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Sustainable Urban Drainage Systems for reducing Flood Risk at the Catchment Scale: The Seveso River Basin Case Study

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Rapid urbanization significantly impacts the water balance by altering surface characteristics, increasing impervious surface area, and the risk of flood hazards due to replacing natural ecosystems, resulting in changes to the local hydrological cycle. The Seveso River basin in the Lombardy region is among the most urbanized areas in Italy and Europe. The basin's excessive urbanization and continuous residential and industrial expansion make intervening with structural Sustainable Urban Drainage Systems (SUDS) challenging. This study examined the influence of urbanization on stormwater runoff and flow rate considering the maximum hypothetical daily storm from 1980 to 2023, resulting in a 6% increase in stormwater runoff for the basin and around 10% for peak discharge at the closure of the basin. The application of SUDS, such as green roofs and permeable pavement (PP), compared with the 2023 situation decreased stormwater runoff by 18 and 2 percent, and peak flow by 22 and 3 percent.

Keywords: *urbanization, urban stormwater, flood risk, runoff, sustainable urban drainage systems*

Introduction

Flooding is widely recognized as one of the most severe natural disasters, destroying urban areas and costing tens of billions of dollars in property and human lives (Nkiruka et al. 2023). Human activities can influence flood behavior, reducing or increasing the magnitude of flood damage (UCHEGBU 2003). The increase in impermeable surfaces due to urbanization has caused substantial hydrological effects (Bell et al. 2016). This resulted in increased floods, posing a serious hazard to human lives and the built environment. Urbanization-induced land use, topography, and hydrology changes affect urban flood risk (Seemuangngam and Lin 2024). The changes disturb the urban hydrological cycle and increase the quantity of stormwater runoff, raising the danger of local floods in cities (Zölch et al. 2017).

Runoff simulation, like the confluence process to the stormwater network, is an important part of the modeling process. In this sense, hydrologic methods calculate catchment runoff using precipitation excess, with infiltration being the primary process that causes precipitation losses. This runoff can be computed based on numerous ways, but the relative efficiency of a single method about others cannot be determined definitively (Luo et al. 2022).

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When dealing with the increased risk of flooding caused by climate change and human interventions in global landscapes, conventional 'grey' infrastructure (e.g., dams and dikes) is no longer adequate to respond to current rates of land use changes and increasing frequency of weather extremes (Potočki et al. 2021). Nature-based solutions (NBS) can act as a valuable complement to conventional 'grey' infrastructure for stormwater management (e.g., dams and dikes) in reducing flood risks as these 'green' solutions are perceived to be more flexible and multifunctional (Hartmann et al. 2019).

Sustainable Urban Drainage Systems (SUDS) is an integrated network of constructed vegetated areas and open spaces (i.e., green roofs, rain gardens, porous pavements, etc.) utilized to conserve natural ecosystem principles and functions while also providing a wide range of benefits to people and wildlife (Tang et al. 2021). From the stormwater management point of view, SUDS minimize the volume and peak of generated runoff, being acknowledged as a sustainable technique to alleviate floods in urban areas (Ciriminna et al. 2022).

Green roofs are often characterized as extensive or intensive based on substrate layer thickness. Extensive green roofs are typically 15 cm thick or less, with short-rooted, drought-resistant plants (Carson et al. 2013). Extensive green roofs are more commonly used since they are lighter, cheaper, and require less care than intense systems (Berndtsson 2010).

Permeable Pavements (PPs) are one of the SUDS and can be utilized in sidewalks, roadways, playgrounds, or parking lots, among other places (Kuruppu et al. 2019). PPs differ from other types of SUDS in that they ensure a hard surface while also offering infiltration and detention capacity, eliminating the need for additional land for detention facilities and serving as an alternative to impermeable surfaces. This is especially essential in metropolitan areas with high land prices, impermeable sites, and little or no space for stormwater retention (Zhu et al. 2021).

