SCALING SPONGE CITY STRATEGIES: INTEGRATING SUSTAINABLE STORMWATER MANAGEMENT WITHIN EUROPEAN POLICY AND URBAN PLANNING FRAMEWORKS

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_ Lujain Ben Khadra

Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary, ben.khadra@mik.pte.hu, [0009-0000-7230-6429]

_ János Gyergyák

PhD, Associate Professor, Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary, gyergyak.janos@mik.pte.hu, [0000-0003-2091-2704]

_ Judit Pál-Schreiner

Faculty of Engineering and Information Technology, University of Pécs, Pécs, Hungary, pal-schreiner.judit@mik.pte.hu

ABSTRACT

Urban areas across Europe face increasing challenges from flooding, water scarcity, and climate-induced stress. This paper explores scalable implementation of Sponge City strategies such as green roofs, permeable pavements, stormwater tanks, and rain gardens. It examines their integration within the EU Water Framework Directive and the European Green Deal, with particular attention to local planning regulations and governance. Through analysis of European case studies, this paper identifies technical, financial, and institutional enablers and obstacles. It concludes with policy recommendations for facilitating multi-scalar integration, stakeholder coordination, and investment in nature-based stormwater management. The outcomes provide a roadmap for achieving resilient, climate-adaptive urban systems in Europe.

KEYWORDS _ *Stormwater Management, Urban Planning Regulations, European Policies, Macro-Scale Implementation, Sustainable Cities*

INTRODUCTION

Rapid urbanization has overwhelmed conventional drainage systems, increasing the risk of flooding and climate-induced disruptions (Chris Zevenbergen, Transitioning to Sponge Cities: Challenges and Opportunities to Address Urban Water Problems in China, 12 September 2018) In the past 50 years, over 11,000 climate-related disasters caused two million deaths and $3.64 trillion in damages (WMO, 2022) (Liyun Zeng, August 2023) Historically, European cities responded with engineering solutions like the UK's underground drainage (1859) and Germany's 'zero increase in drainage' policy (1990s) (Panmao Zhai, July 2019) Today, cities increasingly adopt nature-based solutions (NbS) such as Sustainable Urban Drainage Systems (SUDS) to restore hydrological balance and reduce risk (Telvio H. S. Francisco, 2022) China's Sponge City model, implemented in cities like Wuhan and Shanghai, shows how green roofs, permeable surfaces, and wetlands can mitigate floods and enable water reuse (Chaohui Zhang, 14 March 2019). Similarly, the UK applies localized SUDS—rain gardens, detention basins—within a policy-driven framework (Elizabeth Stewart, 2021). Scaling these approaches in Europe demands alignment with EU directives, coordinated governance, and integrated adaptation planning _(Telvio H. S. Francisco, 2022).

LITERATURE REVIEW

Legal Framework for Sustainable Water Management in the European Union

EU Directives the EU Water Framework Directive (WFD) is the cornerstone of water policy in Europe, promoting integrated water management via river basin planning. Supporting legislation such as the Groundwater Directive, Drinking Water Directive, and Floods Directive set quality and risk standards. The European Green Deal further advances sustainability through green infrastructure promotion and funding (Agency, 2023).

A. The Water Framework Directive (WFD) and its Supporting Legislation

The Water Framework Directive (WFD) (2000/60/EC) sets the foundation for EU water policy, aiming for good environmental status across all waters through river basin management. Supporting directives address specific issues, including:

- The Groundwater Directive (2006/118/EC) focuses on preventing contamination and ensuring chemical safety for groundwater.
- The Drinking Water Directive (EU 2020/2184) sets quality standards for potable water and mandates monitoring.
- The Bathing Water Directive (2006/7/EC) ensures public health by regulating recreational waters.
- The Environmental Quality Standards Directive (2008/105/EC) limits hazardous substances in surface waters.
- The Urban Wastewater Treatment Directive (91/271/EEC) ensures wastewater treatment to protect ecosystems.
- The Nitrates Directive (91/676/EEC) regulates agricultural pollution in water.
- The Floods Directive (2007/60/EC) requires flood risk management plans to mitigate extreme weather risks.

B. Coastal and Marine Water Protection

The Marine Strategy Framework Directive (2008/56/EC) aims to protect marine ecosystems, while other regulations address marine pollution, including ship-source pollution (Directive 2005/35/EC).

C. International Cooperation

The EU collaborates on transboundary water management through agreements like the Helsinki Convention and the Danube River Protection Convention, and regional frameworks such as the OSPAR Convention for the North-East Atlantic.

D. The Role of the European Parliament

Parliament has advocated for water as a human right through initiatives like Right2Water (2013) and supports policies for water reuse, circular economy integration, and reducing plastic pollution (Christian Kurrer, 2024)

The Sponge City Concept

The Sponge City Concept (SCC) uses natural accumulation, infiltration, and purification to manage urban water through Low-Impact Development (LID) and Green Infrastructure (GI) (GI) (Qian Yu, 21 November 2023). It enables 70–90% stormwater recycling via retention, storage, and reuse (Albert Z. Jiang, 24 February 2021). Unlike LID, WSUD, and SUDS, SCC offers a holistic framework for urban water management at macro, medium, and micro scales (Yaoxue Li, 22 March 2022) . It integrates flood risk management with urban design, preventing floods while supporting water reuse. SCC also enhances economic resilience, urban liveability, and investment in infrastructure, reinforcing climate adaptation and sustainable growth (Chris Zevenbergen, Transitioning to Sponge Cities: Challenges and Opportunities to Address Urban Water Problems in China, 12 September 2018).

