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Flooded with potential: urban drainage science as seen by early-career researchers

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ABSTRACT

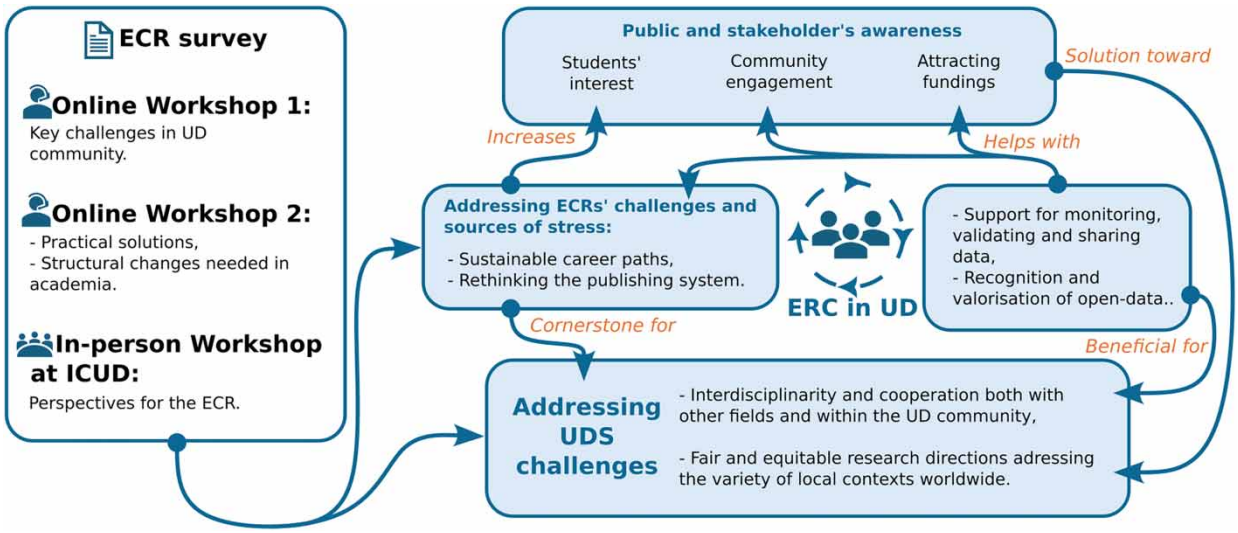
This opinion paper reflects on the current challenges facing urban drainage systems (UDS) research, along with solutions for fostering sustainable development. Over the course of a year-long project involving 92 participants aged 24–38, including PhD candidates, post-doctoral researchers, and early-career academics, we identified critical challenges and opportunities for the sustainable development of UDS. Our exploration highlights four key challenges: limited public visibility leading to resource constraints, insufficient collaboration across subfields, issues with data scarcity and data sharing, and geographical specificities. We emphasise the importance of raising public and political awareness regarding UDS's vital role in climate adaptation and urban resilience, advocating for blue-green infrastructure and open data practices. Additionally, we address systemic academic barriers that hinder innovative research. We call for a shift away from metrics that prioritise quantity over quality. We recommend establishing stable career pathways that empower early-career researchers. This paper aims to catalyse a broader community dialogue about the future of UDS research, uniting voices from various career stages. By presenting actionable recommendations, we aim to inspire fundamental changes in research conduct, evaluation, and sustainability, ensuring the field of UDS is prepared to meet pressing urban water management challenges worldwide.

Key words: academic culture, data sharing, early-career researchers, interdisciplinary collaboration, sustainable development, urban drainage systems

HIGHLIGHTS

- During a year-long project, involving 92 early-career researchers, we identified challenges and opportunities for urban drainage systems (UDS) research.
- We examine four UDS-specific challenges: limited public visibility, lack of interdisciplinary collaboration, data scarcity, and geographical variability.
- We explore two systemic academic barriers: issues with the publishing system and the precarious academic career path.

GRAPHICAL ABSTRACT



INTRODUCTION

Sewer and drainage systems have been used since ancient times to handle waste- and stormwater (Burian & Edwards 2002; Cun *et al.* 2019). As cities grew, reliance increased on sewer networks to ensure public and environmental health. This growing reliance has led to a need to better understand the processes related to the sewer networks, giving rise to the academic field of *urban drainage systems* (UDS). The understanding of chemical, biochemical, physical, hydrological, and hydrodynamic processes of UDS has resulted in various design standards, monitoring requirements, and best practices. Despite the lack of a quantifiable study on this topic, we believe academic research has positively influenced the design, maintenance practices, and operation of UDS. For example, research on the effectiveness of blue-green infrastructure (BGI) in mitigating pluvial flooding, reducing combined sewer overflows, and enhancing pollutant removal has shifted the focus towards retaining stormwater locally, rather than channelling it into the sewer network (Alves *et al.* 2019; Liu *et al.* 2021). Nevertheless, several key research challenges and shortcomings continue to exist.

Urban areas face increasingly complex challenges in draining and discharging wastewater and stormwater due to the growing proportion of impervious surfaces, rising populations, and the intensifying impacts of climate change (Francisco *et al.* 2023). Compounding the issue, more frequent and intense storm events can overwhelm existing drainage infrastructure, resulting in urban flooding and pollutant discharge into natural water bodies. Financial constraints faced by water and wastewater utilities often limit their ability to invest in necessary upgrades and maintenance, exacerbating the situation. Furthermore, much of the existing infrastructure is aging and in need of rehabilitation, resulting in reduced reliability and increased risks. The urban drainage academic community aims to better understand these problems and develop new methods to counter them.

This manuscript presents the perspectives of early-career researchers (ECRs) on urban drainage academic practices, considering barriers and opportunities in working towards resolving UDS-related issues. As ECRs, who contribute significantly to

scientific output in urban drainage (Larivière 2012; McDowell *et al.* 2014) and whose relative influence is projected to grow (Rørstad & Aksnes 2015), we face numerous challenges in a non-perfect academic system, including uncertain futures, a rapidly changing research field and research practices, and inundation of publications coupled with the pressure to publish (Woolston 2019; Mutongoza 2023). Through this opinion paper, we aim to highlight critical research challenges, propose future research directions, and advocate for scientific reforms to enhance practical impact. Inspired by and going beyond similar discussions in other disciplines (McDowell *et al.* 2014; van Hateren *et al.* 2023), we hope to enrich the dialogue with insights and fresh perspectives on the obstacles faced by ECRs.