This study aims to determine the effect of urbanization on stormwater runoff and its management alternatives comparing the years of 1980, 2007, and 2023. Evaluation of the potential flood damage vulnerability of the 2023 situation, and the application of SUDS such as green roofs and PP, alongside their impacts.

Study Area

The Seveso basin, part of the much larger Po basin, is one of the most densely populated and industrialized areas in Europe, situated in the Lombardy territory of Northern Italy. Since approximately 44 % of this basin has urbanized regions, it is a prime illustration of the tremendous hydraulic-environmental difficulties that come with extensive urbanization of a territory (Ceppi et al. 2021, Masseroni and Cislaghi 2016, Raimondi et al. 2020). The industrial, agricultural, and livestock sectors in the basin, which are of enormous national and international importance, have a significant impact on the hydro-environmental balance. Moreover, the growth of metropolitan cities has restricted river space, resulting in the loss of natural features, deteriorated water quality and environment, and increased flood danger (Bocchi et al. 2012). It has been estimated that 104 floods have occurred in Milan since 1976

having a proportion of 2.6 floods each year (Raimondi et al. 2020). The overall percentage of urbanization has steadily increased, from 11.1% in 1954 to 32.0% in 1980 and 44.7% in the year 2000. Vice versa, no major increments were detected in the last two decades, and the urbanized area barely changed by roughly 2% over twenty years (Ceppi et al. 2021). Figure 1 shows the root of the river from Como to Milan, and the river runs underground before reaching Milan City in the north (Parco Nord Milano).

Figure 1. *Seveso River from Como to Milan (The Geographical Reference System is EPSG:32632 - WGS 84/UTM zone, 32N)*

Materials and Methods

The SCS-CN method, due to its simplicity, predictability, and stability (Ponce and Hawkins 1996), was used to determine a preliminary assessment of the relationship between Digital Elevation Model (DEM), soil properties, and Land use by the HEC-HMS and GIS-powered software model (Mishra et al. 2003).

Figure 2 depicts the full procedure for the method employed in this study. The basin was created using HEC-HMS software from the DEM map with the exact root of the Seveso River, and the endpoint of Parco Nord Milano. Land use and soil categories were intersected using GIS techniques (QGIS version 3.28.4), resulting in areas associated with hydrologic soil groups (HSGs) and land use, which were used to calculate the CN value for each sub-basin in 1980, 2007, and 2023. To investigate the impact of urbanization, runoff for each subbasin was calculated using the HEC-HMS software under hypothetical storms with 107 mm of daily precipitation.

For the year 2023, the runoff output data for each sub-basin was used to model a 2D flood depth map of the Seveso basin by means of the HEC-RAS software, and such flood depths were later applied through specific depth-damage functions to generate the map of flood damage vulnerability for the basin.

For the 2023 scenario, new CN values and runoff were calculated assuming different SUSD scenarios, such as green roofs for urban fabric areas and permeable

pavement (PP) for road and related development sites. CN values for green roofs published in the literature vary significantly in different climate areas; earlier research, which aimed to establish empirical connections for green roof runoff using the CN or Runoff Coefficient (C_v) methodologies, yielded CN values ranging from 88 to 95.5 for 30 extensive green roofs (Soulis et al. 2017). Fassman-Beck et al. (2016), analyzed the rainfall and runoff volume of 21 green roofs and calculated the mean CN value as 84 for larger rainfall events. The obtained CN values for the studied green roofs were 84, 87, 89, and 90 for slope gradients of 2, 7, 15, and 25% (Getter et al. 2007). Following Hunt and Collins, 2008, the CN value for PPs was assumed between 75 to 80.

Figure 2. *Methodology Chart*

Seveso River Basin

The Hydrologic Modeling System (HEC-HMS) of the US Army Corps of Engineers was used to simulate the complete hydrologic processes of the Seveso basin system. The software includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing.

