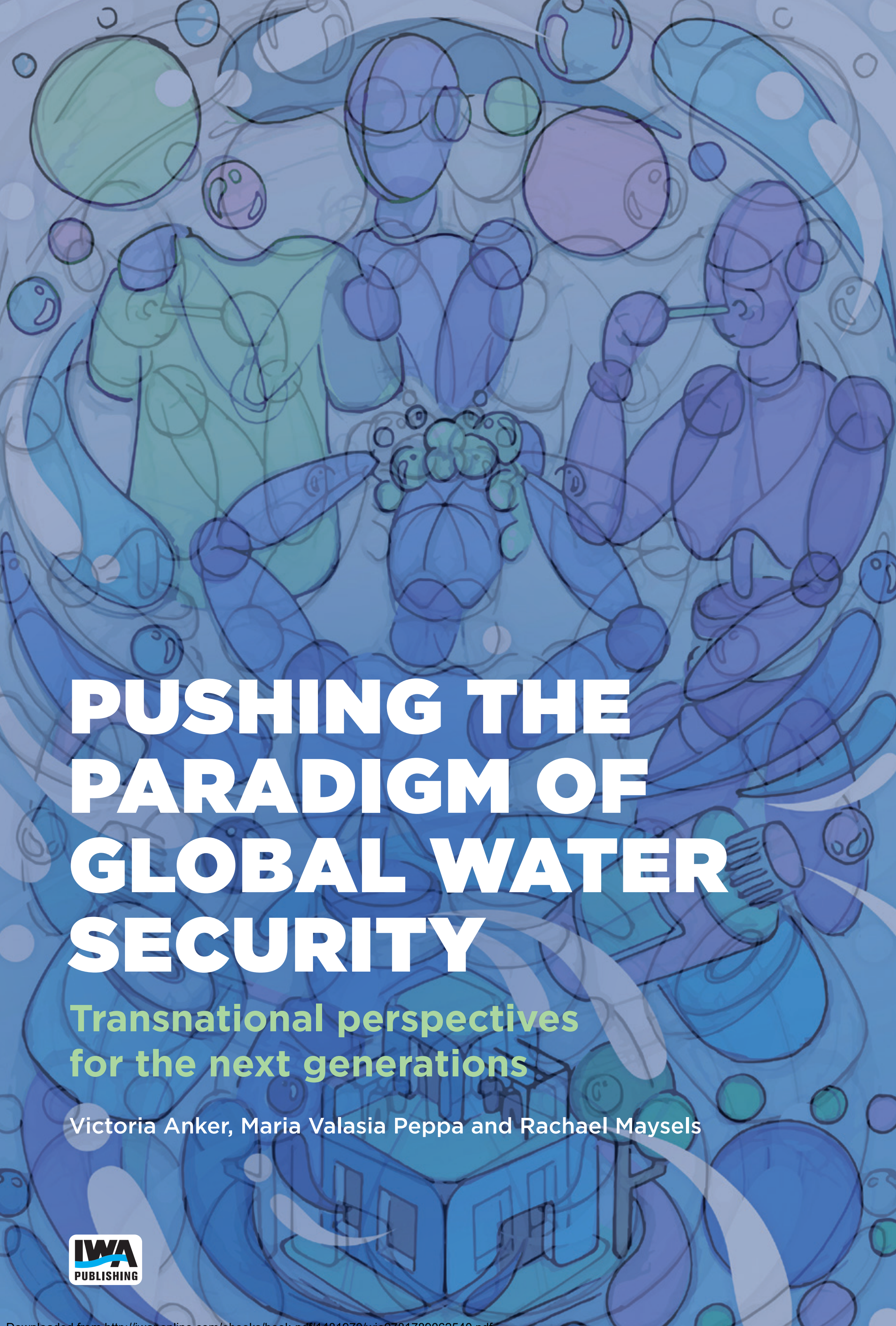

PUSHING THE PARADIGM OF GLOBAL WATER SECURITY

Transnational perspectives for the next generations

Victoria Anker, Maria Valasia Peppa and Rachael Maysels

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Contents

Preface

Victoria Anker

The idea for this book emerged five years ago, when the first cohort of the Early Career Network of the Water Security and Sustainable Development Hub met at our first in-person Assembly in Malaysia, September 2019. The authors have weathered geopolitical conflict and a global pandemic, as well as cuts to the UK's Official Development Assistance – which saw our programme's budget reduced by a third. The book was initially conceived as a way to bridge barriers – disciplinary, geographical, and cultural – while bringing together a group of burgeoning scholars and their networks to discuss the global and local challenges of water security.

What we present here is an amalgamation of our personal and professional efforts to address these challenges. The nuance of this book is in our methodology: transnational cooperation, collaboration across disciplines, and diagnostic problem-solving. While we do not promise a single solution (there is no such thing as 'one size fits all'), we believe this timely contribution broadens the discussion around water security through its firm rejection of reductionist approaches to this most complex of 'wicked problems'.

Most notably, this book pushes for the radical acceptance of the indivisibility of environmental conservation, social stability, and economic vitality. We resist the temptation of 'green growth', recognising it as little more than neoliberalism in disguise. The brilliance, innovation, and recall to tradition that emerge through this book demonstrate the importance of solutions that are informed by a plurality of knowledge types (from scientific and technical to indigenous and local) and generated through collaboration and partnerships to support the attainment of socio-ecological justice.

Foreword

Richard Dawson

As the Director of the Water Security and Sustainable Development Hub, I am delighted to write the foreword for this book. It is an astonishing output; conceived and led entirely by early career researchers from the outset. Bringing together a team of over 40 early career researchers and partners from around the world would be a remarkable achievement at any time, but it is even more remarkable given they have navigated conflicts in their countries, adapted to budget cuts, and lived through a global pandemic.

Water security is fundamental to our environment, health, well-being, and economy. Yet water insecurity is a daily reality for billions of people; be that inadequate access to clean water and sanitation, or exposure to water disasters such as floods and droughts. These pressures are becoming more acute around the world in the face of conflict, pollution, damage to ecosystems, uncontrolled development, and climate change.

The book is a timely and urgent reminder of the need to take a broad, collaborative, and more proactive approach to addressing water security. It is quite distinctive in the way it explores water security through multiple perspectives, drawing upon case studies and experiences from around the world. The book foregrounds the voices of early career researchers, non-governmental organisation and industry practitioners, indigenous and local communities, and government agencies. I encourage you to explore this as an anthology, to read the text but also to watch and listen to the voices at the front line of water security.

When developing the vision and research programme for the Water Security Hub, we placed great importance on the development of the next generation of researchers and practitioners from the beginning. There is no silver bullet, no single action, that will solve our water security problems. The Water Security Hub has focused on training and capabilities in a systems approach that engenders collaboration, facilitates learning from other disciplines, and enables more holistic strategies to address water security. This book showcases how collaboration across scales, sectors, and borders is essential for a more sustainable and water-secure future. I hope the authors are as proud as I am of everything they have achieved through their hard work: their collaborative and interdisciplinary approach is embodied in this book.

Acknowledgements

Victoria Anker

I am extremely appreciative of my fellow co-editors, Rachael Maysels and Maria Valasia Peppa, who have led this process gracefully and with unfailing commitment to this book amidst a myriad of other priorities.

I am grateful to all our contributors for their patience, perseverance, and passion, and for joining a five-year journey of discussion, collaboration, and learning, while responding graciously to feedback, suggestions, and questions.

I am thankful to our International Advisory Board – Amare Haileslassie, Apolinar Figueroa Casas, Barbara Evans, Maggie Roe, Sandhya Rao, and Zainura Zainon Noor – for supporting the development of this book since its inception. I'd also like to thank our senior colleagues – Alan Nicol, Claire Walsh, David Werner, Jaime Amezaga, Lata Narayanaswamy, Miguel Peña Varón, Richard Dawson, and Tom Curtis – for their insightful and informative feedback.

Many, many thanks to our media specialists –Esteban Andres Diaz Narvaez, Livia Douse, and the team at Roots and Wings (especially Alan Ramsay and Jake Conrad) – for their incredible work translating our words into such beautiful visualisations and videos.

Additional thanks to our funder, UK Research and Innovation, and in particular Catherine Flynn for championing our creativity; Ankush Nimbria and Radikha Modi for their astute observations; and all our managers who have supported us as this project has progressed.

Thanks to David Chaquea-Romero and Eduar Esteban Córdoba Rodríguez for the conceptualisation and design of our striking cover illustration.

As ever, I am indebted to Caroline Grundy for theoretical conversations, methodological musings, and practical solutions. Thank you for your unwavering support and unshakeable confidence in this endeavour.

About the Authors

Naming conventions vary greatly across the geographies, ethnicities, and cultures of our contributors. To avoid insults and confusion, contributors are listed A–Z by their personal name.

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Introduction

Victoria Anker, Rachael Maysels, Maria Valasia Peppa, Cindy Lee and Xanthe Polaine

This book brings together early career researchers, non-governmental organisation (NGO) and industry practitioners, indigenous and local communities, and government agency workers to interrogate the concept of water security. By collating their multicultural perspectives, diverse contributions, and illustrative media, this book challenges the current anthropocentric, technocratic narrative of water security, according to which: water security is solely for humans; development initiatives and interventions are driven by neocolonial and neoliberal ideologies; the socio-cultural approach to water security is secondary to a technical, engineering-based approach; and interdisciplinarity is not practical in its application.

Water security has evolved significantly over the past few decades, with various sectors adapting the concept to suit their own definitions of 'successful' water security (Polaine *et al.*, 2022a). Initially focused on a narrow, human-centred perspective, the paradigm now includes social, economic, and environmental dimensions, reflecting the wide range of definitions and understandings, as discussed by Chiluwe and Claassen (2020). This broadening scope has made water security a complex and dynamic issue, one that is challenging to define or measure the 'success' of. Its growing relevance and interconnectedness have led to widespread adoption of a specific vision of water security by global and regional organisations, including multilateral bodies, governments, and NGOs (Staddon & Scott, 2018), making it a central element in current sustainable development and funding discourses (Cook & Bakker, 2012).

Still, with the uptake of this specific vision by large organisations with a central focus on international development and state building, water security discourse has become dominated by top-down thinking and often omits the voices of those at the centre of the water security crisis, namely indigenous communities, women and girls, youth, and environmental activists. Consequently, the current water security discourse does not reflect the diversity of the paradigm, or its evolving and dynamic nature. The purpose of this book is not to contribute to the water security definition debate. Rather, we seek to (i) address the imbalance in, and segregation of, water security perspectives; (ii) critique current discourses around water security; and (iii) offer solutions to address development injustices and overcome sectoral silos.

CONCEPTION

Water knows no borders or bounds: 153 countries around the world share nearly 900 rivers, lakes, and aquifer systems. While using defined spaces like river basins or water catchment areas can make water security easier to approach, we cannot reduce water systems to these physical parameters (Polaine *et al.*, 2022b). Doing so places an undue emphasis on technical and economic efficiency, overlooking socio-ecological values (Mukhtarov, 2008).

To expand the meaning of water security and move away from a narrow water-centric framing, Zeitoun (2011) presents water security as a 'web', with water security at the centre, governed by social and physical processes, but also influenced by interconnected issues such as climate security, water resources security, national security, food security, energy security, and human/community security. In this analogy, water security is a function of these interdependencies at multiple levels.

Expanding on Zeitoun's conceptual tool, this book understands water security through an interdisciplinary lens with diverse concerns encompassing quality, quantity, health, land practices, governance, ecology, livelihood, economy, and so on (Narayanaswamy *et al.*, 2023). Such complex socio-ecological factors make water security a wicked problem (Bjornlund *et al.*, 2018) that can only be addressed – so the authors of this book contend – by bringing together multi-skilled teams from all backgrounds and sectors, with different lived experiences, to share different perspectives, ideas, and knowledge.

While we operate in different contexts, we are all working on common issues and seek to share our respective insights and experiences. As a global project tackling water security issues across a variety of locations, we know how important it is that we work together through interdisciplinary dialogue, knowledge generation and knowledge exchange among stakeholders, industry, communities, and researchers. Capacity building is another key vehicle of our interventions – both for our stakeholders and for our fellow researchers.[1] By this, we mean building the capacity of researchers and stakeholders to address aspects of water security within their local communities, increasing the capacity of researchers and stakeholders to work together to address those same issues and complexities, and building on the capabilities of researchers to work in new, interdisciplinary ways and become research leaders in their own fields.

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[1] Stakeholder has a wide range of different meanings for colleagues and was selected as the most appropriate term that encompassed all 'relevant groups' engaged with our research. However, we acknowledge the conflicting uses of this term within the broader academic community, especially in the context of decolonising research. For a comprehensive discussion of alternative terms, we point readers towards Reed *et al.* (2024), which was published as this book was going to print.

CONSTRUCTION

Thanks to our previous experience of working collectively across the globe, we soon realised that any book on such a broad topic as water security needed a clear framework in which we could all situate ourselves. Instead of taking a thematic, geographic, or disciplinary approach, and thereby risk reinforcing the intellectual barriers we seek to disrupt, we chose to identify three core principles for water security – justice, knowledge, and collaboration. In doing so, we wanted to acknowledge the locally specific conditions in which we work, while simultaneously highlighting common principles that underpin (or that should underpin) any approach to meaningful (and sustainable) solutions.

The challenges faced by each of the countries in which we work and study are unique, and there is no template for addressing water security. However, we all agree that water security cannot be sustainable unless it centres socio-ecological justice (SEJ), recognises a plurality of knowledge systems, and fosters collaboration not competition. While sustainability can be seen as a separate paradigm, we opine that sustainability is an inherent driver and marker of water security for environmental conservation, social stability, and economic vitality (Haileslassie *et al.*, 2020). Water security that leaves no one and nothing behind must leave no one and nothing out. In our opinion, this cannot be achieved without justice, knowledge, and collaboration because, while the water crisis is becoming progressively acute (Sultana, 2018), it does not affect all people equally – in fact, it disproportionately impacts marginalised communities (Boelens *et al.*, 2018).

These three principles come together to inform and enable a proactive approach to sustainable water security. Proactive management is not a commonly used term in the field of water security but, simply defined, it involves planning for potential threats to safe water supplies, which we argue should be situated within broader socio-ecological systems. It is an approach that focuses primarily on preventive (proactive) measures to manage water risks and ensure sustainable water security, instead of responsive (reactive) measures to deal with water-related crises (Figure I.1) (Madani, 2014).

A proactive management paradigm recognises the complexity of water systems and the associated uncertainties, as well as the water sector's interrelation with other sectors. By better understanding how water systems behave at different scales and how threats arise, it tackles the root of problems in a holistic and progressive manner, rather than treating the symptoms of the problem as they occur. In doing so, a proactive approach manages water rather than controlling it. Such an approach should explore a range of possible solution pathways that include non-structural solutions related to policies, legislation, and institutional arrangements, as well as structural solutions such as storage systems, diversions, water supply augmentation, water distribution networks, and development systems (Cooper, 2016; Madani, 2014).[2]

[2] The Sendai Framework Terminology on Disaster Risk Reduction provides a good working definition on the terms 'structural' and 'non-structural': https://www.undrr.org/terminology/structural-and-non-structural-measures

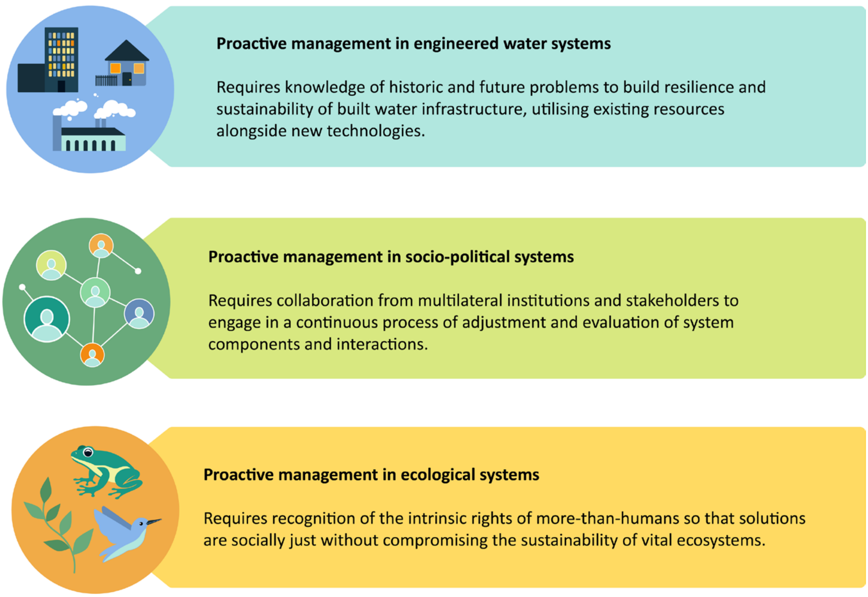


Figure I.1 Proactive management for sustainable water security. (Credit: rootsandwings. design).

ORGANISATION

This book is organised around three principles that we propose are necessary to achieving water security – justice, knowledge, and collaboration – and without which we argue a proactive management approach, that benefits humans and more-than-humans, is impossible. Each principle begins with an introduction that explores the principle's significance for and role in achieving water security, followed by a brief explanation of its theoretical underpinnings, practical application, or lived experiences.

- Principle 1 – justice: we argue that without justice we cannot have true water security for all beings (human and more-than-human). Through a series of spotlights, this section explores the intersectional application of social, ecological, and socio-ecological justice.
- Principle 2 – knowledge: we argue that without knowledge, we cannot have inclusive water security. Through a series of spotlights, this section explores methods, tools, and frameworks to create an integrated knowledge base for a data-to-action approach.
- Principle 3 – collaboration: we argue that without collaboration, we cannot have equitable water security. Through a series of spotlights, this section explores modes of participation and engagement that bolster capabilities.

The chapters that follow demonstrate the principle in action through a collection of 'spotlights' offering up localised, dynamic approaches to water security. We use the term 'spotlight' because these case studies are not prescriptive, nor are they the only solution to the challenges of water insecurity. Spotlights primarily present case studies from areas of study across our research programme: the Upper Cauca River Basin (Río Cauca) of Colombia; the Central Rift Valley, Abbay Basin, and Awash Basin of Ethiopia; the Yamuna River Basin of India; and the Johor River Basin (Sungai Johor) of Malaysia, with features from cases in Palestine and the UK as well. While the biophysical and socio-cultural conditions of these regions differ in many ways, the commonalities that emerge from the case studies and the localised, dynamic approach towards interdisciplinary research can be adapted to basins throughout the world.

Finally, in our conclusion, we demonstrate how these principles feed into a proactive management approach for water security. This provides a framework for how water can be managed holistically by navigating injustices in water systems, integrating pluralistic knowledge systems, and encouraging collaboration and equitable partnerships.

Throughout this volume we include a range of media to illustrate our spotlights, such as infographics, sonorous postcards, videos, and interactive images. These serve as visual aids that highlight lived experiences from the hidden voices on the forefront of the fight for water security.

Whether from a technical, social, or political background, we invite readers to imagine what an ideal paradigm of water security could be while reading, listening, and interacting with the spotlights throughout this book. In challenging the existing technocratic and top-down power structure of the current paradigm of water security, we hope to deconstruct the barriers to a future of true water security for all human and more-than-human beings.

THE PROJECT[3]

This book emerged out of the Water Security and Sustainable Development Hub, a five-year, challenge-led research programme, funded by UK Research and Innovation via the Global Challenges Research Fund, as part of the UK's Official Development Assistance. In alignment with the United Nations' Sustainable Development Goals, the Water Security Hub works at scale across the globe to (i) provide a response to critical development challenges and (ii) promote the long-term economic growth and welfare of low- and middle-income countries. The Early Career Network is comprised of over 100 members from 11 countries with extensive knowledge and lived experience regarding water security.[4]

[3] This work was supported by the Water Security and Sustainable Development Hub funded by the UK Research and Innovation's Global Challenges Research Fund [grant number: ES/S008179/1].

[4] Across the full five years, the broader Water Security Hub team included over 200 members, from 16 countries.

REFERENCES

Bjornlund H., Nickum J. E. and Stephan R. M. (2018). The wicked problems of water quality governance. *Water International*, **43**(3), 323–326, https://doi.org/10.1080/02508060.2018.1452864

Boelens R., Perreault T. and Vos J. (eds.) (2018). Water Justice. Cambridge University Press, https://doi.org/10.1017/9781316831847

Chiluwe Q. W. and Claassen M. (2020). Systems perspectives on water security: An applied review and conceptual framework. *Environmental Policy and Governance*, **30**(6), 332–344, https://doi.org/10.1002/eet.1889

Cook C. and Bakker K. (2012). Water security: debating an emerging paradigm. *Global Environmental Change*, **22**(1), 94–102, https://doi.org/10.1016/j.gloenvcha.2011.10.011

Cooper M. (2016). Conclusions: the future of sustainable water management. In: Sustainable Water Management: New Perspectives, Design, and Practices, K. Nakagami, J. Kubota and B. I. Setiawan (eds.), Springer, Singapore, pp. 175–185, https://doi.org/10.1007/978-981-10-1204-4_12

Haileslassie A., Ludi E., Roe M. and Button C. (2020). Water values: discourses and perspectives. In: Clean Water and Sanitation, W. L. Filho, A. M. Azul, L. Brandli, A. L. Salvia and T. Wall (eds.), Springer, Cham, Switzerland, pp. 1–10, https://doi.org/10.1007/978-3-319-70061-8_140-1

Madani K. (2014). Water management in Iran: what is causing the looming crisis? *Journal of Environmental Studies and Sciences*, **4**, 315–328, https://doi.org/10.1007/s13412-014-0182-z

Mukhtarov F. G. (2008). Intellectual history and current status of integrated water resources management: a global perspective. In: Adaptive and Integrated Water Management, C. Pahl-Wostl, P. Kabat and J. Möltgen (eds.), Springer Berlin, Heidelberg, Germany, pp. 167–185, https://doi.org/10.1007/978-3-540-75941-6_9

Narayanaswamy L., Ferritto R., Hillesland M., Anker V., Singhal S., Maysels R. M., Bantider A., Charles K., Doss C., Kumar A., Mdee A., Neo S.-M., Pinzón F. and Mengistu B. T. (2023). Why a feminist ethics of care and socio-ecological justice lens matter for global, interdisciplinary research on water security. *Frontiers in Human Dynamics*, **5**, 1212188, https://doi.org/10.3389/fhumd.2023.1212188

Polaine X. K., Dawson R., Walsh C. L., Amezaga J., Peña-Varón M., Lee C. and Rao S. (2022a). Systems thinking for water security. *Civil Engineering and Environmental Systems*, **39**(3), 205–223, https://doi.org/10.1080/10286608.2022.2108806

Polaine X. K., Nicol A., Amezaga J., Berihun M., Dessalegn M. and Haile A. T. (2022b). Problemscapes and hybrid water security systems in central Ethiopia. *Frontiers in Water*, **4**, 800926, https://doi.org/10.3389/frwa.2022.800926

Reed M. S., Merkle B. G., Cook E. J., Hafferty C., Hejnowicz A. P., Holliman R., Marder I. D., Pool U., Raymond C. M., Wallen K. E., Whyte D., Ballesteros M., Bhanbhro S., Borota S., Brennan M. L., Carmen E., Conway E. A., Everett R., Armstrong-Gibbs F., Jensen E., Koren G., Lockett J., Obani P., O'Connor S., Prange L., Mason J., Robinson S., Sjukla P., Tarrant A., Marchetti A. and Stroobant M. (2024). Reimagining the language of engagement in a post-stakeholder world. *Sustainability Science*, **19**, 1481–1490, https://doi.org/10.1007/s11625-024-01496-4

Staddon C. and Scott C. A. (2018). Putting water security to work: addressing global challenges. *Water International*, **43**(8), 1017–1025, https://doi.org/10.1080/02508060.2018.1550353

Sultana F. (2018). Water justice: what is matters and how to achieve it? *Water International*, **43**(4), 483–493, https://doi.org/10.1080/02508060.2018.1458272

Zeitoun M. (2011). The global web of national water security. *Global Policy*, **2**(3), 286–296, https://doi.org/10.1111/j.1758-5899.2011.00097.x

doi: 10.2166/9781789062540_007

Principle 1

Justice – introduction

Rachael Maysels and Shivani Singhal

> 'The imbalance of water is the imbalance of the person. The human is not the one that dominates the world. Our existence is fleeting. We cannot indebt ourselves beyond our own existence, this is a rule established from the origin. To exist without creating harm and retribute all that is received.'
>
> Alfonso Torres-Villafañe, indigenous Arhuaco from the Sierra Nevada of Santa Marta, Colombia

Our first principle is that, without justice, we cannot have true water security for all beings (human and more-than-human). Through a series of spotlights, this section explores the intersectional application of social, ecological, and socio-ecological justice (SEJ).

