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Supplementary Materials

Text S1. Study Area

The study site was an urban area located in Gwangju (35°09′33.12″N, 126°50′49.63″E), a southern province of South Korea. It covered an area of 0.0125 km^2 and included a separated sewer system. This urban area was originally planned and developed during the 1990s in South Korea. The study area was a commercial zone characterized by predominantly impermeable surfaces (~85%), including office buildings, a parking lot, and restaurants, along with a residential area. The climate of the study area is classified as monsoon, with heavy rainfall concentrated in the summer season. It shows an average annual rainfall of 1,391 mm, with maximum temperature of 29.3℃ and minimum temperature of -1.9℃ [Fig. S1].

Text S2. LID Modules in the SWMM

The calculation of infiltration fluxes in the surface layer involves considering both direct runoff and runoff from the impervious layer [1]. In this study, the infiltration rate (f_1) (cm min^{-1}) is estimated using the following Green-Ampt equation [2] [Fig. 2(a)]:

$$f_1 = K_s(1 + \frac{(\phi-\theta_1)(d_1+\psi)}{F}) \tag{S1}$$

Here, K$_s$ indicates the soil's saturated hydraulic conductivity (cm min^{-1}), θ_1 denotes the moisture content at the top of the soil layer, d$_1$ indicates the pond depth on the surface (cm), ψ indicates the suction head where infiltration wetting occurs, and F represents the cumulative total amount of water infiltrated per unit area. The modified Green–Ampt equation provides an estimation of the infiltration rate, corresponding to the intensity of rainfall until the soil reaches saturation [3].

The soil layer simulates the movement of water (f_2) from the soil into the storage layer [Fig. 2(b)]. The movement of water in soil can be calculated using the following Darcy's law, which employs the same approach as the SWMM groundwater module [1].

$$f_2 = K_s \exp\big(-HCO(\phi-\theta_2)\big), \theta_2 > \theta_{FC} \tag{S2}$$

$$f_2 = 0,\ \theta_2 \le \theta_{FC} \tag{S3}$$

Here, f_2 denotes the rate of soil percolation (cm min^{-1}), the decay constant *HCO* is obtained from the moisture retention curve, θ_2 represents the moisture content of the soil layer, and θ_{FC} refers to the moisture content at field capacity in the soil.

Text S3. HYDRUS-1D

The governing equation for the flow of variably saturated soil can be calculated using the Richards equation [4]:

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial Z}\left[K(h)\left(\frac{\partial h}{\partial z}\right)+1\right] \tag{S4}$$

Here, θ represents the volumetric soil water content (L L^{-1}), t denotes the time (T^{-1}), K(h) indicates the hydraulic conductivity (LT^{-1}), h represents the soil water pressure head (L), and Z represents the vertical space (L).

The van Genuchten model for hydraulic properties is represented by the following equations [4, 5]:

$$\frac{\theta-\theta_r}{\phi-\theta_r} = \left[\frac{1}{1+(a\Psi)^n}\right]^m \tag{S5}$$

$$\frac{K(h)}{K_{sat}} = \left(\frac{\theta-\theta_r}{\phi-\theta_r}\right)^{1/2}\left[1-\left(1-\left(\frac{\theta-\theta_r}{\phi-\theta_r}\right)^{\frac{1}{m}}\right)^m\right]^2 \tag{S6}$$

where θ is the water content (L L^{-1}), θ_r is the residual water content (L L^{-1}), ϕ is the porosity (L L^{-1}), m = 1 − 1/n, $K(h)$ represents the hydraulic conductivity (LT^{-1}), and K_{sat} is the saturated hydraulic conductivity (LT^{-1}).