This opinion paper and our findings therein come from a year-long initiative that gathered perspectives from PhD students, post-doctoral fellows, and other early-career academics worldwide (Figure 1) to address key research issues and challenges in urban drainage. Using a survey with 92 participants, informal discussions, three online workshops, and a final in-person session at the 16th International Conference on Urban Drainage (ICUD) in 2024 in Delft, the Netherlands, we identified persistent challenges, their root causes, and strategies for meaningful academic contributions. Results from the discussion were documented and summarised by a key writing team, who also prepared the survey and the sessions. Through a collaborative and iterative writing process, this work was produced as a conclusion of the year-long exercise. This work is organised in two parts: Part I analyses four barriers unique to urban drainage research and offers solutions. Part II addresses broader academic practices and examines how they impact ECRs and, consequently, the future of urban drainage academic practices.

PART 1: academic issues and suggested solutions specific to UDS

One of the key aims of the survey and the workshops was to elicit barriers that inhibit progress in our field. Based on their results, we identified four main themes as the major barriers: (1) the lack of public visibility and resources; (2) the highly interdisciplinary nature of research in the urban environment; (3) data scarcity; and (4) the differences in socio-economics, climate, regulatory frameworks, and existing infrastructure across local and regional contexts.

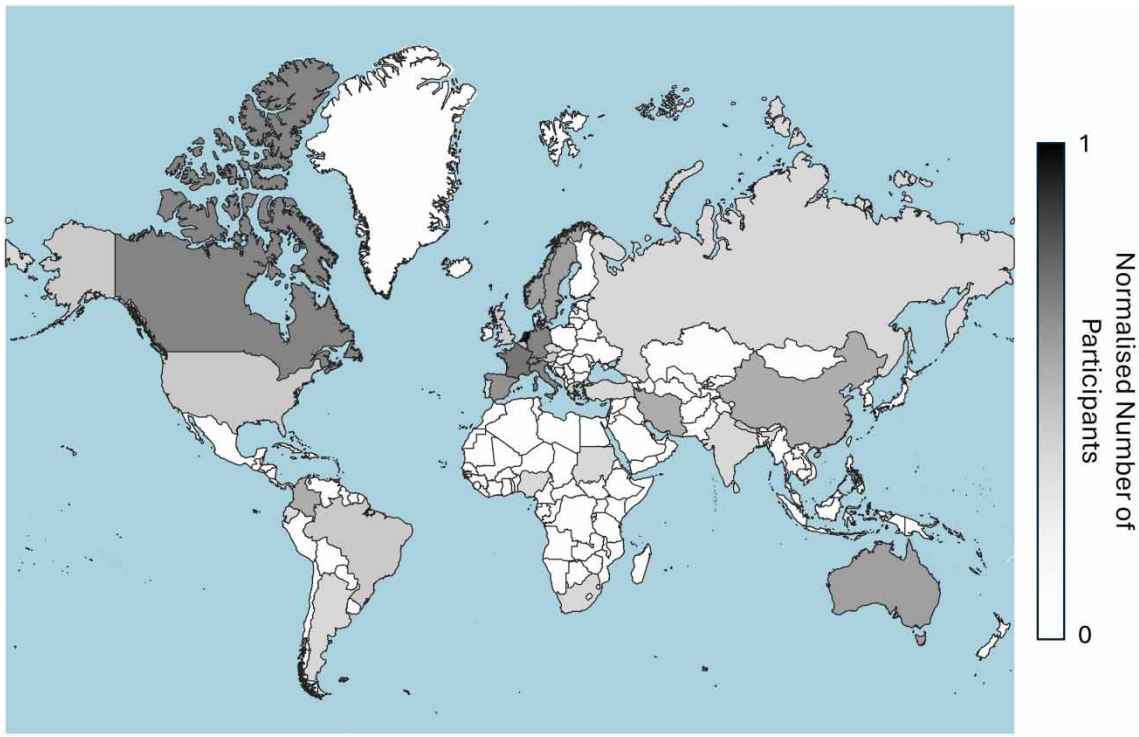


Figure 1 | Overview of the background of the participants. This visualisation highlights the countries the participants are from, are residents of, or have worked or studied in the past. Values are max–min normalised (e.g., 1 for the Netherlands, the country with the highest number of participants).

PART 1.1. – Lack of public visibility and lack of resources are interconnected, and the solution starts with raising awareness

UDS often remain unseen to the public, resulting in an 'out of sight, out of mind' mentality. This, in turn, leads to a lack of financial resources in the urban drainage field, reflected in the relatively low replacement rates of aging infrastructure. The chronic underfunding of urban drainage infrastructure, as well as institutional barriers such as sparse research funding opportunities and skilled labour shortages, have been highlighted as major barriers for academic innovation in the past (Chocat *et al.* 2004; Shkaruba *et al.* 2021). Considering the direct funding of research, we identify a current mix of three main funding structures for urban drainage research: (1) targeted calls by (inter)national research funding agencies; (2) industrial partner funding (i.e., contract research or consultancy with municipalities, water boards, or privately operated companies); and (3) open research calls. The bulk of the research funding in our field comes from the first two structures. This mix of funding can make it difficult to maintain a continuous line of research. Targeted calls and funding from industrial partners often lead to research directions being driven from outside of academia, only partly supported by a select group of senior academics. It also means that the views of early-career academics have an even smaller potential impact on future research directions, as those funding streams often prioritise the input of established researchers.

