A framework for assessing urban flood risk considering adaptation effectiveness

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ASIA-PACIFIC INTEGRATED MODEL

Introduction

Floods, especially in urban areas with high percentage of impermeable surfaces and dense population, can cause low-lying flooding, posing indirect risks such as economic crises caused by damage to electricity, gas and water supply. While existing methods for mitigating urban flooding have focused on the volume expansion of sewage systems, these structural measures are expensive and primarily aimed at water treatment, making them no sustainable alternative to unpredictable rainfall. Thus, strategies have been proposed and applied over the past decade to control runoff and delayed peak flow by restoring natural hydrologic circulation and maximizing infiltration and detention capacities at source. In this study, utilizing the GI(Green Infrastructure) concept, it was to clear the interaction of GI and urban water system outflow based on a simulation through the inspection process. This study conducts the following studies aiming to investigate the effect of GI implementation on urban flooding.

Materials and method

- **(Study sites)** Commercial area, 200ha, Lowland located, High impermeability. Repeated flooding occurs despite improvements in urban water systems.

Flooding (2010, 2011) → Sewerage restoration project (2013~2018) → Flooding (2020)

- **(Meteorological data)** Rainfall data was collected and used in five-minute resolution of automated weather station (37.5131 °N, 127.0470 °E) observations. Events are divided into three cases; (a) 2011 rainfall recording the highest duration (22hr), (b) 2010 rainfall recording highest one-hour intensity (74.5mm / h), (c) 2020 rainfall recording the most 10-minute strength (18.5mm)

Rainfall period	Estimated flooded time	Sum of precipitation	Duration time	Maximum precipitation	
2010.09.21. 8:00 - 22:00	2010.09.21. 14:00 - 15:00	275.5mm	14hr	(1hr) 74.5mm (10min.) 17mm	UDS1
2011.07.27. 01:00 – 23:00	2011.07.27. 09:00 – 10:00	294.2mm	22hr	(1hr) 60.0mm (10min.) 12.0mm	UDS1
2020.08.01 10:05-14:50	2020.08.01 12:30-13:30	35.5mm	4.75hr	(1hr) 33.5mm (10min.) 18.5mm	UDS2

- **(Urban drainage system model)** All hydrodynamic analysis of the study was Bae et al. (2020) was performed based on the sewage network implemented in SWMM (Infiltration processes; Horton's method, Flow routing; Dynamic wave). The model was calibrated by changing manning's coefficient, infiltration rates, and depression storage for both the permeable and impermeable surface of all sub-catchments.
- **(Adaptation options)** Two GI techniques were considered for green roof and permeable pavement. Green roof mainly provides infiltration and evapotranspiration, while the permeable pavement functions to temporarily under-water before being released to the sub-watershed outlet in the underground drain.

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Results

- For rainfall events with long durations, the effect of the adaptation practice was better than those with short durations and high intensity (Fig. 1)
- Adaptation practice lowered peak flooding in the first two-fifths of the flood time (Fig. 2 (a))
- Assuming that the green infrastructure adaptation practice is applied to the study site where UDS improvement has been made, the effect similar to that of UDS improvement was shown (Fig. 2(b)

Scenario	Flooded volume (10^6 L)			Peak flows (CMS)			Peak time			Surface runoff(mm)		
	2010	2011	2020	2010	2011	2020	2010	2011	2020	2010	2011	2020
Base	172.35	55.89	5.85	42.54	39.63	31.06	14:50	8:15	12:45	264.02	271.88	37.92
S1	120.14	30.17	-	39.86	36.89	-	16:45	8:45	-	233.52	235.07	-
S2	149.18	55.10	-	40.79	39.20	-	16:45	8:15	-	250.18	257.02	-
S3	99.98	30.10	0.43	41.79	36.75	26.64	16:45	8:45	12:45	219.59	220.11	27.41
S4	132.99	42.33	-	39.91	38.00	-	16:45	8:15	-	242.43	246.73	-
S5	133.79	43.07	-	40.28	38.17	-	16:45	8:15	-	242.45	246.74	-

- S1: Green roof only
- S2: Permeable pavement only
- S3: Green roof + Permeable pavement
- S4: Green roof + Permeable pavement (Priority area, 48%)
- S5: Green roof + Permeable pavement (Overall area, Equal ratio to S4)

Table. 1 *Summary of results for baseline and adaptation scenarios under flood events*