SIGNIFICANCE OF PRINCIPLE

In 2010, the United Nations (Resolution 64/292) recognised the human right to water and sanitation. This right underpins UN Sustainable Development Goal 6 (Clean Water and Sanitation for All). And this in itself opens up a discussion of fairness and equity: if 'all' should have access to clean water and sanitation, we must consider justice within the context of water security. As things stand, the human rights framework for water and sanitation is limited, often focusing on technocratic solutions implemented by private industry rather than addressing more complex issues such as governance, power dynamics, and exclusion of non-human and marginalised social groups (Bakker, 2010; Boelens *et al.*, 2018; Karunananthan, 2019).

Within the water security paradigm, we must focus our attention on justice to shed light on the complex power imbalances within decision-making. Both human and more-than-human communities are in crisis all over the globe – thus, environmental and social crises are inseparable (Furman & Gruenewald, 2004). It is important to hold this in mind as we make meshed injustices and embedded power relations visible, informing our overall analysis.

At the same time, the water crisis is becoming progressively more acute (Sultana, 2018). Water shapes societies and control of water directly relates to larger socio-political processes of power (Joy *et al.*, 2014). Water is a multi-sectoral entity that connects various categories: it is simultaneously social, economic, political, institutional, cultural, spiritual, and ecological. Water thus becomes a lens through which to understand complex socio-ecological issues and injustices (Sultana, 2018). As such, when a water justice approach is applied to analyse various land and nature conflicts, it creates a pathway for political action and decision-making, affecting a greater number of diverse users. In other words, water is not just about water but encompasses broader issues of democracy, citizenship, and development (Sultana, 2018). Through this lens, a more integrated understanding of land and water issues within governance emerges. This is necessary to build alliances between social and environmental justice movements (Franco *et al.*, 2013).

Justice is a complicated concept with multiple meanings depending on who defines it. Questions such as 'justice for whom or what?' and 'justice for what purpose?' must be asked. We argue against a singular understanding or approach towards water justice, instead advocating for it to be addressed from the perspective of how it is experienced and defined by individuals or collective subjects in specific contexts (Boelens *et al.*, 2018). A relational, contextual, and situational conceptualisation of justice is more compatible with a lived approach, as it allows for plurality. And this relative understanding of justice must also be matched by the identification of common core issues that transcend localised understanding, which is lacking in the conventional approach to water security (Joy *et al.*, 2014).

Moreover, it is important to review historical complexities related to socio-economic fabrics and shifting spatial and political boundaries in conjunction with emerging injustices (Joshi, 2015). This is particularly crucial in the case of historically marginalised communities, where water and environmental injustices are tied to longstanding processes of colonialism, imperialism, neoliberalism, and patriarchy (McGregor *et al.*, 2020; Ulloa, 2017). This approach to justice does not romanticise 'local' or 'traditional' 'communities' (Joy *et al.*, 2014), but instead recognises and considers lived experiences and realities from local perspectives. Efforts to address justice issues need to engage with these experiences and restructure the governance system according to a more equitable, socially just, environmentally sustainable, and democratic axis (Joy *et al.*, 2014).

THEORETICAL UNDERPINNINGS

The contemporary Western understanding of justice as deserved fairness and equity dates back to ancient Greek philosophers. According to Plato, 'justice' was one of the four virtues needed to live a 'good life'; building on this, Aristotle considered 'justice' to be of the highest importance out of the four virtues, as it encourages the individual to be of benefit to the community (Hamedi, 2014). Across most Western ontologies, including the Universal Declaration of Human Rights, this legally based, state-enforced framework has been upheld.

In the modern era, Fraser (2008) presents a framework of social justice consisting of three main dimensions – redistribution, recognition, and participation – that can be applied in all social movements. When it comes to redistribution, Fraser argues resources must be justly distributed, with a prioritisation of groups that have faced egregious injustices. According to this logic, recognition for the historically marginalised is needed, especially given the socio-cultural preference among certain groups to affirm differences rather than be recognised as the same as others (Wijsman & Berbés-Blazquez, 2022). When these groups, then, are not recognised accordingly by various actors, from the state to their fellow citizens, even in their own communities, this can negatively impact them across a variety of realms, including the material, social, cultural, and financial. Similarly, participation is an important dimension in Fraser's social justice framework: through a participatory process and engaged governance, potentially negative outcomes can be limited and policies designed fairly. This is particularly important when adjusting for local contexts, as will be demonstrated throughout the spotlights in this section. The participatory process itself implies a certain respect for democracy and an awareness of power relations (Rutt & Gulsrud, 2016).

So, the social justice movement emphasises that humans deserve and should prioritise justice. However, the ecological justice movement argues that more-than-human beings and entities also have intrinsic rights unrelated to their instrumental value to humans (Baxter, 2005; Kopnina, 2014). Proponents of ecological justice do not claim that more-than-human species should be considered over humans, but rather that these beings have endured heinous injustices without being able to speak up for themselves. According to this framing, our ethics to care for each other as humans should be extended to the more-than-human world (Shoreman-Ouimet & Kopnina, 2015). This can be seen in recent legislation that grants legal rights of personhood to rivers, such as the case of the Yamuna River in India (later overturned) and the Cauca River in Colombia (O'Donnell, 2020) (Figure P1.1).

For many indigenous peoples, the notion of justice centres around their ontological belief that there is no separation between them and their environment, which is distinct from dualistic Western ontology (McGregor *et al.*, 2020; Ulloa, 2017). Reciprocity is a foundational concept in indigenous environmental justice – and this is also central to the SEJ movement, which emphasises mutual respect and caring among all beings to maintain territorial balance (Blanco Moreno & Peña Varón, 2023; McGregor *et al.*, 2020).

Many branches of social and environmental justice favour an anthropocentric approach, while the ecological justice movement prefers an eco-centric approach. Building on indigenous philosophies, SEJ is now emerging as a fascinating middle ground, as a branch of justice that synthesises social and ecological systems of meaning (Yaka, 2020). Various prominent authors in water justice research (Boelens *et al.*, 2018) are also proponents of SEJ, and propose adding it to Fraser's framework of environmental justice (recognition, representation, and redistribution) as a much-needed fourth dimension. We consider this nuanced branch of justice to be critical for the future of justice in water security, shifting away from a model where humans and nature are placed in opposition to each other and towards an understanding of ourselves as part of, not rulers of, the natural world.

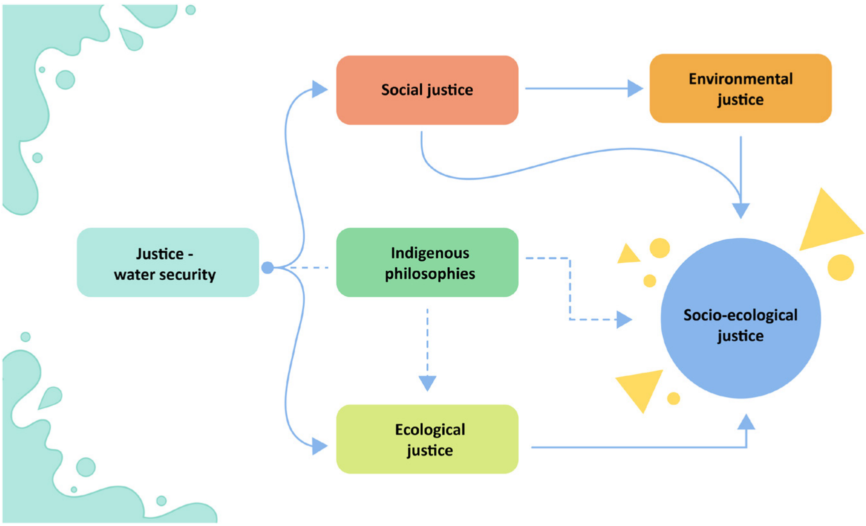


Figure P1.1 Conceptual map of branches of justice related to water security (Credit: rootsandwings.design).

AUTHOR CONTRIBUTIONS

The spotlights that sit in this section are united by the theme of justice while showcasing different branches of justice in water security. We feature case studies from Colombia, Ethiopia, India, Malaysia, Palestine, and the UK.

In Chapter 1, Social Justice – Recognition and Representation, authors Carolina Blanco Moreno, Wan Asiah Nurjannah Wan Ahmad Tajuddin, and Nasser Tuqan analyse the two interconnected dimensions of recognition and representation in the context of social justice for water security. According to Carolina, recognition consists of social relationships that are established through hegemonic valuation processes that are institutionalised, which confer a certain status on each social group. By focusing on community-based organisations that follow traditional methods of using and managing water for human consumption at the local rural level in Colombia, Carolina examines how social justice relates to indigenous environmental justice and ecological justice.

In the spotlight that follows, Nurjannah explores the link between access to information and procedural justice in the Johor River Basin in Malaysia. This case study argues for procedural justice in planning to ensure that people are treated with respect and decency. Nurjannah shows that while individuals and groups might appear to be emphasising material aspects of water quality and quantity, they are essentially struggling for justice in its various forms. Thus, even if groups do not explicitly phrase their actions in terms of justice, their demands for rights are in some way or another marked by this.

Subsequently, Nasser argues that managing water scarcity via 'efficiency' has become the bastion of the mainstream approach to water security, leveraging a neoliberal discourse that reduces justice agendas to a cost/benefit analysis. The concept of efficiency as it pertains to water use defines it as a productive resource that aims to benefit all users (Joy *et al.*, 2014). But the language of justice, when confined to quantitative measures, often remains merely performative rather than truly capturing the socio-political complexities. By erasing the border trajectories of socio-ecological change, it ends up producing greater inequalities, as Nasser demonstrates via the case studies he presents. As a result, in the long-term, this strictly technical approach towards water use measurement is ineffective (Hunt & Shahab, 2021).

In Chapter 2, Social Justice – Redistribution, authors Pranav Singh, Shivani Singhal, and Likimyelesh Nigussie present spotlights in which social injustices emerge from inequitable power dynamics, rapid urbanisation, and unequal distribution of water, land, and other resources. Authors approach these injustices from intersectional lenses, recognising that marginalised communities in urban spaces face not only water insecurity but also extreme poverty, discrimination, disease exposure, food insecurity, and more. Pranav takes us into the realities of the informal settlements, or slums, in Delhi, the capital city of India. They highlight the extreme inequity resulting from the lack of policy and infrastructure support for safe water in slums, while there is lush development often just blocks away. While the communities that live in these informal settlements have proven adaptive and resilient, we are reminded that it is too often marginalised communities that are disproportionately burdened by injustices.

Similarly, Shivani presents a case study of tensions between farmers along the Yamuna Basin in India and urban development planners, causing threats to and actual displacement of farming communities. In the two cases of unstable tenure documented in the accompanying video, we see these communities stand up in defence of their biophysical and socio-cultural spaces, self-organising to resist further injustices.

In a solution-offering piece, Likimyelesh then shares a case study showcasing the power of collective action in Addis Ababa, Ethiopia, at the Shenkora 2 Urban Farm. Led and managed by a women's horticulture group, the farm offers a model that can be used to face intersectional challenges, particularly when it comes to the extra layer of difficulties often faced by women in this space.

In Chapter 3, Ecological Justice, Joshua B. Cohen highlights that water security is not just about people accessing water equitably, but also about justice for water as a more-than-human entity that possesses its own rights (Parsons *et al.*, 2021). Ecological justice is rooted in an eco-centric philosophical position (Halsey & White, 1998). In many technical approaches, one runs the risk of failing to recognise cultural traditions and land use, leading to displacement of the marginalised and establishment of absolute control of nature in the service of humans. In such cases, justice and harmony, although ostensibly present, might actually be far from view. But the ecological justice movement advocates for nature to be recognised as part of our shared community. Still, while the concept of ecological justice can be useful in helping to reorient us away from anthropocentrism, it must include humans and their various socio-political and cultural concerns if it is to mean anything at all. This is further demonstrated by author Ashwini More, whose spotlight explores how heritage water systems in India that were initially designed with ecology in mind have drastically changed over time, thanks to colonisation and shifting power dynamics.

In Chapter 4, Socio-Ecological Justice, the final chapter in this principle, the spotlights highlight instances of injustice in historically marginalised communities in Colombia (including the *campesino,* afro-descendant, and indigenous) and how their interconnected relationships with water, nature, and their territories offer a pathway towards true justice for all beings.[1]

Rocio Manzano Quintero and Natalia Duque underline the limitations of the neoliberal and anthropocentric approach towards justice and instead advocate for SEJ that enmeshes 'all subjects' of nature and society (Pope *et al*., 2021). Through an SEJ lens, we can recognise the relationality and contextuality of multiple dimensions within justice. Thus, we can attempt to create a link between redistribution and cultural recognition plus political participation of the excluded and silenced (Zwarteveen & Boelens, 2014). Rocio writes from her perspective as a *campesina* community leader, bringing voice and visibility to her community's issues.

In an attempt to highlight hidden voices, we also present four videos in this chapter, in which members of *campesino,* afro-descendant, and indigenous communities share their experiences directly. Through these first-hand accounts, we bear witness to the importance of kinship when it comes to the interconnected human–nature relationship, the fight to defend one's territory (and everything in it), and ways to incorporate socio-ecological justice as a main principle of water security.

REFERENCES

Bakker K. (2010). Privatizing Water: Governance Failure and the World's Urban Water Crisis. Cornell University Press, Ithaca, NY, US. https://www.cornellpress.cornell.edu/book/9780801467004/privatizing-water/ (accessed 22 April 2024)

Baxter B. (2005). A Theory of Ecological Justice, 1st edn. Routledge, Abingdon, Oxfordshire, UK. https://www.routledge.com/A-Theory-of-Ecological-Justice/Baxter/p/book/9780415758543 (accessed 22 April 2024)

Blanco Moreno C. and Peña Varón M. (2023). Relationship between community water management, conceptions, and struggles for justice in Southwest Colombia, *Environmental Justice*, **16**(3), 230–243, https://doi.org/10.1089/env.2022.0065

Boelens R., Perreault T. and Vos J. (eds.) (2018). Water Justice. Cambridge University Press, Cambridge, UK, https://doi.org/10.1017/9781316831847

[1] *Campesino:* while this term translates to 'peasants' in English, it encompasses a specific demographic of rural smallholder farmers in Latin America. As such, the Spanish term will be utilised throughout the book.

Franco J., Mehta L. and Veldwisch G. J. (2013). The global politics of water grabbing. *Third World Quarterly*, **34**(9), 1651–1675, https://doi.org/10.1080/01436597.2013.843852

Fraser N. (2008). Scales of Justice: Reimagining Political Space in A Globalizing World. Columbia University Press, New York, US. https://cup.columbia.edu/book/scales-of-justice/9780231146807 (accessed 22 April 2024)

Furman G. C. and Gruenewald D. A. (2004). Expanding the landscape of social justice: a critical ecological analysis. *Educational Administration Quarterly*, **40**(1), 47–76, https://doi.org/10.1177/0013161X03259142

Halsey M. and White R. (1998). Crime, ecophilosophy and environmental harm. *Theoretical Criminology*, **2**(3), 345–371, https://doi.org/10.1177/1362480698002003003

Hamedi A. (2014). The Concept of Justice in Greek Philosophy (Plato and Aristotle). *Mediterranean Journal of Social Sciences*, **5**(27), 1163–1167, https://doi.org/10.5901/mjss.2014.v5n27p1163

Hunt D. V. and Shahab Z. (2021). Sustainable water use practices: understanding and awareness of Masters level students. *Sustainability*, **13**(19), 1–29, https://doi.org/10.3390/su131910499

Joshi D. (2015). Like water for justice. *Geoforum*, **61**, 111–121, https://doi.org/10.1016/j.geoforum.2015.02.020

Joy K. J., Kulkarni S., Roth D. and Zwarteveen M. (2014). Re-politicising water governance: exploring water re-allocations in terms of justice. *Local Environment*, **19**(9), 954–973, https://doi.org/10.1080/13549839.2013.870542

Karunananthan M. (2019). Can the human right to water disrupt neoliberal water policies in the era of corporate policy-making? *Geoforum*, **98**, 244–253, https://doi.org/10.1016/j.geoforum.2018.07.013

Kopnina H. (2014). Environmental justice and biospheric egalitarianism: reflecting on a normative-philosophical view of human-nature relationship. *Earth Perspectives*, **1**(8), https://doi.org/10.1186/2194-6434-1-8

McGregor D., Whitaker S. and Sritharan M. (2020). Indigenous environmental justice and sustainability. *Environmental Sustainability*, **43**, 35–40, https://doi.org/10.1016/j.cosust.2020.01.007

O'Donnell E. (2020). Rivers as living beings: rights in law, but no rights to water? *Griffith Law Review*, **29**(4), 643–668, https://doi.org/10.1080/10383441.2020.1881304

Parsons M., Fisher K. and Crease R. P. (2021). Decolonising Blue Spaces in the Anthropocene. Palgrave Macmillan, Cham, Switzerland. https://library.oapen.org/handle/20.500.12657/47268 (accessed 22 April 2024)

Pope K., Bonatti M. and Sieber S. (2021). The what, who and how of socio-ecological justice: tailoring a new justice model for earth system law. *Earth System Governance*, **10**, 100124, https://doi.org/10.1016/j.esg.2021.100124

Rutt R. L. and Gulsrud N. M. (2016). Green justice in the city: a new agenda for urban green space research in Europe. *Urban Forestry & Urban Greening*, **19**, 123–127, https://doi.org/10.1016/j.ufug.2016.07.004

Shoreman-Ouimet E. and Kopnina H. (2015). Culture and Conservation: Beyond Anthropocentrism, 1st edn. Routledge, London, UK, https://doi.org/10.4324/9781315858630

Sultana F. (2018). Water justice: why it matters and how to achieve it. *Water International*, **43**(4), 483–493, https://doi.org/10.1080/02508060.2018.1458272

Ulloa A. (2017). Perspectives of environmental justice from indigenous peoples of Latin America: a relational indigenous environmental justice. *Environmental Justice*, **10**(6), 175–180, https://doi.org/10.1089/env.2017.0017

Wijsman K. and Berbés-Blázquez M. (2022). What do we mean by justice in sustainability pathways? Commitments, dilemmas, and translations from theory to practice in nature-based solutions. *Environmental Science & Policy*, **136**, 377–386, https://doi.org/10.1016/j.envsci.2022.06.018

Yaka Ö. (2020). Justice as relationality: socio-ecological justice in the context of anti-hydropower movements in Turkey. *Die Erde: Journal of the Geographical Society of Berlin*, **151**(2–3), 167–180, https://doi.org/10.12854/erde-2020-481

Zwarteveen M. Z. and Boelens R. (2014). Defining, researching and struggling for water justice: some conceptual building blocks for research and action. *Water International*, **39**(2), 143–158, https://doi.org/10.1080/02508060.2014.891168

doi: 10.2166/9781789062540_00015

Chapter 1

Social justice – recognition and representation

Carolina Blanco Moreno, Wan Asiah Nurjannah Wan Ahmad Tajuddin and Nasser Tuqan

The just recognition and representation of water users and watershed inhabitants throughout the processes of planning, assessment, and management is key to ensuring social justice in water security. In this chapter, the authors present case studies in which a lack of recognition and representation has systemically led to disparities in Colombia, Malaysia, and Palestine. They also offer alternative pathways through which members of the public might be included in decision-making and communities as a whole might be empowered, promoting the sustainability of water systems as well as improving the evaluation and management of these systems.

1.1 ASSOCIATIVITY FOR THE RECOGNITION OF COMMUNITY WATER MANAGEMENT, COLOMBIA

Carolina Blanco Moreno

Community water management (CWM) is a traditional way of using and managing water for human consumption at the local rural level, as practised by community-based organisations (CBOs).[1] In rural areas of Latin America and the Caribbean, CBOs are the main providers of drinking water: there are about 80 000 CBOs providing water and sanitation services to approximately 70 million people in rural areas in the region (Arrojo, 2022). In Colombia, these organisations emerged in the mid-20th century in response to the population's pressing need for wider access to water; state and international organisations subsequently promoted them, as part of programme implementation in Latin

[1] For ease of reading, community water management organisations (CWMOs) and CBOs are used interchangeably throughout the book.

America, financed by the Inter-American Development Bank and the World Bank in the 60 s, and through a Colombian institutional framework to promote social participation and territorial decentralization in the 90 s. CBOs are non-profit and based on solidarity, with diverse funding schemes.

Thanks to community organisational processes, CBOs have become responsible for water management at a local level throughout rural Colombia, not only ensuring the provision of water for human consumption but also the protection and conservation of water sources. Authors like Pérez-Rincón (2002) assert that CBOs display 'good performance' when it comes to water provision; others praise the central role they have assumed in guaranteeing water provision in remote areas, supporting the UN-recognised Human Right to Water and Sanitation (HRWS) for rural and peri-urban populations (Ombudsman's Office, 2013). However, CBOs still experience various difficulties in guaranteeing this right, mainly with regard to water safety and quality, because they can count on only limited investment, support, and recognition from the Colombian government. In addition, CBOs encounter problems due to their lack of formal structure and the limited resources available to them for operation and maintenance tasks.

The struggle for recognition

The current regulatory framework for the provision of public services (Law 142/1994) was designed for a profit and/or urban model (Congress of the Republic of Colombia, 1994). The community aspect of CBOs remains outside this scope. Although the Colombian government has made some legislative arrangements that include different perspectives in the provision of public services (Decree 1898 of 2016) and recognise alternative solutions for water supply for human consumption in rural areas, it has not established a specific category for CBOs, based on characteristics such as their community, solidarity, and non-profit status (the different perspectives included by the government were based on geography, i.e. municipal and dispersed rural areas).

In addition, CBOs face multiple conflicts within their territories, including disagreements among their own partners, with other neighbouring CBOs, and with other actors who use water differently. As a result, while CBOs play a central role in local conflict resolution, they also sometimes carry out acts of resistance and denunciation against the affectation of common goods and the violation of the HRWS for their inhabitants.

Associativity as a pathway to recognition

As a way to (re)gain power in the face of privatisation threats and dismissal of the CBO management model by the state, many CBOs have implemented a framework of associativity. 'Associativity' can be understood as the process by which CBOs ally themselves with other organisations in an attempt to strengthen their position and increase recognition. This process can take place at different levels – local, regional, national, and transnational – resulting in the development of diverse forms of organisation to facilitate the allies' joint actions to achieve their objectives (Blanco Moreno, 2023).

In Colombia, the first CBO associations arose in the late 20th and early 21st centuries. Currently, two organisations supporting associativity are present at the national level: the Colombian Confederation of Community Organisations of Water and Sanitation Services (COCSASCOL) and Colombia's National Network of Community Water Management Organisations (RNAC). COCSASCOL was established in 2015 and aims to strengthen the CWM model via increased representation and political advocacy in public policies at the institutional level. RNAC emerged in 2011 to defend public ownership and the principles of CWM.

These associations at the national level are, in turn, part of networks at the international level. COCSASCOL is part of the Latin American Confederation of Community Organisations of Water and Sanitation Services (CLOCSAS), created in 2012: its purpose is to promote the associativity of CBOs across Latin America and the Caribbean and to increase the visibility of CWM. RNAC is part of the Inter-American Surveillance Network for the Defence and Right to Water (Red VIDA), formed in 2003 to uphold water as a public good and a fundamental right, and to defend against privatisation.

COCSASCOL and RNAC are integrated into regional groups, in turn strengthening CBO associations at the local level. This process of articulation in Colombia can be seen in Figure 1.1. In the Valle del Cauca region, there are two regional association processes: the Association of Community Organisations Providing Water and Sanitation Services of Colombia (Aquacol) and the Federation of Rural Community Water Supplies of Valle del Cauca (FECOSER).

Aquacol, which is a member of COCSASCOL (thus bridging the gap between the regional and national levels), is itself made up of 37 local CBOs. Aquacol aims to contribute to improvements in the provision of public water and sanitation services among CBOs in Colombia. Meanwhile, FECOSER, which is a member of RNAC (at the national level), is made up of 124 local CBOs. FECOSER aims to defend everyone's right to water, contribute to the conservation of water resources, and promote the rational use of water. Aquacol supports one municipal association and FECOSER 10 municipal associations. Thus, Aquacol and FECOSER promote associativity at a local level, with the goal of improving overall CWM and political advocacy, such as in their respective municipal development plans.

Success of associativity

All these associative processes across various levels, which have been interwoven over the past two decades, have ultimately allowed these associations of CBOs to be recognised as legitimate interlocutors across the same range of levels – local, regional, national, and international.

At the national level, thanks to the organisations' dogged pursuit of recognition, alongside their focus on bringing the national government's attention to the targets of the UN's Sustainable Development Goals, a National Community Water Management Board was formed in Colombia in August 2019. This entity includes representatives from both the Vice Ministry of Water and Sanitation of Colombia and representatives from CBO associations, supporting the participation of CBOs in public policies.