Another significant obstacle within urban drainage academia is the scarcity of skilled personnel. The limited number of civil engineering graduates, in comparison to the projected increased need due to urbanisation and aging infrastructure, exacerbates this issue. For instance, a survey of Swedish water and wastewater organisations indicated a need to grow by 19% in the number of employees in the coming 3 years in order to fulfil their needs (Swedish Water & Wastewater Association 2024). In the Netherlands, a project called *Operation Strong Water*[1] has recently started, aiming to attract a larger workforce to the urban water sector to solve an issue of similar magnitude as the Swedish case. Enhancing the sector's attractiveness is crucial to addressing the ongoing issues of insufficient and unevenly distributed funding, the shortage of skilled professionals, and the limited research opportunities in the urban drainage field. It is imperative to increase public awareness (decision-makers as well as citizens, including younger generations) regarding the benefits of UDS.

Often, the public becomes aware of the importance of UDS only after a catastrophic event caused by extreme rain. Our survey revealed that personal experiences or exposure to news about urban flooding and water quality issues motivated 64% of respondents to pursue a career in UDS. While these developments can draw attention to UDS, educating the public about the complexity and extended timelines required for urban drainage improvements is crucial for maintaining community support when immediate results are not visible. We should also prioritise highlighting sustainable solutions instead of reactive and short-term investments. Given the close ties between UDS, climate change, and the environment, academic communication plays a critical role, with open-access publications and science communication training as potential avenues for improving public understanding. Collaborating with various stakeholders in these efforts can also ease the demands on researchers' time, enhancing their ability to effectively engage the public through approaches like serious games and other educational tools.

Not only should we raise public awareness in reaction to a catastrophe, but we should also actively and proactively communicate about the importance of UDS in improving urban cleanliness and reducing cities' impacts on the environment. Citizens in the United Kingdom are much more aware of UDS now that there are stricter rules on combined sewer overflow (CSO) emissions, monitoring, and data reporting (Usher 2023). More recently, the efforts to clean the Seine River in France in preparation for the 2024 Olympic Games in Paris have highlighted the importance of UDS in safeguarding the health of the river and the potential recreational benefits for inhabitants (Winston Nicklin 2024). When accompanied by educational measures, implementing BGI can also positively impact the visibility of our field. This can be achieved by highlighting the role of BGI in urban water management, along with their co-benefits in creating greener, more attractive urban landscapes that provide social benefits. We should ensure that citizen science tools are deployed on the themes of UDS to further raise awareness and help citizens reappropriate urban water.

Finally, apart from the public, decision-makers shaping future policies and development actions must also be well-informed about the relationship and interdependencies between UDS and public health, flood mitigation, water quality issues, water use patterns, and the broader socio-economic repercussions. By emphasising the importance of UDS in protecting communities and the environment, we can promote greater investment in this field. Researchers have a role in developing knowledge

[1] www.operatiesterkwater.nl – Resource is in Dutch only, but can be translated using free online tools. (Accessed: 28-2-2025)

and collaborations, and in disseminating information, but governments must also understand the UDS's role in responding to climate urgencies, biodiversity loss, and other planetary boundaries at risk.

Part 1.2. – Interdisciplinarity in urban water management: challenges, opportunities, and the role of early-career researchers

Urban water management has evolved to become a multidisciplinary field. Originating in civil engineering, particularly the rise of BGI, has meant that the discipline now integrates various sciences – including hydraulics, hydrology, water chemistry, biology, material science, soil science, mathematics, economics, computer sciences, urban planning, legal science, and social science, as pointed out by Bertrand-Krajewski (2021). This integration often stimulates the growth of new research areas by combining diverse disciplines, such as ecohydrology, merging biology, ecology, and hydrology to better understand dynamic urban environments (Wilkening *et al.* 2024). The growing trend towards a multidisciplinary approach is beneficial, as it drives the emergence of new fields and offers clear frameworks for the further development of sustainable urban water management.

However, the adoption of an interdisciplinary approach to urban drainage poses several challenges. These challenges are primarily due to the vertical specialisation of younger researchers, the general tendency of research groups to focus solely on their specific fields, the structural division between university departments, and the communication challenges arising from differing disciplinary approaches and vocabulary. Additionally, many editorial boards of journals and conference organisers, along with organisations supporting research and governing authorities, have yet to actively promote or encourage interdisciplinary and transdisciplinary research efforts. The result is that our scientific community often fails to examine problems from different perspectives and to optimally leverage existing knowledge from other disciplines on related topics. A noted side effect of interdisciplinary research, however, is the reduced 'productivity' in terms of output (Leahey *et al.* 2017). In Part II, we will further set out why we believe that this side effect should not be considered negative per se. Beyond productivity concerns, publishing multidisciplinary work faces challenges due to the discipline-specific structure of academic journals.

Cooperation between researchers, industrial partners, and governmental organisations (e.g., municipalities and water boards) is needed to effectively translate research into action. For instance, in Malm & Löfdahl (2020), an 'action-based research' approach is adapted where research outcomes directly translate into tangible improvements within participating organisations. This is supported by a competence-building component to bridge the gap in the availability of skilled labour and improve public awareness of UDS. Such multifaceted approaches ensure that research findings are directly applicable, contribute to capacity building within stakeholder organisations, and promote sustainable solutions. However, industrial and research partners differ in terms of time and resource constraints as well as in end goals. In collaboration, it is important to balance the perspectives of both academic researchers, including ECRs, and industry partners when selecting research topics. Indeed, input from researchers on topic selection can help focus on innovative and emerging areas as opposed to tried-and-tested industry standards. This can, in turn, yield more interest and advancement in the field.

Among the successful strategies to promote an interdisciplinary scientific approach, research teams from different backgrounds can co-supervise early-career scientists (i.e., PhD candidates), making them the key to coordinating, concentrating, and applying knowledge from various disciplines. Mitigating communication barriers between researchers from different fields can begin at the undergraduate or graduate level through interdisciplinary education. Encouraging early-stage collaboration between students from various disciplines can help them build essential skills and develop a shared language that will be crucial in their future professional work. Fostering these early interactions can help mitigate communication barriers and enhance collaboration in complex fields later on. The open-ended and open-structured nature of such interdisciplinary collaboration boosts creativity by encouraging students to solve problems across different fields (Rhoten *et al.* 2009).

