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Block-based planning to retain stormwater in urban catchments

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Abstract

We explore the potential for block-based interventions to improve stormwater management and comply with the European Urban Wastewater Directive by reducing combined sewer overflow (CSO). Urban blocks—defined as polygons enclosed by cleaned road networks—serve as spatial units for identifying suitable Low Impact Developments (LIDs). Using *UrbanWaterBlocks*, an open-source Python toolkit, we automate the delineation of urban blocks, calculation of key spatial and demographic attributes, and assessment of decentralization potential for stormwater interventions. The methodology was demonstrated on two districts of Leipzig, Germany—Mitte and Süd—where LID types such as bioretention cells and infiltration shafts were considered. Our approach supports scalable, reproducible, and data-driven pre-feasibility studies for decentralized stormwater management in urban catchments with limited data.

Highlights

- Automated urban block generation and attribute calculation from open source data
- Sizing of LIDs based on geospatial available information and extreme design storms
- Assessment of LID potential at block scale

Introduction

Urban stormwater management faces increasing challenges due to climate change, ongoing urbanisation and the limited capacity of centralised drainage systems. Existing combined sewer systems are often inadequately sized to cope with the intensity of extreme weather events. Reducing combined sewer overflow (CSO) volumes has become a key objective for European cities to meet the Urban Waste Water Treatment Directive (91/271/EEC) requirements. There is a pressing need to adapt stormwater infrastructure by incorporating additional retention and pre-treatment measures to improve the resilience of cities. Planning tools are needed to facilitate pre-feasibility analysis for implementing LIDs to reduce CSO events, also in the absence of detailed sewer network models. We aim to apply a block-based approach to urban catchments in European cities, demonstrating its effectiveness for the preliminary planning of additional stormwater retention measures. To support this scale of analysis, we build on the MUST-B (Management of Urban Stormwater at Block-level) approach, which estimates the maximum potential for BGI implementation at the block level (Khurelbaatar et al., 2021). We present *UrbanWaterBlocks*, a modular Python-based pipeline that operationalizes the MUST-B approach for decentralized stormwater planning. This streamlined, datareduced pipeline for identifying feasible LIDs options takes into account the constraints of the urban environment, providing support to increase cities' resilience to urban flooding.

Methodology

Using the district boundary as input, we extract OpenStreetMap (OSM) road data and generate urban blocks with our Python-based tool, *UrbanWaterBlocks*. These blocks serve as functional spatial units for assessing decentralized stormwater management options. Block-level attributes such as sealing degree and population are derived using open geospatial datasets through automated routines. We compute design storms with return periods from 5 to 100 years through extreme frequency analysis. We calculate the maximum capacity of the stormwater infrastructure for each design storm to minimise the runoff within the functional units. The methodology follows the approach introduced in Lippera et al (2025), assuming a fixed LID type (e.g., bioretention cells) and associated equivalent water accumulation characteristics. The unsealed connected area within the blocks constrains the maximum capacity of the LIDs. A metric for the decentralisation potential of each block is computed to account for the highest generated impervious runoff within the blocks and the capacity of the technology to contain it given the available space for installation. A set of scenarios is then generated for the configuration of LIDs technologies at the block-scale.

Case studies

Within Leipzig, we selected two contrasting districts—Mitte and Süd—to highlight how the pipeline performs in areas with different surface conditions. The Süd district, with an area of 16.95 km², and the Mitte district, spanning 13.95 km², each feature a diverse mix of urban structures, including residential, commercial, and recreational zones.

Results and discussion

The application of the *UrbanWaterBlocks* pipeline to Leipzig resulted in the delineation of urban blocks consistent with the actual spatial representation of the city. In total, 2,804 blocks were generated for the entire city. Block attributes were computated for the blocks located within both selected districts. Figure 1 show key spatial attributes for decentralized stormwater management. The sealing degree map highlights areas with high imperviousness (yellow) where interventions are most needed, while violet areas indicate more permeable surfaces. The largest contiguous unsealed areas (green) represent available space for infiltration, and the largest inscribed rectangles (orange) identify practical footprints for implementing LID infrastructure. Together, these maps support targeted planning for runoff reduction within urban blocks. The decentralization potential analysis indicated that many urban blocks possess a capacity to retain substantial portions of stormwater runoff through bio-retention cells and infiltration shafts under various design storm scenarios.

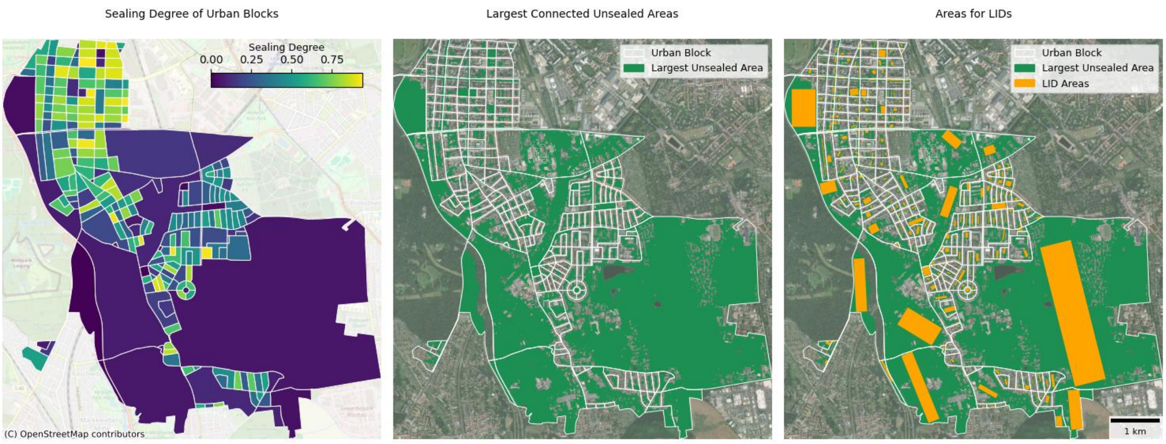

Figure 1. Example of key block attributes generated by UrbanWaterBlocks for LID planning in Leipzig Süd, showing sealing degree (left), largest contiguous unsealed areas (middle), and potential LID footprints (right).

Conclusions and future work

The case studies of Leipzig Mitte and Süd districts have shown that our approach can be easily scaled to different urban settings to facilitate decision-making when exploring different LIDs options. The block-based strategy can reduce urban runoff by excluding road runoff and retaining, storing and infiltrating impervious runoff at the block level. Urban planners and local authorities can use this tool to explore other stormwater management strategies to improve the existing drainage system, in line with the renewal of the EU Urban Wastewater Treatment Directive, and as an initial basis for funding schemes.

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