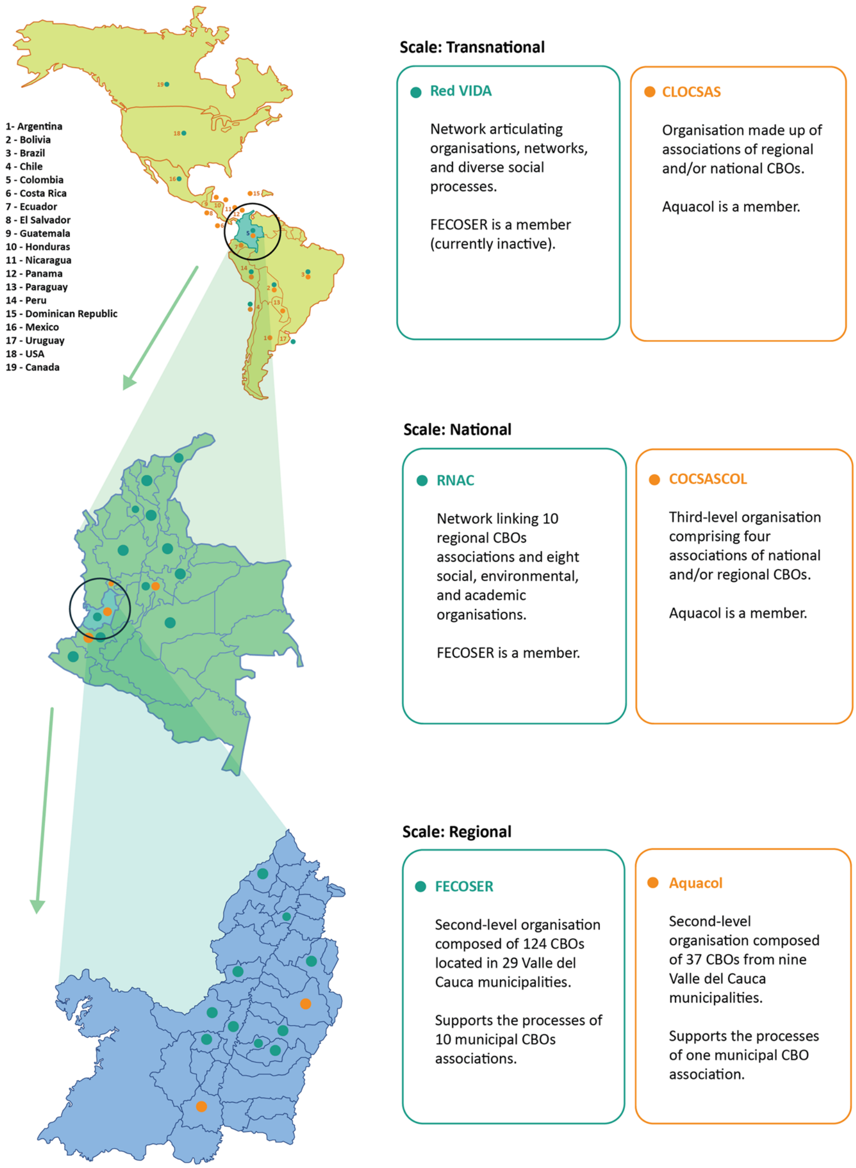


Figure 1.1 Locations and interconnection of associative networks. (Credit: rootsandwings.design)

Table 1.1 Advancements in the recognition of CBOs (Credit: Carolina Blanco Moreno).

Law	Advancement in the Recognition of CBOs
Decree 819 of 2020	Rural subsidy for CBOs during the pandemic and the possibility of concluding public–community agreements, in which entities can contribute public resources without affecting the assets of the community organisation
Decree 1210 of 2020	Inclusion of small-scale animal husbandry and irrigated cultivation for family subsistence in the category of accepted water uses with the right to access water in scattered rural dwellings
Resolution 0288 of 2020	Incorporation in development plans of monitoring indicators related to access to and supply of water in rural areas
Decree 1688 of 2020	Direct delivery of provision of infrastructure for water for human consumption to CBOs

In this way, CBO associations have managed to influence the definition of and modifications to legislation that improves the recognition of CWM, as captured in Table 1.1.

In addition to this, RNAC developed a bill (in a participatory fashion with its CBOs) that was filed in the Congress of the Republic as Bill 271/22, declaring that: 'By means of which the mechanisms of protection of the right to community water management, the related environmental aspects are guaranteed and a legal framework is established for the relations of the communities organised for the community management of water with the State.'

At the international level, CBO associations have also influenced the recognition of CBOs as key actors to guarantee the human right to water. This is evident in the last two reports submitted by UN special rapporteurs on HRWS, which state that CBOs 'offer valuable lessons for democratic water governance based on a human rights approach, participation, and collective responsibility' (Arrojo, 2022) and that they '[should] also play monitoring roles' (Heller, 2020).

Conclusion

Associativity has contributed to wider recognition of CBOs after more than two decades of struggle. Arguably, CBOs' strategy of associativity reflects indigenous environmental justice in its three dimensions, as defined by Fraser (2013): *redistribution*, concerning the right of all human beings and other forms of life to water resources; *representation*, the right to participate in the construction and development of the regulatory and legal framework of water management; and *recognition*, the quest to be recognised and respected like other forms of management. CBOs have ultimately followed a trajectory of vindication, harnessing their particular characteristics, which correspond to their unique worldviews, in order to create and endorse a new form of administration and management of water.

1.2 ACCESS AND JUSTICE: AN EVALUATION OF PUBLIC PARTICIPATION IN WATER AND DEVELOPMENT PLANNING IN MALAYSIA

Wan Asiah Nurjannah Wan Ahmad Tajuddin

This case study explores the link between access to information and procedural justice via public participation. Public participation can serve three purposes: consensus and stability, conflict reduction and increased consciousness, and containment and bargaining (Dola & Mijan, 2006). Ultimately, public participation is founded on the right to be informed (Lee & Sun, 2018). This is the first crucial step to take before further participation processes, such as discussion, debates, engagements, and feedback, can occur. Public participation programmes are often related to procedural justice (Yuan, 2021) and are considered vital to democracy.

In any physical development plan for an area, one of the most crucial aspects is undoubtedly water. Degraded water quality, insufficient water availability, and poor sanitation measures are major challenges in planning. Water-related disasters are also an important issue: when planning major infrastructure in vulnerable areas, it is often mandated to carefully consider the risks posed by floods, coastal erosion, or drought, so as to ensure resilience. In essence, recognising and addressing the multifaceted challenges associated with water supply, sanitation, and disaster preparedness are integral components of responsible and sustainable development planning. A conscientious approach to these issues not only safeguards the natural environment but also upholds the rights and well-being of the communities directly affected by these development plans.

Public participation in Malaysia's water planning

Malaysia's planning system has three tiers: the National Physical Plan (national level), the State Structure Plan (state level), and the District Local Plan (district level). Special areas also have Special Area Plans. All of these plans usually cover a period of between five and 20 years. Before the plans can be published and implemented by planning authorities and developers, however, they have to meet several requirements. One such requirement is public participation. In Malaysia, public participation is regarded as a critical component of the planning process, particularly during the formulation and drafting stages of development plans. Indeed, the authorities don't just invite public participation for publicity; they actively gather and consider community objections, changes, and proposals. Malaysian law, as set out in Sections 9 and 13 of the Town and Country Planning Act 1976 (TCPA) (Malaysian Government, 1976), requires

Publicity methods	Publicity period	Amendment of TCPA 1976 to Act A1129
Publish a notice stating that the plan is available for inspection. Publish in three issues of at least two local **newspapers**. One must be in the national language. Make copies of **the plan available for inspection at the places stated in the notice**, with a statement of the length of time (as stated in the notice) within which objections may be made to the Committee.	**State Structure Plan:** not less than one month from the date of the first appearance of the notice in a local newspaper in the national language. The time stated in the notice may be extended once by the State Director by not more than one month in favour of any particular objector. **District Local Plan:** not less than four weeks from the first appearance of the notice in a local newspaper. The time may be extended by not more than four weeks.	Before commencing the preparation of a local plan, the local planning authority shall take such steps as will, in its opinion, secure that: • **Publicity is given** in its area to the draft local plan..., its objectives and the purpose for its preparation, and matters that the local planning authority proposes to include in the plan. • Persons who may be expected to desire an **opportunity of making representations** to the local planning authority... are entitled to and are given an opportunity of doing so.

Figure 1.2 Requirements of publicity methods, as established in TCPA, 1976 (Credit: Livia Douse).

drafts of local and state structure plans to be publicly disseminated. This legal provision enforces transparency and inclusivity in the planning process, ensuring that the perspectives of stakeholders are not only acknowledged but also communicated to those responsible for finalising the plans.

Figure 1.2 shows what is required of the publicity methods outlined in the TCPA, 1976, including the method of publicity, the duration of the publicity period, and the subsequent steps to be taken by the local planning authorities. However, it must be said that, despite the legal provision, the current information dissemination system is rather outdated. For example, in the digital age, with readership of newspapers constantly declining, this is no longer the best or most relevant option to publicise information – indeed, many media outlets have ceased printing and moved to online platforms (Kobiruzzaman & Ahmad Ghazali, 2022). Fortunately, in recent years, there has been a shift towards announcing public participation programmes online and displaying the plans via a dedicated web portal.

When development plans enter the public participation process, members of the public often seek information on strategies for fulfilling water demand and supply, steps to improve the water quality of a region/area, infrastructure provision within the area, and plans to reduce water-related risks. But announcements of public participation programmes made through irrelevant channels may not reach the communities that the development plans will impact. These communities, especially the most marginalised individuals within them, have the right to be fully aware of the developments taking place around them and the steps they can take at the community level to improve their surroundings. The absence of easily accessible data has the potential to worsen the marginalisation experienced by certain communities, thereby contributing to their disempowerment. And this disempowerment hinders the communities' capacity to make well-informed decisions and undertake necessary actions to safeguard their water rights. Moreover, it diminishes their level of influence in decision-making procedures, allowing others to make choices that disregard their unique social and ecological requirements in ways that perpetuate systemic challenges. Information disparity is intricately interconnected with the perpetuation of injustice, as flawed democratic processes amplify existing gaps and intensify the suffering of vulnerable and disadvantaged groups.

Perspectives on the public participation programmes

Given the challenges outlined above, we wanted to get the perspective of members of the public. As such, we spoke with three individuals who had all recently taken part in a public participation programme. What follows are their views on the process, translated from Malay into English – you can also read their views on our interactive map (Figure 1.3).

Person A

Location: Sedili
District: Kota Tinggi
State: Johor, Peninsular Malaysia
Programme duration: 18 December 2022 to 18 January 2023

'Person A', who did not want to be named, did not participate in any on-site events. They stumbled upon the programme when visiting the PLANMalaysia office in Johor Bahru. Johor Bahru is the state capital of Johor, the southernmost state in Peninsular Malaysia, with Singapore just across the border. However, the development plan in question was being drafted for Sedili, located in the north-west of the state, in the district of Kota Tinggi. Sedili is a thriving tourist spot, known for its beaches. Kota Tinggi is a main water catchment area in Johor; its water is brought to the Seluyut dam and the Sungai Gembut barrage and water treatment plant.

When Person A visited PLANMalaysia's office, the Draft Special Area Plan of Sedili, a copy of the executive summary, a brochure, and a feedback form to be filled out by anyone who wished to leave a comment were all on display. Person A said that Sedili was unfamiliar to them, so they did not feel obligated to comment on the draft.

In their opinion, 'The programme gave a good platform for those who wished to do so … The PLANMalaysia staff also informed us that aside from their office, the public participation programme was also held by the beach to attract attention from the local communities. I am unsure if they [PLANMalaysia] received sufficient feedback from the public. Still, the efforts at making people more aware are commendable.'

When asked whether the information provided was comprehensive enough to make people aware of issues pertaining to water, Person A answered, 'In terms

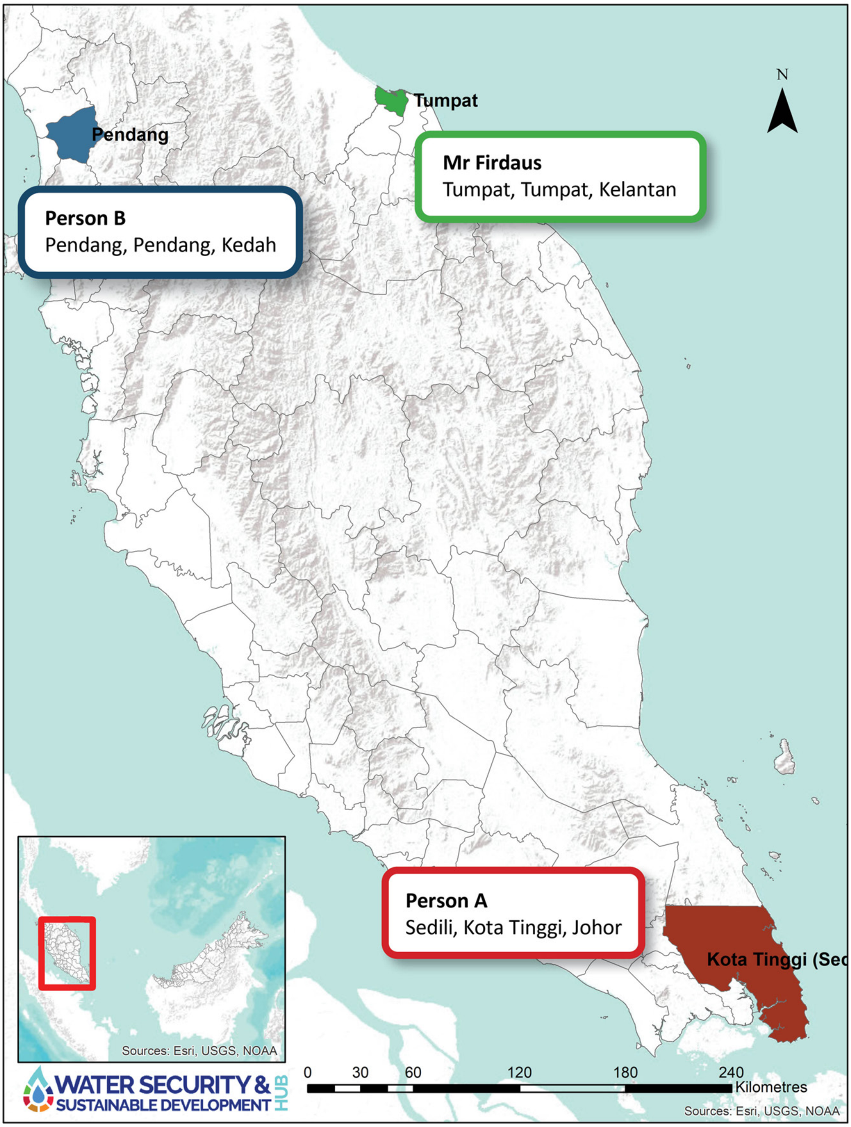


Figure 1.3 Map showing locations of participants. Click the map to view the interactive version (Credit: Samy Mafla Noguera and Livia Douse).

of water supply and sanitation, I am not a local, thus may not know about these areas. However, based on the Special Area Plan provided, there were efforts to strategise integrated river basin management and the management of beach areas … I think the plans for water are in one place, but I am not sure how far the communities understand what is being planned. I know they are planning for something, but I don't know how to detail it to other community members.'

While Person A commended the programme for offering a platform for public engagement, they highlighted a potential justice concern: that the programme, though well-intentioned, seemed to lack inclusivity. This is apparent in the fact that Person A, a non-local, felt unsure about whether they were well-placed or even obligated to comment on the draft. This raises questions about the accessibility and outreach of the programme, especially for individuals who do not reside in the area to be developed but may be affected by the planned developments. The potential justice concern becomes more pronounced when considering Person A's uncertainty about the local communities' understanding of water-related plans, indicating a need for more comprehensive efforts to bridge the information gap and ensure equitable participation in the decision-making process.

Person B

Location: Pendang
District: Pendang
State: Kedah, Peninsular Malaysia
Programme duration: 26 December 2022 to 26 January 2023

'Person B', who also declined to be named, grew up in Pendang, in the state of Kedah. Kedah, in northern Peninsular Malaysia, is the country's main rice producer, with thousands of acres of paddy fields across the state. Rice from the paddy crops is a staple food for the vast majority of Asian people. As a result, many nations in this region view it as a strategic crop that guarantees both political stability and economic growth. Indeed, paddy and rice have been Malaysia's primary sources of self-sufficiency (Firdaus *et al*., 2020). Generally, it takes up to 5000 litres of water to produce 1 kg of rice; continuous water supply is therefore very important. Additionally, it should be stated that most paddy fields are multifunctional, performing flood control, erosion control, and water purification. At present, there are serious concerns that Kedah's current policy will not be able to mitigate the impacts of climate change on agriculture, particularly rice production. Extreme climate variance poses significant challenges for paddy productivity in Peninsular Malaysia, creating concerns around food security as well (Firdaus *et al*., 2020). It is therefore important that such issues, and how all levels of government are addressing such concerns, are communicated to the public to ensure the protection of the livelihood of communities across Malaysia.

Despite growing up in Pendang, Person B had moved out of their parental home to live in another state. They chose to take part in the public participation programme using the online platform. When asked if they found it easy to access, Person B responded, 'Yes, it's comprehensive and complete documentation with much information, especially for the public viewer.' However, Person B also wrote that 'there is a lack of awareness and outreach. The information should be conveyed directly to the population area (e.g., announcement by village head, memos, public announcement).'

Moreover, speaking specifically about the modes of outreach, Person B also expressed, 'This (the online platform) is a good start but it is not reaching out to meet most people and will lack public opinion, especially the local people. Feedback from the affected population is valuable and important.' Person B believed that water security is key to sustainable development, especially in Kedah, but did not see any strategies to improve water supply or environmental conservation in the development plan.

Person B also provided feedback on the development plan. Their comment, which shows an awareness of the environmental impact of the plan, read: 'Kindly ensure the development project will also cover associated factors such as deforestation, river sedimentation, and imbalance in the water supply. We are already experiencing low water pressure, but we hope this can be resolved quickly, especially with an increase in users in the future (both residential and industrial).' Person B recognised the importance of the participatory process and believed the authorities would read and consider their comments because of the open feedback system.

Considered in this context, Person B's engagement reflects the justice principle, emphasising the importance of inclusive outreach, community awareness, and consideration of diverse perspectives in the development planning process for equitable and sustainable outcomes. However, while Person B expressed confidence that their comments would be considered, it remains to be seen whether the feedback will actually be integrated into, or influence, the development plan. The process needs to become more transparent.

Mr Firdaus

Location: Tumpat
District: Tumpat
State: Kelantan, Peninsular Malaysia
Programme duration: 25 January 2023 to 25 February 2023

Mr Firdaus had many positive things to say about the programme he had attended in Tumpat. Tumpat, in the state of Kelantan, is a district located on the east coast of Peninsular Malaysia, which recently faced the worst flood in the region for 31 years, as reported by many Malaysian media outlets (Bernama, 2022). It is important to note how critical flood issues are in this area; public participation programmes held in the area should therefore place this issue at the top of their agendas, informing the public on steps being taken in the planning process, as well as alerting the communities to local actions that they can take. Mr Firdaus commented:

> 'I participated in this programme in its entirety by visiting one of the exhibition spaces that had been set up at a specified location and time. In my case, I went to the local plan exhibition at Ndo Beach in Tumpat, Kelantan. I also took the initiative to spread the information I received to family, friends, and neighbours. I believe the programme is accessible to the general population, as claimed since its inception. This initiative includes more than just announcements on official government websites and social media: it entails opening mobile booths in densely populated sites like public markets, mosques, and administrative buildings. Visiting

> the provided mobile booth makes it simpler for the general public to obtain information.'

He continued:

> 'My personal opinion is that no group is being excluded from receiving the information the government seeks to disseminate. I'm hoping that this organised programme will be well received by all members of society, regardless of their age, race, religion, or other socio-economic factors. I believe this programme will benefit the entire community by providing valuable information and enabling them to support any projects planned for the convenience of the community. Therefore, it is appropriate for the government to expand and improve each programme involving the community through specific organisations to increase their desire to participate in public participation programmes.'

Mr Firdaus's views suggest the programme in Tumpat was highly effective in reaching the community. The programme's publicity efforts included exhibiting the development plan in diverse locations, such as night markets and beaches. The authorities also reached out to the religious facility of this predominantly Muslim community, including the mosque of which Mr Firdaus is a member. However, it is unclear whether they reached out to minority groups of other religious (Buddhist, Hindu, Christian) or ethnic (Siamese, Chinese, Indian) backgrounds who reside in the area and may be impacted by the development plan.

It should be noted that Mr Firdaus was less positive about water issues: 'The problems associated with water, in my opinion, have not been discussed in greater detail. Many aspects of this water issue have not been thoroughly explained to all communities.' He concluded, 'the government should organise more public participation programmes that focus solely on water issues.'

Considering that the area is prone to floods, Mr Firdaus's observation indicates a communication or awareness gap. This communication gap raises concerns about the equitable distribution of resources and the potential for vulnerable communities to be disproportionately affected by water-related challenges. Further efforts should be made to foster transparent and inclusive dialogues and ensure all stakeholders are well-informed and actively engaged in developing comprehensive solutions to address the flood threats that are prone to happen in the region. Involving local stakeholders, experts, and decision-makers in participatory workshops and community-based engagement methods can result in more efficient and enduring flood risk mitigation strategies (Oyediran & Wahab, 2023).

Public participation processes: a new framework

A new framework is needed to ensure procedural justice is achieved and to make the public participation process open and accessible to all. We present the following questions as a template for this framework (Figure 1.4):

To enhance justice in water planning, the authorities must remain dedicated to accountability, openness, and equity – and they have to actively want to interact with the people who are impacted by the decision-making process. As things stand, the level of citizen participation in Malaysia is still at the tokenism

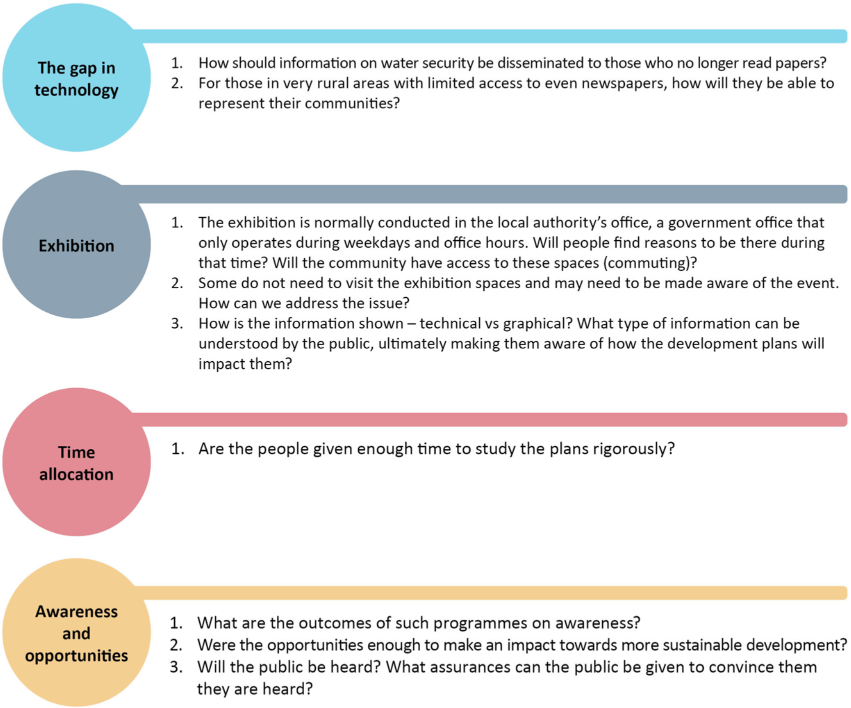


Figure 1.4 A framework for enhancing public participation processes (Credit: Livia Douse).

level, as argued by Marzukhi *et al.* (2022), indicating a need to improve the execution of citizen participation. There also needs to be more transparency on whether the comments and objections made by the public are weighted and valued. Even if planning is supposedly participatory, the authorities' final decisions may overrule objections made by members of the public without their knowledge. The public needs to see how their thoughts and concerns have impacted the decisions to implement the plans. There should be follow-up programmes, not one-time events, to ensure the projects are socially and environmentally sustainable. Thus, the decision-making process will become more open, transparent, and ultimately successful.

1.3 SOCIAL JUSTICE IN WATER SECURITY THROUGH SYSTEMS PERFORMANCE ASSESSMENT: THE CASES OF COLOMBIA AND PALESTINE

Nasser Tuqan

Holistically addressing water security based on systems thinking will allow for increased water use efficiency, ensuring equitable flow of benefits (ESCAP, 2013). Looking at water systems exclusively through the industrial lenses of 'water as economic good' and productivity has increasingly been recognised as dangerously flawed. There is no shortage of examples of when the failure to recognise the complexity of water systems has led to severe damage. These examples include: transboundary water disputes where upstream and downstream nations clash over water allocation without fully grasping the intricate ecological, social, and political dynamics at play; and the frequent cases of mismanagement and diversion of water resources in several regions which resulted in environmental catastrophes and regional tensions among those sharing basins.

Performance indicators in this context are not only easy to understand but can also be widely applied. As Markic (2014) notes, using them in decision-making processes has long been effective. The classical definition of water use efficiency is the ratio of water beneficially used to the total applied. In agriculture, it is the crop yield per unit of water used in irrigation, famously known as 'productivity'. However, these definitions, despite their overwhelming popularity, fail to address important issues such as irrigation water recovery, water reuse, and water quality, and they also do not distinguish between water consumption and water use (Haie & Keller, 2014; Jensen, 2007; Jensen *et al*., 1980; Pereira *et al*., 2012; Willardson *et al*., 1994). Incomplete and/or faulty system representation leads to inequitable and unjust redistribution.