Sponge City Challenges

Implementing sponge city strategies faces technical, financial, regulatory, and public acceptance challenges. Issues include inaccurate flood risk estimation, limited groundwater data, and unsuitable designs due to insufficient research (Faiza Chikhi C. L., 2023). High costs, uncertain maintenance expenses, and weak private-sector involvement create financial barriers, while inconsistent policies and outdated building codes hinder progress (Hui Li, 28 August 2017). Fragmented planning and urbanization worsen flood risks, causing infrastructure damage and economic losses (Chris Zevenbergen, Transitioning to Sponge Cities: Challenges and Opportunities to Address Urban Water Problems in China, 12 September 2018). Governance gaps, land-use conflicts, and lack of national design standards further limit adoption. Inadequate subsidies and weak private investment pose financial hurdles, making large-scale Integrated Urban Water Management (IUWM) difficult to scale (Gill, 2021).

_ Implementation Challenges

A major challenge in scaling Sponge City strategies is integrating nature-based solutions (NbS) into existing urban policies. The EPA Network and ENCA emphasize the need for coordinated governance across local, regional, and EU levels to address policy fragmentation that hinders NbS adoption (group E. N., 2023). Despite benefits like improved water absorption and quality, barriers such as institutional hurdles, limited recognition, and policy gaps in integrated water management persist. Capacity-building and data-driven decision-making are crucial for overcoming these challenges. Pilot projects serve as testbeds to demonstrate the effectiveness of NbS and guide broader implementation. Stronger policy frameworks, as highlighted by the European Commission, are needed to support urban water management and Sponge City integration (Simon Ryfisch, December 2023). At different scales, challenges vary micro-scale solutions such as green roofs, permeable pavements, and rain

gardens require consistent maintenance; macro-scale interventions, like city-wide retention systems, involve high costs and long implementation timelines; while medium-scale efforts such as blue-green corridors and urban parks offer benefits but may fall short during extreme events. Effective Sponge City implementation ultimately depends on policy alignment, multi-level cooperation, and adaptive, climate-resilient strategies (Yaoxue Li, 22 March 2022).

_ Policy and Financial Integration for Scaling Sponge Cities

Integrating sponge city strategies into the EU Water Framework Directive (WFD) through River Basin Management Plans (RBMPs) and Programs of Measures (PoMs) enhances flood resilience and water quality. Public engagement via education and citizen participation supports sustainable water management. Increased investment in nature-based solutions, including subsidies, low-interest loans, and EU funding, is essential for widespread adoption. Policy alignment with financial support will accelerate implementation, fostering sustainable, water-resilient urban development. (Environment, 2023).

Policy and Governance Integration

The success of Sponge City strategies relies on both financial resources and policy coherence. Research on China's program emphasizes integrating water management into urban planning. European cities must align adaptation policies with EU directives like the Water Framework Directive and the European Green Deal for a unified approach. Long-term success requires sustained funding and measurable targets to ensure effective resource allocation (Faiza Chikhi C. L., 2023).

_ Policy Alignment with EU Directives

The Water Framework Directive (WFD) mandates that water bodies achieve good ecological status, supporting green infrastructure adoption (group N. R., 2021). By integrating nature-based solutions like permeable pavements and green roofs into River Basin Management Plans (RBMPs), cities improve water quality and biodiversity. The European Green Deal complements the WFD by promoting urban sustainability through green infrastructure and financial mechanisms, contributing to the EU's climate neutrality goal by 2050 (Environment, 2023) Aligning policies with these directives allows cities to leverage EU funding and integrate Sponge City principles effectively.

_ Multi-Level Governance

The European Environment Agency (EEA) highlights the importance of multi-level governance to address policy fragmentation. Coordination between local, regional, and national governments ensures climate adaptation strategies are effective and tailored to urban needs, with political commitment enhancing municipal action (UN, 2023).

_ Stakeholder Engagement

Engaging diverse stakeholders is crucial for successful urban adaptation. Public and private sector collaboration, along with community involvement, ensures that climate measures are both effective and equitable. The United Nations Human Settlements Program highlights those participatory decision-making fosters social acceptance and long-term viability (Habitat). By aligning policies, fostering governance collaboration, and engaging stakeholders, European cities can build resilient, sustainable urban spaces through Sponge City strategies.