Moreover, support from funding organisations for cross-disciplinary research initiatives could present an opportunity to enhance and strengthen interdisciplinary collaboration. This avenue offers significant potential to address complex water-related challenges by bringing together diverse expertise and fostering partnerships across various disciplines and borders. To address this, journals could benefit from fostering greater collaboration across fields and seeking reviewers with the skills to evaluate interdisciplinary research. Structural changes, such as increasing the number of interdisciplinary journals and providing training for reviewers handling multidisciplinary submissions, would also be valuable steps. Additionally, it would be helpful for the academic system to start recognising and rewarding interdisciplinary efforts, encouraging a shift in both research and publishing.

In this context, we believe that a UDS-wide ECR community can play a key role in defining the pathway for a more interdisciplinary scientific approach and support ECRs within this broader research environment. Networks such as the Young Hydrological Society, the International Association for Hydraulic Research's Young Professional Network, and the International Water Association's Young Water Professional have demonstrated effectiveness in connecting individuals working in similar fields. As a product of this ECR initiative, we are currently working on the development of a new platform to share ideas, discuss them openly, and collaborate, allowing ECRs to build on each other's knowledge.

Through this platform, we aim to effectively leverage the diversity of backgrounds in our field and transform the challenges associated with interdisciplinarity into strengths. Although a platform like this could also be beneficial to more senior researchers, limiting it to ECRs ensures that there is no dependency relationship between participants. This would provide better support for newcomers to the field, helping them grasp its interdisciplinary nature. Relying on senior colleagues is essential for quickly achieving a significant level of scientific maturity. However, it is important to spread awareness within the scientific community that young researchers can build their own relationships early on in their careers. These created collaborations can then provide real added value for their personal scientific growth as well as for their research groups.

Part 1.3. – A more systematic way of sharing data and information holds the key to moving urban drainage research forward

To better understand the dynamics within urban drainage networks, reliable data on various parameters (e.g., water levels, flow velocity, and chemical composition) are essential (e.g., Oberascher *et al.* 2022). However, even the most extensive operational monitoring networks cover only a relatively small number of locations compared to the vastness of the urban drainage networks being studied (Schellart *et al.* 2021). While these networks are designed, operated, and maintained primarily by entities responsible for drainage system operations, they are often focused on meeting legislative requirements (e.g., the revised Urban Wastewater Treatment Directive in the European Union) and addressing immediate operational needs. In contrast, research-driven monitoring could address long-term issues like system sustainability and the impacts of emerging challenges, such as climate change or new pollutants, through increased collaboration with research institutions.

To achieve this monitoring gap, long-term monitoring projects, ideally spanning several years or even decades, should be established. This is, however, particularly challenging given the short timelines of typical research projects (usually lasting less than 5 years). Additionally, the availability of funding for such long-term data collection is limited, making it difficult to secure the necessary resources to ensure consistent, high-quality data over extended periods (see Section 1.1). This complexity is exacerbated by the need for specialised equipment and information–communication–technology (ICT) tailored to the unique requirements and conditions of each study site.

Examples of successful long-term, research-oriented monitoring networks do exist (e.g., the Urban Water Observatory by EAWAG, Switzerland[2]; (Blumensaat *et al.* 2025) OTHU by INSA Lyon, France[3]; Minneapolis-St. Paul Long Term Ecological Research (LTER) Programme by NSF, USA[4]). However, given that UDS are highly location-specific, more of these monitoring networks should be implemented to capture different UDS characteristics. To do this most effectively, financial and time sharing across institutes, through cooperative projects like the Co-UDlabs project (Co-UDlabs 2021) should be further explored. In particular, the potential of new technologies, such as low-cost submersible sensing, non-contact sensing (e.g., radar, spectral, and image-based) techniques, and data acquisition and transmission technologies, should be explored in such academic long-term monitoring networks.

The data from either research-specific monitoring networks or from 'real' UDS networks should, where possible (understanding privacy and cybersecurity limitations), be shared openly in the community. There are a few examples of such initiatives, like the Stream website in the UK[5] or the UWO in Switzerland (Blumensaat *et al.* 2025). More of these systems should become available to understand dynamics under a range of different UDS designs, operations, and characteristics. To this end, open data sharing should be framed as a proactive demonstration of their commitment to transparency, resource optimisation, and the well-being of the community. By engaging actively in research efforts aimed at optimising and

[2] https://www.eawag.ch/en/department/sww/projects/urban-water-observatory/ – Overview and updated website of the UWO. (Accessed: 28-2-2025)

[3] https://deep.insa-lyon.fr/eo/content/othu – Overview and updated website of the OTHU. (Accessed: 28-2-2025)

[4] https://mspurbanlter.umn.edu/ – Overview and updated website of the MSP LTER. (Accessed: 28-2-2025)

[5] https://www.streamwaterdata.co.uk/ – Website accessing the UK data sharing initiative *STREAM*. (Accessed: 28-2-2025)

understanding UDS, these entities show dedication to advancing system efficiency and environmental responsibility, thus fulfilling ethical obligations while building public trust and credibility.

Likewise, the open sharing of data, methodologies, and models following the FAIR principles, which enhance the findability, accessibility, interoperability and reusability of digital assets (Wilkinson *et al.* 2016), is a very positive development within the scientific community but has not yet been fully exploited by the urban drainage community. One of the main hurdles is that large datasets derived from monitoring networks struggle to disseminate all metadata effectively and comprehensively. This challenge remains largely unexplored, as only a limited number of UDS models and datasets are currently available, with the Bellinge dataset (Pedersen *et al.* 2021) being among the most notable examples. Equally, the sharing of models and codes through open repositories following the FAIR principles should be encouraged beyond sharing on request. The findability of datasets and their usefulness should be one of the priorities of the community. Since producing high-quality datasets takes time, resources and effort, we should ensure that the datasets we publish as a community are easy to find. Other fields in water (e.g., water distribution systems) tend to use benchmarks, models, and datasets for testing and validating methodologies. A set of datasets representing the wide variety of UDS could benefit the community in developing transferable methods. This touches directly on the relationship and dependencies between academia and practice, which underpins a lot of potentials, as well as barriers within urban drainage research (see, for example, Section 1.1 regarding academic funding).

