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Synergy effects of low impact development and urban drainage systems on urban flooding

Guo, H.*, Dong, X.* and Zeng, S.*
*School of Environment, Tsinghua University, Beijing, China, 100086

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Summary of key findings

By building a virtual study area and a virtual drainage system, different drainage systems combined with different scale of LID measures are simulated for different rainfall scenarios based on the SWMM model. For drainage systems with a low design return period, LID measures can reduce more amount of urban flooding and work more effectively to mitigate the impact of excess stormwater due to extreme rainfalls. For a certain drainage system, LID measures will work more effectively and reduce more amount of urban flooding when the rainfall intensity becomes stronger. The synergy effects of LID measures and urban drainage systems need to be considered when planning the stormwater management.

Background and relevance

Traditionally, urban flooding is solved by expanding and upgrading the existing drainage system, which has been proved unsustainable and costly. Therefore, low impact development (LID) can be a good way to support urban drainage systems and to mitigate urban flooding during extreme rainfalls. LID measures are distributed runoff management measures that seek to control stormwater by reducing imperviousness and retaining, infiltrating and reusing stormwater on the development site where it is generated. The hydrological performance of LID measures has been studied on laboratory scale as well as watershed scale. However, little study has considered the synergy effects of LID measures and urban drainage systems. For different drainage systems, LID may have different performance. This study intends to figure out how LID measures of different scale will perform when combined with different drainage systems by modelling and simulation and to analyse the uncertainties from the rainfall characteristics.

Methodology

As a real case study area has a settled drainage system and cannot support the analysis of different drainage systems, a virtual case study area is built for this study. The virtual area is consisted of 100 square sub-catchments and there is a combined drainage system in this area. All the parameters of the area and the drainage system are reasonably selected according to a real area in Kunming, a city in the South of China. The drainage system can be redesigned according to different return periods and the LID measures can be replaced by different scales.

For the simulation, drainage systems of 1 year, 3 years and 5 years return period are selected; 0% (no LID), 30%, 60% and 90% LID placement of the area which are available for LID measures are selected. Each placement of LID is consisted of 5 kinds of LID measures. The basic rainfall scenario is selected as 10 years return period, 1 hour duration and Chicago rainfall pattern with location of peak intensity r=0.5. To analyse the uncertainties from the rainfall characteristics, scenarios of 30 years and 50 years return period, 2 hours and 3hours duration and location of peak intensity r=0.25 and r=0.75 are selected.

Results and Discussion

The result of the basic rainfall scenario is presented in Figure 1. For a certain drainage system, the total amount of flooding and the scale of LID placement are in almost linear relationship, with the linear correlation R=-0.9987, -0.9952 and -0.9937 respectively. But the slopes for different drainage systems are different and the 1 year return period drainage system has the largest absolute slope value. This is because LID measures can effectively reduce the generation of surface runoff. The 1 year return period drainage system has the least ability to drain runoff surface, so LID measures contribute the most to mitigate the impact of excess stormwater for drainage systems.

It can be estimated according to the linear relationship, that to make the 1year drainage system have the same flooding amount with the 3 years drainage system, about 50% placement of LID measures are needed. Therefore, LID can be an alternative to simply updating the existing drainage system if the standard of drainage system is to be improved. Moreover, if a new area is to be planned, different combination of drainage system and LID placement can be chosen according to the area`s characteristics. For example, for the virtual area, if the flooding amount is to be reduced to 30000m^3, 1 year drainage system with about 87% placement of LID, 3 years drainage system with about 40% placement of LID and 5 years drainage system with about 20% placement of LID are all feasible.

For other rainfall scenarios, the total amount of flooding and the scale of LID placement are in similar relationship as well. The result of different return periods of rainfall is presented in Figure 2. As the return period of the rainfall increases, absolute value of slopes of the linear relationship increase for all drainage systems. That means, when there are more excess stormwater, LID measures can work more effectively and reduce more amount of flooding. When the duration and the location of peak intensity change, the values of slopes will change accordingly for all drainage systems, but they just change slightly.

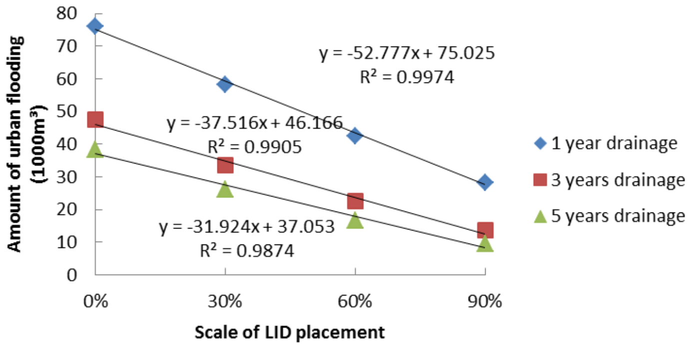

Figure 1 Amount of urban flooding for the basic rainfall scenario

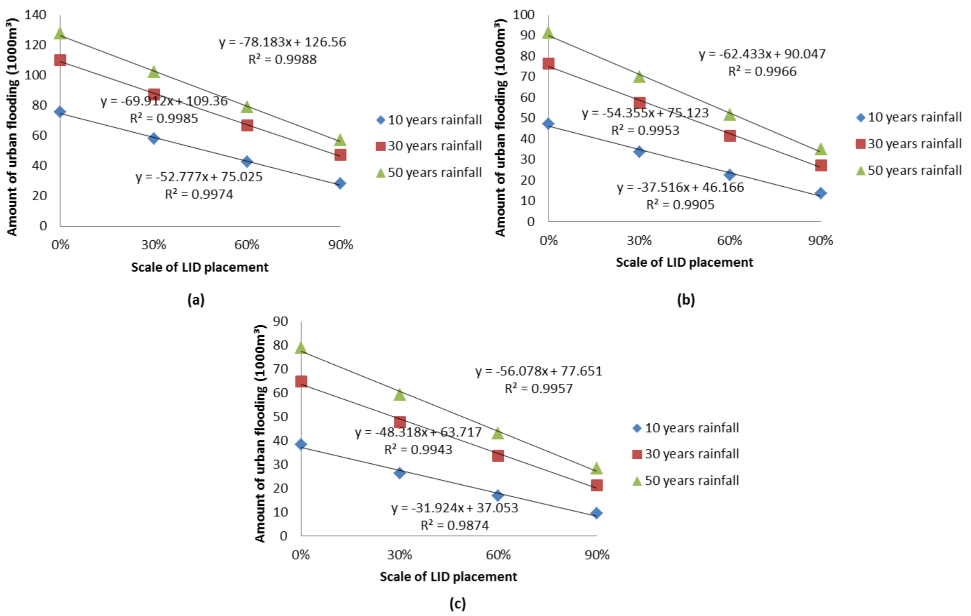

Figure 2 Amount of urban flooding for rainfalls of different return periods: (a) 1 year drainage system; (b) 3 years drainage system; (c) 5 years drainage system

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Presenting Author

Dr Dong Xin
School of Environment, Tsinghua University, China

Is the presenting author an IWA Young Water Professional? N
(i.e. an IWA member under 35 years of age)

Bio: Dong Xin, School of Environment, Tsinghua University, China