These blind spots have caused water use efficiency experts, especially engineers, to neglect critical issues beyond the technical aspects of water saving. Indeed, an explicit focus on social justice has been largely overlooked, particularly when it comes to addressing water-related issues. These issues include the impact of water use systems (WUSs) on the sustainability of water sources, on downstream stakeholders, and on neighbouring systems; the WUSs' resilience to major pressures (such as climate change); their social and economic costs versus benefits; and the different stakeholder perspectives on WUSs (e.g. residents versus policymakers). Attempts to overcome those shortcomings have so far mainly focused on the physical characteristics of water with little attention to social, economic, environmental, and political factors.

This case study illustrates how the assessment of water systems performance can be a powerful instrument for advancing social justice. By emphasising the fundamental concepts of recognition, representation, and distribution (Fraser, 2008), we aim to address the multifaceted dimensions of social injustice in the realm of water security. Our focus on recognition extends beyond technical aspects, acknowledging and validating the diverse perspectives involved in a WUS. In addition, through our emphasis on true representation, we recognise that diverse voices, often marginalised, should have a meaningful role in decision-making processes. Finally, the pursuit of redistribution addresses the inequalities and disparities to ensure equitable distribution of water and benefits.

The three interconnected core precepts on which our approach will be based are: systems thinking, social justice, and water balance. In reality, water is used within WUSs that host many stakeholders governed by complex dynamics. This list of stakeholders (both human and non-human) includes those who live in, benefit from, and are affected by or make the decisions for these systems. There is a need to reframe models simulating WUSs to equitably represent stakeholders. Endeavours devoid of political considerations have tangible consequences, and evidently, injustice often leads to conflict, such as in the case of privatising drinking water in Cochabamba, Bolivia (Olivera & Lewis, 2004). Despite the complexity of WUS dynamics, nature offers a simple and consistent concept that must prevail in any given WUS: water balance.

Sustainable efficiency (sefficiency)

Water balance is key for equitable water security, and this is not limited to its hydrological definition. Sustainable efficiency (sefficiency), first introduced in 2012 (Haie & Keller, 2012), is a composite multi-level indicator that is fundamentally based on water balance. The most powerful feature of sefficiency is that it weights water quantity, quality, and beneficence, with the latter referring to the significance (beneficence) of water flow paths, as defined by the system's diverse stakeholders. To our mind, this inclusive approach makes a lot more sense than classical water system definitions such as productivity. To illustrate this, let's look at three hypothetical farms (Figure 1.5), all of which use the same amount of applied irrigation to produce the same amount of yield. According to productivity formulae, these farms are equally efficient. However, looking at farms 1 and 2, which both produce the same crop, through the lens of sefficiency produces different results: the efficiency of these farms cannot be identical, given that farm 1 discharges heavily polluted agricultural wastewater. Applying the same lens to a comparison of farms 2 and 3 similarly shows that their efficiency values cannot be identical as they produce different crops, even if they use the same amount of irrigation to produce the same yield and comparable levels of agricultural wastewater. The crop that has a

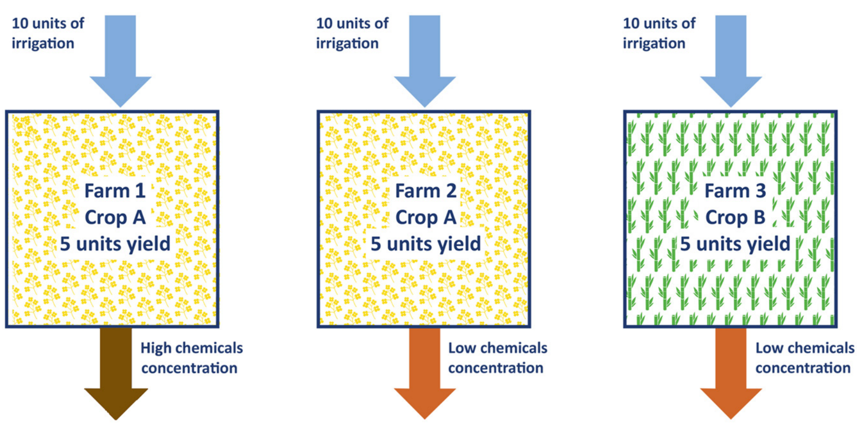
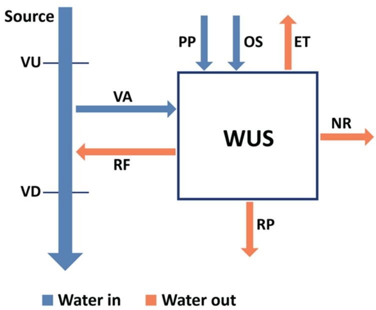


Figure 1.5 Hypothetical farm efficiencies: blue arrows represent irrigation applied to the farms, brown and orange arrows represent agricultural wastewater flowing out of farms. (Credit: rootsandwings.design)

higher socio-economic value for WUS residents must be associated with higher efficiency on a systems level.

As a water balance-based indicator, sefficiency requires every single water path flowing in or out of a WUS (Figure 1.6) to be defined. Such definitions should be fundamentally centred around the concept of recognition (Fraser's justice framework), acknowledging various identity groups, cultures, and experiences. Systems could be defined geographically (e.g. by region or city), hydrologically (by basin or catchment area), culturally (by community or ethnic group), politically (by jurisdiction) or based on water use sectors (by urban or agricultural use). Adapting sefficiency as a performance indicator through stakeholder participation in the modelling process leads to a more realistic representation, not only of the stakeholders within the WUS but also of their complex interactions and relationships. At its core, the concept of sefficiency aims for inclusivity which, if achieved, will pave the way towards environmental sustainability and social justice.



Variable	Meaning
ET	Evapotranspiration
NR	Nonreusable stream
OS	Other sources
PP	Precipitation
RF	Return flow
RP	Potential return
VA	Volume of abstracted water
VD	Volume of water at down stream
VU	Volume of water at upper

Figure 1.6 Hypothetical WUS schematic including all water path types. (Credit: rootsandwings.design)

It is imperative that we construct perspectives that are accountable to valid and nuanced accounts of physical reality, while also being committed to social justice and action. To do so, each inflow or outflow path needs to be assigned a quality weighting reflecting its water quality parameters and a beneficence weighting representing its beneficial value from the perspective of the water system user. Recognising more-than-human beings, such as water bodies, wildlife, and aquatic life, is also crucial, alongside identifying the socio-political and economic hierarchical processes that contribute to certain individuals being more marginalised than others. Accordingly, the idea here is to provide a tool that can convey hidden as well as apparent voices. Sefficiency creates space for these perspectives, thus distinguishing itself from other attempts to address such issues.

The formulae for sefficiency

Sefficiency assesses performance at three different levels, macro, meso, and micro, which differ based on the dynamics between the WUS and its main water resource. Macro-sefficiency (*MacroSE*) assesses the impact of a WUS on the main source. Meanwhile, meso-sefficiency (*MesoSE*) deals with the relation between micro and macro levels, indicating the impact of return instances generated by the WUS; it examines, among other things, the impact of WUS on downstream users, including ecosystems. Finally, micro-sefficiency (*MicroSE*) assesses the internal dynamics within a WUS; it does not consider the WUS's returns or impact on the main source (Haie, 2016; Haie & Keller, 2014).

For the case studies under consideration in this spotlight, we are going to take sefficiency at the meso level. To calculate meso-level sefficiency, we use the following equation:

$$MesoSE = \left[\frac{ET + NR + i(RF + RP)}{VA + OS + PP - c(RF + RP)}\right]_s \tag{1.1}$$

The annotation *s* reflects the usefulness criterion, which is the useful portion of flows considering their quality and value weights (as calculated in equation 1.2). The presence of *i* or *c* before the efficiency level indicates the model – *iMesoSE* means *MesoSE* calculated as in full inflow model, while *cMesoSE* refers to *MesoSE* calculated as in consumption model. *iMesoSE* gives the percentage of total useful inflow that is useful outflow, whereas *cMesoSE* provides the percentage of efficient consumption that is useful consumption.

$$\begin{aligned} X_q &= W_{qX} \times X \\ X_b &= W_{bX} \times X \\ W_{sX} &= W_{bX} \times W_{qX} \\ X_s &= W_{sX} \times X \end{aligned} \tag{1.2}$$

where:

X_q: the quality dimension of X
X_b: the beneficial dimension of X
W_{qX}: the quality weight of X
W_{bX}: the beneficial weight of X
W_{sX}: the usefulness weight of X

Further details about the three different sefficiency levels, including proof of equation (1.1), the distinction between inflow and consumption models, and the link between these two totals and the saving mechanisms, can be found in the method's development publications (Haie & Keller, 2008, 2012).

TECNiCAFÉ

Colombia produces more coffee than any country in the world, except for Brazil and Vietnam (Ceballos-Sierra & Dall'Erba, 2021). In a country where agriculture is a prominent sector, it is estimated that coffee constitutes 17% of Colombia's overall crop production, making it the most valuable agricultural product in the country (Ramirez-Villegas *et al*., 2012). However, climate change is expected to impact the production of coffee in most parts of the globe, including Colombia (Iscaro, 2014).

Figure 1.7 Location of TECNiCAFÉ with respect to Cajibío municipality in south-western Colombia. (Credit: Livia Douse)

Another of the key challenges for coffee farmers and commercial producers is that, until now, global coffee prices have been stable at relatively low rates. As such, the farmers and producers shifted most of their focus towards land and water use productivity (yield per unit of applied irrigation) (Sachs *et al.*, 2019). The important factor to notice here is that decisions around water use and farming practices are driven and managed by politics at various scales. When WUSs fail to pay attention to these complex networks, they hide social injustice.

According to the National Federation of Colombian Coffee Farmers (*Federación Nacional de Cafeteros*), there are more than 600 000 farmers growing coffee across Colombia, and for most of them it is their only livelihood. The Cauca Department, located in the south-west of the country, is home to more than 90 000 families cultivating over 93 000 hectares of Arabica coffee per year. In Cajibío municipality in the heart of the Cauca Department (Figure 1.7), exceptional-quality coffee is produced at TECNiCAFÉ, which describes and conducts itself as an organisation whose mission is to carry out transformative innovation in the world of coffee – it focuses on obtaining high-quality coffees through sustainable solutions. TECNiCAFÉ farmlands encompass an area of around 150 hectares or 1.5 km^2. Part of this land is used for commercial coffee production, while the rest is used for experiments.

Cajibío and its neighbouring municipalities, especially in the northern part of Cauca, have been suffering for decades from the effects of the deadly armed conflict in Colombia (Aguirre & Manyoma, 2019). This multifaceted conflict, which was fuelled by – and ultimately exacerbated – the severe inequity in resource distribution, especially regarding land and water, has disproportionately affected the poorest people in the most rural and remote areas (Meltzer & Rojas, 2005). Having signed an extremely fragile peace agreement in 2016, Colombia has little choice but to pursue long-term environmental sustainability objectives (Suarez *et al*., 2018) through the representation of historically suppressed voices to reinforce the prospect of peace.

TECNiCAFÉ plays a significant role in the post-conflict landscape. It incubates local coffee smallholder farmers (*campesinos*) who require post-conflict support, such as those who were forcefully displaced, single mothers, and young ex-guerrillas.[2]

We identified the coffee-growing cycle at TECNiCAFÉ as a WUS. Coffee plants on site are rainfed with no form of applied irrigation needed. Thus, it is a WUS with a single inflow path. In any agricultural system, evapotranspiration (ET), or the amount of water the coffee plants consumptively use, is typically the most significant outflow. While constructing our water balance model using the data for the 2016 season as a case study, we estimated ET to be around 0.36 million cubic metres (Mm^3). On the other hand, precipitation (PP) in that season was around 3.16 Mm^3, nearly nine times more. From a productivity standpoint, these figures lead to a severely low performance, at an 11.4% productivity rate.

Our original aim was to use sefficiency to assess the impacts of climate change on the system's performance. Thus, we looked at the World Bank's Climate Change Knowledge Portal (World Bank, n.d.) and used the temperature and PP projections under two shared socio-economic pathways (SSPs), namely SSP1-1.9 and SSP2-4.5, for the periods of 2020–39 and 2040–59, comparing them with the existing conditions (2016 season). SSP1-1.9 sets out the optimistic scenario, according to which the 1.5°C objective of the Paris Agreement is achieved, while SSP2-4.5, known as the middle-of-the-road scenario, represents a pathway where no significant improvements to the current situation are made and climate change continues unchecked (IPCC, 2021).

In our hypothesis, we had assumed that the projected changes in climatic conditions would have significant impacts on the system's water balance and efficiency. However, the hydrological changes, especially in ET, and efficiency rates under all future scenarios have shown a negligible impact of climate change on TECNiCAFÉ's operations. Under scenario SSP2-4.5 in 2020–39, for example, where minimum temperature increases by 3.8%, maximum temperature increases by 2.7%, and PP decreases by 2.4%, performance rates only changed by 0.2 percentage points.

So, TECNiCAFÉ's performance is poor on the basis of productivity, and climate change is not projected to change this in the next 40 years. But these traditional lenses fail to reveal the real story: they don't have the capacity to include TECNiCAFÉ's mission or its sustainable practices; for example, it only uses natural solutions for soil and water management, such as mulching. In addition, they don't reflect the perspectives of the historically marginalised *campesinos* who benefit from the organisation as a business incubator (Figure 1.8).

[2] *Campesino:* while this term translates to 'peasants' in English, it encompasses a specific demographic of rural smallholder farmers in Latin America. As such, the Spanish term will be utilised throughout the book.

Figure 1.8 Illustration of TECNiCAFÉ farm (Credit: rootsandwings.design).

The real story can be told, however, using sefficiency. Through water balance, the notion that any precipitation that isn't used to grow plants is 'wasted' falls apart. Similarly, by considering water quality, the site's avoidance of chemicals gets the appreciation it deserves. Through assigning beneficence values to the different water flow paths, the hidden voices of those single mothers, who lost their loved ones in violent conditions and were then offered a more hopeful chapter in life by working at TECNiCAFÉ, become audible in a mathematical model. According to our sefficiency-based model, TECNiCAFÉ scored 44%. Although the result indicates clear areas for improvement, it was significantly more representative than the 11.4% generated by traditional efficiency models.

The Jordan Valley

The agricultural sector in Palestine is undoubtedly deteriorating. According to the World Bank, its contribution to the national gross domestic product dropped from 9.3% in 1999 to only 4% in 2012 (World Bank, 2012). This can be demonstrably linked to the shortage of water. While the average global agricultural water use was 68% of the total water withdrawn in 2014 (WWAP, 2019), the Palestinian agricultural sector used less than 43% in 2015 (PWA, 2017). In addition, the Israeli occupation of Gaza (27 October 2023–ongoing at time of publication) imposes severe territorial constraints that limit investment and infrastructural development in agriculture, causing significant food insecurities among the Palestinian population. This reality is abundantly clear in the Jordan Valley, home to 50% of the West Bank's agricultural lands, on which 60% of Palestine's total vegetables are produced (WAFA, 2015). It should be stated that 87% of the Palestinian part of the Jordan Valley falls into the category of Area C (EcoPeace Middle East, 2015), which is Israeli-controlled territory subject to substantial restrictions when it comes to land access, infrastructural works, and water resource development.

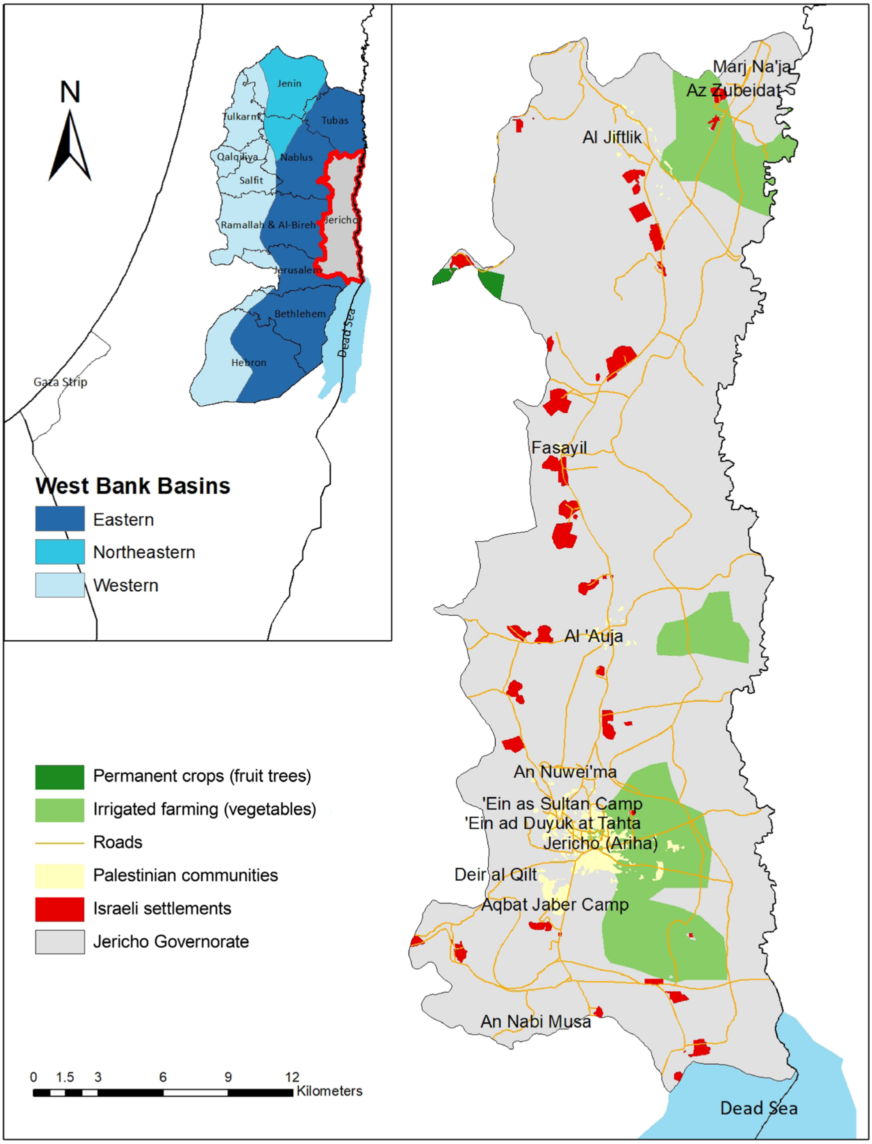


Figure 1.9 Jericho Governorate (Credit: Nasser Tuqan).

A key challenge in Palestine is the reliance on groundwater that is heavily restricted, severely low quality (especially in Gaza), and often weaponised. According to the Palestinian Water Authority (PWA), groundwater aquifers, which are the only accessible natural freshwater resource for the Palestinians, make up more than 95% of their total supplies (PWA, 2017). However, groundwater is a highly unstable water source, vulnerable to climate change. Moreover, due to population growth and acute irregularities in urban development, influenced by the geopolitical complexities, Palestinians have been over-pumping from their wells at unsustainable rates. For instance, the abstraction rate from the Eastern Aquifer Basin (EAB) increased from 23 Mm^3 in 2003 (Lautze & Kirshen, 2009) to 42 Mm^3 in 2011 (PWA, 2012), then to 53 Mm^3 in 2012 (PWA, 2013), and finally to nearly 65 Mm^3 in 2015, according to the last published PWA update (PWA, 2017).

Agricultural activities in the Palestinian part of the Jordan Valley, particularly in the Jericho Governorate (which constitutes more than 70% of the valley's total area), were defined as our WUS. These activities are, by far, the largest user of EAB abstractions. According to PWA official reports, farmers in Jericho used 24.2 Mm^3 (57.6%) out of the abstracted 42 Mm^3 during the 2010/11 season (PWA, 2012). These abstractions were used to irrigate 80 different field crops, trees, and vegetables, ranging over 36.3 km^2 of farmlands (Figure 1.9) (PCBS, 2012).

There are a vast number of stakeholders that can be identified here. For this study, however, we were interested in the dynamics of water resource management, and therefore chose to focus on the difference in perspectives between the farmers and the water managers. To that end, we interviewed the Director General of Water Resources Management at PWA, Eng. Theeb Abdelghafour, and surveyed a random sample of 40 local farmers. This selection of farmers considered both population density and geographic distribution across the study area. For instance, 30% of the sample were farmers from Jericho City, which is the area of the highest density; another 30% were from the northern villages (green areas in the north, as shown in Figure 1.9); and the remaining 40% were from the remaining villages across the governorate.

Building a hydrological model to establish water balance is the final step before calculating sefficiency results. When we did so in this case, we conclusively found that crop water demand (required irrigation) during that season to meet the recorded agricultural activities must be at least 14.4 Mm^3 (60%) more than PWA-reported abstractions from EAB. This major finding exposed a severely alarming reality: the hydrological model only indicates the minimum missing quantity from what is reported. Although what was actually abstracted from EAB will never be known, it is most certainly higher than the reported (24.2 Mm^3) and unreported (14.4 Mm^3) abstractions combined. This is because water losses in irrigation always occur.

Abdelghafour confirmed this finding and explained that a substantial number of unregistered wells and springs can be found on old and family-inherited properties, which farmers do not report in fear of closure. This issue can be viewed through the lens of legality and regulations, reflecting negatively on the Palestinian authorities, especially in the context of weaponisation of water due to the occupation. However, the indisputable reality is that people

Figure 1.10 Illustration of Jordan Valley (Credit: rootsandwings.design).

need water to grow and produce their food. Those farmers did not dig a well in their backyard to fill in a swimming pool; they are instead victims of a failed government, a brutal occupation, or a combination of both (Figure 1.10).

In the Jordan Valley case, the question of the system's sefficiency figures became irrelevant, and rather invalid, as soon as we had embarked on the results of the water balance model. In a WUS where reported abstractions are much less than what is being used, the entire narrative shifts from performance and efficiency into unpacking the reality of dire and, in this case, unjust conditions. The system's characterisation in its hydrological sense through water balance, which is a fundamental preliminary step in calculating sefficiency, became a tool to depict the reality of those who live in the system.

The water balance-based approach exposes this inconvenient reality, uncovering the misery of the status quo and the utter hopelessness of an entire population due to a century of conflict and the current occupation. This is just another example of people figuring out solutions to meet their unmet demands. Critically, however, the sustainability of EAB is in question, especially considering the absence of collaboration under the existing political atmosphere, as well as climate change projections of an even drier future in this part of the world.

Conclusion

Water indicators, including water use efficiency, are double-edged swords. On one hand, they can be used effectively to signify the state of progress in a WUS, saving time and effort for many implicated actors. They can also be used as a powerful vehicle to deliver complex ideas in an incredibly simple format. On the other hand, there is no shortage of examples where common reductive indicators are used by powerful actors to further exclusion and underrepresentation. The use of the latter indicators is not the way forward if we are to hear the voices of a poor single mother *campesina* in Cajibío or a struggling, oppressed tomato farmer in Jericho.

Conflicts often drive destruction, oppression, and severe inequality, leading to further injustices. Whether in Latin America or the Middle East, those pains are not only felt in combat zones but also in WUSs. Interestingly, the Colombian *campesina* and the Palestinian farmer will have quite similar stories of land confiscation, territorial disputes, forced displacement, water access restrictions, and yield erosion. One would imagine that these obstacles could be addressed if their voices were heard. However, it is apparent that many of the powers that be in technology and administration have recurrently overlooked the importance of representing such voices. It is no secret that engineering training is fundamentally centred around creativity in problem-solving over scrutinising problem characterisation and representation of key actors.

Sefficiency is an attempt to call for a more just approach to calculating and modelling water use efficiency. However, scaling such inclusive tools, whether they be sefficiency or something similar, either through adoption, scrutiny, or recreation, represents a quest to revolutionise the status quo. Traditional approaches have long been in place, even if they are quite reductive to our understanding of WUSs and their dynamics and interactions. One must obviously think of water use within systems, and systems thinking adds a certain complexity, dynamicity, and interdependence, which a human brain often tries to avoid (Anderson & Johnson, 1997). As indicated by the cases of TECNiCAFÉ and the Jordan Valley, systems-level performance assessments should consider water balance, quality, and beneficence dimensions. These are not just commendable concepts; they are fundamental components of WUSs, if these systems are to support social justice.

In its application, sefficiency allows for flexibility, challenging the notion that every scenario requires the detailed estimation of micro-, meso-, or macro-sefficiency. A tangible example is seen in the Jordan Valley, where the construction of a water balance model reveals profound insights without necessitating exhaustive efficiency calculations. This underlines a broader concept – particularly relevant in severely water-scarce systems – that understanding the dynamics of the system may outweigh the emphasis on overall efficiency.[3]

Sefficiency, however, does not aim to provide an all-encompassing solution that absolves water managers and engineers from concerns about genuine representation. Instead, it offers a valuable perspective to stakeholders, urging them to recognise the importance of adopting a systems-thinking approach. While sefficiency is not presented as a catch-all solution, it serves as a starting point for ongoing improvement. One avenue involves adopting a more participatory approach: engaging stakeholders in the refinement process can contribute essential breadth to the model. Additionally, incorporating economic games

[3] See Tugan *et al.* (2020) for the sefficiency application in Jordan Valley, including technical details.

