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Editorial

Green Infrastructures for Urban Water System: Balance between Cities and Nature

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Abstract: Urban water systems face severe challenges such as urbanisation, population growth and climate change. Traditional technical solutions, i.e., pipe-based, grey infrastructure, have a single purpose and are proven to be unsustainable compared to multi-purpose nature-based solutions. Green Infrastructure encompasses on-site stormwater management practices, which, in contrast to the centralised grey infrastructure, are often decentralised. Technologies such as green roofs, walls, trees, infiltration trenches, wetlands, rainwater harvesting and permeable pavements exhibit multi-functionality. They are capable of reducing stormwater runoff, retaining stormwater in the landscape, preserving the natural water balance, enhancing local climate resilience and also delivering ecological, social and community services. Creating multi-functional, multiple-benefit systems, however, also warrants multidisciplinary approaches involving landscape architects, urban planners, engineers and more to successfully create a balance between cities and nature. This Special Issue aims to bridge this multidisciplinary research gap by collecting recent challenges and opportunities from on-site systems up to the watershed scale.

Keywords: environmental benefits; ecosystem services; water policy; performance assessment

1. Introduction

Urban water systems face severe challenges such as urbanisation, population growth and climate change. Green Infrastructure can help cities to adapt to these challenges by bringing a balance between cities and nature [1–3]. Traditional technical solutions, i.e., pipe-based, grey infrastructure, have a single purpose and are proven to be unsustainable compared to multi-purpose nature-based solutions [4]. Green Infrastructure encompasses on-site stormwater management practices, which, in contrast to the traditional grey infrastructure, are often decentralized [5,6]. Technologies such as green roofs, walls, trees, infiltration trenches, wetlands, rainwater harvesting and permeable pavements exhibit multi-functionality, which is of increasing importance for the evaluation of their performance in different parts of the world. For example, in Europe, the European commission launched the EU Research agenda for nature-based solutions and Re-Naturing Cities, requiring the evaluation of different performance criteria from an environmental, social and economic point of view. Nature-based solutions for urban water systems should therefore not only be capable of reducing stormwater runoff or retaining stormwater in the landscape, but they should also preserve the natural water balance, enhancing local climate resilience and also delivering ecological, social and community services.

Nevertheless, the technical interplay of Green Infrastructure with the traditional grey infrastructure is of great interest—hybrid solutions—to enable the use of synergies and facilitate a successful co-existence of both types of infrastructures [7].

Creating multi-functional and multi-beneficial systems, however, also warrants multidisciplinary approaches involving landscape architects, urban planners, engineers and more to successfully create a balance between cities and nature.

This Special Issue aims to bridge this multidisciplinary research gap by collecting recent challenges and opportunities from on-site systems up to the watershed scale.

The intended scope of this special issue encompasses:

- integrated, multi-disciplinary approaches
- pollution control, water quantity vs. quality
- operation and maintenance
- transitions processes and retrofitting
- design, optimisation and interaction with traditional system
- urban micro-climate, climate resilience, sustainability
- socioeconomics, policy
- ecosystem services, environmental benefits
- smart green infrastructure
- life cycle assessment

This Special Issue encompasses seven papers, covering a broad range of challenges and solutions on Green Infrastructure worldwide (Poland, US, Germany, China, Cyprus, Australia). With very different climates, policies, challenges and opportunities addressed by the contributions, this Special Issue offers a comprehensive collection of international studies. Different kinds of technologies such as green roofs, wetland roofs, in-stream treatment, permeable pavements, bioretention cells and rainwater harvesting are addressed, highlighting the diversity of Green Infrastructure.

2. Overview of This Special Issue

The seven contributions to this Special Issue include one review on multi-purpose wetland roofs and span topics of policy, regulation and financial aspects, design performance and evaluation as well as spatial analysis and issues of data availability.

2.1. Review on Multi-Purpose of Wetland Roofs

Zehnsdorf et al. [8] reviewed the application of wetland roofs as a decentralized water management option and discussed how this ecotechnology is increasingly utilized around the world and examines different experiences and possible applications. Of particular interest in this review is the historical development of this technology and how it contributes to biodiversity and climate regulation in buildings, and at the same time to stormwater management, making wetland roofs a multi-functional technology for urban areas.