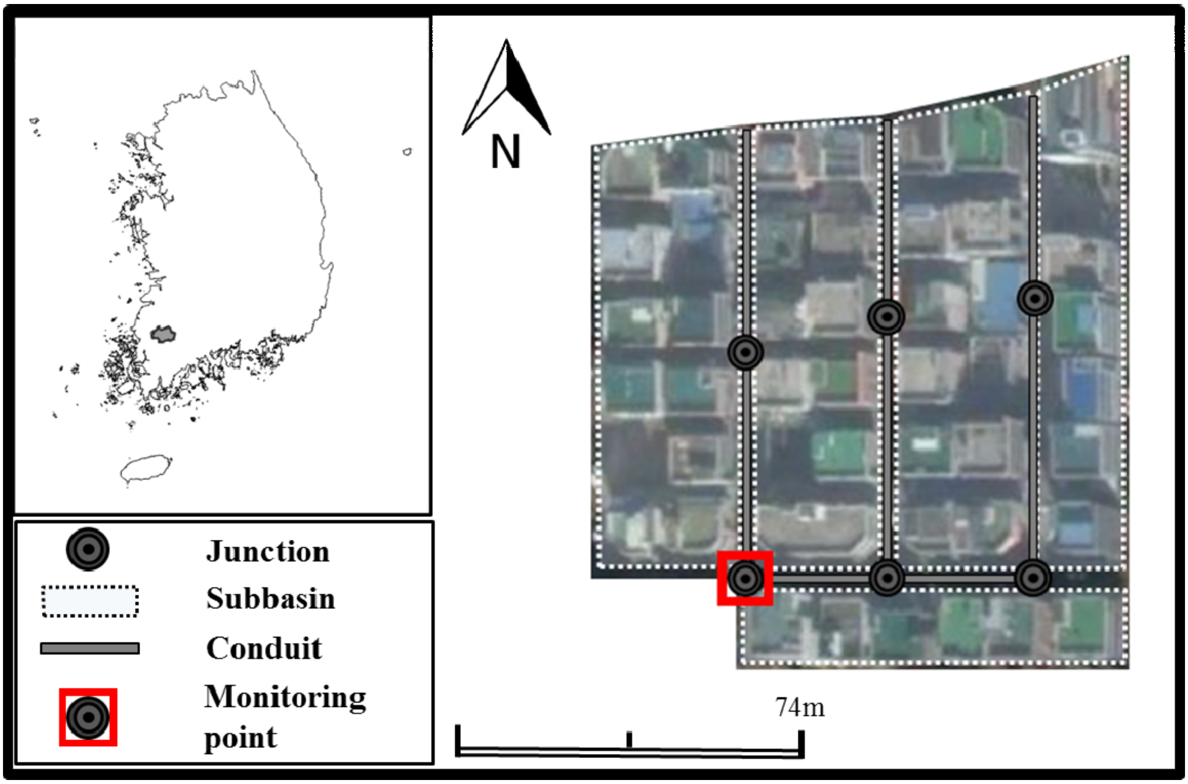

Fig. S1. Map of the study area, including junctions, sub-basins, conduits, and the monitoring location (35°09′33.12″N, 126°50′49.63″E) (Google, 2014).

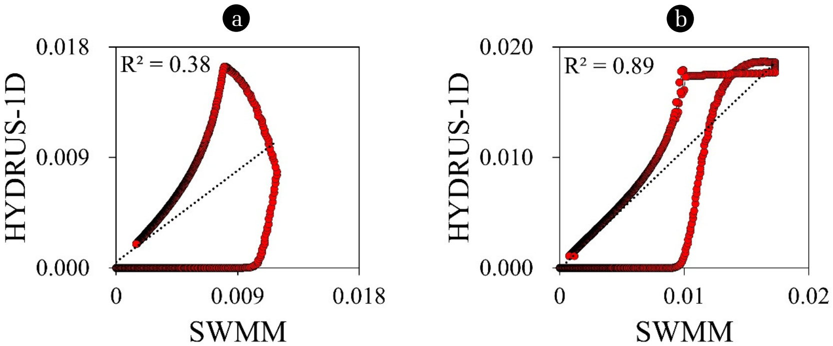

Fig. S2. Scatter plots of infiltration rates between the SWMM and the HYDRUS-1D model's under (a) unsaturated soil and (b) saturated soil conditions.