(Thielmann *et al.*, 2021) into the methodology can prove instrumental in refining the representation of the socio-economic benefits in the sefficiency model.

In this spotlight, both case studies show how important it is to represent the hidden voices within WUSs in a systemic and engineering-based framework. This might appear to be a no-brainer that should be adopted and applied at many levels, including policymaking. However, to lay the essential foundations for this inclusive approach, substantial efforts are needed – at the grassroots level as well as in academia, non-profit organisations, for-profit corporations, and governmental entities. We will then be able to build upon this foundation to foster a more comprehensive and equitable representation of voices within WUSs, promoting a collaborative environment that spans diverse sectors of society.

Despite some room for improvement, sefficiency serves as a compelling call to action for practitioners, engineers, and academics, especially those rooted in physical and natural sciences. It encourages us consider the often-overlooked voices within WUSs. This call goes beyond an ethical imperative; it resonates with the fundamental principle of doing what is right. Recognising and representing these hidden voices is not just a moral responsibility but a crucial step towards establishing more equitable redistribution and sustainable water management practices, ensuring that the intricacies of these systems are not only acknowledged but woven into the fabric of decision-making processes.

REFERENCES

Aguirre E. and Manyoma P. (2019). Agricultural supply chains prioritization for development of affected areas by the Colombian conflict. In: Advanced Studies in Multi-Criteria Decision Making, S. B. Amor, A. T. de Almedia, J. L. de Miranda and E. Aktas (eds.), 1st edn. Chapman and Hall/CRC, New York, US, 111–121, https://doi.org/10.1201/9781315181363

Anderson V. and Johnson L. (1997). Systems Thinking Basics: From Concepts to Causal Loops. Pegasus Communications, Westford, Massachusetts, US. https://people.sabanciuniv.edu/atilgan/CEM-Spring17/Books/6.Anderson-Johnson_SystemsThinkingBasics.pdf (accessed 22 April 2024)

Arrojo P. A. (2022). Human Rights to Safe Drinking Water and Sanitation of People in Impoverished Rural Areas. Report of the Special Rapporteur on the human rights to safe drinking water and sanitation, A/77/167, UN Human Rights Office of the High Commissioner, Geneva, Switzerland. https://www.ohchr.org/en/documents/thematic-reports/a77167-human-rights-safe-drinking-water-and-sanitation-people (accessed 19 April 2024)

Bernama. (2022). 'Tumpat residents facing 'worst flood in 31 years''. New Straits Times, 19 December. https://www.nst.com.my/news/nation/2022/12/862404/tumpat-residents-facing-worst-flood-31-years (accessed 19 April 2024)

Blanco Moreno C. (2023). La asociatividad: una estrategia para el fortalecimiento y el reconocimiento de la gestión comunitaria del agua en el Valle del Cauca, Colombia (Associativity: A strategy for the strengthening and recognition of community water management in Valle del Cauca, Colombia). PhD thesis, Environmental Sciences, Universidad del Valle, Cali, Colombia.

Ceballos-Sierra F. and Dall'Erba S. (2021). The effect of climate variability on Colombian coffee productivity: a dynamic panel model approach. *Agricultural Systems*, **190**, 103126, https://doi.org/10.1016/j.agsy.2021.103126

Congress of the Republic of Colombia. (1994). Ley 142 de 1994: Por la cual se establece el régimen de los servicios públicos domiciliarios (Law 142 of 1994: By which the regime of home public services is established). 11 June, Bogotá, Colombia. https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=2752 (accessed 19 April 2024)

Dola K. and Mijan D. (2006). Public participation in planning for sustainable development: operational questions and issues. *International Journal on Sustainable Tropical Design Research & Practice*, **1**(1), 1–8, http://psasir.upm.edu.my/id/eprint/2421/1/1-Kamariah.pdf (accessed 5 June 2024)

Economic and Social Commission for Asia and the Pacific (ESCAP). (2013). Water Security and the Global Water Agenda: A UN-Water Analytical Brief. Institute for Water, Environment & Health, United Nations University, Hamilton, Ontario, Canada. https://hdl.handle.net/20.500.12870/4206 (accessed 22 April 2024)

EcoPeace Middle East. (2015). Regional NGO Master Plan for Sustainable Development in the Jordan Valley, Tel Aviv-Yafo, Israel. https://ecopeaceme.org/wp-content/uploads/2022/03/Regional_NGO_Master_Plan_Final.pdf (accessed 22 April 2024)

Firdaus R. B. R., Leong Tan M., Rahmat S. R. and Senevi Gunaratne M. (2020). Paddy, rice and food security in Malaysia: a review of climate change impacts. *Cogent Social Sciences*, **6**(1), 1818373, https://doi.org/10.1080/23311886.2020.1818373

Fraser N. (2008). Scales of Justice: Reimagining Political Space in A Globalizing World. Columbia University Press, New York, US. https://cup.columbia.edu/book/scales-of-justice/9780231146807 (accessed 22 April 2024)

Fraser N. (2013). Fortunes of Feminism: From State-Managed Capitalism to Neoliberal Crisis. Verso Books, London and New York City, UK and US. https://www.versobooks.com/en-gb/products/2305-fortunes-of-feminism (accessed 5 June 2024)

Haie N. (2016). Sefficiency (sustainable efficiency) of water–energy–food entangled systems. *International Journal of Water Resources Development*, **32**(5), 721–737, https://doi.org/10.1080/07900627.2015.1070091

Haie N. and Keller A. A. (2008). Effective efficiency as a tool for sustainable water resources management. *Journal of the American Water Resources Association (JAWRA)*, **44**(4), 961–968, https://doi.org/10.1111/j.1752-1688.2008.00194.x

Haie N. and Keller A. A. (2012). Macro, meso, and micro-efficiencies in water resources management: a new framework using water balance. *Journal of the American Water Resources Association (JAWRA)*, **48**(2), 235–243, https://doi.org/10.1111/j.1752-1688.2011.00611.x

Haie N. and Keller A. A. (2014). Macro, meso, and micro-efficiencies and terminologies in water resources management: a look at urban and agricultural differences. *Water International*, **39**(1), 35–48, https://doi.org/10.1080/02508060.2013.863588

Heller L. (2020). Progress Towards the Realization of the Human Rights to Water and Sanitation. Report of the Special Rapporteur on the human rights to safe drinking water and sanitation, A/HRC/45/11, UN Human Rights Office of the High Commissioner, Geneva, Switzerland. https://www.ohchr.org/en/documents/thematic-reports/ahrc4510-progressive-realization-human-rights-water-and-sanitation (accessed 19 April 2024)

Intergovernmental Panel on Climate Change (IPCC). (2021). Summary for policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.

B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.), Cambridge University Press, Cambridge, UK and New York, NY, US, pp. 3–32, https://doi.org/10.1017/9781009157896.001

Iscaro J. (2014). The impact of climate change on coffee production in Colombia and Ethiopia. *Global Majority E-Journal*, **5**(1), 33–43.

Jensen M. E. (2007). Beyond irrigation efficiency. *Irrigation Science*, **25**(3), 233–245, https://doi.org/10.1007/s00271-007-0060-5

Jensen M. E., Harrison D. S., Korven H. C. and Robinson F. E. (1980). The role of irrigation in food and fiber production. In: Design and Operation of Farm Irrigation Systems, G. J. Hoffman, R. G. Evans, M. E. Jensen, D. L. Martin and R. L. Elliot (eds.), American Society of Agricultural Engineers, St. Joseph, Michigan, US, 15–41.

Kobiruzzaman M. M. and Ahmad Ghazali A. H. (2022). Social media impact on traditional media: a review on the reason behind the closure of Utusan Malaysia. *International Journal of Education and Knowledge Management*, **5**(2), https://doi.org/10.37227/IJEKM-2022-01-1176

Lautze J. and Kirshen P. (2009). Water allocation, climate change, and sustainable water use in Israel/Palestine: the Palestinian position. *Water International*, **34**(2), 189–203, https://doi.org/10.1080/02508060902903175

Lee T.-P. and Sun T.-W. M. (2018). Public participation. In: Global Encyclopaedia of Public Administration, Public Policy, and Governance, A. Farazmand (ed.), Springer, Cham, Switzerland, pp. 5171–5181, https://doi.org/10.1007/978-3-319-20928-9_2720

Malaysian Government. (1976). Town and Country Planning Act 1976. Act 172, Laws of Malaysia. https://tcclaw.com.my/wp-content/uploads/2020/12/Town-and-Country-Planning-Act-1976.pdf (accessed 5 June 2024)

Markic D. (2014). A review on the use of performance indicators in the public sector. *TEM Journal*, **3**(1), 22–28, https://www.temjournal.com/documents/vol3no1/TemJournalFebruary2014_22_28.pdf (accessed 22 April 2024)

Marzukhi M. A., Abdullah J., Leh O. L. H., Zanudin K. and Danial M. H. (2022). The challenges of public participation in the Malaysian planning system. *Planning Malaysia Journal*, **20**(4), 195–209, https://doi.org/10.21837/pm.v20i23.1161

Meltzer J. and Rojas C. (eds.) (2005). Elusive Peace: International, National, and Local Dimensions of Conflict in Colombia. Palgrave Macmillan, New York, US, https://doi.org/10.1007/978-1-137-09105-5

Olivera O. and Lewis T. (eds.) (2004). Cochabamba! Water War in Bolivia. South End Press, Cambridge, Massachusetts, US. https://archive.org/details/cochabambawaterw00osca (accessed 5 June 2024)

Ombudsman's Office. (2013). La Gestión Comunitaria del Agua (Community Water Management). Imprenta Nacional de Colombia (National Printing House of Colombia), Bogotá, Colombia. https://www.habitatbogota.gov.co/sites/default/files/documents/2017-09/La%20gestio%CC%81n%20comunitaria%20del%20agua.pdf (accessed 19 April 2024)

Oyediran K. K. and Wahab B. W. (2023). Building urban flood resilience through community participation in urban areas of kebbi state, Nigeria. In: Handbook of Research on Managing the Urban-Rural Divide Through an Inclusive Framework, A. A. Popoola, H. H. Magidimisha-Chipungu and L. Chipungu (eds.), IGI Global, Hershey, PA, pp. 146–166, https://doi.org/10.4018/978-1-6684-6258-4.ch009

Palestinian Central Bureau of Statistics (PCBS). (2012). Agricultural Census 2010 Final Results – Jericho & Al Aghwar Governorate. Palestinian Central Bureau of Statistics and Ministry of Agriculture, Ramallah, Palestine. https://www.pcbs.gov.ps/pcbs_2012/Publications.aspx?catid=41 (accessed 22 April 2024)

Palestinian News & Info Agency (WAFA). (2015). *Al'aghwar Alfilastinia* (The Palestinian part of the Jordan Valley). http://info.wafa.ps/ar_page.aspx?id=9663 (accessed 22 April 2024)

Palestinian Water Authority (PWA). (2012). Annual Status Report on Water Resources, Water Supply, and Wastewater in the Occupied State of Palestine 2011. Ramallah, Palestine.

Palestinian Water Authority (PWA). (2013). Status Report of Water Resources in the Occupied State of Palestine – 2012. Ramallah, Palestine.

Palestinian Water Authority (PWA). (2017). Groundwater Resources – Utilization 2015. Ramallah, Palestine. http://www.pwa.ps/page.aspx?id=NL8EMVa2547842781aNL8EMV (accessed 22 April 2024)

Pereira L. S., Cordery I. and Iacovides I. (2012). Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agricultural Water Management*, **108**, 39–51, https://doi.org/10.1016/j.agwat.2011.08.022

Pérez-Rincón M. A. (2002). Comparing the management of water services in Colombia's small towns and villages. *Waterlines*, **21**(1), 13–14, https://doi.org/10.3362/0262-8104.2002.039

Ramirez-Villegas J., Salazar M., Jarvis A. and Navarro-Racines C. E. (2012). A way forward on adaptation to climate change in Colombian agriculture: perspectives towards 2050. *Climatic Change*, **115**(3), 611–628, https://doi.org/10.1007/s10584-012-0500-y

Sachs J. D., Cordes K. Y., Rising J., Toledano P. and Maennling N. (2019). Ensuring Economic Viability and Sustainability of Coffee Production. Columbia Center on Sustainable Investment, New York, US.

Suarez A., Árias-Arévalo P. A. and Martínez-Mera E. (2018). Environmental sustainability in post-conflict countries: insights for rural Colombia. *Environment, Development and Sustainability*, **20**(3), 997–1015, https://doi.org/10.1007/s10668-017-9925-9

Thielmann I., Böhm R., Ott M. and Hilbig B. E. (2021). Economic games: An introduction and guide for research. *Collabra: Psychology*, **7**(1), 19004, https://doi.org/10.1525/collabra.19004

Tugan N., Haie N. and Ahmad M. T. (2020). Assessment of the agricultural water use in jericho governate using sefficiency. *Sustanability*, **12**(9), 3634, https://doi.org/10.3390/su12093634

UNESCO World Water Assessment Programme (WWAP). (2019). The United Nations World Water Development Report 2019: Leaving No One Behind. UNESCO, Paris, France. https://www.unesco.org/en/wwap/wwdr/2019 (accessed 22 April 2024)

Willardson L. S., Allen R. G. and Frederiksen H. D. (1994). Elimination of Irrigation Efficiencies. Paper presented at the Irrigation Planning and Management Measures in Harmony with the Environment session, 13th Technical Conference, 19–22 October, United States Committee on Irrigation and Drainage (USCID), Denver, Colorado, US. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=6d6909ba2429e54d83e8e3f836352d1de1d13715 (accessed 22 April 2024)

World Bank. (2012). Fiscal Crisis, Economic Prospects: The Imperative for Economic Cohesion in the Palestinian Territories. Economic Monitoring Report to the Ad Hoc Liaison Committee, Washington, DC, US. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/350371468141891355/fiscal-crisis-economic-prospects-the-imperative-for-economic-cohesion-in-the-palestinian-territories-economic-monitoring-report-to-the-ad-hoc-liaison-committee (accessed 22 April 2024)

World Bank. (n.d.). Country: Colombia. Climate Change Knowledge Portal. https://climateknowledgeportal.worldbank.org/country/colombia/climate-data-projections (accessed 22 April 2024)

Yuan M. (2021). How the perception of public official on organizational culture influences procedural justice in environmental policy processes. *Frontiers in Psychology*, **12**, 626210, https://doi.org/10.3389/fpsyg.2021.626210

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Chapter 2

Social justice – redistribution

Pranav Singh, Shivani Singhal and Likimyelesh Nigussie

The ways in which water (and other resources) are distributed directly impacts access to safe and sufficient water. Politics, pricing, and infrastructure all affect water supply systems and distribution networks. In urban settings such as Delhi, India and Addis Ababa, Ethiopia, systemic strains from the rapidly expanding populations and uneven development have made matters worse. The following case studies showcase the intersectional social injustices experienced in these cities in relation to inadequate water distribution and displacement, and put forward proposals for more just solutions in which historically marginalised peoples are supported to become more resilient, innovative, and empowered.

2.1 WATER INJUSTICE IN SLUMS: A CASE STUDY OF SETTLEMENTS ALONG BARAPULLAH DRAIN, DELHI, INDIA

Pranav Singh

Delhi is a city of stark contrasts, where gleaming neighbourhoods coexist with sprawling slums, creating a complex tapestry of urbanisation and inequality. At the heart of the city is the Barapullah Basin, which stretches alongside the Barapullah Drain, a 12-km stormwater drain that marks a region of geographic, socio-economic, and historical significance dating back to the 11th century (Sengupta, 2023). Numerous slum settlements are dotted along the periphery of this drain, grappling with profound challenges related to water access, sanitation, and land tenure security. These challenges epitomise the broader issue of water justice, whereby marginalised communities are disproportionately burdened by inequitable access to clean and reliable water sources, perpetuating cycles of poverty and vulnerability.

Contextual background

For over 40 years, the 25 slums along the Barapullah Drain in Delhi have served as vital hubs of affordable housing for migrating families from low-income backgrounds. Spread across an average area of 1.45 hectares, these settlements accommodate approximately 470 households each. However, the economic landscape within these communities presents challenges, with only 27.5% of residents participating in the workforce and each household earning an average monthly income of 10 000–20 000 Indian rupees (Rs.), well below Delhi's average of Rs. 32 500. Sanitation facilities are inadequate, with only 26% of households having individual toilets, leading to reliance on dysfunctional community facilities. Water supply, averaging 40 litres per capita per day, primarily relies on public standposts, with limited treatment and concerns over potability. Consequently, over half of residents have stated that they are willing to pay for improved water services (i.e. access to potable water in their homes). During monsoon seasons, flooding is frequent, displacing residents and creating health hazards as wastewater enters houses.

To focus on the positive, most communities (22 out of 25) have reported significant improvements in their water supply over the years: they noted that shortages were primarily experienced during peak summers and that quality issues had diminished overall (Janya Collective, 2023b). The three slums that raised complaints about water scarcity are dispersed across the basin, indicating localised factors driving water scarcity rather than a uniform basin-wide issue. This dispersion also underscores the need for nuanced, context-specific solutions tailored to the unique challenges faced by each community rather than broad, one-size-fits-all approaches.

Disparities of water injustice

In this case study, we delve into the three slum settlements along the Barapullah Drain that are facing severe water challenges, bringing out the systemic issues faced by residents. These slums are Nehru Ekta Camp and SPJP Camp in RK Puram, and New Priyanka Camp in Sarita Vihar. Specifically, we focus on injustice in water services thanks to service disparities, access disparities, quality disparities, gender disparities, affordability, and policy injustice; at the same time, we look at the various measures of resilience these communities have employed (Figure 2.1).

Service delivery disparity

None of the three slums have piped water supply through the Delhi Jal Board (DJB), leading to a dire situation in water delivery. Water tankers serve as the primary source for drinking purposes, with deliveries occurring every alternate day in Nehru Ekta Camp and SPJP Camp, and twice a day in New Priyanka Camp. Other sources available to the three communities are shared standposts connected to DJB-managed borewells, operating for two hours in the morning and two hours in the evening. However, the borewells' reliance on groundwater results in poor water quality, characterised by elevated levels of suspended solids and E. coli contamination (Janya Collective, 2023a), rendering it suitable

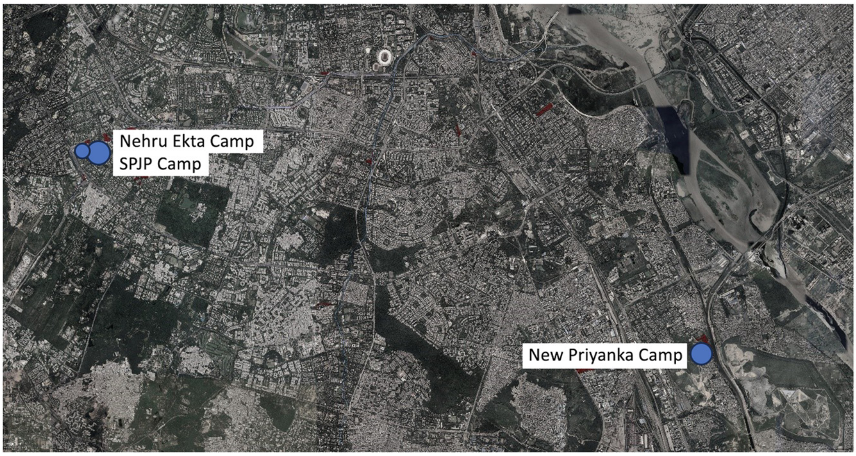

Figure 2.1 Aerial view of Delhi identifying the three slum locations in the Barapullah Basin. (Credit: Pranav Singh).

only for non-consumptive uses, such as washing and bathing. Because these standposts are shared by many families, low pressure is experienced at the end of the network, adding to the time spent collecting water. All in all, a lack of reliable infrastructure underscores the poor service delivery that compels residents to resort to makeshift solutions to their water needs, relying on distant sources, sporadic supply from tankers, and individual water bottles (Figure 2.2).

(a) (b)

Figure 2.2 Photographs showing (a) DJB water tanker in Nehru Ekta Camp and (b) common standpost. (Credit: Pranav Singh).

Figure 2.3 Photograph from Hanuman Camp of a community standpost adjacent to Barapullah Drain. (Credit: Pranav Singh).

Access disparities

In light of the poor service delivery, access to clean and reliable water remains a huge challenge. Any standposts are shared by between seven and 20 families. But pipelines and standposts are often broken, causing loss of water and pressure, and intermixing of wastewater. Periods of water scarcity force residents to travel to DJB-managed potable water sources outside settlements, which can be found anywhere from 250 to 600 metres away from various parts of the three slums. Carrying loads of water is a daily endeavour that can consume hours of time. Access disparity is further compounded by the irregular and unreliable delivery of water tankers and substandard water quality (Figures 2.3–2.6).

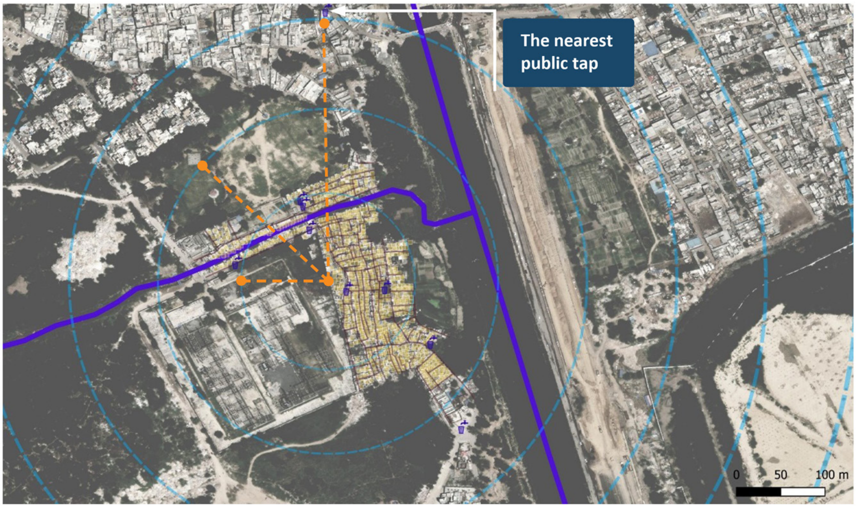

Figure 2.4 Map of Priyanka Camp showing distance to nearest DJB water source in times of emergency. (Credit: Pranav Singh).

Quality disparities

Residents of both Nehru Ekta Camp and SPJP Camp see elevated levels of suspended solids in their water supply, rendering it unsuitable for direct consumption. Despite this, community members resort to filtering the water through cloth for non-consumptive purposes. Conversely, residents of New Priyanka Camp face a more pressing danger, with evidence of E. coli contamination in their water supply posing significant health risks.

Gender disparities

More than 80% of the people in these communities who engage in the daily carrying of water from tankers or public taps are women and children (Janya Collective, 2023b). This disproportionate burden not only places additional strain on women and children but also results in significant loss of productive time and labour, as they are compelled to dedicate considerable efforts to the task of securing water supplies. Consequently, women are often barred from pursuing income-generating activities or accessing educational opportunities, while children frequently miss out on school due to their involvement in water collection activities (CURE, 2022). This gendered division of labour not only perpetuates existing inequalities but also underscores the need for gender-sensitive interventions (Figure 2.7–2.9).

Affordability

A few households in the camps have installed water storage tanks of 200–500 litres, so that they can collect rainwater and then employ reverse osmosis

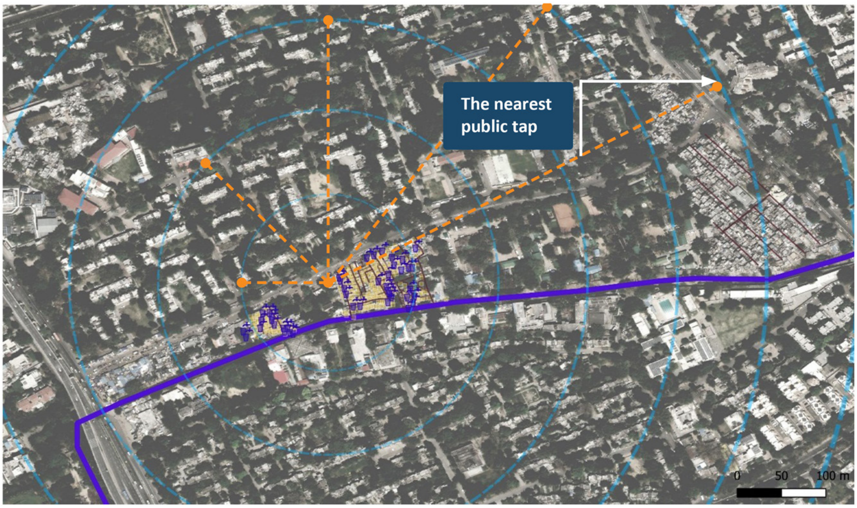

Figure 2.5 Map showing Nehru Ekta Camp and SPJP Camp and the distance to nearest DJB water source in times of emergency. (Credit: Pranav Singh).

