Hydrological simulation of green infrastructures coupled with an urban rainfall-runoff model

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1. INTRODUCTION

Urbanization have increased storm water runoff volume, flow rates and peak flows and decreases flow time and low flows (Shuster et al,2005). This fast urbanization processes had also impacted the local urban water systems. Several researches had reported that urbanization is considered to be the one major cause of pollution of water resources (Cronin et al., 2003). On the other hand, a more popular problem is the frequent flooding events which had increased the management costs. Urban areas have shown to be among the most vulnerable systems to the adverse impact of heavy rainfalls. Floods are becoming more frequent and more devastating than ever before as urban areas are enlarging and becoming denser (Chen et al., 2009). Society suffers yearly from the consequences of (flash) floods, with mortality nearly homogeneous over different continents.

Urban forests or urban vegetation is a kind of important urban infrastructure that has many environmental benefits. Vegetation plays an important role in preventing soil erosion and thus protecting soil structure and infiltration capacity by reducing raindrop energy by canopy interception. Also, urban forests had provided more green spaces for the city which could reduce urban heat island (UHI) effect and improve the air quality (Nowak et al., 2018). The beneficial of urban vegetation on the aspect of hydrology or water resource management is also conspicuous. Different kinds of green infrastructures (GIs) have improved the hydrological cycle and alleviated the burden of traditional drainage systems (Wang et al., 2018) by means of infiltration, storage and interception.

Reliable assessment of hydrological processes are crucial for human lives, environmental protection and infrastructures or goods safety. Water movement in urban areas is however not well understood, and so are the physical principles that regulate this movement as well as the interactions occurring between the hydrological processes. Scientific understanding can be supported by detailed and consistent measurements and by hydrological modelling. Those urban hydrology issues will become more and more important in the decades ahead (Fletcher et al., 2013).

2. MATERIAL AND METHOD

2.1 Study site

We chose the Kunimigaoka Area in Sendai City, Japan for the case study (Fig.1). KA is located in the north-western part of the uptown of Sendai City, which covers approximately 50 hector with a medium gradient slope topography. KA is featured with a temperate monsoon climate and the annual average rainfall and temperature are 1254 mm and 12.4C, respectively. KA is an old uptown where urbanization degree is rather complete and the land use shows little change after 2000. The urban land use accounts for over 90% of the total in this region. The storm water was firstly drained to a regulating pond and then to a downstream river. The drainage system of KA can be divided into two parts, one being the sewer network in the Northern part of KA which accounted for most of the drainage areas; the other is a located in the southern part beside the regulating pond.

Fig.1. Watershed of Kunimigaoka Area

2.2 Hydrological simulation design

The EPA Storm Water Management Model (SWMM) was selected for this study, as it provides all features required to meet the aims of this research. SWMM is widely used for single- or long-term event simulation of runoff quantity and quality in urban areas (Zoppou, 2001; Rossman, 2010). The spatially explicit character of SWMM allowed us to build high-resolution model to characterize the complicated overland flow routing. The core process in SWMM delineates the targeted catchment into a collection of sub-catchments that receive rainfall and generate runoff, then transport excess storm water from sub-catchments to assigned outlets through sewer networks (Rossman, 2010). General runoff routing described in the SWMM model was generated from upstream disconnected impervious sub-catchments and flowed through down-stream pervious sub-catchments.

2.3 Green infrastructures scenarios

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Several different green infrastructures were considered and compared in this study. The first one is the current urban canopy and vegetation (UC). This green infrastructure will consider effect of all the greening in the area as well as their seasonal variations by introducing the remote sensed NDVI data. The NDVI data were firstly converted to LAI, and then LAI were converted to canopy storage capacity which represent the interception ability. Three other green infrastructures were also considered: the green roof (GR), porous pavement (PP) and permeable trench (PT).

3. RESULT AND DISCUSSION

In this study, we apply the long series annually rainfall of year 2018, into the model. The effects of single GIs as well as GI combinations were calculated.

The results showed that GI is effective in reducing flooding within the study area (fig.2). The flooding cannot be eliminated under the different GI scenarios for all rainfall events, and the effectiveness of the various GI practices was diminished under scenarios of heavier rainfall. Therefore, combinations of green and gray infrastructure will result in improved flood mitigation effects. Because of the high densities of buildings, the combinations which include GR showed relatively better performances.

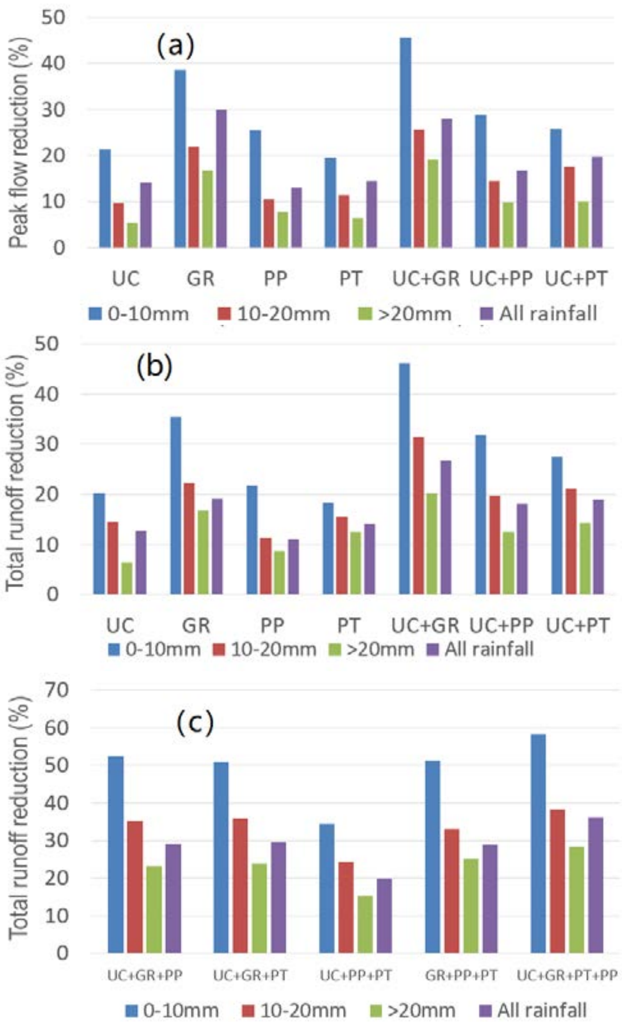

Fig.2 Runoff reduction effect with different green infrastructures and combinations.

4. CONCLUSIONS

From the above explanation, we can conclude as follows:

1. In urban catchment, the different kinds of green infrastructures were effective in reducing flooding within the study area.
2. The combinations of green infrastructures showed better runoff mitigation performance than single GIs. Green roof had good potential for runoff control.

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