In this study, the basin was derived by suggesting the exact root of the Seveso River from the Open Street Map data set on the digital elevation model (DEM) from the Lombardy Region center, using HEC-HMS version 4.11. Since this river flows underground before reaching Milan City in the northern part (Parco Nord Milano), that location was deemed the basin's endpoint. Figure 3 shows the resulting basin of the Seveso River and reaches, with 7 main sub-basins.

Figure 3. *Seveso River Sub-basins, Reaches, and Junctions*

Data Collection

Hydrologic Soil Groups

The area has two main geological units divided by a semi-permeable septum: a top unit of gravelly sand with the phreatic layer and a lower unit with sandy-silty soils and a semi-confined aquifer (Masseroni and Cislaghi 2016). According to Lombardy Region data, the basin is divided into three primary HSGs based on the soil's infiltration and permeability (Figure 4). B is defined as soils with moderate infiltration rates, C as soils with slow infiltration rates, and D as soils with extremely slow infiltration rates when are thoroughly wetted (Mishra et al. 2003).

Figure 4. *Seveso Basin Soil Groups, B as Moderate, C as Slow, and D as Extremely Slow Infiltration Rates When Are Thoroughly Wetted*

Source: Lombardy Region, Report on the state of the environment.

Land Use Characteristics

The land use was retrieved using the regional LULC reference map (DUSAF by Lombardy Region). As shown in Tables 1 and 2, DUSAF categorizes land use into three levels, the first of which includes five primary coverage types (urbanized regions, agricultural areas, forest, and semi-natural habitats, wetlands, and water bodies), which are further described at the second and third levels. Figure 5 depicts the distribution of the main land use categories for the Seveso basin for the years 1980, 2007, and 2023.

Figure 5. *Seveso Basin Land Use Map for Years 1980, 2007, and 2023*

Source: DUSAF by Lombardy Region.

The distribution of the main land use types in the basin for each year is reported in Figure 6. From 1980 to 2023 urban areas increased from 32% to 50% in the basin. Mainly agricultural areas transformed into urbanized regions, and the forest and seminatural lands. Wetlands and water bodies were left with no considerable change.

Figure 6. *Main Land Use Types for the Basin for the Years 1980, 2007, and 2023*

Figure 7 depicts for each sub-basin the distribution of the first level of DUSAF categories, which contain five land use types for the year 2023. Subbasins 2, 5, 6, and 7 are primarily covered by artificial surfaces, while basins 1, 3, and 4 are dominated by forest and seminatural regions.

Figure 7. *LULC for Each Sub-basin for the Year 2023*

Meteorological Data

The Po Valley has a transitional climate between the Mediterranean and Central European climates, characterized by anticyclonic patterns and westerly circulations (Confalonieri et al. 2009). According to Ceppi et al. (2021), the 24-hour annual maximum precipitation for the 40 years between 1981 and 2020 ranged from 45 mm to 107 mm, with a mean value of 75 mm (Figure 8). The study area's rainfall pattern was modeled after hypothetical storms with total daily precipitation values of 45, 75, and 107 mm.

Figure 8. *24-hour Annual Maximum Precipitation for the Seveso Basin*

Source: Ceppi et al. 2021.

Definition of Curve Numbers (CNs)

The runoff curve number is an empirical quantity in hydrology that predicts direct runoff or infiltration due to excess rainfall. Higher CN values determine more surface runoff. CN values were defined based on land use and soil types from 0 to 100 following Gilewski and Węglarz (2018) (see Table 1).

Table 1. *CN Values Based on Land Use and Hydrologic Soil Group*

Class	Land use	Curve numbers for HSG			
		A	B	C	D
112	Discontinuous urban fabrics	54	70	80	85
121	Industrial, commercial, and transport units	85	90	92.5	94
131	Mineral extraction sites	77	86	91	94
211	Non-irrigated arable land	65	76.5	84	88
231	Pastures	30	58	71	78
242	Complex cultivation patterns	30	58	71	78
243	Land principally occupied by agriculture	78	83	86	88
311	Broad-leaved Forest	30	55	70	77
312	Coniferous forest	36	60	73	79
313	Mixed forest	30	55	70	77
321	Natural grasslands	39	61	74	80
324	Transitional woodland-shrub	30	55	70	77

Source: Gilewski and Węglarz 2018.