Figure 2.6 Photographs from Nehru Ekta Camp and SPJP showing dirty water from standposts. (Credit: Pranav Singh).

treatment methods (costing around Rs. 5000). Other families resort to buying bottled water from local vendors at the cost of Rs. 30 per 20 litres, especially during medical emergencies. But only about 10% of households across all three slums can afford these measures, and so it remains an inadequate solution for the broader community (Figure 2.10–2.12).

Figure 2.7 A common scene from a slum showing women engaged in household chores, including filling water vessels and washing clothes and utensils. (Credit: Pranav Singh).

Figure 2.8 Women in SPJP Camp seen filling water through community taps with low pressure. (Credit: Pranav Singh).

Policy injustice

The uneven, inadequate policy framework governing water delivery in slum settlements perpetuates injustice. The DJB supplies water to slums primarily through standposts or else, where water pipe extension is not feasible, through water tankers, citing the lack of land tenure security. This stands in stark contrast to the strategy adopted for other settlement types, where water is provided through at-home taps. This disparity is furthered by the *Central Public Health and Environmental Engineering Organisation*, a body of the Indian government, which recommends the provision of 42 litres per capita per day (LPCD) for slums, significantly lower than the norm of 172 LPCD for the rest of Delhi (Aijaz, 2020). This discrepancy underscores the systemic inequities inherent in water governance, whereby marginalised communities are deprived of access to an adequate and stable water supply. Additionally, policies favouring the relocation of slum dwellers and the absence of affordable housing options further exacerbate this injustice, as they fail to address the underlying issues of tenure security.

Figure 2.9 Children in Nehru Ekta Camp carrying water from a tanker. (Credit: Pranav Singh).

Figure 2.10 Photograph of New Priyanka Camp showing 500-litre water storage tanks installed at a few homes. (Credit: Pranav Singh).

Consequences of water injustice

The water disparities outlined in this case study have severe consequences on the residents of the camps. Economically, the lack of access to clean and reliable water sources hinders productivity and income generation opportunities, perpetuating cycles of poverty and economic stagnation. The reliance on makeshift solutions, such as water tankers and shared standposts, further exacerbates the financial stress on already marginalised communities,

Figure 2.11 Photograph of Nehru Ekta Camp showing 500-litre water storage tanks installed at a few homes. (Credit: Pranav Singh).

Figure 2.12 Photographs from Nehru Ekta Camp and New Priyanka Camp showing use of bottled water. (Credit: Pranav Singh).

as they are forced to allocate scarce resources to purchasing water or investing in alternative water treatment methods. This economic strain not only limits their ability to meet basic needs but also undermines their ability to advance socio-economically in the long-term.

Additionally, the poor quality of water sources poses significant health risks to residents, including waterborne diseases such as diarrhoea, cholera, and typhoid. This not only results in physical suffering but also places additional financial strain on households due to increased healthcare costs and loss of income from missed workdays. This logic also applies to women and children, who disproportionately carry the burden of water collection and therefore dedicate significant time and effort to securing water for household use, often at the expense of educational and economic opportunities. The lack of access to clean water notably jeopardises the health and cognitive development of children (UNICEF, 2023). In extreme cases, water-related health hazards have also led to premature loss of life.

Despite all this, the residents have exhibited remarkable resilience as they seek to overcome the barriers to water supply on a daily basis. These three communities, and the communities in the slums settled all along the Barapullah Drain in general, showcase the power of collective wisdom, expertise, action, and grassroots innovation when it comes to navigating the complexities of urban life. For instance, families in Nehru Ekta Camp have come together to install shared motor pumps equipped with flexible outlet pipes that allow each family a window of 15 minutes to fill their water tanks, promoting equitable resource distribution (Janya Collective, 2023b). Residents of SPJP Camp, meanwhile, have turned to their local temple, leveraging whatever water is available inside the temple's premises. The SPJP and New Priyanka Camp communities are also exploring local water conservation approaches, repurposing many defunct public spaces for water harvesting and recycling mechanisms. Across these

Figure 2.13 People reusing buckets and containers to store water, a common sight in the slums. (Credit: Pranav Singh).

settlements, people can be seen employing makeshift filtration processes, such as using clothes to filter substandard water available through standposts. These adaptive approaches aid the communities in surviving the plight of water scarcity, contamination, and inadequate infrastructure, and their stories serve as a testament to the strength of the human spirit in the face of adversity. By amplifying the voices of marginalised communities and advocating for inclusive policies through such case studies, we strive to pave the way for transformative change, realising a more just and equitable future where access to clean water becomes not only a basic necessity, but a fundamental human right (Figure 2.13).

2.2 UNTOLD STORIES: FARMERS LIVING ALONG THE YAMUNA, DELHI, INDIA

Shivani Singhal

Water is critical to the physical and social production of urban space (Gandy, 2004). The boundaries between land and water are blurred and have been rewritten by various actors over time (Coelho & Raman, 2013: 148). Such complex and fluidly changing human–nature relations can be seen in the floodplains of Delhi, India's capital, where waterscapes feature river pollution, floods, and evictions.

In July 2013, the water of the Yamuna River in Delhi rose to its highest level in 45 years, inundating various projects on the floodplains and causing more than 16 000 people to be shifted to relief tents (Mollan & Slow, 2023). The intense flooding was seemingly sudden and unforeseen. But it must be said that the floodplains have been degraded as a result of human actions over the years: Kumar (2023) identified ‘rouge’ development as one of the leading causes of severe socio-ecological degradation. Indeed, ongoing river rejuvenation plans by the state and the judiciary are predicted to exacerbate such floods in the future. This urban construction in conjunction with ecological rationalities, then, reveals a set of anomalies and contradictions.

The stretch of the Yamuna River that runs through Delhi is the most polluted river in the country (Yamuna Monitoring Committee, 2020). The river rejuvenation plan in the city, a prototype that is to be copied in 351 urban stretches of polluted rivers across India, claims to make the floodplains available for flooding (National Green Tribunal, 2019). Previously considered barren, the floodplains are redefined as vital blue-green spaces to achieve a ‘world-class’ status, aligning with global economic interests. However, this pursuit of homogenised ‘world-class’ aesthetics marginalises informal workers and erases their narratives from the city’s development discourse (Follmann, 2014).

This reimagining, however, involves state bodies ‘reclaiming’ land from thousands of small-scale farmers in the area: the Delhi Development Authority (the city’s planning body), via the Master Plan Delhi 2041 (introduced in 2021),[1] and the National Green Tribunal (the national environmental court) are forcefully evicting all ‘rural’ farmers from the Delhi floodplains. To ‘modernise’ the area, 10 parks with a ‘world-class’ environmental vision will then be constructed: there are plans to plant expensive trees and grass, erect statues, and open cafes (Sharma, 2023). In other words, this modernisation seeks to create a ‘sanitised’ version of urban nature (Smith, 2008). In this, it adheres to previous construction patterns, whereby high-profile engineering projects such as bridges, dams, railway lines, luxury apartments, and mega temples have been built on the floodplains, paying little attention to the ‘natural ways’ of the river (Follmann, 2014; Ghertner, 2010; Gilmartin, 1995). As these plans take shape, there is a risk that the river will be channelised to an even greater extent in order to protect these new investments. Moreover, these evictions completely erase the rich socio-ecological history of the area, hollowing out the floodplains so that they become a ‘non-space’ (Baviskar, 2020). Scapegoating of the urban poor has become part of the official discourse of rejuvenating urban ecologies (Baviskar, 2020; Coelho & Raman, 2013).

These interconnected, multidimensional factors can be understood through the environmentalism of the dispossessed theory, deeply associated with the rural Global South (Babu, 2016; Guha & Martínez-Alier, 1997; Kashwan, 2018; Kumar, 2016; Linkenbach, 2009; Rangan, 2004; Vasan, 2021). This theory argues that conservation that doesn’t take into consideration the livelihood and tenure security of local communities is meaningless (Bryant & Lawrence, 2005) and ultimately results in ineffective long-term ecological outcomes. In

[1] The Master Plan for Delhi is a statutory plan that informs the spatial development of the city.

other words, it is more common to meet conservation targets when the policies at play empower local people, provide cultural benefits, and decrease livelihood costs (Oldekop *et al.*, 2015). Specifically, targeted community agriculture and conservation initiatives have been found to revitalise distressed areas (Krings & Schusler, 2020: 323). And as a general rule, it is possible to drive sociological and ecological evolution at the same time; indeed, co-management through increased institutional collaboration and protection of tenure rights in conservation zones typically delivers greater benefits (Oldekop *et al.*, 2015). However, most conservation policies fall back on formulaic strategies, prioritising these factors to a partial, unsatisfactory extent, or else not at all (Mawdsley, 2004). This produces contradictory results, causing human–nature relationships to become strained (Hua *et al.*, 2022).

Presently, the top-down approach spearheaded by the elite, primarily through governmental and judicial channels, only acknowledges a narrow comprehension of floods, rivers, and floodplains. And views of the small-scale farmers and fishers are rarely heard. Ignoring such factors compartmentalises the technical framing of floods and separates the natural from the social.

Untold stories: voices from the floodplains

This video documents the presence of these small-scale farms, and the transformation of the floodplains through greenwashing techniques by the elite. It contrasts the elite's environmental imaginary and capture of urban nature against the farmer's environmental reality and the backdrop of increasing pollution in the Yamuna.

For this research, fieldwork was conducted from March 2021 to September 2023. Secondary data, including policy documents, court cases, non-governmental organisation (NGO) reports, and newspaper articles related to the rejuvenated Yamuna initiative in Delhi, was analysed. Primary data included 54 semi-structured interviews with a wide variety of actors such as small-scale farmers, government officers, lawyers, environmentalists, civil society activists, cultural actors, and middle-class residents of Delhi. The results are largely presented from the perspective of the farmers being dispossessed.

The farmers have intersectional characteristics based on gender, class, caste, ethnicity, and region, which dictate their values, beliefs, and behaviours. Power dynamics operate in subtle ways, as individuals hold multiple and overlapping social identities across various scales (Chung & Milkoreit, 2021; Singhal, 2024). It is crucial to acknowledge that not all farmers face economic disadvantages: some have major connections and own abundant land, property, and financial assets. By contrast, farmers who have more recently migrated to the area often find themselves trapped in debt with few opportunities to improve their situation. In the video, two such comparative land-leasing farmers share their lived experiences of river pollution, floods, and evictions. Both the farmers are older men and have been anonymised due to the ongoing court cases associated with this matter.[2]

2.3 SOCIAL JUSTICE IN WATER SECURITY CONSIDERATIONS FOR URBAN AGRICULTURE INITIATIVES: THE CASE OF SHENKORA 2 MULTI-PURPOSE GARDEN IN ADDIS ABABA, ETHIOPIA

Likimyelesh Nigussie

Urban agriculture plays a significant role in addressing issues such as food insecurity, environmental injustice, income inequality (Prudic *et al.*, 2019), and is often conceptualised as a way to address these social justice concerns (Giraud, 2021). However, achieving social justice goals through urban agriculture is not always straightforward; challenges include governance issues and the need for broader support networks involving government, practitioners, and non-profit organisations (Hammelman, 2019). Urban agriculture also competes for resources like land and water with other urban activities that are also influenced by policies and plans (Wadumestrige *et al.*, 2021).

Access to and distribution of high-quality water are essential for the sustainability and equity of food production in urban areas (Mok *et al.*, 2014), yet the relationship between water security and urban agriculture is often overlooked, leading to injustices. Studies show that urban agriculture contributes substantially to water withdrawal in urban areas (Ramaswami *et al.*, 2022), which can have environmental implications, such as the depletion of local water sources or contamination from urban runoff (Hoekstra *et al.*, 2018). In addition, the distribution of water resources in urban agriculture is often unequal, causing access difficulties for marginalised groups like smallholder farmers, women farmers, and indigenous communities (Hamilton *et al.*, 2014). This inequitable distribution perpetuates social and economic disparities, presenting significant challenges for poor and marginalised populations. Factors such as competition for water, pricing mechanisms, rapid urbanisation, population growth, and inadequate water resource management contribute to water scarcity and insecurity for marginalised populations (Prakash & Molden, 2020).

In order to promote equitable access, community involvement, and sustainable practices, then, we must consider socio-ecological justice in water security, to create resilient and just urban food systems (Fernández Andrés, 2017; Narayanaswamy *et al.*, 2023; Radonic & Zuniga-Teran, 2023) (Figure 2.14).

Ethiopia's rapid urbanisation and rising food and living costs have led to the rise of urban agriculture as a sustainable solution to the soaring living costs as well as unemployment, particularly for low-income and vulnerable groups. A

[2] To capture good audio quality, a multimedia expert visited the site alongside Ashish Sharma, a male researcher. It was noted that female farmers and family members were not comfortable with being recorded in this case.

Figure 2.14 The Shenkora 2 Multi-Purpose Garden: (a) colleagues visiting the garden and (b) crops. (Credit: Cindy Lee Ik Sing).

local government in Gulele sub-city, in collaboration with NGOs, has facilitated urban agriculture for HIV/AIDS-impacted women and elderly grandparents, promoting healthier lifestyles and generating income opportunities.

This case study is informed by a qualitative research methodology: we collected data from farmers engaging in urban agriculture at Shenkora 2 in Gulele, with focus group discussions in February 2020 and in-depth interviews in February 2024. A total of 95 members, including 88 women and seven men, are part of the multi-purpose garden at Shenkora 2; the children and grandchildren of these members also work there during their leisure time. This not only creates learning opportunities, but also encourages the children to become members of the horticulture association when they get older and their relatives are no longer active. The Shenkora 2 women's horticulture group is run by a committee of women farmers who lead activities, mobilise participants, ensure equitable resource-sharing, manage finances, and represent members' voices in decision-making processes. The group receives support, including resources and advisory services, from local government, NGOs, and civil society organisations. According to the women (and few men) farmers, practising urban agriculture allows them to regularly access fresh produce, diversify their diets, and increase their income and participation in the workforce. They also indicated that the garden influences their emotional and social values, fostering solidarity, connection, and resilience.

Still, our results show that the farmers face challenges in maximising the potential of urban agriculture due to limited access to water, particularly during dry seasons and droughts. They obtain water from various sources, including tap water, rainwater, surface water (mainly from springs), and groundwater (from shallow wells). The Urban and Peri-Urban Agriculture Policy and Strategy for Addis Ababa (Bureau of Trade and Industry Development, 2013) also supports access to water for these groups by promoting water harvesting, shallow groundwater tables, and subsidised rates for the pipeline water system – particularly for vegetable producers living with HIV-AIDS. However, accessing water from these sources is challenging due to seasonal rainwater availability, chlorinated tap water, limited water storage tank capacity, higher payment rates for pipeline water systems, and declining water from springs and shallow wells.

Access to water is particularly challenging for women who are elderly and/or have health issues, with their capacity for work therefore limited. Some of the plots are located at the top of the site, up a steep hill; collecting water from springs located at the level of the terrain therefore requires these women to climb while carrying 10-litre cans, which is gruelling work. Strategies to support these women include giving them preferential access to tap water, allowing them to store water in small containers located on their plots, and having other volunteers fetch water for them from the spring. A civil society organisation has also developed a neighbouring spring to pump water from a pondage, store it in a water tank, and supply it to plots via piped systems. However, this is not exactly a sustainable solution, as the farmers claim that maintenance and energy costs associated with pumping water exceed their revenue from urban agriculture.

In sum, Shenkora 2 site farmers face water use challenges due to seasonality, chlorination, and lack of policy. Elderly and physically weak women and men are disproportionately affected, reinforcing socio-economic disparities. To ensure a sustainable, inclusive, equitable, and resilient water system, it is essential to promote gender-responsive and socially inclusive water technologies and practices. This includes providing affordable water-smart technologies that do not require much labour and cost.

REFERENCES

Aijaz R. (2020). Water Supply in Delhi: Five Key Issues, ORF Occasional Paper No. 252, Observer Research Foundation. https://www.orfonline.org/research/water-supply-in-delhi-five-key-issues (accessed 23 April 2024)

Babu S. (2016). Evolving texture of environmentalism and submergence of justice: a critical note on the Narmada Valley protest in India. *Interface: A Journal on Social Movements*, **8**(1), 142–156. https://www.interfacejournal.net/wordpress/wp-content/uploads/2016/06/Issue-8-1-Full-PDF.pdf (accessed 23 April 2024)

Baviskar A. (2020). Uncivil City: Ecology, Equity and the Commons in Delhi. Sage YODA Press, New Delhi, India.

Bryant R. and Lawrence K. (2005). Penitent destroyer? The Philippine State in pursuit of environmental justice. In: The State and the Global Ecological Crisis, J. Barry and R. Eckersley (eds.), MIT Press, US, pp. 117–135, https://doi.org/10.7551/mitpress/6439.003.0008

Bureau of Trade and Industry Development. (2013). Urban and Peri-Urban Agriculture Policy and Strategy for Addis Ababa. Bureau of Trade and Industry Development, Addis Ababa City Administration, Ethiopia.

Centre for Urban and Regional Excellence (CURE). (2022). Unequal Everyday, Institute of Development Studies, University of Sussex, Brighton, UK. https://cureindia.org/assets/files/GESI%20Report%20final-BP.pdf (accessed 23 April 2024)

Chung E. and Milkoreit M. (2021). Who are your people? The effect of political ideology and social identity on climate-related beliefs and risk perceptions. *Politics, Groups, and Identities*, **11**(3), 1–21, https://doi.org/10.1080/21565503.2021.1992287

Coelho K. and Raman N. V. (2013). From the frying pan to the floodplain: negotiating land, water, and fire in chennai's development. In: Ecologies of Urbanism in India: Metropolitan Civility and Sustainability, H. Joshi and A. Viguier (eds.), Hong Kong University Press, Hong Kong, pp. 145–168, https://doi.org/10.5790/hongkong/9789888139767.003.0006

Fernández Andrés J. (2017). Can Urban Agriculture Become a Planning Strategy to Address Social-Ecological Justice? Degree project in environmental strategies, School of Architecture and the Built Environment, KTH Royal Institute of Technology, Stockholm, Sweden. https://www.diva-portal.org/smash/get/diva2:1153064/FULLTEXT01.pdf (accessed 24 April 2024)

Follmann A. (2014). Delhi's changing riverfront: bourgeois environmentalism and the reclamation of Yamuna's floodplain for a world-class city in the making. In: Ville et Fleuve en Asie du Sud: Regards Croisés (City and River in South Asia: Crossed Perspectives), H. Joshi and A. Viguier (eds.), Presses de l'Inalco Collection, Paris, pp. 121–139, https://doi.org/10.4000/books.pressesinalco.457

Gandy M. (2004). Rethinking urban metabolism: water, space and the modern city. *City*, **8**(3), 363–379, https://doi.org/10.1080/1360481042000313509

Ghertner D. A. (2010). Calculating without numbers: aesthetic governmentality in Delhi's slums. *Economy and Society*, **39**(2), 185–217, https://doi.org/10.1080/03085141003620147

Gilmartin D. (1995). Models of the hydraulic environment: colonial irrigation, state power and community in the Indus basin. In: Nature Culture Imperialism: Essays on the Environmental History of South Asia, D. Arnold and R. Guha (eds.), Oxford University Press, Delhi, pp. 210–236. https://archive.org/details/natureculture imp0000unse (accessed 5 June 2024)

Giraud E. (2021). Urban food autonomy: the flourishing of an ethics of care for sustainability. *Humanities*, **10**(1), 48, https://doi.org/10.3390/h10010048

Guha R. and Martínez-Alier J. (1997). Varieties of Environmentalism: Essays North and South. Earthscan, Oxfordshire, UK. https://www.routledge.com/Varieties-of-Environmentalism-Essays-North-and-South/Guha-MartinezAlier/p/book/9781853833298 (accessed 23 April 2024)

Hamilton A. J., Burry K., Mok H-F., Barker S. F., Grove J. R. and Williamson V. G. (2014). Give peas a chance? Urban agriculture in developing countries. A review. *Agronomy for Sustainable Development*, **34**, 45–73, https://doi.org/10.1007/s13593-013-0155-8

Hammelman C. (2019). Challenges to supporting social justice through food system governance: examples from two urban agriculture initiatives in Toronto. *Environment & Urbanization*, **31**(2), 481–496, https://doi.org/10.1177/0956247819860114

Hoekstra A. Y., Buurman J. and van Ginkel K. C. H. (2018). Urban water security: a review. *Environmental Research Letters*, **13**(5), 053002, https://doi.org/10.1088/1748-9326/aaba52

Hua H., Wang Y., Ding Z., Liu H., Zhou S. and Liu Y. (2022). Relationship, discourse and construction: the power process and environmental impact of the Honghe Hani Rice Terraces as a World Heritage Site. *International Journal of Environmental Research and Public Health*, **19**(24), 17100, https://doi.org/10.3390/ijerph192417100

Janya Collective. (2023a). Laboratory Report on Drinking Water Quality. Enkay Test House, Delhi, India.

Janya Collective. (2023b). Water Access and Quality Survey in Barapullah Basin [Primary Survey]. Delhi, India.

Kashwan P. (2018). Democracy and the environment: an ecological economics research agenda. *Ecology, Economy and Society–the INSEE Journal*, **1**(1), 33–41, https://doi.org/10.37773/ees.v1i1.8
Krings A. and Schusler T. M. (2020). Equity in sustainable development: community responses to environmental gentrification. *International Journal of Social Welfare*, **29**(4), 321–334, https://doi.org/10.1111/ijsw.12425
Kumar S. (2016). Agrarian transformation and the new rurality in Western Uttar Pradesh. *Economic & Political Weekly*, **51**(26–27), 61–71. https://www.jstor.org/stable/i40165953 (accessed 23 April 2024)
Kumar A. (2023). 'Development gone 'rogue' and the high flood in Delhi'. *The Wire*, 20 July. https://thewire.in/environment/development-rogue-flood-delhi (accessed 23 April 2024)
Linkenbach A. (2009). Doom or salvation? Utopian beliefs in contemporary development discourses and environmentalism. *Sites: A Journal of Social Anthropology and Cultural Studies*, **6**(1), 24–47, https://doi.org/10.11157/sites-vol6iss1id96
Mawdsley E. (2004). India's middle classes and the environment, *Development and Change*, **35**(1), 79–103, https://doi.org/10.1111/j.1467-7660.2004.00343.x
Mok H-F., Williamson V. G., Grove J. R., Burry K., Barker S. F. and Hamilton A. J. (2014). Strawberry fields forever? Urban agriculture in developed countries: a review. *Agronomy for Sustainable Development*, **34**, 21–43, https://doi.org/10.1007/s13593-013-0156-7
Mollan C. and Slow O. (2023). 'Delhi floods: Key roads under water as Yamuna River swells'. *BBC News*, 13 July. https://www.bbc.co.uk/news/world-asia-india-66184551 (accessed 23 April 2024)
Narayanaswamy L., Ferritto R., Hillesland M., Anker V., Singhal S., Maysels R. M., Bantider A., Charles K., Doss C., Kumar A., Mdee A., Neo S-M., Pinzón F. and Mengistu B. T. (2023). Why a feminist ethics of care and socio-ecological justice lens matter for global, interdisciplinary research on water security. *Frontiers in Human Dynamics*, **5**, 1212188, https://doi.org/10.3389/fhumd.2023.1212188
National Green Tribunal. (2019). Manoj Mishra vs Union of India & Ors., L.P.A. No. 681/2019.
Oldekop J. A., Holmes G., Harris W. E. and Evans K. L. (2015). A global assessment of the social and conservation outcomes of protected areas, *Conservation Biology*, **30**(1), 133–141, https://doi.org/10.1111/cobi.12568
Prakash A. and Molden D. (eds.) (2020). Water in Himalayan Towns: Lessons for Adaptive Water Governance. IWA Publishing, London, UK, https://doi.org/10.2166/9781789061901
Prudic K. L., Wilson J. K., Toshack M. C., Gerst K. L., Rosemartin A., Crimmins T. M. and Oliver J. C. (2019). Creating the urban farmer's almanac with citizen science data. *Insects*, **10**(9), 294, https://doi.org/10.3390/insects10090294
Radonic L. and Zuniga-Teran A. (2023). When governing urban waters differently: five tenets for socio-environmental justice in urban climate adaptation interventions. *Sustainability*, **15**(2), 1598, https://doi.org/10.3390/su15021598
Ramaswami A., Boyer D., Nixon P. and Jelinski N. (2022). A hybrid method to quantify household urban agriculture gardening: implications for sustainable and equitable food action planning. *Frontiers in Sustainable Food Systems*, **6**, 997081, https://doi.org/10.3389/fsufs.2022.997081
Rangan H. (2004). From Chipko to Uttaranchal: development, environment, and social protest in the Garhwal Himalayas, India. In: Liberation Ecologies: Environment, Development and Social Movements, R. Peet and M. Watts (eds.), Routledge, London, pp. 205–226, https://doi.org/10.4324/9780203032923

Sengupta A. (2023). 'Mehrauli: the oldest 'city' of Delhi, inhabited for over a thousand years'. *The Indian Express*, 17 February. https://indianexpress.com/article/explained/mehrauli-oldest-city-of-delhi-explained-8450259/ (accessed 23 April 2024)

Sharma V. (2023). 'Delhi's floodplain projects set back by years'. *Times of India*, 20 July. https://timesofindia.indiatimes.com/city/delhi/floodplain-projects-set-back-by-years/articleshow/101970674.cms (accessed 23 April 2024)

Singhal S. (2024). Uncovering the Silences: Environmental Knowledges in the Floodplains of Yamuna, Delhi, Decolonial Subversions. http://decolonialsubversions.org/docs/pdfs/2024/6.1_Singhal.pdf (accessed 23 April 2024)

Smith N. (2008). Uneven Development: Nature, Capital, and the Production of Space, 3rd edn. The University of Georgia Press, Athens, Georgia, US. https://ugapress.org/book/9780820330990/uneven-development/ (accessed 23 April 2024)

UNICEF. (2023). Triple Threat: How Disease, Climate Risks, and Unsafe Water, Sanitation and Hygiene Create A Deadly Combination for Children. United Nations Children's Fund, New York. https://www.unicef.org/reports/triple-threat-wash-disease-climate (accessed 02 April 2024)

Vasan S. (2021). We are all environmentalists! Framing life in the National Green Tribunal, India, *Journal of Developing Societies*, **37**(2), 151–166, https://doi.org/10.1177/0169796X211001229

Wadumestrige Dona C. G., Mohan G. and Fukushi K. (2021). Promoting urban agriculture and its opportunities and challenges: a global review. *Sustainability*, **13**(17), 9609, https://doi.org/10.3390/su13179609

Yamuna Monitoring Committee. (2020). Final Report of the Yamuna Monitoring Committee. National Green Tribunal. https://greentribunal.gov.in/sites/default/files/news_updates/Final%20Report%20by%20Yamuna%20Monitoring%20Committee%20in%20OA%20No.%2006%20of%202012.pdf (accessed 23 April 2024)

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Chapter 3
Ecological justice

Joshua B. Cohen and Ashwini More

Taking inspiration from indigenous philosophies, as well as more recent academic research such as the work of Aldo Leopold and Rachel Carson, proponents of ecological justice hold that more-than-human nature has intrinsic value and moral standing in its own right (Washington *et al.*, 2018; Wienhues, 2020). This chimes with recent attempts to recognise the agency of more-than-human beings – not just as instantiations of a general kind, but potentially as different types of entity with lives and stories of their own (Ingold, 2021; Ogden *et al.*, 2013; Pacini-Ketchabaw *et al.*, 2016).