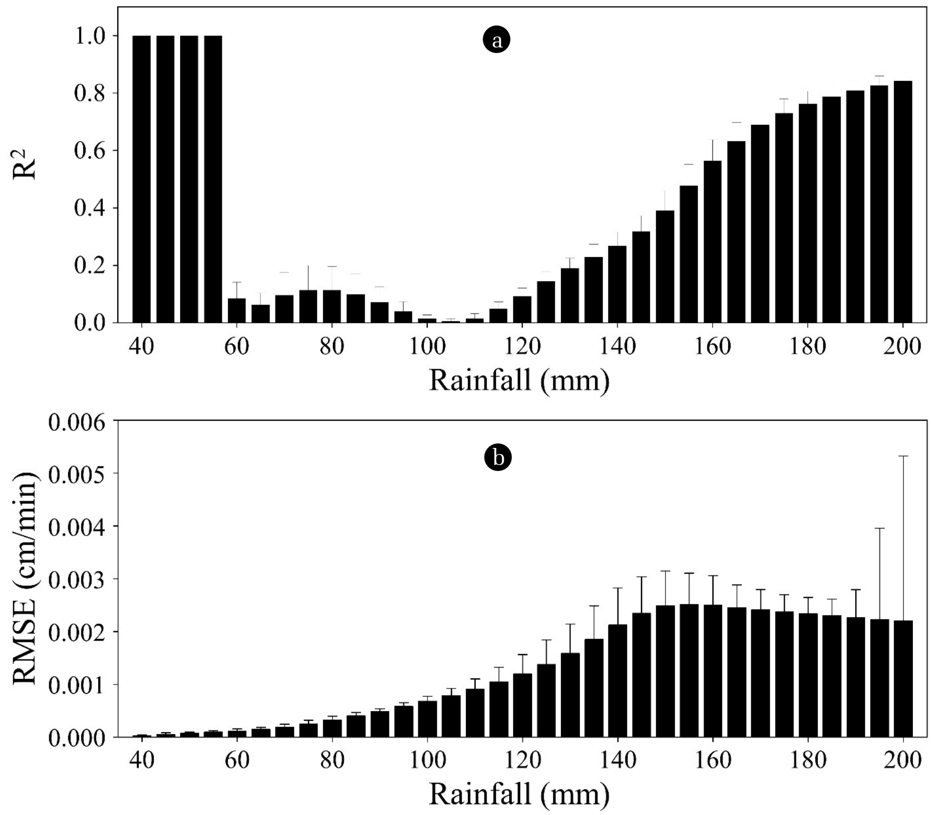

Fig. S3. (a) R^2 and (b) RMSE values of the SWMM evaluated with the HYDRUS-1D model's infiltration rate under different rainfall scenarios.