For the remaining Land use categories, CN values were defined based on Cronshey's Urban Hydrology for Small Basins manual (1986, see Table 2):

Table 2. *CN Values Are Based on Land Use and Hydrologic Soil Groups*

Class	Land use	Curve numbers for HSG			
		A	B	C	D
111	Continuous urban fabric	98	98	98	98
122	Road and rail networks and associated land	98	98	98	98
132	Dump sites Poor condition (grass cover < 50%)	68	79	86	89
133	Construction sites (Developing urban areas)	77	86	91	94
141	Green urban areas in good condition (grass cover > 75%)	39	61	74	80
142	Sport and leisure facilities Fair condition (grass cover 50% to 75%)	49	69	79	84
22	Agricultural areas	63	71	78	81
411	Wetlands	90	92	94	96
51	Water bodies	100	100	100	100

Source: Cronshey 1986.

Finally, a composite curve number (CN_C) was calculated for each sub-basin, having sub-areas with different soil groups and land covers, by weighting the CN values for the individual sub-areas in proportion to their land area (A_i) as shown in equation 1 (Shadeed and Almasri 2010):

$$CN_C = \frac{CN_1A_1 + CN_2A_2 + \cdots + CN_iA_i + \cdots + CN_nA_n}{\sum_{i=1}^{n} A_i} \quad 1$$

Flood Damage

HEC-RAS, developed by the United States Army Corps of Engineers, is simulation software used in computational fluid dynamics, primarily to model the hydraulics of water flow via natural rivers and other channels (Ogras and Onen

2020). In this study, HEC-RAS version 6.5 was used to investigate the 2D spatial distribution of water depths throughout stormwater runoff calculated by HEC-HMS software (following Papaioannou et al. 2018). Then to estimate the basin damage vulnerability, flood depth-damage functions of the Europe (Huizinga et al. 2017) were applied to the water depth of each land use categories (Figure 9).

Figure 9. *Depth Damage Function Curves for a: 1.1 Urban Fabrics, b: 1.2.1 Industrial or Commercial Units, c: 1.2.2 Road and Rail Networks and Associated Land, and d:2. Agricultural Areas*

Source: Huizinga et al. 2017.

Table 3 shows the equation for damage factor and depth and the average maximum damage value for each land use category:

a. 1.1 Urban fabrics.
b. 1.2.1 Industrial or commercial units.
c. 1.2.2 Road and rail networks and associated land.
d. 2. Agricultural areas.

In comparison to agricultural areas, urban areas have a substantially higher average maximum damage value, making them more vulnerable to flood damage.

Table 3. *Damage-depth Functions: Y is the Damage Factor and X is the Flood Water Depth (m)*

Category	Class	Damage depth function	The average maximum damage value (€/m2)
a	1.1	$y = -0.0328x^2 + 0.3574x$	750
B	1.2.1	$y = -0.0239x^2 + 0.3341x$	621
C	1.2.2	$y = -0.0361x^2 + 0.3618x$	24
D	2	$y = -0.0605x^2 + 0.4918x$	0.77

SUDS Scenarios

SUDS were implemented in the urban fabric areas assuming green roofs for all the built areas, while PP was assumed for roads and associated areas. Figure 10 shows the spatial distribution and areas of each sub-catchment that was considered for SUDS scenarios.

Figure 10. *Map of the Urban Fabric Land Use Where Green Roofs Were Simulated - Road and Rail Networks and Associated Lands Where PP Was Assumed*

Since assuming the presence of green roofs has a direct effect on runoff, the CN values of Continuous and discontinuous urban fabric were changed from 98 to 84 for all the soil groups (following Liu et al. 2020). To analyze the effect of permeable pavements, the CN value of road and rail networks and associated land changed from 98 to 75 (following Hunt and Collins 2008).