In the following case studies, Joshua uses the bio-centric perspective of *ecological justice* to explore what justice for *peatlands* might actually mean in the shifting human context of climate change adaptation. Acknowledging that there is no real distinction between nature and culture, given how deeply entangled nature – in particular peatlands – is with human history, politics, and economy, Joshua exposes the intersections of large-scale landscape interventions and issues of human inequality, power, and coercion, while questioning whether ecological justice can be truly separated from anthropocentrism. This question is further explored by Ashwini, who considers heritage water systems in India and how their function has changed over time: initially designed to be aligned with nature's patterns for mutual benefit (humans and more-than-humans), they have been overpowered by anthropic activities and power shifts over time.

3.1 ECOLOGICAL JUSTICE IN THE REALM OF PEATLAND RESTORATION AND CARBON STORAGE IN THE UK

Joshua B. Cohen

> '**peat,** spongy material formed by the partial decomposition of organic matter, primarily plant material, in wetlands such as swamps, muskegs,

bogs, fens, and moors … The wetlands in which peat forms are known as peatlands.'

Kopp (2022)

The UK is now enthusiastically treating one of the ecosystems it formerly maligned and abused – peatlands – as a part of the solution to its, and the planet's, ecological woes. Such woes include, but are not limited to, flooding, biodiversity loss, water quality, and climate change; the latter is particularly significant because of peat's impressive capacity to store carbon.

As a starting point when thinking about what ecological justice for peatlands in the UK could mean, I draw on the key principles outlined in the Universal Declaration for the Rights of Wetlands, as proposed by Gillian Davies, among others (Davies *et al.*, 2021). It declares:

'… that all wetlands are entities entitled to inherent and enduring rights, which derive from their existence as members of the Earth community … These inherent rights include the following:

(1) The right to exist
(2) The right to their ecologically determined location in the landscape
(3) The right to natural, connected and sustainable hydrological regimes
(4) The right to ecologically sustainable climatic conditions
(5) The right to have naturally occurring biodiversity, free of introduced or invasive species that disrupt their ecological integrity
(6) The right to the integrity of structure, function, evolutionary processes and the ability to fulfil natural ecological roles in the Earth's processes
(7) The right to be free from pollution and degradation
(8) The right to regeneration and restoration'

(rightsofwetlands.org, n.d.)

Peatlands' ecological and social destruction

Measured against these principles, peatlands in the UK have suffered many injustices, especially during the latter period of colonial modernity. People have been digging trenches to drain water from their lands since before the Romans arrived in Britain. However, it was in the 17th century, as Britain both violently created and tapped into a global, perpetually expanding market, that drainage grew on an unprecedented scale (Holden *et al.*, 2004; Rippon, 2006). From this point onwards until the mid-20th century, drainage efforts focused mainly on lowland wetlands (Holden *et al.*, 2004; Proulx, 2022). So, the destruction of wetlands as a process is inextricably linked to the origins of capitalism, driven by the institutions, sciences, policies, and laws that primarily advanced the interests of Britain's ruling classes. As is well documented (Holden *et al.*, 2004; Merchant, 1989; Proulx, 2022; Wilson *et al.*, 2010; Young *et al.*, 2017), wetlands had to be 'improved' and made 'productive' in response to the needs of textile and other agro-industrial processes. They were redefined by knowledgeable men of letters as 'pestilential', 'stinking' 'wastes', and those that lived from their bounty were categorised as degraded forms of humanity, in need of saving and civilising through the virtues of hard work (Merchant, 1989; Proulx, 2022).

Such debasement of the ecosystem continues to this day in common perceptions of peatlands and in everyday language. In England, a 'bog' is also a toilet, and no one wants to get stuck in a 'quagmire'.[1] And the treatment of peatlands is dominated by a centuries-long approach to flooding in Britain in which the accepted, common-sense 'solution' has been to encourage water to leave landscapes as fast as possible, resulting in straightened, concrete-hardened, culverted, and life-discouraging waterways up and down the country (Purseglove, 2015). All of this – from intensified agro-industry, to drained wetlands, to simplified and impoverished river systems – was then exported directly or indirectly to Britain's colonies in the creation of what Rohan D'Souza has termed a 'colonial hydrology' (D'Souza, 2006; Tvedt, 2011). The human injustices linked to this are almost beyond comprehension, including the devastating Pakistan floods of 2022 which affected 33 million people (Mohmand *et al.*, 2023).

Returning to England, many who made their livelihoods from formerly vast fenlands lost access to these vital lowland landscapes when they were enclosed and drained by the landed gentry from the 17th century onwards (Proulx 2022). After World War II and auxiliary efforts to 'feed Britain', government incentives then led to a massive acceleration in the drainage of upland (i.e. higher elevation) peatlands to grow crops and create pasture for livestock – thereby erasing a long-established and more sustainable balance in upland ecosystems (Holden *et al.*, 2004; Schofield, 2022). As Holden *et al.* observe, 'Britain is one of the most extensively drained lands in Europe … and drainage of peatlands has played a fundamental role in the history of British farming' (Holden *et al.*, 2004:05). It is worth noting that this is emphatically *not* a critique of livestock farmers or landowners, many of whom still struggle today within an uncertain, shifting policy landscape and economic context (Ogawa *et al.*, 2023). Rather, it is to point out that, alongside many rural people and farmers, peat has been – and continues to be – buffeted by political decisions made hundreds of miles from where the impacts of such decisions are felt.

These processes were also key, especially in the 17th to early 20th centuries, in creating a class of people with no land, forcing millions to sell their labour in exploitative factory conditions in expanding industrial cities (Foster *et al.*, 2021; Thompson, 1968). Taking a more bio-centric perspective, we might argue, in line with Moore (2015) and Collis (2016), that the peatlands, alongside the rivers into which they drain, and the more-than-human world more generally, have become part of a global 'biotariat': their life processes give 'free' surplus value – in the form of well-fertilised soil and clean water, for example – to capitalist processes, in a similar way to the unpaid portion of human labour. The result is that, today, only around 20% of the peatlands in the UK, and just 13% of those in England, are in a near-natural state (Bain *et al.* 2011; UK Government, 2021) (Figure 3.1).

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[1] A quagmire is an area of wet, boggy ground that a person might sink into; in extended use, it also refers to an unpleasant or difficult situation.

Figure 3.1 Ilkley Moor, Yorkshire, North-West England. (Credit: Joshua B. Cohen).

As argued by myself and colleagues elsewhere (Cohen *et al.*, 2023), all of this is part of a broader, longer process by which any premodern, animist relationship to waters as living ancestral beings was fundamentally undone by what Aimé Césaire calls 'thingification' through colonisation (Césaire, 2001). That is, we have moved towards a fantasy 'world made of things connected only by their presence in space, from which they were extractable to whatever extent was humanly possible, [and in which] Life and ecological relations were incidental and optional extras' (Green, 2020: 40). We might well note here that thingification is metaphysically parallel and foundational to the creation of the commodity form central to our current global political economy – everything and anything can in principle be exchanged for anything else through the magical medium of money.

Sights and sounds of Ilkley Moor

Such thoughts lie behind my multimedia intervention (Figure 3.2). Here, I am inspired by various artists, including Kathy Hinde, Lara Weaver, Maggie Roe, and Cosmo Sheldrake, who creatively use hydrophones to tap into hidden soundscapes as a way to shift our perception of the environment and our relation to it. In so doing, they draw us into the worlds beneath our feet (Hinde, n.d.; Sheldrake, 2020), reframe attitudes to the boggy, squelchy aspects of ecosystems (Weaver, 2022), and situate us bodily and sensually in Earth's dynamic fluxes (Hinde, 2021).

My multimedia image and sound piece resonates with this trend. This sonorous postcard, featuring submerged peat pool hydrophone and open-air

Figure 3.2 The peatlands of Illkey Moor: a sonorous postcard. (Credit: rootsandwings.design).

microphone recordings, aims to draw attention in a meditative mode to the layers of ongoing, emplaced, specific more-than-human and human lives that have and make peatlands. There is nothing else, no out, nowhere outside of our entangledness in this thin critical sliver of Earth and atmosphere that is and gives life (Latour & Weibel, 2020).

In this case, the sliver is the popular visitors' site of Ilkley Moor, Yorkshire, in the north-west of England. Ilkley is an iconic blanket peatland, a landscape 'saturated with meaning' (Flint & Jennings, 2020) where standing stones and rock carvings attest to millennia of human presence – which some scholars have in turn connected to premodern animist modes of communicating and negotiating with a sentient landscape (Hutton, 2013; Wallis, 2009, 2013). Enclosed in the 16th century and subsequently subject to drainage and burning in the interests of grouse hunters and walkers, who valued the heathery but potentially less peat-friendly landscapes thus produced, Ilkley Moor has been in public hands since the 19th century (Smith & Atherden, 1985). Contestations over hunting on and access to the moor continued well into the 20th century (Blenkinsop, 1958), with Bradford City Council eventually banning hunting in 2018 (McIntyre, 2019). Today, through organisations such as the Environment Agency and the Friends of Ilkley Moor, various kinds of restoration activities are underway across the moor, including blocking of drainage channels, planting of sphagnum moss, and building of 'leaky dams' (McIntyre, 2019).

I hope the reader will be able to take a moment in this overland-underland watery soundscape, so as to have it playing in their mind as they read the rest of this case study.

Peatlands' ecological restoration

If we think of the scale of destruction and the overall poor condition of the UK's peatlands, as well as of the waters that are inextricably part of them, we are clearly a long way from ecological justice. Nevertheless, the past couple of decades have seen a notable and sustained shift towards a different understanding of the UK's hydrological processes, in which the value of working with nature has been recognised. A change of collective heart in regard to the UK's peatlands has brought concerted efforts to restore lowland and upland peatlands, backed up by various policies,[2] significant political will, and EU and UK government and private finance.

Up and down the country, on and in uplands and lowlands, in the sky, in outer space, in universities, online, and on TV, a range of actors – from researchers to conservationists, non-governmental organisations, farmers, artists, politicians, government ministries, digger drivers, satellite and drone operators, and masses of volunteers – are passionately advocating for and physically working to assess, map and 're-wet' the UK's peatlands. All of this is aimed at restoring a significant portion of them to their precolonial status (Bradley *et al*., 2022; Harris & Baird, 2019; Waylen *et al*., 2016). Certainly, some progress has been made, and we are likely to see some more, as we move towards a peatland model that reflects, at least to some extent, the wetland rights proposed by Gillian Davies.

Justice for peatlands?

With restorative efforts like these occurring in many parts of the UK, we begin to question: can we see the outlines of some kind of ecological justice for peatlands emerging? I think we need to be extremely careful here – for at least two significant reasons:

(1) *The motivations behind this increased political interest in peatlands are not entirely pure*. A key, consistent message underscoring the excitement around and interest in peatland restoration is peatlands' ability to store carbon on a vast scale. They are 'our largest terrestrial carbon store', according to the England Peat Action Plan (UK Government, 2021: 022). Healthy peatlands' ability to store carbon for thousands of years (as opposed to only hundreds with trees), alongside their propensity to emit carbon when degraded, make them a clear priority for the UK government, which is attempting to meet ambitious 2050 net-zero carbon targets (UK Government, 2021). While policy documents also point to peatlands' various other 'ecosystem services', alongside the government's plans to reduce greenhouse gas emissions, the pressing climate change challenges make peatlands' carbon-storing ability the clear focal point – and thereby often equate peat to its carbon content.

(2) *The plans to fund the scaled-up restoration needed to meet the requirements of the first point are somewhat hazy*. Another key, consistent message across policy documents is that the government intends to finance restoration through carbon credits and 'natural

[2] Key policies include the UK Peatland Strategy and the England Peat Action Plan.

capital markets'. A core aim here is to integrate peatlands within the UK Emission Trading Scheme (ETS), so that the government and national and international businesses can offset the carbon they emit elsewhere by buying the carbon stored or else (hopefully) to be stored, in (restored) peatlands. This is problematic for a number of reasons. Not only do recent studies question whether such schemes actually reduce emissions and environmental degradation (Greenfield, 2023), but this rests on the assumption that one part of the Earth can be traded for another, as if 'life and ecological relations were incidental and optional extras' (Green, 2020).

Conclusion

Clearly, significant resources are going to be needed if peatlands are to be restored to their full potential: perhaps finances raised by the ETS and other schemes might help the UK's peatlands see some kind of justice. But it is concerning that these landscapes are potentially being instrumentalised and again turned to the needs of global capital. This is an issue of resilience – but it is arguably as much about making capitalism resilient to its own contradictions as anything else. Will companies and governments be able to continue business (more or less) as usual, polluting elsewhere while reinventing peatland places as their natural banks, as a biotariat whose surplus value as a carbon sink can literally pay their debts for them? Does it matter if UK peatlands are used this way if more and more of them enjoy the kinds of rights set out above? From a whole Earth perspective, the risk remains that, if emissions are not significantly reduced, right number four in the Universal Declaration for the Rights of Wetlands, 'the right to ecologically sustainable climatic conditions', upon which all other rights effectively hinge, will be totally undercut.

Thinking more locally, there are many questions yet to be raised or adequately answered about who benefits most from peatlands – especially in the context of them being primarily valued by decision-makers for the carbon they store and for the monetary value associated with this. Will the government and businesses find it more 'efficient' to deal with large landowners in order to meet their net carbon aims? What about the implications for sheep and cattle, tangible beings that have been deeply culturally embedded in the ecosystem over centuries, potentially being replaced by abstract carbon credits as a dominant form of social value? These questions, among many others, are why I, alongside colleagues at the University of Leeds, am developing an approach to studying – in a much more comprehensive and rigorous way than the brief thoughts presented here – the risks involved in remaking peatland as carbon credit, as natural capital, as a de-relationed 'thing' once more. Since peatlands' ecological relations have always included people, the foregoing argument suggests that, while the concept of ecological justice can be useful in helping to reorient us away from human exceptionalism and centrism, it by necessity must include human beings within its considerations if it is to mean anything at all.

3.2 WATER HERITAGE FROM INDIA'S PAST

Ashwini More

Habitation and the management of water resources have long been symbiotic, intertwined facets of human civilisation, as documented by scholars such as Aldaya *et al.* (2019) and Anderson *et al.* (2019). How societies perceive and value water informs how it is managed, underscoring the importance of recognising water as a fundamental human right (UN Resolution 64/292 [2010]). And beyond its utilitarian function, water has served as a space for leisure and community engagement. Exploring how people interact with water in recreational settings unveils its role as a nexus for social cohesion and communal bonding. Understanding the historical context of water management and its links to justice is crucial in fostering equitable access to water resources and cultivating vibrant, inclusive communities.

This study delves into historical water management principles observed in India, offering insights into the water values that have shaped past civilisations. By analysing a wide array of secondary literature, including archives, master plans, research papers, and news articles, this study aims to unravel the intricate tapestry of water management practices that has defined India's heritage. Various case studies are used to illustrate different aspects of a shared idea. We explore a wide variety of stories because obtaining a thorough historical account for each case study proves challenging, due to the absence of comprehensive historical records. While we cannot presume uniform management of all water heritage, the aim is to present history through a speculative lens, drawing upon analogous historical instances to visualise likely scenarios.

Water heritage infrastructures can play a notable role in curbing water insecurity (More *et al.*, 2022). As this video shows, humans have interacted with natural resources for centuries, and have innovated ingenious solutions to meet their needs.

If we look at the historic management of water, it is apparent that water values and governance played and continue to play an intrinsic part in addressing water management systems. These, in turn, play a significant role in shaping civilisations and cultures (Crouch, 1993). It is unsurprising, then, that different regions have responded differently to the water-related challenges they face, whether stemming from scarcity or abundance. This diversity of responses has manifested in various infrastructure models that have evolved over the years, in the form of *qanats* (underground channels) in Iran or *baolis* (stepwells) in northern India, among many others. These types of structures varied in their functions but often provided multiple services: for instance, *baolis* provided drinking water, water for cleaning and bathing, and a space for the community to gather and rest from the summer heat, all while recharging the groundwater. The success of the infrastructure relied heavily on how it was managed.

Traditionally, local people relied on themselves to manage water for thousands of years (Agarwal & Narain, 1997). But given the escalating impacts of climate change, such as extreme weather events, there is a pressing need to explore alternative strategies for addressing these challenges effectively. By re-evaluating and adapting proven strategies from history, we can develop innovative approaches tailored to the unique challenges of the present climate crisis. In this case study, we explore historic water management and water values in India and consider how to apply these to cases in the present.

Looking to the past

Historical records in India indicate that societies considered building water management systems one of the highest acts of service (Wescoat *et al.*, 2021). In light of this, the powerful and wealthy were motivated to develop, build, and maintain water infrastructure for the common good of the citizens. For example, as per the Kakatiya ideology, associated with the Kakatiya dynasty (12th–14th century) of the eastern Deccan region of India, constructing and de-silting tanks were listed among the seven most virtuous deeds a ruler on Earth could undertake (Green *et al.*, 2020). This made water security and management appealing to the rulers, regardless of their personal biases or preferences, thus ensuring an adequate water supply for a flourishing kingdom's growing population – and underscoring the vital role water plays in our lives. As such, a leader would often construct a new tank when they came to power (Green *et al.*, 2020): this construction would certainly be motivated by political gains, but the tank also benefitted the citizens by providing clean and safe drinking water and safeguarding water and food security. It can, therefore, be argued that these acts of benevolence are intertwined with the principle of the right to clean and safe drinking water.

To illustrate this further, let us examine *qanats* or *karez*, underground channels made by tapping into water from foothills with rainwater harvesting recharge points, used (in some cases) for drinking and irrigation purposes. These channels were carefully designed and crafted to ensure the proper flow of water, and they were particularly beneficial in arid and semi-arid regions, as they protected water resources from evaporation. *Qanats*, originally designed in Iran, are found worldwide; in parts of India, such as Bidar, Karnataka, they are called *karez*. The *karez* of Bidar, dating from the 15th–16th centuries, tell us a story of anticipatory and active planning from the past and one of community stewardship in the present.

To take the first point, when a new settlement was planned where the heritage city of Bidar now stands, the water network, called the Naubad Karez, was built first, before the rest of the settlement. This clearly demonstrates how important the city administration considered water services to be. During the planning process, the authorities also took into consideration the need to ensure the city would have enough potable water, even in the event of a siege (Govindankutty, 2016). Resilience and adaptability were embedded into the planning.

This generally chimes with historical water management practices. While the governance of these heritage water systems always varied, there is one similarity that we can draw upon. For instance, in the *Arthashastra*, a treatise written by Kautilya in the 2nd–3rd century BCE, the text not only mentions that a king should construct water reservoirs, but adds that the king could, in other cases, assist others in constructing water bodies by providing land, routes, trees, and implements. Similarly, according to records from the 18th-century Maratha administration, none of the local taxes were allocated specifically for rural drinking water infrastructure development. Instead, this relied on a mix of local funding, charitable donations, mandatory labour contributions, and loans – the latter were frequently sought after (Wescoat *et al*., 2021). Moreover, in Kikruma, in the north-eastern region of India, the practice of water–forest–farm management known as *zabo* has been passed down through generations and lives on to this day. Farmers collectively assess and maintain harvesting tanks, channels, and water distribution arrangements (Amenla & Shuya, 2021). These examples highlight the diversity of governance approaches while emphasising the corollary of community involvement and ownership.

Looking to the present

Unfortunately, communities have now become largely disconnected from these resources, and water-sensitive behaviours and values have been lost, specifically in urban areas. Multiple factors have led to the disuse of this infrastructure, including haphazard planning, overuse of groundwater, pollution, and more. However, we would like to highlight one factor in particular: the shift from decentralised, local water management approaches to centralised, command-and-control approaches. This started during the colonial era, as the power to rule local lands shifted to a ruler disconnected from the lands and their challenges. As power shifted, responsibilities changed too, moving from the community to the state. This began with governance of water resources and was eventually reflected in the water resources themselves. For instance, water from various lakes used by locals in Bengaluru was diverted into a newer, deeper reservoir. This transfer of water eventually alienated the communities that were dependent on and responsible for the older system's upkeep. And in time, their reduced dependency on the sites of the system also left them open to encroachment, land use changes, pollution, and so forth (Sudhira *et al*., 2007). Thus, the land that was once so crucial to water management is now more valued for urban housing than water.

A similar process happened with *baolis*, stepwells that provided multiple utilities (Figure 3.3). As mentioned above, these stepwells were used to draw groundwater for drinking while also providing a space to bathe and relax and a tank to recharge the groundwater. This fostered a close connection between communities, their drinking water, and their leisure: these spaces served as focal points for community interactions, strengthening cultural and social bonds. Additionally, the *baolis* also encouraged citizens and users to value and respect water by virtue of the fact that they were a tangible and visible part of their landscape: they cultivated a sense of environmental stewardship and appreciation for natural resources. By nurturing these connections and preserving communal water spaces like *baolis,* then, we might ensure our communities' continued vitality and resilience. The experience of water,

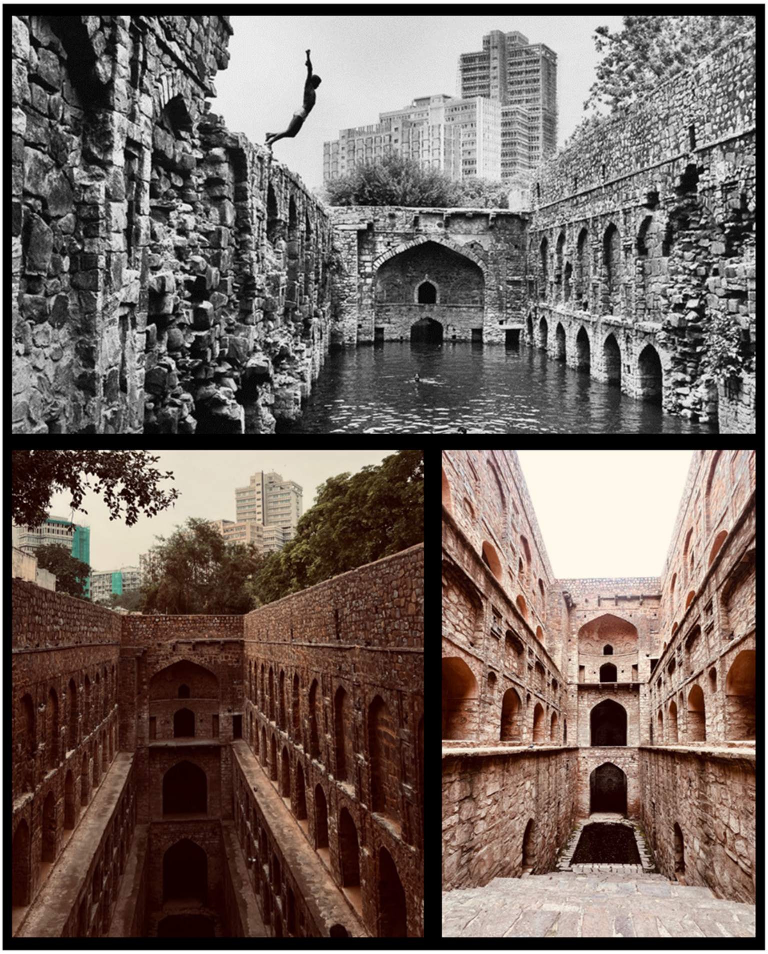

Figure 3.3 Agrasen Baoli with water to the third level, 1971, (top, credit: Raghu Rai); and with water to the first level, 2023, (bottom left and right, credit: Ashwini More). Click on the image to view it as an online slider.

particularly groundwater, is now lost in many modern urbanscapes (Marathe, 2021). A particularly striking example of this disconnection presents itself in the case of the sub-city of Dwarka in Delhi, which was constructed and inhabited for over 15 years before receiving a piped water supply (Kumar *et al.*, 2021).

