Urban transformation towards resilient blue-green infrastructures (BGI)

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Problem definition and relevance: Urban areas are increasingly affected by heavy rainfall, heat waves and draughts as a consequence of climate change. Therefore, cities need to adapt to increasing weather extremes especially with regard to water (blue) and green infrastructure. Nowadays, it is evident that traditional sewerage systems are neither capable nor adequate to deal with such contrary weather events and that rainwater should be managed much more in the area and within the local water cycle rather than drained to the rivers. Likewise, it is clear that green infrastructure is needed to improve urban climate, mitigate heat waves, provide recreation room and, in particular, support local retention, storage and infiltration of rainwater. Green infrastructure thus forms a crucial element of blue infrastructure and, vice versa, blue infrastructure needs to provide sufficient water for urban green. Therefore, cities need to develop both their water (blue) and green infrastructures in an integrated manner that provides resilience against increasing weather extremes. Moreover, green and blue infrastructure is increasingly seen as means of providing livable urban spaces and urban ecosystem services including biodiversity. Nevertheless, BGI is still far from mainstream (1). Green and blue infrastructure is mostly developed incrementally and often subordinated to residential development. Apparently, BGI development is still inhibited by various technical, cognitive, economic, organizational and regulatory barriers. Social co-benefits and conflicts associated with BGI are often poorly assessed.

Research objectives and mission: We aim to support sustainable BGI development by assessing technological, organizational, social and legal challenges as well as benefits and conflicts and by developing viable solutions in terms of technology, integrated planning, governance, legal framework and capacity building. While particular emphasis is placed on the handling of stormwater, drought, heat, irrigation and cooling we also assess further benefits and trade-offs including, for example, with regard to energy efficiency, quality of life and social attitudes towards NBS. Therefore, we integrate various UFZ capacities in the relevant fields of sustainable urban development, including on monitoring and modelling of heat, cooling and health effects as well as sociological and legal aspects.

USP - Why at the UFZ? By its wide range of disciplinary capacities, the UFZ offers unique opportunities to provide the abovementioned multidisciplinary integrated assessment of all relevant (technological, societal, health and ecological) aspects of BGI development. BGI development is currently subject of two UFZ integrated research platforms: “CITYTECH (CT)” brings together UFZ scientist from different disciplines in an inter- and intra-disciplinary approach and is aimed at, i.a., integrated management of water quantity and quality as well as urban cooling and heating. In addition, the platform “Sustainability Transformations” (ST) conducts social science and governance related research on the realization of BGI in the context of transformations towards resilient cities. UFZ has also established extensive co-design cooperation networks, e.g. with the City of Leipzig, enabling extensive model projects and transdisciplinary research.

Results and Achievements

- **A potential analysis towards a runoff-free urban district** was developed for the Federal Environmental Agency (2) showing potentials, effects and legal conditions for a transformation towards a local wastewater and stormwater management. It demonstrated that decentralized measures of urban management of stormwater at the block level can significantly reduce the hydraulic and also material load on the central drainage system (2).
- **With the City of Leipzig as a highly committed model partner** (awarded one of six German model cities by the Federal Ministry of Education and Research) we cooperate(d) in various projects to develop model solutions for multifunctional BGI. Concepts for the adaptation of these infrastructures to climate change were developed and implemented at block- and city district level (3,4,5). Based on the project results, it is planned that 25% of the city districts will be disconnected from the central sewerage system for rainwater management.
- **BGI technology** is a core part of our research with a focus on the development, optimization and implementation of BGI as building blocks for integrated urban planning. Of particular importance

is research into the multifunctionality of these infrastructures. Therefore, research infrastructures and prototypes have been installed that bring together interdisciplinary research groups, as exemplarily established in the UFZ network "Green Roof Research". Around twenty scientists are researching the potential of these different infrastructures for storing rainwater, purifying urban water and also cooling the environment through evapotranspiration.