We note that another challenge consists in following the FAIR principles themselves. Indeed, the community should point towards smart data collection (i.e., with robust routines to ensure the quality of datasets as well as a prioritisation of the data to be collected), rather than excessive data collection with poor data quality routines (Zolghadr-Asli *et al.* 2024). Sharing data as supplementary material in an open-access repository or as a data paper, is increasingly recommended as part of publishing guidelines. However, open data does not necessarily ensure good documentation of the data and the reproducibility of the results. Requiring a peer review process for making datasets available could help to address this issue. Open-access repositories tend to have a technical review of datasets, while data papers may favour a scientific review (Mayernik *et al.* 2015). These papers should not only consider the data structure but also the uncertainties related to the measurement describing the precision of the sensors, the installation, the calibration, or the data processing. We argue that both technical and scientific reviews are needed to ensure good quality of datasets. It could be made easier by agreeing within the community on standards for data sharing to avoid overly demanding reviews of larger datasets.

We, therefore, see shared community standards as essential, and they should be defined as early as possible. This should be a key responsibility for one of the existing international collaborative structures, as this will allow more widespread and rapid uptake and dissemination. We believe that the Joint Committee on Urban Drainage[6], a specialist group under the IWA and IAHR, would be well-positioned to assume a coordinating role for developing and maintaining standards, such as an ontology for urban drainage, facilitating the implementation of good practice of dataset documentation. This could be through the formalisation of tasks to the Joint Committee on Urban Drainage (JCUD) working groups, including those organising the various UDS conferences, or facilitating the acquisition of necessary financial means. The JCUD working group could have among their responsibilities the requirement to maintain those standards, harmonising practices among the different subfields of urban drainage. From the perspective of ECRs, we do want to emphasise that the extensive standardisation and documentation of datasets should not be a task placed on the shoulders of doctoral students without offering sufficient training in data management best practices and without compensating the additional time required for this task. A possible compensation would be the acceptance and promotion of datasets publications in data journals (e.g., *Data in Brief*[7], *Chemical Data Collections*[8], *Scientific Data*[9], and *Earth System Science Data*[10]) as inherent parts of PhD theses. In addition to an overview of the scientific nature of the work, data papers include detailed information about the data itself, including the circumstances of its collection, its structure, and potential uses.

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[6] www.jcud.org – Website of the Joint Committee Urban Drainage, falling under the International Water Association (IWA) and International Association for Hydraulic Research (IAHR). (Accessed: 28-2-2025)

[7] https://www.sciencedirect.com/journal/data-in-brief – *Data in Brief* Elsevier journal

[8] https://www.sciencedirect.com/journal/chemical-data-collections – *Chemical Data Collections* Elsevier journal

[9] https://www.nature.com/sdata/principles – *Scientific Data* Nature journal

[10] https://www.earth-system-science-data.net/ – *Earth System Science Data* Copernicus journal

Part 1.4. – From global north metropolis-centric research, towards fair, equitable, and systematic assessment of UDS challenges

Another key difficulty in urban water management is the wide variety of contexts. The challenges in a city with a dense city centre and a combined sewer system built one hundred years ago differ drastically from those in a recently expanded city where all the infrastructure is newly constructed. Similarly, the context differs between a large city that can hire several water engineers dedicated to urban drainage and a remote municipality that may, at best, hire one water engineer for wastewater, stormwater, and drinking water. Differences in local climate characteristics cause drastic variations in the performance and capacity of infrastructure, such as green infrastructure. It is challenging to generalise findings between these different contexts.

The awareness of the variety of contexts raises several additional questions that are more directly related to our community of researchers: Where is it most critical to improve our knowledge of UDS, and how do we prioritise them? Are we funding enough projects to cover a wide variety of contexts? How do we deal with temporarily changing conditions such as in a conflict-ridden region? As we often conduct research near a university hosting an urban drainage research group, we must question how much research is transferable and if our topics are biased by preferred partners for research projects. A significant portion of our research concentrates on issues crucial to post-industrial nations, like managing aging infrastructure. Indeed, our survey, which involved participants who lived in 36 different countries (see Figure 1), identified poor UDS management in the respondents' country of residence as a key issue. Our survey was distributed through the cumulative network of the first authors, including distribution through various urban drainage academic programs primarily in Europe, North America, and Australia. Less-represented areas had fewer respondents due to a lack of author contacts in these areas, despite attempts to reach these areas through ECRs with connections to them (i.e., previous places of work or study).

Globally, however, aging infrastructure is less of a central issue as billions of people still live without access to a sewered sanitation system. Our community can make additional efforts to better understand processes, optimise systems for non-sewered areas, participate in the dissemination of knowledge and experience, and overcome traditional barriers to cooperation like language (e.g., the RISE programme funded by the Welcome Trust). Such research directions should be done through cooperative projects with local stakeholders. We believe that the current paradigm, which derives funding from stakeholder investment in large cities in the Global North, favours research that directly privileges Global North metropolises. Although this could initially appear positive as it addresses challenges in large impervious areas that are responsible for a large part of environmental degradation and contribute to flooding, it also leads to a significant underrepresentation of the knowledge, priorities, and ideas of other groups in research topics.

To overcome the geographical specificity of infrastructure, and therefore the difficulty of solving the underlying scientific questions raised in Part I, increasing international collaboration is necessary. As discussed in the previous section, our community should prioritise data sharing as a key contribution, as it helps generalise research across various site-specific conditions. The Catchment Attributes and Meteorology for Large-Sample Studies datasets (CAMELS) employed by the hydrology community since 2017 are an example of success in overcoming the challenges of geographical specificity. Nevertheless, within these collaborations, we emphasise the benefits of institutes working with case studies outside of their own national boundaries.

