

Restoring the Urban Water Balance: a Proxy-Based Approach to Assess Climate Adaptation Need and Nature-Based Solutions

Francesco Del Punta^{1,*}, Ningzhou Li¹, Hauke Sonnenberg¹, Jonas Neumann², Andreas Matzinger¹ and Leilah Haag³

¹*Kompetenzzentrum Wasser Berlin, Germany*

²*RTPU Kaiserslautern-Landau, Germany*

³*Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen, Berlin, Germany*

Abstract

Urban areas are increasingly exposed to environmental risks such as heat stress, pluvial flooding, and combined sewer overflows, all of which are intensifying under climate change and growing urbanization. Accurately modelling these processes at city scale is essential for informed planning, yet physically based models remain computationally demanding, data-intensive, and often limited to small pilot areas. In this context, water balance modelling emerges as a powerful and practical alternative, offering a simplified yet robust framework to capture the key hydrological processes governing urban environmental dynamics. This study demonstrates the value of a simplified urban water balance model (ABIMO) as a screening and diagnostic tool to assess multiple environmental risks across the entire city of Berlin. By partitioning precipitation into evapotranspiration, runoff, and groundwater recharge for more than 57,000 spatial units, the model provides a consistent and spatially explicit representation of how water is redistributed in the urban environment.

A central concept is the deviation of the urban water balance from a natural reference state (ΔW), which serves as an integrative indicator of anthropogenic alteration. The results show that this relatively simple metric correlates meaningfully with outputs from more complex physical models describing near-surface air temperature, flood volumes, and sewer overflow discharges. These correlations highlight the fundamental role of hydrological processes in shaping a wide range of environmental risks: reduced evapotranspiration contributes to urban heat islands, increased runoff amplifies flood hazards, and higher effective imperviousness drives sewer system overload.

Beyond predictive capability, the main advantage of water balance modelling lies in its efficiency, scalability, and transparency. Compared to complex model chains, it requires fewer inputs, minimal calibration, and significantly lower computational effort, making it accessible to a wider range of users, including municipalities with limited technical resources. This enables rapid, city-wide assessments that can inform early-stage decision-making, identify priority areas, and guide the allocation of resources before committing to detailed simulations. Furthermore, the conceptual simplicity of water balance components facilitates communication with stakeholders and supports interdisciplinary planning processes.

The approach is particularly well suited to the planning and evaluation of nature-based

solutions, such as green roofs, infiltration systems, and urban greening measures, as changes in ΔW consistently reflect their hydrological effectiveness and co-benefits across multiple risk domains.

Overall, this study underscores the importance of water balance modelling as a unifying and scalable tool in urban environmental assessment. While it does not replace detailed physical models, it effectively bridges the gap between data availability and planning needs, enabling a shift from localized, resource-intensive analyses to comprehensive, city-wide risk screening. By explicitly linking hydrological indicators to the performance of nature-based solutions, the approach supports more integrated and actionable strategies for climate adaptation. As this becomes an increasingly urgent priority, such simplified yet informative methods are essential for advancing resilient and water-sensitive urban planning.

Keywords: water-balance, modelling, nbs, water-sensitive urban planning, climate adaptation

References

- Glugla, G., Goedecke, M., Wessolek, G. and Fürtig, G. 1999 Langjährige Abflußbildung und Wasserhaushalt im urbanen Gebiet Berlin., pp. 34-42.
- Guericke et al., (2023). Evaluation of the deviation from the annual natural water balance of urban areas – Proposition of a model approach, Novatech Conference Paper.
- Sonnenberg H, Del Punta F (2025). kwb.rabimo: R Implementation of Water Balance Model Abimo. R package version 2.1.0, <https://github.com/kwb-r/kwb.rabimo>.
- SenStadt (2025). Umweltatlas Berlin, Klimamodellierung 2022. Dokumentation der Klimamodellierung <https://www.berlin.de/umweltatlas/klima/klimaanalyse/2022/methode/>, Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen Berlin.
- Knoche, F., Schumacher, F., Zamzow, M., Sohr, J., Rehfeld-Klein, M., Matzinger, A., Johne, U., Meier, I., Rouault, P., Pawlowsky-Reusing, E. und Schütz, P. (2024). Perspektiven für den urbanen Gewässerschutz durch dezentrales Regenwassermanagement. Conference paper, Aqua Urbanica 2024, Scientific Board der Aqua Urbanica, Graz.