Results

The stormwater runoff was computed using HEC-HMS software. Figure 11 shows HEC-HMS stormwater runoff predictions for each sub-basin for a hypothetical daily storm with 107 mm precipitation. Runoff was simulated considering the land use distribution in 1980, 2007, and 2023. Considering the same precipitation pattern and soil group for each year, land use change mainly urbanization as the main factor, affects the runoff composition, since the increase of runoff during the time for each sub-basin and the basin was seen.

Figure 11. *Stormwater Runoff for Each Sub-basin Considering a Hypothetical Daily Storm with 107 mm Precipitation*

Figure 12 depicts the stormwater flow rate for the endpoint of the basin for years 1980, 2007, and 2023, showing the increment of peak flow due to urbanization.

Figure 12. *Peak Flow at Basin Closure Considering the 1980, 2007, and 2023 Land Use (Hourly Precipitation in mm is Also Shown in the Secondary Y-axis)*

The hydrological and hydraulic characteristics of the catchment and river were studied for the year 2023, and then SUDS were applied to the same year to assess the impact of stormwater runoff control. Different hypothetical daily storm precipitation was assumed as 45, 75, and 107 mm, and the runoff volume was calculated by means of HEC-HMS for each sub-basin (Figure 13).

Figure 13. *Runoff (mm) Predicted for Each Sub-basin for Hypothetical Daily Storm Precipitations of a: 45, b:75, and c:107 mm*

Figure 14 shows the 2d spatial distribution of flood water depth computed by HEC-RAS. The model was implemented by using the runoff volumes for each sub basin predicted by HEC-HMS with the hypothetical daily storm precipitation of 107 mm.

Figure 14. *Water Depths Derived from Generated Runoff*

Figure 15 shows the potential damaging vulnerability of the Seveso basin. Urban areas close to the river channel are more susceptible to damage and economic costs.

Figure 15. *2D Spatial Distribution of Damage Vulnerability*

Figure 16 shows the damage vulnerability map of the catchment in terms of LULC and flood depth. The average value for each sub-basin was calculated to determine which sub-basin is more susceptible to Seveso flooding, given a constant hypothetical storm value for the whole basin. Downstream basin number s_7 was identified as the most vulnerable sub-basin due to its high urban density and the accumulation of water from other upstream sub-basins.

Figure 16. *Sub-basin Damage Vulnerability*

Figure 17 shows the mean CN value of each sub-basin and the mean value for the whole basin, for different SUDS.

Figure 17. *CN Value for the 2023 Situation Considering no SUDS, Green Roof, and PP Scenarios*

The runoff of the SUDS scenarios was then compared with the 2023 scenario assuming the 107 mm daily precipitation. Figure 18 shows the runoff amounts estimated for different SUDS scenarios compared with the no SUDS scenario.

Figure 18. *Runoff for 2023 Situation with no SUDS, Green Roof, PP, and Both Green Roof and PP Scenarios*

The application of green roofs and PP on runoff generation has the highest effect on sub-basin number 7 and the lowest effect on sub-basin number 4.

For the whole Seveso River basin, the application of SUDS resulted in an 18, 2, and 21 percent reduction in runoff compared to the 2023 no SUDS scenario for green roofs, PP, and both scenarios, respectively.

Figure 19 shows the peak flow rates for the No SUDS, Green roof, PP, and green roof and PP scenarios assuming the same precipitation.

Figure 19. *Simulation of Peak Flow Rate at the Basin Closure Comparing the 2023 Condition (No SUDS), and SUDS Scenarios (i.e., Green Roofs, PP, and Green Roofs and PP*

The Green roof and PP scenario determined a decrease of the peak flow rate by 25% compared to the 2023 No SUDS scenario.