In the context of UDS, we would promote the adoption of the International Association for Hydrological Sciences' approach by designating a topic for analysis within a scientific decade. The urban drainage community could emulate these scientific decades, which have demonstrated the potential to significantly enhance understanding in a subsection of the hydrologic sciences (Hrachowitz *et al.* 2013). The hydrological field has formalised these community efforts, as evidenced by their ability to reach a broad consensus on key questions (Blöschl *et al.* 2019). We encourage this form of collaboration and advocate for its implementation and coordination in both informal and formal settings. Therefore, we should consider conducting a broader survey among not only academics but also urban drainage practitioners and decision-makers, building on our previous survey and the early work conducted by Tondera *et al.* (2023). Smaller initiatives, akin to the *battle of the networks*[11] in the drinking water sectors and the battle *of leakage detection*[12], can form a beneficial step-up platform for wider community engagement and are now a part of the *Urban Drainage* Modelling Conference, 2025[13].

[11] https://wdsa-ccwi2024.it/battle-of-water-networks/ – Battle of Water Networks

[12] https://battledim.ucy.ac.cy/ – Battle of the Leakage Detection and Isolation Methods

[13] https://www.uibk.ac.at/en/congress/udm2025/udm-nbs-combat/ – Battle of the Nature-Based Solutions. (Accessed: 2-3-2025)

Part 2 – Academic practices: How they inhibit UDS research and research implementation

During the ECR workshops, we discussed issues beyond the UDS domain and thereby focused on more general academic practices. From our survey, we see that there is only limited belief that current academic practices can resolve the issues identified in Part I. We will therefore argue that fundamental changes are necessary within academic practices and propose concrete measures to achieve this goal. Two main aspects of the academic culture will be discussed in depth: (1) the publishing system and (2) academic career paths. Although we take a UDS perspective, the main arguments presented here are applicable to academic culture in the wider sense.

Part 2.1. – Rethinking academic publishing: addressing systemic challenges and promoting quality and accessibility

The academic publishing system is currently facing a crisis. Dissemination of academic ideas has traditionally gone through peer-reviewed journals to enable a review of the validity of the conclusions against the methodology and results. This system, designed at a time when the scientific community was much smaller and when scientific publications were printed in paper journals, is today being challenged by new ways of communication and increasing scientific production. Compiling the number of publications per commonly read journal in the urban drainage fields shows an over six-fold increase in the number of publications over the course of two decades (Figure 2). This trend, which may at first glance be coming from a positive improvement in scientific production, is also the consequence of an increasingly profit-driven approach to science, and more generally, the *publish or perish* phenomena (De Rond & Miller 2005). *Publish or perish* comes from the tendency to quantify academic impact using metrics related to their publication record (e.g., *H*-index, number of citations), pushing academics to publish as much as possible, at the cost of scientific quality (Adler & Harzing 2009). These problems were already highlighted in the early 2000s but still resulted in the exponential rise in publications. It points towards a difficulty to change this mentality, despite widespread acknowledgements of the problem.

If we fail to find a solution to the *publish or perish* problem, it will become increasingly harder to rely on the quality of the peer review process, as reviewers will become overwhelmed with the number of papers to review. This conversation has already occurred at the editors' level in other fields, with the notion that we should publish less but more impactful research (Jin 2024). From our perspective, a logical starting point could be to put less pressure on ECRs to publish. In most institutions, PhD theses are still expected, though not formally required, to contain 2–4 published papers, a practice frequently perpetuated by supervisors, departmental pressures, or implicit benchmarks for academic competitiveness. Candidates often face pressure to conform to this informal standard to satisfy the expectations of the examination committee. Returning to the

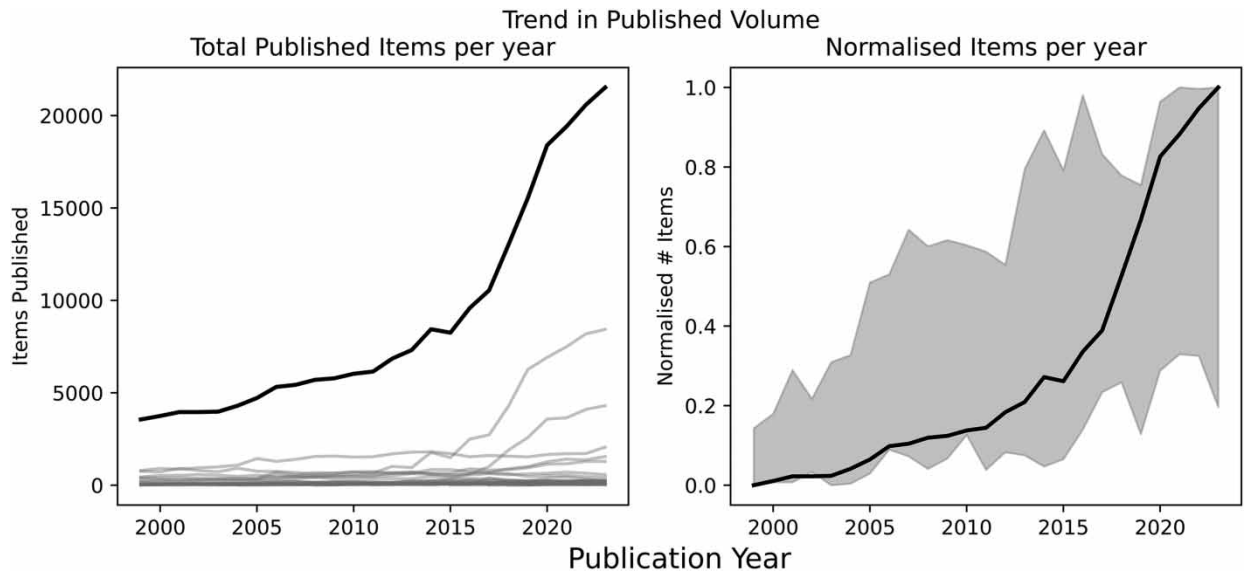

Figure 2 | Development of the number of publications in journals related to the urban drainage field, showing a nearly six-fold increase since the early 2000s. Left: Individual trends, per journal, marked by the grey lines and the total trend in black. Right: Normalised values (min–max), with the grey shade here indicating 90%iles for normalised number of publications per journal. Journal details are provided in the Appendix in Section S1.