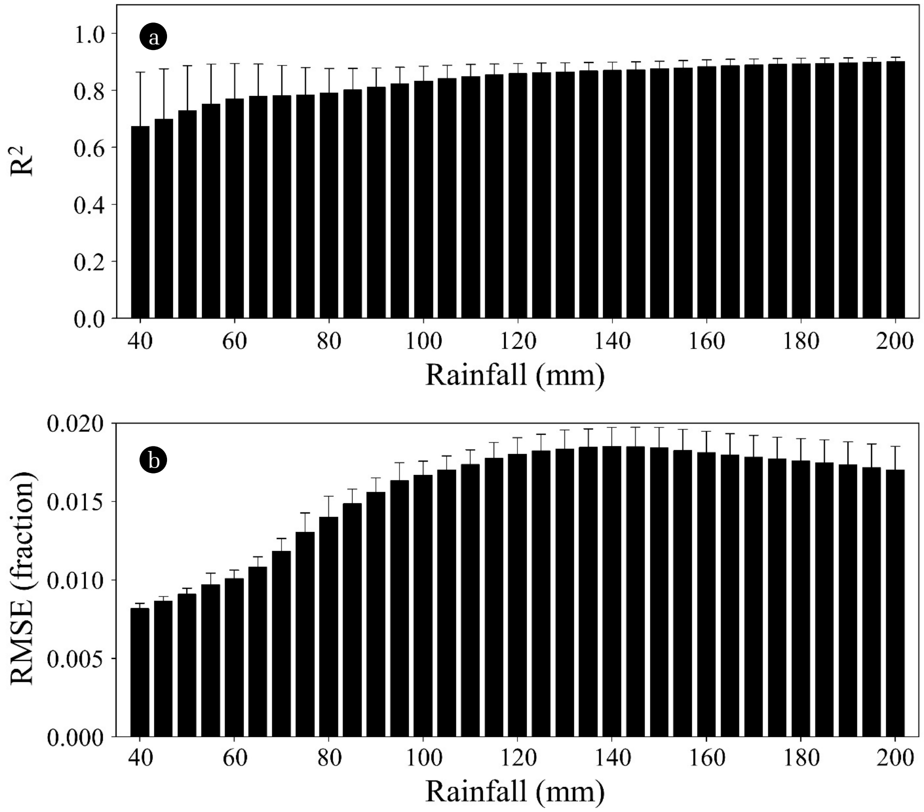

Fig. S4. (a) R^2 and (b) RMSE values of the SWMM evaluated with the HYDRUS-1D model's soil moisture under different rainfall scenarios.

Table S1. Sensitivity of infiltration-related parameters in the SWMM with different ranges of rainfall volume (mean ± SD).

Parameters	**Rainfall volume (mm)**			
	0~50	**50~100**	**100~150**	**150~200**
Mean of EEs				
Field capacity	233 ± 182	243 ± 189	247 ± 188	223 ± 164
Porosity	35.4 ± 20.6	40.6 ± 34.4	36.9 ± 21.7	37.1 ± 23.9
Saturated K	21.3 ± 13.1	22.0 ± 14.1	24.1 ± 16.0	23.4 ± 15.0
K-slope	20.2 ± 10.3	20.9 ± 10.3	19.9 ± 9.2	20.5 ± 10.6
Suction head	0.029 ± 0.033	0.032 ± 0.036	0.038 ± 0.061	0.078 ± 0.232
Standard deviation of EEs				
Field capacity	297 ± 284	357 ± 421	329 ± 256	278 ± 220
Porosity	55.9 ± 32.7	80.9 ± 145.0	56.7 ± 35.3	64.4 ± 51.3
Saturated K	41.3 ± 23.9	44.2 ± 30.0	53.3 ± 45.8	48.6 ± 33.6
K-slope	32.6 ± 12.2	33.5 ± 12.1	32.6 ± 11.6	32.8 ± 12.5
Suction head	0.095 ± 0.101	0.120 ± 0.127	0.146 ± 0.227	0.448 ± 1.55

Table S2. Sensitivity of underdrain-related parameters in the SWMM with different ranges of rainfall volume (mean ± SD).

Parameters	**Rainfall volume (mm)**			
	0~50	**50~100**	**100~150**	**150~200**
Mean of EEs				
Flow Coefficient	0.31 ± 0.33	2.93 ± 0.57	3.29 ± 0.43	3.57 ± 0.60
Flow Exponent	2.89 ± 2.94	12.1 ± 0.52	12.7 ± 0.43	13.0 ± 0.31
Standard deviation of EEs				
Flow Coefficient	0.62 ± 0.69	4.14 ± 2.72	4.01 ± 1.78	5.04 ± 2.95
Flow Exponent	2.36 ± 2.45	3.40 ± 0.53	3.82 ± 0.60	3.88 ± 0.54

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