Conclusion

The present paper investigates the effect of urbanization in the study area on stormwater runoff for the whole basin and sub-basins. Urbanized areas increased from 32% to 50% from 1980 to 2023. Urbanization increased the stormwater runoff volume by about 6% for the whole basin, and peak flow rate by about 10% at the basin closure.

The HEC-RAS software generated a 2D flood depth water map for the Seveso River, which was then intersected with water depth graphs to determine the damage vulnerability of the entire basin and each sub-basin. Sub-basin S-7, which collects water from upstream and has a higher percentage of urban area, was found to be the most damaged by a river flood.

Different SUDS for runoff and flood control were applied to the 2023 No SUDS scenario to improve the water balance in the basin. For the whole basin, application of the SUDS scenarios resulted in 18, 2, and 21 percent decrease in runoff with respect to the current situation, for green roofs, PP, and both scenarios respectively. Application of both Green roof and PP, compared to the situation of 2023 decreased the peak stormwater flow by 25%.

References

Bell CD, McMillan SK, Clinton SM, Jefferson AJ (2016) Hydrologic response to stormwater control measures in urban watersheds. *Journal of Hydrology* 541, PART B (Oct): 1488–1500.

Berndtsson JC (2010) Green roof performance towards management of runoff water quantity and quality: A review. *Ecological Engineering* 36(4): 351–360.

Bocchi S, La Rosa D, Pileri P (2012) Agro-ecological analysis for the EU water framework directive: an applied case study for the river contract of the Seveso Basin (Italy). *Environmental Management* 50(4): 514–529.

Carson TB, Marasco DE, Culligan PJ, McGillis WR (2013) Hydrological performance of extensive green roofs in New York City: observations and multi-year modeling of three full-scale systems. *Environmental Research Letters* 8(2): 024036.

Ceppi A, Gambini E, Lombardi G, Ravazzani G, Mancini M (2021) SOL40: forty years of simulations under a climate and land use change scenario. In *EGU General Assembly Conference Abstracts*, EGU21-12496.

Ciriminna D, Ferreri GB, Noto LV, Celauro C (2022) Numerical comparison of the hydrological response of different permeable pavements in urban area. *Sustainability* 14(9): 5704.

Confalonieri R, Acutis M, Bellocchi G, Donatelli M (2009) Multi-metric evaluation of the models WARM, CropSyst, and WOFOST for rice. *Ecological Modelling* 220(11): 1395–1410.

Cronshey R (1986) *Urban hydrology for small watersheds.* US Department of Agriculture, Soil Conservation Service, Engineering Division.

Fassman-Beck E, Hunt W, Berghage R, Carpenter D, Kurtz T, Stovin V, et al. (2016) Curve number and runoff coefficients for extensive living roofs. *Journal of Hydrologic Engineering* 21(3): 04015073.

Getter KL, Rowe DB, Andresen JA (2007) Quantifying the effect of slope on extensive green roof stormwater retention. *Ecological Engineering* 31(4): 225–231.

Gilewski P, Węglarz A (2018) Impact of land-cover change related to urbanization on surface runoff estimation. In *MATEC Web of Conferences*. EDP Sciences, 03014.

Hartmann T, Slavíková L, McCarthy S (2019) *Nature-based flood risk management on private land: Disciplinary perspectives on a multidisciplinary challenge*. Springer Nature.

Huizinga J, De Moel H, Szewczyk W (2017) *Global flood depth-damage functions: Methodology and the database with guidelines*. Joint Research Centre (Seville site).

Hunt WF, Collins KA (2008) *Permeable pavement: Research update and design implications*. North Carolina Cooperative Extension.

Hydrologic Engineering Center (2016) *HEC-RAS, River Analysis System, User's Manual, CPD-68*. Davis, CA: U.S. Army Corps of Engineers.

Kuruppu U, Rahman A, Rahman MA (2019) Permeable pavement as a stormwater best management practice: a review and discussion. *Environmental Earth Sciences* 78(May): 327.

