A Pan-European dataset of hydrological monitoring from urban stormwater Nature-Based Solutions

Un jeu de données paneuropéen de suivi hydrologique provenant de solutions fondées sur la nature pour la gestion des eaux pluviales urbaines

Yao Li[a*], Tinghao Huang[a], Utsav Adhikari[b], Emmanuel Berthier[c], Ico Broekhuizen[b], Ilaria Gnecco[d], Giasemi Morianou[e], Nikolaos Ntoulas[e], Anna Palla[d], David Ramier[c], Jérémie Sage[c], Martin Seidl[a], Konstantinos Soulis[e], Hayath Zime Yerima[a], Marie-Christine Gromaire[a]

a: LEESU, ENPC, Institut Polytechnique de Paris, Univ Paris Est Creteil - yao.li@enpc.fr; tinghao.huang@enpc.fr; martin.seidl@enpc.fr; hayath.zime-yerima@enpc.fr; marie-christine.gromaire@enpc.fr
b: Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technolog - utsav.adhikari@ltu.se; ico.broekhuizen@ltu.se
c: Cerema, Equipe TEAM- jeremie.sage@cerema.fr; david.ramier@cerema.fr; Emmanuel.Berthier@cerema.fr
d: Department of Civil, Chemical and Environmental Engineering, University of Genova - ilaria.gnecco@unige.it; anna.palla@unige.it
e: Laboratory of Soil Science and Agricultural Chemistry, Agricultural University of Athens - giasemi.mor@gmail.com; ntoulas@aua.gr; k.soulis@gmail.com

RÉSUMÉ

Les solutions fondées sur la nature pour la gestion des eaux pluviales urbaines (NBSsw) sont de plus en plus utilisées dans les villes européennes pour réduire les risques d'inondation et soutenir l'adaptation climatique. Cependant, les observations hydrologiques comparables entre différents types de NBSsw et climats restent limitées. Pour combler cette lacune, nous présentons un jeu de données pan-européen intégrant des mesures hydrologiques haute résolution issues de 12 sites représentant sept types de NBSsw pour la gestion des eaux pluviales, incluant toits végétalisés, jardins de pluie, biofiltres routiers, noues d'infiltration, bassins de rétention végétalisés, parkings perméables végétalisés et arbres de pluie. Les variables suivies incluent précipitations, débits entrants et sortants, niveaux d'eau, humidité du sol et variables météorologiques, accompagnées de métadonnées détaillées et de procédures de contrôle qualité. Ce jeu de données constitue le premier benchmark hydrologique NBSsw couvrant différents climats européens, offrant des séries temporelles homogènes et accessibles pour des comparaisons inter-sites, le développement de modèles et l'évaluation scientifique des performances hydrologiques des NBSsw.

ABSTRACT

Nature-Based Solutions (NBSsw) are increasingly deployed in European cities to manage stormwater, reduce flood risk, and support climate adaptation. Yet, comparable hydrological observations across different NBSsw types and climatic conditions remain scarce. To address this gap, we compiled a Pan-European dataset of high-resolution hydrological monitoring from 12 sites hosting seven types of stormwater NBSsw (green roofs, raingardens, roadside biofilters, infiltration swales, vegetated detention basins, green parking lots, and stormwater trees). The dataset integrates harmonized measurements of rainfall, inflow, water levels, soil moisture, outflow, and meteorological variables, complemented by site-level metadata and standardized quality-control procedures. These observations capture full rainfall-runoff responses of NBSsw under real operational conditions across diverse climates and designs. By providing consistent, openly accessible time series, this dataset establishes the first European benchmark for NBSsw hydrology, enabling cross-site comparisons, model development, and evidence-based evaluation of NBSsw performance. All data and documentation are available through site-level DOIs in the GreenStorm community on Zenodo platform.

KEYWORDS

Nature-Based Solutions, Stormwater management, Hydrological monitoring, Europe, Dataset

1 INTRODUCTION

Urbanization combined with climate driven hydrological extremes challenges conventional grey infrastructure for stormwater management (Li et al., 2024). Nature-Based Solutions for stormwater management (NBSsw) have emerged as multifunctional infrastructures capable of mitigating flood risks while providing ecological and social benefits (Soulis et al., 2017). Despite rapid adoption, hydrological understanding of NBSsw performance across climatic gradients remains limited due to sparse, heterogeneous monitoring (Huang et al., 2025). Existing datasets are often short-term, low-resolution, or regionally constrained, limiting model calibration, benchmarking, and cross-site comparison.

