Comprehensive benefit assessments of green infrastructure

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Abstract Green infrastructure (GI), a resilient solution, could effectively solve water problems in urban areas. Compared to the single function of grey infrastructures, controlling rainfall runoff volumes, the comprehensive benefits of GI are more significant. In this study, a comprehensive benefit assessment system of 5 different GI, including 18 indicators from disaster reduction benefits, economic benefits, environmental benefits and social benefits, has been established. The new established performance assessment system has been successfully applied to Jinan Daminghu Sponge City Construction pilot area.

Keywords: urban water management; green infrastructure; comprehensive benefit assessment; Sponge City; Jinan.

Study Area

Daminghu District, a Sponge City Construction pilot area, is located in Jinan city, China. The study area is about 39 km^2. The terrain is higher in the south, lower in the north, higher in the east and lower in the west. The 24h design storm with 5-year, 10-year and 20-year return period are shown in Figure 1. The 3 kinds of GI were designed in this area. They were green roofs (0.26km^2), sunken greenbelts (0.31km^2) and porous pavement (0.18 km^2), respectively.

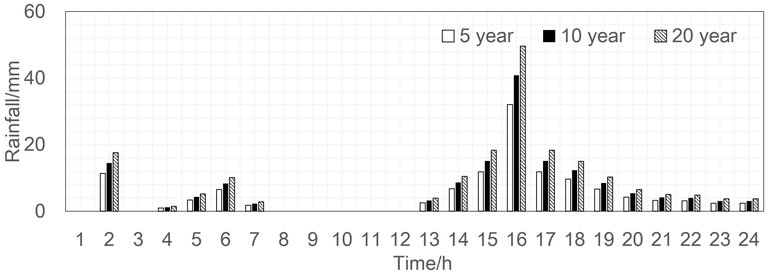

Figure 1: 24h design precipitation process in Jinan.

Methods

Different kinds of GI have different structures and functions. In this study, we establish a comprehensive benefit assessment system of 5 different GI within the urban context. The 5 kinds of GI are green roofs, bioretentions, permeable pavement, rainfall harvesting and bioswales, respectively. The system includes 18 indicators (Table 1) from disaster reduction benefits (No.1-5), economic benefits (No.6-9), environmental benefits (No.10-15) and social benefits (No.16-18).

In view of the characteristics of study area and existing data, 4 indicators were selected to evaluate the comprehensive performances of GI, i.e., reduces inundation area, reduces direct economic loss, increases groundwater recharge volumes and improves air quality. The flood simulation numerical model and flood risk analysis software (FRAS) and flood damage assessment software developed independently by IWHR were adopted to evaluate the first two indicators. For the increases of groundwater recharge volumes and air quality improvement, the empirical equations were used to calculate the values.

Table 1: Comprehensive performance evaluation indicators of GI.

	1	2	3	4	5	6	7	8	9
	Volume capture ratio of annual	Reduces inundation area	Reduces affected population	Reduces affected GDP	Reduces direct economic loss	Reduces grey infrasturcture needs	Increases avaliable water supply	Reduces water treatment	Reduces energy use
Green roofs	●	●	●	●	●	●	✖	○	●
Bioretention	●	●	●	●	●	●	✖	○	○
Permeable pavements	●	●	●	●	●	●	✖	○	✖
Rainfall harvesting	●	●	●	●	●	●	●	○	✖
Bioswales	○	○	○	○	○	○	○	○	○
	10	11	12	13	14	15	16	17	18
	Reduces non-point source pollution	Improves habitat	Increases groundwater recharge	Improves air quality	Mitigates urban heat island	Reduces noise pollution	Improves aesthetics	Improves community cohesion	Enhances public education
Green roofs	●	●	✖	●	●	●	●	○	●
Bioretention	●	●	●	●	●	○	●	●	●
Permeable pavements	●	✖	○	✖	✖	●	✖	✖	●
Rainfall harvesting	●	✖	✖	✖	✖	✖	✖	✖	●
Bioswales	●	●	○	●	●	○	●	○	●

● Yes ○ Maybe ✖ No

Results and Conclusions

The results show that the inundation area reduction rates are 11.02%, 9.32% and 8.02%, and the direct economic loss reduction rates are 13.86%, 4.28% and 4.09% under the 24h design storm with 5-year, 10-year and 20-year return period, respectively. With the increase of rainfall volumes, the corresponding effectiveness of GI on rainfall runoff reduction decreases. However, the groundwater recharge volumes increase with the increases of rainfall volumes. The corresponding groundwater recharge volumes are 2.23 million m^3, 2.86 million m^3 and 2.87 million m^3 under three different rainfall return periods. In addition, the constructed green roofs could reduce 0.38-0.61 t/yr NO_2, 0.74-1.17 t/yr O_3, 0.29-0.52 t/yr SO_2 and 0.14-0.17 t/yr PM10. GI also improves the aesthetics of living environment. In Yingxiongshan Road of Daminghu pilot area, the former impervious surface are replaced by rain gardens and bioretentions, which significantly improve the environment, and increase recreational opportunities.

Bibliography

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