2.2. Policy, Regulations and Financial Aspects

Herzog et al. [9] conducted interviews with water management professionals to understand the current opportunities and challenges of implementing Green Infrastructure. Different knowledge gaps in the context of cold season performance, life-cycle costs and regulatory limitations were identified. The authors discuss the inconsistencies in water quality performance of Green Infrastructure and infer that in-stream treatment strategies are essential for basin-wide pollution management. Therefore, an engineered hyporheic zone is proposed as in-stream treatment strategy for stormwater pollution control. Overcoming barriers for innovative stormwater treatment is also discussed.

Godyń et al. [10] discuss different rainwater management strategies for the retrofitting of housing estates. In Poland, investments in Green Infrastructure are still not common practice. Lack of local

policies and financial aspects were identified as key barriers. In particular, fees for rainwater drainage as an economic incentive to install innovative approaches is seen as too low to attract prospective investors. Given technological and societal benefits of Green Infrastructure, increasing the financial profitability (rate for return and payback period) would require that the incentive nature of rainwater fees is strengthened by higher municipal fees to motivate investors.

Akhter et al. [11] investigated the performance of different stormwater management systems.

The design and associated installation costs for conventional and hybrid drainage systems as a combination of grey and green infrastructure were analysed. A significant cost reduction (up to 19%) compared to conventional systems costs was determined, making the hybrid solution economically attractive for the investigated case study.

2.3. Design, Performance Evalutaion and Long-Term Experiments

Charalambous et al. [12] evaluated the long-term performance of green roofs in a semi-arid climate. The challenge of dry weather periods in combination with short intense rainfall events was investigated with a roof top experiment together with water balance computations. The results showed significant stormwater retention even during deficits in irrigation of the plant species on the green roof. No significant impact of substrate type and plant species on the stormwater retention was identified. As such, a combination of the green roof and rainwater harvesting system is proposed, demonstrating even further stormwater runoff reduction.

2.4. Spatial Analysis and Data Availability

Smets et al. [13] investigated how spatial land use configurations influence stormwater runoff. With different design experiments, the correlation of different landscape metrics with functional runoff connectivity was analysed and underlying mechanisms characterized. The systematic analysis showed that a fine-grained landscape with many small impervious areas should be favoured over course-grained landscapes. Even small changes in landscape patterns were identified to change the runoff, thereby encouraging all kinds of even small installations of Green Infrastructure in urban areas.

Randall et al. [14] tackled the problem of an insufficient level of detail in spatial data for hydrological modelling in cities by using remote sensing data. With satellite imagery, a detailed land cover map of an urban catchment was created and evaluated by means of hydrological modelling. However, automated classification alone did not reach high classification accuracy, while an inclusion of refining rules and additional data, such as elevation and parcel delineation, further improved the overall accuracy. Even for large storm events, considerable portions of the runoff volume could be retained with Green Infrastructure.

3. Conclusions

This Special Issue aims to bridge this multidisciplinary research gap by collecting recent challenges and opportunities from on-site systems up to the catchment scale. Creating multi-functional, multiple benefit systems, however, also warrants multidisciplinary approaches across expert domains in order to balance cities and nature. All contributions of this Special Issue on *"Green Infrastructures for Urban Water System: Balance between Cities and Nature"* acknowledge that it requires an integrated use of available technologies and maximization of their full potential to realize these multi-purpose approaches.

There are still barriers in policies and regulations, and it is difficult to realize the multiple benefits of the purely economic aspects of Green Infrastructure. These can only be identified with an integrated and broader view of the overall systems, which is usually not accounted for in decision-making. The contributions to this Special Issue addressed these challenges by reporting successful implementations worldwide and presenting experiences, novel design approaches and configurations to further stimulate the continued implementation of Green Infrastructure. Regardless of scale, even small strategies could also yield remarkable improvements—an encouragement towards all kind of implementations of Green Infrastructure. Finally, performance monitoring remains a crucial factor for efficient design and to convince

decision makers on the efficacy of these systems as well as to gain improved knowledge on system performance over the long-term, which is essential for accurate life cycle costing and further uptake.

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