The GreenStorm project (https://arceau-idf.fr/projets/greenstorm) addresses these limitations by compiling and harmonizing long-term, high-resolution hydrological monitoring from NBSsw sites across Europe. The resulting dataset spans diverse climates (mediterranean, temperate, sub-arctic) and NBSsw typologies, establishing the first European benchmark for NBSsw hydrology. This enables systematic evaluation of NBSsw performance and supports model development and evidence-based urban water planning.

2 MATERIALS AND METHODS

2.1 Study sites and climatic contexts

The dataset includes 12 NBSsw sites in France, Greece, Italy, and Sweden, spanning latitudes from 37°59'N to 64°46'N (Figure.1). Sites cover a variety of urban contexts, from dense metropolitan areas (Paris, Athens) to medium-sized Nordic towns (Skellefteå, Växjö), and Mediterranean ports (Genoa). Each site hosts one or more of seven NBSsw types: green roofs, raingardens, roadside biofilters, infiltration swales, vegetated detention basins, green parking lots, and stormwater trees. A summary of their types, locations, and monitoring period and objectives is provided in Table 1.

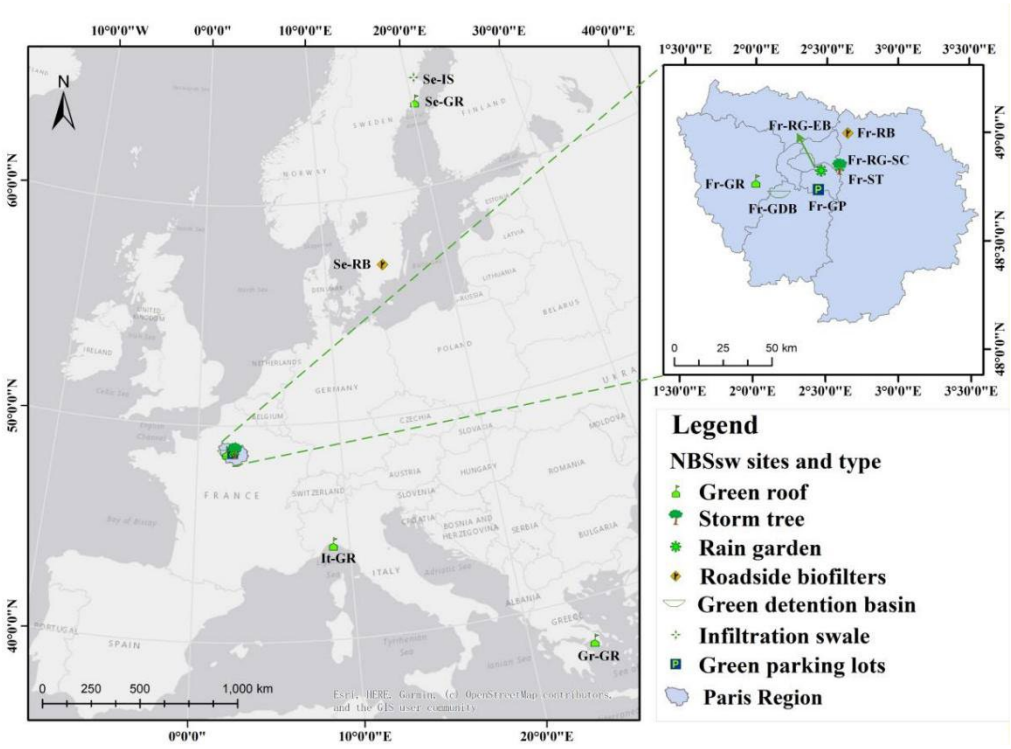

Figure1: The spatial distribution of all NBSsw sites.

Table 1. Overview of study sites, including country, site, NBS type, climate, and location.