PhD thesis itself as a standalone document could have significant benefits, such as pertaining to the efficiency at which PhD candidates can work. The choice of format, in any case, should rest on the preference of the PhD candidates themselves, as opposed to external cultural or career-driven pressures.

More than just jeopardising the quality of reviews, the increasing number of publications makes it complicated to keep track of the advances in the field. It becomes more important to prioritise which paper should be read in depth. This is particularly a concern in a field where multidisciplinary approaches are becoming more important (cf., Part 1.2). Additionally, being able to prioritise which articles to focus on is a skill that is developed over years of academic experience. ECRs, necessarily new to the field, disproportionately suffer from the increased volume of publications, particularly in the first stages of their research. With the peer review system starting to break down, the onus of understanding the academic quality and validity of the papers falls on the reader themselves. This again is disproportionately challenging for those new to the UDS field.

Given the inter- and multidisciplinary nature of our research, easy access to new research in each discipline is key. While it could be argued that artificial intelligence (AI) solutions may help researchers navigate an increasing flow of papers, important questions need to be addressed. Using generative AI or algorithms for recommending and summarising relevant papers for a specific question brings issues that may be more concerning than the increasing number of papers: the alarming question of the ethics of algorithms (Mittelstadt *et al.* 2016). We need to make sure, especially in research, that we understand how such AI models or algorithms work and to what extent their recommendations are transparent or biased. If more powerful tools for paper searching must be used, we need more effort in labelling papers. Guidelines should be developed on this in the coming years.

Another widely discussed issue related to the publishing system is the financial aspect. In the past, authors of a scientific manuscript would pay an editor to handle the review and publish the paper in a printed journal that other scientists would buy to access the information. Nowadays, even though most scientific works are published online (a process that is less costly for the publishers), publication prices and journal subscription fees are increasing. It appears that (private) journals are profiting from, often public, money invested in research.

There are two aspects to consider on the financial side of publishing: from the reader's perspective (considering the accessibility of research, for example) and from the authors' perspective. For the reader, the recent trend is pushing for more open access as a positive development, as it enables anyone to read the latest developments in various fields. This development is partially driven by the funding agencies that increasingly mandate open-access publishing of results. Considering the authors' perspective, publishing open access is often linked to an increase in the price on the publishing side. This leads to additional disparities between unfunded and funded research, as well as increasing publishing barriers for researchers with a lower budget –typically young researchers and researchers from low- and middle-income countries. Publishing structures around pre-print and corrected-proof repositories (HAL, arXiv, and ResearchGate) allow all research to be freely available without additional costs for authors and take away a large barrier for all researchers to both get their work out there and read the latest developments. The widespread dissemination of non-peer-reviewed works, however, has risks associated with it that should be better understood in our field and in scientific publishing in general before we set on a particular publishing structure. IWA Publishing *Subscribe to Open* offers an interesting potential publishing structure. However, the fact that it does not cover fees for independent researchers and provides only limited coverage for low-income countries still leaves room for improvement.

Last, the publishing focus on 'novelty' has restrained the dissemination of studies reproducing earlier findings. This is of concern, as those studies are important in the consolidation of knowledge, which therefore has become less of a key focus. Additionally, papers or a database of methodologies showing methods that did not work are critically needed. Both of those types of research results are nowadays reshaped as 'novel' papers, which is what publishers seek out. It makes it complicated to identify those different types of research results that are crucial for the advances of the field. From conversations with ECRs and senior academics alike, there seems to be near consensus on this issue. Given this consensus, we are surprised that studies reporting inconclusive results or methodologies that did not achieve desired outcomes are still not widely published. On a positive note, collaborative efforts in our field to compile and publish comprehensive books on various UDS topics, freely available through IWA publishing, are increasing and can give ECRs a good first introduction and a base upon which to build their research.

Part 2.2. – Promoting sustainable academic career paths to ensure impactful research and personal well being

The importance put on the publishing system as a metric for academic success has significant ramifications besides those highlighted in the previous section. Currently, pursuing an academic career is perceived by ECRs as very stressful. High

stress is likely to have a negative impact on the quality of the research and development of the ECRs (Bozzon *et al.* 2017). Instead of pushing ECRs to fulfil publishing performance, it might be a better long-term strategy to enable them to spend time developing their knowledge on several UDS-centred multidisciplinary topics, varying from policies to AI techniques, and metrology. This will make stronger academics and more impactful research possible. A variety of courses for ECRs, developed by several of the institutes with a strong UDS research group related to their respective expertise, could be set up with minimal central coordination. Allowing ECRs to take more time for their personal development in the UDS field should be considered when considering their profile, which is now frequently reduced to cumulative indices and other key performance indicators (KPIs). Considering the use of KPIs and cumulative indices, we reject the notion that they necessarily or invariably reflect prestige or quality, as their representative nature can be strongly influenced by gatekeeping and systematic biases in the publishing system (Lerback *et al.* 2020). There has been sporadic discussion on these topics among academics in informal settings, but a strong statement has not been made. We therefore urge our more senior colleagues to join in finding a better way to judge the quality of research(ers) beyond easily gamed KPIs. Such an adaptation of different methods can only be achieved when the entire field agrees to do things differently.

Another major source of stress is coming from how uncertain and demanding the typical career path is. The typical academic career path has shifted considering continuous affiliation: before a researcher could go through their academic path (undergraduate, post-graduate, post-doctoral, and tenure-track, or towards professorship) in a single institute, something that is less common as the post-doctoral stage of the career is often expected to be had abroad. We see this as a double-edged sword: we value the additional diversity of thought a researcher can obtain when moving between institutes, but the expectation to have such geographically varied experience becomes precarious. Within the ECRs in the urban drainage field, there is a strong willingness to relocate temporarily (less than 6 months) for research purposes. However, longer relocations (more than 2 years) are significantly less preferred, with most ECRs not willing to relocate abroad for these extended periods of time. This is largely due to personal reasons, but increasingly also due to political and logistical difficulties associated with relocation (e.g., educational visas, residency permits, ability to work, and travel costs).

