due to rainwater harvesting and 2 cm decline in maximum flow depth. The inundated area decreased by about 10% with the applications of permeable pavements and maximum flow depth decreased by 7cm. The combination of rainwater harvesting and permeable pavements resulted in about 13% reduction in inundated area

Keywords: Hazard map, Flo-2D model, Rain harvesting, Permeable pavements

1. Introduction

Urbanization accompanying man-made hydrologic modifications brings many adverse effects on nature environment, and induces problems of water shortage, floods, water pollution etc. (Zhang and Hu, 2014). Moreover, these problems will be exacerbated along more development and urbanization. To address these concerns, low impact development (LID) was introduced as a stormwater management strategy to maintain or replicate the predevelopment hydrologic regime by using best management practices (Newcomer et al., 2014). This action received much attention from urban water managers and hydrologists, and became a hot research topic. The main LID techniques include bio-retention areas, permeable pavements, rainwater harvesting and green roof. To date, research has reported that LID practices reduced runoff as much as 40-90% and meet at least 50% of non-potable water for human uses from individual LID site. However, currently there is little quantitative information of the impacts of these practices on urban flood control and water resources at watershed scale. The objective of this study is to assess the performance of LID practices on urban waterlogging mitigation at the watershed scale.

2. Methods

2.1 Study area

The study area, covering an area of 54.29 km^2, is located in Nanjing, China. The population is about 0.6 million. The watershed is surrounded by the Qinhuai River and the Yangtze River. Due to the low elevation below the average water level of the Qinhuai River in the rainy season, it is one of the most seriously waterlogged areas in Nanjing (Zhang et al., 2016).

2.2 Inundation simulation

FLO-2D is a flood routing model that simulates channel flow, unconfined overland flow and street flow over complex topography. The detailed information can be found in the literature of (Wu et al., 2013) and the model manual. Rainwater harvesting is quantified by the parameter of grid initial rainfall abstraction. Permeable pavements are quantified by the parameter of grid impervious area ratio. Hazard map is defined as a discrete combined function of the event intensity and return period. Intensities are defined in terms of the maximum water depth (h) and the product of the maximum velocity multiplied by the maximum depth (vh), shown in Table 1.

2.3 Scenarios of LID practices application

The rainwater harvesting is applied on the building roofs. There are about 55% of roofs are available (Zhang et al., 2012). Permeable pavements are applied on parking lots, piazzas and non-busy roads. In this study, we consider 50% of these areas are rebuilt as permeable surface. Four scenarios are assumed.

S1: Existing condition of the watershed
S2: Implementation of rainfall harvesting (55% roofs)
S3: Implementation of permeable pavements (50%)
S4: Rain harvesting combined with porous pavements

3. Results and conclusion

Table 2 shows the area of different hazard level under four scenarios in a 100-year rainfall event. It was found that the influence of implementation of rainwater harvesting on flood control is not obvious, about 4% reduction in hazard zone area and 2 cm decline in maximum flow depth. But there was 14% decrease in the area of high hazard level. The applications of permeable pavements resulted in about 10% inundated area reduction and 7 cm decline in maximum flow depth. Especially, there was 48% decrease in the area of high hazard level. The inundated area decreased by about 13% and there was 9cm reducing in maximum inundated depth under the scenario 4.

In summary, LID practices have well effectiveness on flood mitigation. Especially, the practices have good performance in reducing the area with high hazard level. In addition, permeable pavement has better performance than rainwater harvesting

Reference

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Table 1 Definition of water flood intensity

	Maximum depth (h, m)		Maximum velocity multiplied by the maximum depth (vh, m^2/s)
High	h＞1.2	or	vh＞1.5
Medium	0.6＜h＜1.2	or	0.5＜vh＜1.5
Low	0.1＜h＜0.6	and	0.05＜vh＜0.5

Table 2 Maximum inundated depth and area of different hazard level under four scenarios

	Maximum depth (m)	Area of different hazard level (km^2)			
		Low	Medium	High	Total
S1	1.36	1.53	3.53	0.5	5.56
S2	1.34	1.5 (-2%)	3.42 (-3%)	0.43 (-14%)	5.35 (-4%)
S3	1.29	1.5 (-2%)	3.25 (-8%)	0.26 (-48%)	5.01 (-10%)
S4	1.27	1.46 (-5%)	3.19 (-10%)	0.2 (-60%)	4.85 (-13%)