Liu W, Feng Q, Chen W, Wei W (2020) Assessing the runoff retention of extensive green roofs using runoff coefficients and curve numbers and the impacts of substrate moisture. *Hydrology Research* 51(4): 635–647.

Lombardy Region, Destinazione d'Uso dei Suoli Agricolo Forestali (DUSAF 7.0) Available at: http://www.cartografia.regione.lombardia.it.

Luo P, Luo M, Li F, Qi X, Huo A, Wang Z, et al. (2022) Urban flood numerical simulation: Research, methods and future perspectives. *Environmental Modelling & Software* 156(Oct): 105478.

Masseroni D, Cislaghi A (2016) Green roof benefits for reducing flood risk at the catchment scale. *Environmental Earth Sciences* 75(Mar): 579.

Mishra SK, Singh VP, Mishra SK, Singh VP (2003) SCS-CN Method. In *Soil Conservation Service Curve Number (SCS-CN) Methodology,* 84–146.

Nkiruka EM, Chinedu AD, Smart UN (2023) Landuse, landcover change dynamics and flooding in the lower Niger basin Onitsha, South Eastern Nigeria. *Land Use Policy* 131(Aug): 106748.

Ogras S, Onen F (2020) Flood analysis with HEC-RAS: a case study of Tigris River. *Advances in Civil Engineering* (Feb): 1–13.

Papaioannou G, Efstratiadis A, Vasiliades L, Loukas A, Papalexiou SM, Koukouvinos A, et al. (2018) An operational method for flood directive implementation in ungauged urban areas. *Hydrology* 5(2): 24.

Ponce VM, Hawkins RH (1996) Runoff curve number: Has it reached maturity? *Journal of Hydrologic Engineering* 1(1): 11–19.

Potočki K, Bekić D, Bonacci O, Kulić T (2021) Hydrological aspects of nature-based solutions in flood mitigation in the Danube River Basin in Croatia: Green vs. Grey approach. In *Nature-Based Solutions for Flood Mitigation: Environmental and Socio-Economic Aspects*, 263–288. Springer.

Raimondi F, Dresti C, Marchioni M (2020) Integrated Strategies for River Restoration and Land Re-Naturalization in Urban Areas: A Case Study in Milan, Italy. *Urban Water Systems & Floods III* 194(12): 11123.

Seemuangngam A, Lin H-L (2024) The impact of urbanization on urban flood risk of Nakhon Ratchasima, Thailand. *Applied Geography* 162(Jan): 103152.

Shadeed S, Almasri M (2010) Application of GIS-based SCS-CN method in West Bank catchments, Palestine. *Water Science and Engineering* 3(1): 1–13.

Soulis KX, Ntoulas N, Nektarios PA, Kargas G (2017) Runoff reduction from extensive green roofs having different substrate depth and plant cover. *Ecological Engineering* 102(May): 80–89.

Tang S, Jiang J, Zheng Y, Hong Y, Chung E-S, Shamseldin AY, et al. (2021) Robustness analysis of storm water quality modelling with LID infrastructures from natural event-based field monitoring. *Science of the Total Environment* 753(Jan): 142007.

Uchegbu S (2003) Management of Flood Plains and Wetlandsin Nigeria. *Journal of Nigerian Environmental Society* 1(1): 69–76.

U.S. Army Corps of Engineers, Hydrologic Engineering Center (2012) H*EC-HMS Hydrologic Modeling System, User's Manual, Version 4.0, CPD-74A*. Davis, CA: Hydrologic Engineering Center.

Zhu Y, Li H, Yang B, Zhang X, Mahmud S, Zhang X, et al. (2021) Permeable pavement design framework for urban stormwater management considering multiple criteria and uncertainty. *Journal of Cleaner Production* 293(Apr): 126114.

Zölch T, Henze L, Keilholz P, Pauleit S (2017) Regulating urban surface runoff through nature-based solutions–an assessment at the micro-scale. *Environmental Research* 157(Aug): 135–144.