NBS type	Country	Site	Climate*	Location- WGS84	Code
Green roofs	France	Trappes	Temperate oceanic	48.77247°N, 2.00628°E	**Fr-GR**
	Greece	Athens (AUA)	Hot-summer Mediterranean	37.98446°N, 23.70666°E	**Gr-GR**
	Italy	Genoa (UNIGE)	Humid Mediterranean	44.40036°N, 8.96347°E	**It-GR**
	Sweden	Umeå	Subarctic	63.80334°N, 20.28964°E	**Se-GR**
Roadside biofilters		Växjö	Cool temperate oceanic	56.89122°N, 14.77739°E	**Se-BF**
Rain gardens	France	Compans	Temperate oceanic	48.99591°N, 2.64745°E	**Fr-RB**
		École du Breuil		48.82292°N, 2.46163°E	**Fr-RG-EB**
		Sense city		48.84186°N, 2.590010°E	**Fr-RG-SC**
Storm trees				48.84183°N, 2.59012°E	**Fr-ST**
Green parking lots		Villeneuve		48.73549°N, 2.44274°E	**Fr-GPS**
Green detention basin		Jardin Argenté		48.71150°N, 2.16968°E	**Fr-GDB**
Infiltration swale	Sweden	Skellefteå	Subarctic	64.76877°N, 21.01496°E	**Se-IS**

* The climate classification for each site follows the Köppen-Geiger climate classification system (Beck et al., 2018).

2.2 NBSsw monitoring and hydrological processes

Monitoring targets the key hydrological processes: precipitation, surface runoff, storage (at the surface, in the soil or in an internal storage layer), infiltration, evapotranspiration, and controlled outflow. Variables measured include: (1) Meteorological: rainfall, temperature, humidity, solar radiation, wind speed, and/or PET calculated based of this data; (2) Hydrological: inflow, outflow, overflow, water levels, soil moisture; (3) Metadata: NBSsw design, substrate, vegetation, drainage configuration. Measurement intervals range from 1-minute to daily, capturing event-based dynamics and seasonal variations.

2.3 Data harmonization and quality control

All sites followed standardized procedures for: (1) Harmonizing variable names, units, and timestamps (ISO 8601, UTC); (2) Quality control: sensor calibration, outlier removal, missing value flagging; (3) Documentation of site-specific uncertainties and measurement methods. The dataset allows direct cross-site comparison and supports modeling efforts without additional preprocessing.

3 DATASET AVAILABILITY

The GreenStorm dataset is organised as a series of site-level data packages, each deposited in Zenodo with its own DOI. All datasets are grouped under the *GreenStorm Community (*https://zenodo.org/communities/greenstorm/*)*, which provides a unified entry point to access and reuse hydrological observations from NBSsw across Europe. All datasets are open access and can be freely reused under their respective licences. A corresponding data paper is currently under submission, which provides methodological details and guidance for dataset application.

4 CONCLUSIONS

The GreenStorm Pan-European dataset provides the first coordinated hydrological benchmark for stormwater NBS across multiple European climates. Its long-term, high-resolution observations and harmonised documentation offer a reliable foundation for cross-site comparison, model development, and evidence-based planning of urban stormwater interventions. By making all site-level datasets openly accessible through the GreenStorm Zenodo community, this resource supports research, engineering practice, and policy efforts aimed at strengthening climate-resilient urban water management.

LIST OF REFERENCES

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific Data*, *5*(1), 180214. https://doi.org/10.1038/sdata.2018.214

Huang, T., Sage, J., Técher, D., & Gromaire, M.-C. (2025). Hydrological performance of bioretention in field experiments and models: A review from the perspective of design characteristics and local contexts. *Science of The Total Environment*, *965*, 178684. https://doi.org/10.1016/j.scitotenv.2025.178684

Li, Y., Wang, P., Lou, Y., Chen, C., Shen, C., & Hu, T. (2024). Assessing urban drainage pressure and impacts of future climate change based on shared socioeconomic pathways. *Journal of Hydrology: Regional Studies*, *53*, 101760. https://doi.org/10.1016/j.ejrh.2024.101760

Soulis, K. X., Valiantzas, J. D., Ntoulas, N., Kargas, G., & Nektarios, P. A. (2017). Simulation of green roof runoff under different substrate depths and vegetation covers by coupling a simple conceptual and a physically based hydrological model. *Journal of Environmental Management*, *200*, 434-445. https://doi.org/10.1016/j.jenvman.2017.06.012