Another benefit of encouraging longer stays of ECRs in a single research institution is to improve knowledge retention. A large portion of the 'hands-on' research is currently done by ECRs. During research projects, those ECRs develop the skills necessary to carry out the research. It is vital for the continued success of UDS academia that these skills are retained within the host institutes. Relying on PhD candidates and post-doctoral researchers to the extent that we currently do means that the practical skills become volatile and continued research lines become more difficult to retain. Senior academics, who stay longer in the same institution, cannot invest sufficient time into the development and retention of practical skills, often because they are occupied with other competing priorities such as applying for grants and fulfilling administrative duties. Changing our approach to practical knowledge retention at different levels is critical to ensure efficient and sustainable academic practices.

Another way of ensuring practical skill retention is by encouraging part-time academic positions combined with a part-time position in industry or at governmental organisations that could represent a major benefit in the urban drainage field. From a lecturing perspective, this means that students get taught best practices in industry combined with state-of-the-art innovations. It can also ensure easier uptake of academic insights into practice by reducing the distance between universities and practice. Furthermore, it opens the potential to have more graduates be retained in academia without increased investment from universities. However, transparency and a clear division of what role they play in various projects must be safeguarded to ensure academic integrity.

Alongside a part-time position, the adoption of remote working, necessitated during the COVID-19 pandemic, can lead to interesting new forms of cross-boundary collaboration. Remote working demonstrated the possibility of more flexible work practices, especially in research-centred academic works, and the importance of (work-related) mental health. To support work-life balance and personal-wellbeing, remote work options and good mental health strategies and services should continue to be available. The efficacy and availability of such accommodations, however, often depend on departmental cultures or dispositions of individual supervisors or advisors who may or may not receive formal training on the subject. Remote working in combination with a significant portion of research being performance-based on modelling and using online datasets gives the opportunity for 'remote post-doc' positions. We see this position as one where a post-doc works for one university, funded through their (externally acquired) funding, whilst being present at another. Regulatory requirements around visas and tax regulations can be a barrier, particularly with increasing international tensions. However, we urge universities to leverage their relative influence to facilitate this form of remote working. We see this as a potential

significant improvement, as this would not only benefit the personal lives of those who are now required to move countries to further their careers, but it would also strengthen inter-institutional collaborations and is therefore a serious option to consider. Additionally, unnecessary costs and environmental emissions from reduced travel expenses can be avoided. This would free up funds to enable new research or enhance the scope and impact of existing research. Funding schemes, host agreements, and other legislative barriers should be identified and mitigated to facilitate this opportunity.

This form of collaboration also allows research groups to have a greater diversity (e.g., gender, race, sexual orientation, disability, culture, and neurodiversity). This, in turn, allows us to better showcase diverse role models and to identify and address flaws in the system. For example, an inequity in workload relating to researcher gender and parenting was highlighted during the COVID-19 pandemic (Eurofound 2022). Although policies are put in place aiming to ensure better gender equality, the underlying, hidden pressures in the academic career system can negatively impact personal life planning. It is critical that the principles of the policies translate to academic culture, something that is not necessarily felt ubiquitously.

Each of the authors of this manuscript has chosen to be part of the academic field. This is because as a field, it is still highly rewarding on many levels. Despite the critiques we have on current structures, imbalances, and pressures, it is still a world in which we want to be involved. If we can overcome the issues that we have raised above, it will mean that this is possible without having to compromise on other aspects of our lives.

CONCLUSIONS

To achieve sustainable and impactful academia for UDS, we, as ECRs in this field, argue that several changes are needed to transform and prepare our field to face ongoing and upcoming challenges. From our perspective, we need to:

- Increase public and political awareness of the role of UDS in society, the environment, and climate change adaptation, as well as what resources are needed in practice and research to ensure their continued functionalities. Ongoing developments, such as the transition to BGI and open data practices, can help increase awareness, but they require community engagement.
- Ensure that the field of urban drainage adopts more proactive cooperation between subfields. The field has moved from purely water-focused to a broader multidisciplinary view. This has occurred as water infrastructure becomes more visible and more deeply intertwined within urban matrices and as our definition of the boundaries of urban drainage has evolved.
- Transform the field to ensure good-quality datasets and publications, rather than many poor-quality outcomes. At the same time, we need to avoid placing too much high stress and pressure on ECRs that carry out most of the hands-on work. This will require the implementation of technical solutions and structural change in how research is carried out and how researchers are evaluated.
- Ensure that urban drainage research considers the broad variety in local contexts such as geography, size, urban development, organisations, and resources. This is essential to support the development and implementation of solutions that address the diverse needs of urban areas across the world.
- Steer away from overuse of productivity metrics that encourage a high quantity of output, rather than good-quality science. Academia should strive for creativity, exploration, and thoroughness, rather than acting as a publication factory. The latter also risks that the flood of papers drowns out important advances.
- Build an academic work culture that also respects researchers' private lives and mental health and provides viable career paths for talented researchers to stay in academia. Opportunities that are based on luck or require large changes in private life ultimately do not select academics for the right characteristics. Having many short-term employments is precarious for young researchers and does not generate long-term benefits for research groups.

We hope that this project can start a wider conversation within our community on how our field should develop. Although this project focused on an early-career perspective, we would like to continue this conversation with all interested academics. We also hope that this work can lead to meaningful changes without losing the current positive aspects. This manuscript is the first step in setting up a more formalised ECR community, with the kick-off during the 2024 International Conference on Urban Drainage in Delft, the Netherlands. This formalisation is currently being set up and is envisaged as being under the Joint Committee Urban Drainage[iv] umbrella. From this community, we aim to start in-depth discussions on subtopics that are only briefly touched upon here and to highlight paths towards sustainable and impactful academic practices in the Urban Drainage field.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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