- **Typologies and indicators** for standardized planning and assessment of green infrastructures were developed that can also be applied/transferred to BGI (18/19).
- **Benefits, co-benefits and potential conflicts** associated with green and BGI are subject to a broad range of research activities at UFZ: With regard to urban heat and its health effects it was explored how to achieve optimal cooling effects, how to balance the biophysical drivers of heat (10) and tailor them to the specific situation in each neighborhood (11). Social conflicts that may arise from and pose obstacles to greening urban areas were studied in a series of projects covering, not least, the issues of green justice, inclusiveness and gentrification (16). Biodiversity effects and ecosystem services provided by blue and green infrastructure have been analyzed (17).
- **Governance arrangements** and legal frameworks are also the subject of our research making it highly unique. We conducted an analysis (6) of organizational, economic and legal aspects of BGI development. Governance structures and procedures were analyzed through stakeholder interviews and surveys and in cooperation with the German Association of Cities (German Städtetag). Recommendations on the legal and governance framework were developed (7,8), discussed with stakeholders and professional networks (DWA 2022) and presented to decision makers in policy papers (9). Moreover, the social perspective and reception of BGI by citizens were assessed (15).
- **New models of cross-sector communication** have been developed together with our model partner city of Leipzig in order to facilitate integrated infrastructure planning and coordination between the various responsible agencies. A special coordination network was set up in co-design with the heads of the administrative departments, the authorizing officers and the municipal companies. An interdisciplinary steering committee was established to support the paradigm-shift.
- **At EU level and international scale** infrastructure planning tools are developed. Next to EU research partners and SMEs, we co-design urban planning with six EU cities and 4 international city partners. Our research addresses, amongst others, the question of how to integrate BGI and traditional centralized drainage structures and make the latter climate resilient, too. On a global scale, OCTOPUS (12) is contributing to the development of a graph-based optimization of wastewater treatment plants that estimates global cost savings for SGD6. Further methods were developed for monitoring (13) and modeling (5) of BGI.

Outreach and Impact: Our research aims to derive applied solutions within our model projects that can also be recommended and transferred to similar constellations in other cities. Transferable products include technologies, typologies, models and methods. Together with the relevant administrations we develop a specific co-design methodology and a new cooperation structure (steering network) as mentioned above. Recommendations on how to improve the legal and fiscal framework are communicated to the legislators via policy paper (9), and we are advising the federal Government in current efforts to support BGI development through an amendment of the Federal Building Code (BauGB). Based on these achievements co-design methodologies and implementation networks were also extended and transferred to five transboundary river basins in Europe and Africa.

Next Steps / Outlook

- **Future prospects for hydrological and thermal storage cascades:** The idea is to harness the energy potential of hydrological and thermal "heavy rain situations" in a controlled manner. Such energetic use has the great advantage of multiple use of the expensive storage infrastructure. However, it is complex and has to be controlled by a dedicated FDT model system coupled to large-scale weather and climate models (pos. Partners: A. Dahmke, Kiel, and RU SMART MODELS/S.Attinger).

- **Urban water quality**: In terms of water quality, novel strategies for urban water management need integrated smart monitoring, and hydrological exposure modelling strategies. We plan to collaborate on the development of novel assessment methods and strategies aimed at identifying critical pollution pathways of the urban drainage systems (RU Chemicals in the Environment/W.Brack)
- **Establishment of a PHD School**: In order to highlight the research on water quality the PhD college CLEANER will identify control options (microbial activity, absorber capacity, plant-based biotransformation etc.) for decentralized urban water treatment and as a basis for the implementation in BGI using an interdisciplinary approach.
- **Avoiding regional water conflicts**: A pressing question for the nearest future will be to develop solution for an IWRM for the urban, rural and agricultural systems (RU Water/D. Borchard).
- **Synergy with research on "extreme events":** We will seek closer cooperation with UFZ research on extreme events (C. Kuhlicke) as a closely related field of analysis.

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