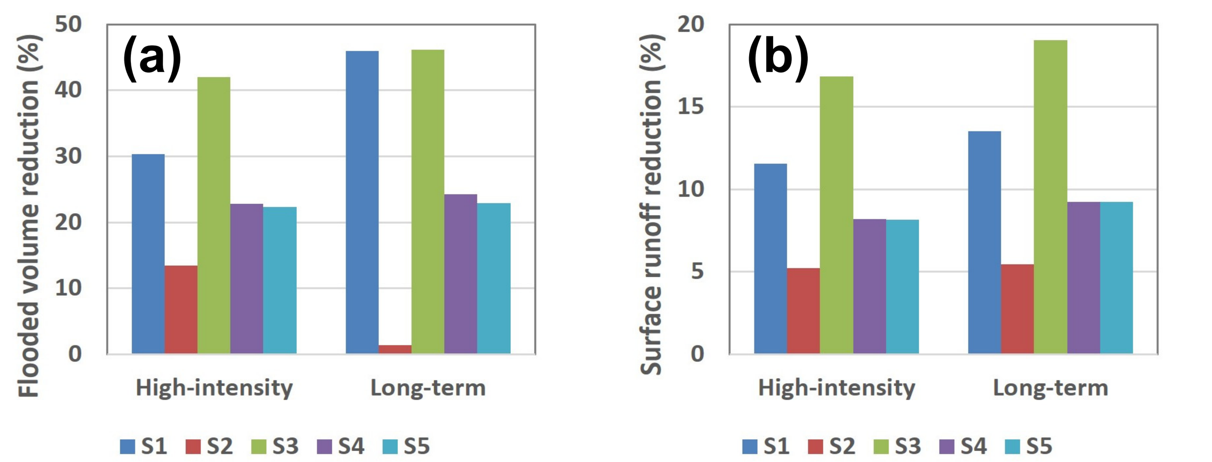

Figure. 1 *(a) Flooded volume and (b) surface runoff reduction rate by flood events and adaptation scenarios*

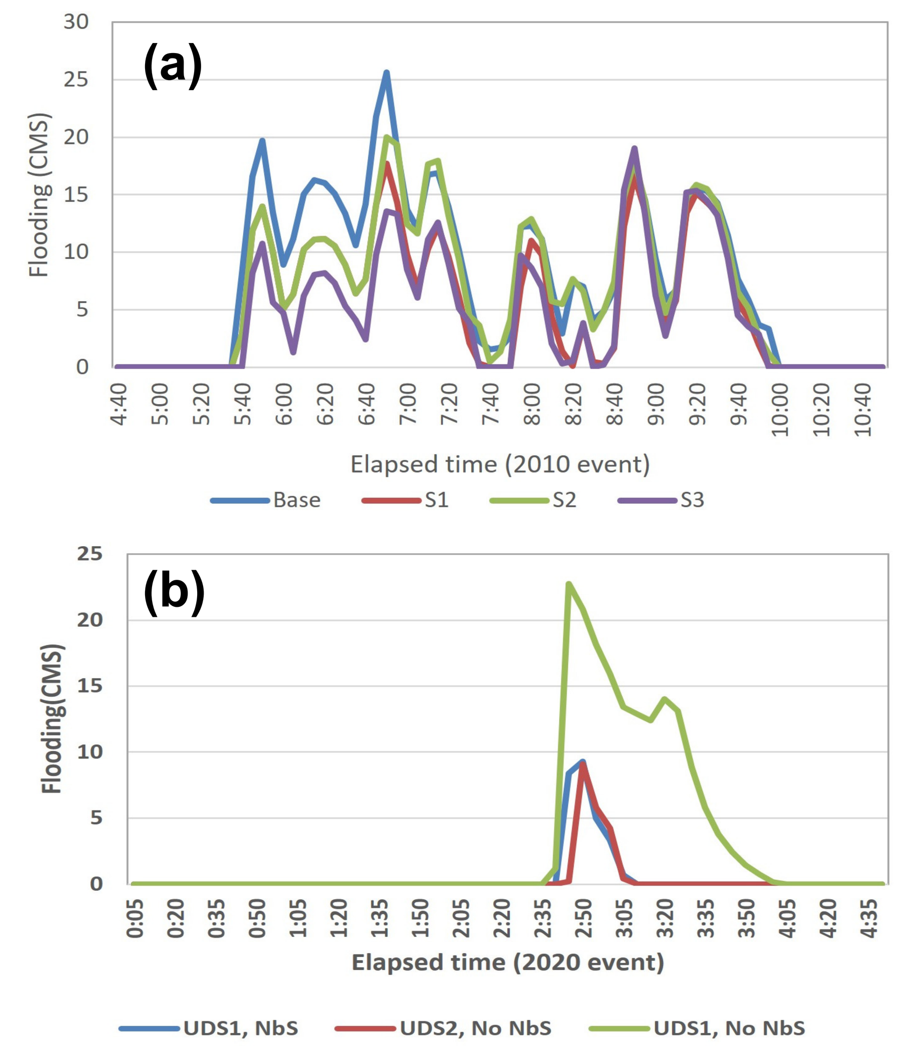

Figure. 2 *(a) Changes in flooding over elapsed time by adaption scenarios (b) Changes in flooding over elapsed time by UDS and adaptation*

Summary and future works

- Quantifying the effects of GI on flood events (changes on different techniques, flood events, and UDS conditions)
- Green roofs > Permeable pavement (per unit area)
- The effect of priority area applied case in this study was not noticeable → consider dividing into smaller spaces
- Runoff or flood characteristics vary by rainfall, additional rainfall events application is needed
- High resolution evaluation is needed for spatial optimization
- Considering cost recovery using cost data