Case Studies

_ The UK's Integration of Sustainable Urban Drainage Systems (SUDS)

The UK integrates Sustainable Urban Drainage Systems (SUDS), including rain gardens, permeable pavements, swales, and green roofs, as a nature-based stormwater solution (Hunt, 2018). Supported

by the Flood and Water Management Act (2010) and National Planning Policy Framework (NPPF), its implementation faces financial, governance, and stakeholder challenges (Department for Environment, 2012) Local authorities struggle to balance long-term benefits with short-term costs, slowing adoption. Pilot projects like Thames Water Rain Gardens showcase feasibility while enhancing biodiversity and aesthetics (Brown, 2020). The UK's experience offers key lessons for European cities, emphasizing cross-sector collaboration and long-term sustainability (Department for Environment, 2012) .

_ Berlin, Germany

Berlin's sustainable water management integrates green infrastructure and decentralized stormwater solutions to address urbanization, impermeable surfaces, and climate variability. Through water-sensitive urban design (WSUD)—including green roofs, permeable pavements, and bioswales—the city reduces runoff and eases pressure on wastewater systems (Prit Salian). A decentralized approach promotes on-site retention and reuse, aligning with the EU Water Framework Directive via retention basins and permeable surfaces to mitigate urban heat and flooding. The Rainwater Agency (Regenwasseragentur) engages the public (Darla Nickel, 2013) while regulations and financial incentives encourage sustainable drainage. Public-private partnerships, such as InfraLab Berlin, foster innovation, alongside an early warning system for bathing water quality (GROUP, n.d.) Challenges include retrofitting older areas, financial constraints, and public resistance to costs and maintenance. Despite these barriers, Berlin remains a leading model for Sponge City strategies in Europe (Prit Salian).

_ Budapest, Hungary

The Budapest South Gate Masterplan is a macro-scale urban redevelopment integrating blue-green infrastructure to enhance flood resilience and stormwater management. Located on Csepel Island, it features retention ponds, permeable surfaces, and riverbank restoration to reduce runoff and support climate adaptation. Despite its benefits, the project faces high costs, governance challenges, and land-use conflicts, while long-term maintenance and financial sustainability remain concerns. Extreme weather events could further test its capacity, but it remains a notable example of large-scale Sponge City implementation in Europe (Ben van Berkel, 2018).

ECONOMIC FEASIBILITY & FUNDING MECHANISM

Implementing Sponge City strategies requires sustainable funding mechanisms that align with policy objectives. A combination of public investment, private sector participation, and innovative financial tools ensures long-term urban water resilience.

Public Support and Awareness

Public perception influences the financial viability of green infrastructure projects. Awareness campaigns and community-driven initiatives have successfully shaped attitudes in cities. The Oxford-Cambridge Arc study shows that public acceptance of green infrastructure increases when communities recognize direct benefits, such as reduced flood risks and improved biodiversity (Shandelle Steadman, 31 Mar 2023). Berlin's Rainwater Agency actively engages residents to demonstrate the advantages of decentralized water management (Darla Nickel, 2013).

Adaptability in Funding Models

China's Sponge City program provides valuable financial insights, showcasing the effectiveness of public-private partnerships (PPPs), government subsidies, and innovative financing tools like

green bonds (Faiza Chikhi C. L., 2023). European cities can adapt these models to local contexts, ensuring financial strategies align with EU policies such as the Water Framework Directive and the European Green Deal (Liang, 1 March 2018). A flexible financing approach, with regular evaluation and adjustment, is key to long-term sustainability

Ensuring Long-Term Financial Viability

Financial Strategies Cities should incorporate dynamic financial strategies into policy cycles for regular assessment and adaptation. Funding mechanisms include EU grants, green bonds, and public-private partnerships. Long-term sustainability depends on flexible, adaptive financing aligned with climate and water directives. Public engagement also enhances acceptance and support for green infrastructure (Yongchi Ma, 10 August 2020).

RECOMMENDATIONS

The recommendations highlight critical gaps in current urban water management practices. Addressing these gaps requires integrating policy frameworks, fostering financial innovation, and prioritizing public engagement. Furthermore, adopting NBS and emerging technologies is essential for ensuring long-term sustainability. By taking these steps, European cities can effectively scale Sponge City strategies and enhance their urban water resilience in the face of climate change.

Table 1: Recommendations for Scaling Sponge City Strategies

Category	Recommendation	Description & Examples
Policy	Strengthen Regulatory Frameworks	Align Sponge City strategies with EU directives (e.g., Water Framework Directive).
	Economic Incentives	Use tax benefits, subsidies, and stormwater fee systems.
	Climate Adaptation Planning	Integrate Sponge Cities into broader urban resilience policies.
Urban Planning	Multi-Functional Land Use	Combine water retention with public spaces
	Nature-Based Solutions	Promote permeable pavements, green roofs, and rainwater harvesting.
	Public Engagement	Involve communities in maintaining green infrastructure.
Financial Feasibility	Sustainable Funding Models	Use Green Bonds and climate finance for large-scale projects.
	Cost-Benefit Analysis	Conduct economic assessments to compare with grey infrastructure.
Sustainability	Maintenance Standards	Develop guidelines for long-term upkeep.
	Community-Led Maintenance	Offer tax credits for local maintenance.
	Monitoring & Assessment	Use digital tools.
Emerging Technologies	Smart Water Management	Implement AI and IoT-based solutions for stormwater management.
	EU-Wide Data Sharing	Create open-access hydrological databases for better decision-making.

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