If we return to present-day Bidar, we find efforts to recapture a sense of connection: in the 2010s, a collaborative effort involving academics, local government, and grassroots organisations led to the restoration of the *karez* system. Initially mistaken for escape routes by locals, the *karez* were rediscovered and identified by the academic Govindankutty. In spring 2015, the local government responded to his research findings by initiating cleaning and conservation efforts; by September, water briefly flowed again, proving the *karez* could be operationalised. There then followed a dry spell during which restoration work continued but, in the summer of 2016, all the city's *karez* systems ran dry for the first time. A volunteer-led non-governmental organisation, YUVAA, then took it upon itself to raise awareness among locals about the *karez* system and how it works. YUVAA also urged the local authorities to undertake desilting and cleaning of wells, advocating for legal measures to safeguard against encroachments on the watershed and protesting the unchecked expansion of deep tube well drilling, as these wells had disrupted the delicate gradients essential for the functioning of the *karez* system.

By September 2016, thanks to restoration efforts and heavy rains, the system was filled with water and has not run dry since, seeing the city of Bidar through drought in the consecutive year. It is remarkable to witness how diverse parties have collaborated effectively on this scheme and how, in particular, the government has welcomed initiative and public involvement. Such collaborations are crucial not only for preserving water heritage but also for enhancing water security overall. This makes it all the more disappointing that, despite the widely documented use of the *karez* systems of Bidar, the state plans to build highways cutting across the town that will endanger the system (Sridhar, 2017). It is baffling to see how today's planning authorities disregard the examples of the past, failing to acknowledge heritage water bodies in city master plans (e.g. in Nagpur and Bengaluru) and leaving them exposed to encroachments and developers (Anparthi, 2016). For example, in the city of Nagpur, two lakes (Police Line Takli and Sanjay Gandhi Lake) were excluded from the City Development Plan 2015 (Nagpur Municipal Corporation, 2015).

Looking to the future

Drawing on the examples given in earlier sections, we can see that the tangible uses of water dramatically affect how communities view and value water. We can also deduce that when administrators have a close link to and understanding of water, they are more likely to have an effective long-term vision for the management of the resource. It is essential to acknowledge and learn from our past, trying to bring or else adapt it in ways that work for our lives now.

Beyond this, it vital that we have a real relationship with water, rather than seeing it as a resource contained in pipes and tankers, hidden from our daily lives. As demonstrated by More *et al.* (2022), hidden linkages such as natural slopes and groundwater recharges allow us to understand urban water cycles holistically. Heritage water systems like *baolis* and *karez* facilitate a deeper understanding of these linkages by illustrating how human activities and climatic patterns influence water dynamics and ultimately affect communities. The example of Bidar shows that we need to shift away from centralised models of governance to mixed models of governance, not just for our water heritage but for all water. Given that water is a human right and a necessity for all living beings, we recommend co-designing experiences and spaces with water that are accessible to everyone.

Overall, water heritage presents a learning opportunity, illustrating as it does the tangible and multiple ways of looking at water, which ultimately promotes community stewardship. This helps people to shift or relink the values they hold today, taking a crucial step towards water security.

See Figure 3.3 to compare the Agrasen *baoli* in the past and the present, or view it as an image slider online.

REFERENCES

Agarwal A. and Narain S. (eds.) (1997). Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems. State of India's Environment, Volume 4, Centre for Science and Environment, New Delhi, India. https://csestore.cse.org.in/usd/soe4.html (accessed 5 June 2024)

Aldaya M. M., Custodio E., Llamas R., Fernández M. F., García J. and Ródenas MÁ (2019). An academic analysis with recommendations for water management and planning at the basin scale: A review of water planning in the Segura River Basin. *Science of The Total Environment*, **662**, 755–768. https://doi.org/10.1016/j.scitotenv.2019.01.266

Amenla I. and Shuya K. (2021). Zabo (Zabü) farming of Kikruma Village, Nagaland, India. In: Innovations in Agricultural Extension, P. S. Adams (ed.), National Institute of Agricultural Extension Management and Michigan State University Extension, Michigan, US. https://www.canr.msu.edu/extensioninternational/Innovations-in-Agricultural-Extension/files/Ch03-Amenla_Zabo-Farming_2021-01-13aa.pdf (accessed 25 April 2024).

Anderson E. P., Jackson S., Tharme R. E., Douglas M., Flotemersch J. E., Zwarteveen M., Lokgariwar C., Montoya M., Wali A., Tipa G. T., Jardine T. D., Olden J. D., Cheng L., Conallin J., Cosens B., Dickens C., Garrick D., Groenfeldt D., Kabogo J., Roux D. J., Ruhi A. and Arthington A. H. (2019). Understanding rivers and their social relations: A critical step to advance environmental water management. *WIREs Water*, **6**(6), e1381. https://doi.org/10.1002/wat2.1381

Anparthi A. (2016). 100-yr-old lake fell off city map, finally "found". The Times of India, 10 October. https://timesofindia.indiatimes.com/city/nagpur/100-yr-old-lake-fell-off-city-map-finally-found/articleshow/54769950.cms (accessed 25 April 2024)

Bain C. G., Bonn A., Stoneman R., Chapman S., Coupar A., Evans M., Gearey B., Howat M., Joosten H., Keenleyside C., Labadz J., Lindsay R., Littlewood N., Lunt P., Miller C. J., Moxey A., Orr H., Reed M., Smith P., Swales V., Thompson D. B. A., Thompson P. S., Van de Noort R., Wilson J. D. and Worrall F. (2011). IUCN UK Commission of Inquiry on Peatlands. University of Plymouth, IUCN UK Peatland Programme, UK. http://hdl.handle.net/10026.1/17516 (accessed 25 April 2024)

Blenkinsop A. (1958). The lords v. the people on Ilkley Moor. *Tribune*.

Bradley A. V., Andersen R., Marshall C., Sowter A. and Large D. J. (2022). Identification of typical ecohydrological behaviours using InSAR allows landscape-scale mapping of peatland condition. *Earth Surface Dynamics*, **10**(2), 261–277. https://doi.org/10.5194/esurf-10-261-2022

Césaire A. (2001). Discourse on Colonialism. Monthly Review Press, New York, US. https://monthlyreview.org/product/discourse_on_colonialism/ (accessed 5 June 2024).

Cohen J. B., Dannreuther C., Fraundorfer M., Mackie C., Martin-Ortega J., Mdee A. and Salazar Sutil N. (2023). Riverkin: seizing the moment to remake vital relations in the United Kingdom and beyond. *People and Nature*, **5**(6), 1877–1892. https://doi.org/10.1002/pan3.10534

Collis S. (2016). Once in Blockadia. Talonbooks, Vancouver, Canada. https://talonbooks.com/books/?once-in-blockadia (accessed 25 April 2024).

Crouch D. P. (1993). Water Management in Ancient Greek Cities. Oxford University Press, Oxford, UK, p. 3. https://global.oup.com/academic/product/water-management-in-ancient-greek-cities-9780195072808 (accessed 25 April 2024).

Davies G. T., Finlayson C. M., Pritchard D. E., Davidson N. C., Gardner R. C., Moomaw W. R., Okuno E. and Whitacre J. C. (2021). Towards a universal declaration of the rights of wetlands. *Marine & Freshwater Research*, **72**(5), 593–600. https://doi.org/10.1071/MF20219

D'Souza R. (2006). Water in British India: The making of a 'colonial hydrology'. *History Compass*, **4**(4), 621–628. https://doi.org/10.1111/j.1478-0542.2006.00336.x

Flint A. and Jennings B. (2020). Saturated with meaning: peatlands, heritage and folklore. *Time and Mind*, **13**(3), 283–305. https://doi.org/10.1080/1751696X.2020.1815293

Foster J. B., Clark B. and Holleman H. (2021). Marx and the commons. *Social Research: An International Quarterly*, **88**(1), 1–30. https://doi.org/10.1353/sor.2021.0003

Govindankutty V. (2016). Historic cultural landscape conservation: rejuvenating Surang-Bhawi system of Bidar. *Urban Update*, **1**, 28. https://archive.org/details/historical-cultural-landscape-conservation-rejuvenating-surang-bhawi-system-of-bidar (accessed 5 June 2024)

Green L. (2020). Rock/Water/Life: Ecology and Humanities for a Decolonial South Africa. Duke University Press, Durham, North Carolina, US. https://www.dukeupress.edu/rock-water-life (accessed 25 April 2024).

Green A. S., Dixit S., Garg K. K., Sandya N. R., Singh G., Vatta K., Whitbread A. M., Jones M. K., Singh R. N. and Petrie C. A. (2020). An interdisciplinary framework for using archaeology, history and collective action to enhance India's agricultural resilience and sustainability. *Environmental Research Letters*, **15**(10), 105021. https://doi.org/10.1088/1748-9326/aba780

Greenfield P. (2023). Revealed: More than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. The Guardian, 18 January. https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe (accessed 25 April 2024)

Harris A. and Baird A. J. (2019). Microtopographic drivers of vegetation patterning in blanket peatlands recovering from erosion. *Ecosystems*, **22**(5), 1035–1054. https://doi.org/10.1007/s10021-018-0321-6

Hinde K. (2021). Never Step into the Same River Twice. South West Creative Technology Network. https://www.swctn.org.uk/2021/03/09/never-step-into-the-same-river-twice/ (accessed 25 April 2024)

Hinde K. (n.d.). Deep Listening Soundscapes. Sonica. https://sonic-a.co.uk/portfolio/deep-listening-soundscapes/ (accessed 25 April 2024).

Holden J., Chapman P. J. and Labadz J. C. (2004). Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration. *Progress in Physical Geography: Earth and Environment*, **28**(1), 95–123. https://doi.org/10.1191/0309133304pp403ra

Hutton R. (2013). Pagan Britain. Yale University Press, London, UK. https://yalebooks.co.uk/book/9780300268348/pagan-britain/ (accessed 25 April 2024).

Ingold T. (2021). The Perception of the Environment: Essays on Livelihood, Dwelling and Skill. Routledge, Abingdon, Oxfordshire, UK. https://www.routledge.com/The-Perception-of-the-Environment-Essays-on-Livelihood-Dwelling-and-Skill/Ingold/p/book/9781032052274 (accessed 25 April 2024).

Kopp O. (2022). Peat. Encyclopaedia Britannica. https://www.britannica.com/technology/peat (accessed 25 April 2024)

Kumar A., Singh N., Cooper S., Mdee A. and Singhal S. (2021). Infrastructural violence: five axes of inequities in water supply in Delhi, India. *Frontiers in Water*, **3**, 727368. https://doi.org/10.3389/frwa.2021.727368

Latour B. and Weibel P. (eds.) (2020). Critical Zones: The Science and Politics of Landing on Earth. MIT Press, Cambridge, Massachusetts, US. https://mitpress.mit.edu/9780262044455/critical-zones/ (accessed 25 April 2024).

Marathe M. (2021). Bāravas: An architectural exploration of the traditional groundwater storage structures of puṇe, India. *Ancient Asia*, **12**(3), 1–15. https://ancient-asia-journal.com/article/10.5334/aa.207 (accessed 5 June 2024), https://doi.org/10.5334/aa.207

McIntyre A. (2019). Call for robust action to protect grouse on Ilkley Moor. Wharfedale Observer, 31 October. https://www.wharfedaleobserver.co.uk/news/18002876.call-robust-action-protect-grouse-ilkley-moor/ (accessed 25 April 2024)

Merchant C. (1989). The Death of Nature: Women, Ecology and the Scientific Revolution. Harper & Row, New York, US. https://archive.org/details/deathofnaturewom00merc (accessed 5 June 2024).

Mohmand S. K., Loureiro M. and Sida L. (2023). What lies beneath Pakistan's disastrous floods. *Current History*, **122**(843), 149–154. https://doi.org/10.1525/curh.2023.122.843.149

Moore J. W. (2015). Capitalism in the Web of Life: Ecology and the Accumulation of Capital. Verso Books, London and New York City, UK and US. https://www.versobooks.com/en-gb/products/74-capitalism-in-the-web-of-life (accessed 25 April 2024).

More A., Walsh C. L. and Dawson R. J. (2022). Re-integration of heritage water systems: spatial lessons for present-day water management. *Blue-Green Systems*, **4**(2), 340–347. https://doi.org/10.2166/bgs.2022.121

Nagpur Municipal Corporation (2015). Nagpur City Development Plan. Jawaharial Nehru National Urban Renewal Mission, Government of India.

Ogawa K., Garrod G. and Yagi H. (2023). Sustainability strategies and stakeholder management for upland farming. *Land Use Policy*, **131**, 106707. https://doi.org/10.1016/j.landusepol.2023.106707

Ogden L. A., Hall B. and Tanita K. (2013). Animals, plants, people, and things: a review of multispecies ethnography. *Environment and Society*, **4**(1), 5–24. https://doi.org/10.3167/ares.2013.040102

Pacini-Ketchabaw V., Taylor A. and Blaise M. (2016). Decentring the human in multispecies ethnographies. In: Posthuman Research Practices in Education, C. A. Taylor and C. Hughes (eds.), Palgrave Macmillan, UK, pp. 149–167. https://doi.org/10.1057/9781137453082_10

Proulx A. (2022). Fen, Bog and Swamp: A Short History of Peatland Destruction and its Role in the Climate Crisis. 4th Estate, London, UK. https://www.4thestate.co.uk/products/fen-bog-and-swamp-a-short-history-of-peatland-destruction-and-its-role-in-the-climate-crisis-annie-proulx-9780008534417/ (accessed 25 April 2024).

Purseglove J. (2015). Taming the Food: Rivers, Wetlands and the Centuries-Old Battle Against Flooding. William Collins, Glasgow, Scotland. https://harpercollins.co.uk/products/taming-the-flood-rivers-wetlands-and-the-centuries-old-battle-against-flooding-jeremy-purseglove?variant=32610139013198 (accessed 25 April 2024).

rightsofwetlands.org (n.d.). Universal Declaration of the Rights of Wetlands. https://www.rightsofwetlands.org (accessed 25 April 2024).

Rippon S. (2006). Taming a Wetland Wilderness: Romano-British and Medieval Reclamation in the Somerset Levels and Moors. Somerset Archaeological and

Natural History Society, Taunton, UK. http://hdl.handle.net/10036/23673 (accessed 5 June 2024).

Schofield L. (2022). Wild Fell: Fighting for Nature on a Lake District Hill Farm. Transworld Publishers, London, UK.

Sheldrake C. (2020). Cosmo Sheldrake: Subterranea. Land Lines Project. https://landlinesproject.wordpress.com/cosmo-sheldrake-subterranea/ (accessed 25 April 2024)

Smith R. T and Atherden M. A. (1985). Recent Vegetative Change and the Management of Ilkley Moor, West Yorkshire. Working Paper 414, School of Geography, University of Leeds, UK.

Sridhar L. (2017). How Bidar beat back the drought. The Hindu, https://www.thehindu.com/news/national/karnataka/how-bidar-beat-back-the-drought/article18282462.ece

Sudhira H. S., Ramachandra T. V. and Subrahmanya M. H. (2007). Bangalore. *Cities*, **24**(5), 379–390. https://doi.org/10.1016/j.cities.2007.04.003

Thompson E. P. (1968). The Making of the English Working Class. Penguin Books, New York, US.

Tvedt T. (2011). Hydrology and empire: the Nile, water imperialism and the partition of Africa. *The Journal of Imperial and Commonwealth History*, **39**(2), 173–194. https://doi.org/10.1080/03086534.2011.568759

UK Government (2021). England Peat Action Plan. Policy paper, Department for Environment, Food & Rural Affairs. https://www.gov.uk/government/publications/england-peat-action-plan (accessed 25 April 2024)

Wallis R. J. (2009). Re-enchanting rock art landscapes: animic ontologies, nonhuman agency and rhizomic personhood. *Time and Mind*, **2**(1), 47–69. https://doi.org/10.2752/175169709X374272

Wallis R. J. (2013). Animism and the interpretation of rock art. *Time and Mind*, **6**(1), 21–28. https://doi.org/10.2752/175169713X13500468476402

Washington H., Chapron G., Kopnina H., Curry P., Gray J. and Piccolo J. J. (2018). Foregrounding ecojustice in conservation. *Biological Conservation*, **228**, 367–374. https://doi.org/10.1016/j.biocon.2018.09.011

Waylen K. A., van de Noort R. and Blackstock K. L. (2016). Peatlands and cultural ecosystem services. In: Peatland Restoration and Ecosystem Services, A. Bonn, T. Allot, M. Evans, H. Joosten and R. Stoneman (eds.), Cambridge University Press, UK, pp. 114–128. https://doi.org/10.1017/CBO9781139177788.008

Weaver L. (2022). Sounds of the Bog and the Apocalypse. The Sonification. https://thesonification.org/2022/09/20/sounds-of-the-bog-and-the-apocalypse/ (accessed 24 April 2024)

Wescoat J. L., Bramhankar R., Murty J. V. R., Singh R. and Verma P. (2021). A macrohistorical geography of rural drinking water institutions in India. *Water History*, **13**(2), 161–188. https://doi.org/10.1007/s12685-021-00274-8

Wienhues A. (2020). Ecological Justice and the Extinction Crisis. 1st edn, Bristol University Press, Bristol, UK. https://doi.org/10.2307/j.ctv16t671c

Wilson L., Wilson J., Holden J., Johnstone I., Armstrong A. and Morris M. (2010). Recovery of water tables in Welsh blanket bog after drain blocking: discharge rates, time scales and the influence of local conditions. *Journal of Hydrology*, **391**(3–4), 377–386. https://doi.org/10.1016/j.jhydrol.2010.07.042

Young D. M., Baird A. J., Morris P. J. and Holden J. (2017). Simulating the long-term impacts of drainage and restoration on the ecohydrology of peatlands. *Water Resources Research*, **53**(8), 6510–6522. https://doi.org/10.1002/2016WR019898

doi: 10.2166/9781789062540_0079

Chapter 4

Socio-ecological justice

Natalia Duque, Rocio Manzano Quintero, Federico Pinzón, Carolina Salcedo, Carolina Blanco Moreno, Vicky Azucena Muelas and Rachael Maysels

In Colombia, we can observe numerous similarities with respect to conditions of 'scarcity', particularly concerning poverty, environmental discrimination, restricted land access, and inadequate management and misapplication of water. It is frequently difficult to access high-quality water, particularly in rural areas, which are home to a significant population of indigenous people, afro-descendants, and *campesinos* (Comisión Económica para América Latina y el Caribe, CEPAL, 2018).[1] These demographics have historically experienced and continue to experience prolonged political, societal, and financial marginalisation, underrepresentation, and disregard by the government. These inequities illustrate the insufficiencies of the traditional justice model, which depends on expansionist and neoliberal-orientated globalised capitalism (Yaka, 2019).

Rural poverty and ecosystem degradation prevail in Colombia due to four major factors: land concentration, land and water use without regard for ethnic identity, conflict overexploitation methods, and political and community interests that undermine socio-ecological integrity (Gamarra Vergara, 2007). These factors are particularly apparent in the south-western departments of Valle del Cauca and Cauca, which are blighted by seemingly insurmountable challenges. Exacerbated by the regions' diverse socio-ecological makeup, conflict often arises, most commonly over land. Indeed, the department of Cauca, for example, exhibits the second-highest degree of inequality in the country in terms of land distribution (Cauca Chamber of Commerce, 2006; Departamento Administrativo Nacional de Estadística, DANE, 2019).

[1] *Campesino:* while this term translates to 'peasants' in English, it encompasses a specific demographic of rural smallholder farmers in Latin America. As such, the Spanish term will be utilised throughout the book.

With this in mind, the authors of this chapter seek to demonstrate the necessity of embracing a socio-ecological justice (SEJ) model, leveraging often-hidden voices from Colombian communities. Indeed, in this chapter, we want to offer spaces for these voices to be heard.

4.1 HIDDEN VOICES OF RURAL *CAMPESINO* COMMUNITIES IN COLOMBIA AND THE NEED FOR SOCIO-ECOLOGICAL JUSTICE

Natalia Duque and Rocio Manzano Quintero

In Colombia, many rural communities are comprised of *campesinos*. The *campesino* community social structure is based on family and community networks, whose livelihood activities include agro-fisheries, agriculture, and agro-mining. These communities also share a profound connection with nature, acquiring land and constructing their territories primarily through their own labour and cultural interactions (Saade Granados, 2020).

Throughout Colombian history, various policies have been introduced that render certain communities invisible; what is ironic is that this political model is itself subordinated to macroeconomic policies influenced by other powerful groups advocating for industrialisation and neoliberal principles. Either way, the policies applied are not designed to affect redistribution, leaving Colombian *campesinos* without the representation and recognition they need to protect their ways of life (Sánchez-Jiménez *et al*., 2021). Additionally, many *campesino* communities have been displaced from their lands through violence, state-sanctioned neglect, and the influence of other powerful entities on the global stage. This has resulted in them settling in desolate forest reserves and jungles, which was initially encouraged by Colombian institutions. Soon, however, these settlers were further abandoned and oppressed (Sánchez-Jiménez *et al*., 2021).

Another consequence of neoliberal capitalist policies is that *campesinos* often find themselves compelled to adhere to laws that are hard to comprehend and implement without adequate support and technical guidance, as the state imposes regulations and institutions with no consideration of the socio-ecological context of *campesinos*. Colombian laws and policies have historically failed to adequately recognise and represent *campesinos*. In response to this, *campesinos* have deemed it essential to devise their own methods of promoting and protecting their identity in accordance with their individual understanding (Sánchez-Jiménez *et al*., 2021). This issue was brought to the forefront by leaders in the Cauca region during the 1990s when they realised the 1991 constitution failed to include them as *campesinos*. As a result, they mobilised to demand inclusion. This demand was finally met in February 2018 when the Supreme Court of Justice ordered the National Administrative Department of Statistics (Departamento Administrativo Nacional de Estadistica) to include *campesinos* in the population census; the Colombian Institute of Anthropology and History (Instituto Colombiano de Antropología e Historia) was also mandated to carry out further studies to define the concept of '*campesino*' in greater detail (Sánchez-Jiménez *et al*., 2021).

The problems of campesino marginalisation and the role of socio-ecological justice

Despite this acknowledgement, *campesino* livelihoods and outlooks remain relatively unchanged in Colombia. Currently, this group remains a marginalised community, with aspects of its identity and connections to the natural world still disregarded, leading to disputes with state and private entities. These become particularly acute when it comes to the allocation and utilisation of land and water resources. This lack of recognition and proper representation is a form of oppression that can harm social groups, as it tends to distribute resources unfairly and misrepresent certain communities (Sánchez-Jiménez *et al.*, 2021).

Various social movements and communities, including the Colombian *campesinos*, oppose the expansionist trends of neoliberal capitalism. They strive for the preservation of civil and ecological resources and fight for their cosmovision. At this pivotal moment, we need a new justice model that will allow us to connect recognition, redistribution, representation, production, and reproduction (Yaka, 2019). Justice, as theorised by Yaka (2019), extends beyond the terminology used in traditional justice theories (which overlooks the relationships between humans and non-humans and their consequences for our societal coexistence); Yaka's theory of SEJ instead reflects how *campesinos* have considered their relationship with their territories for generations.

As this video explains, SEJ positions justice within a relational ontology that upholds an inseparable connection between social and ecological phenomena. This implies an understanding of the entitlements and concerns of 'humans in nature'. The framing of the relationality between human and non-human worlds as a matter of justice is a key concern of SEJ.

Case studies: Campesinos of the Montañuelas community and the rallanderías community

The community of Montañuelas is located in the sub-basin of the Cali River, which runs through the rural area of the city of Cali in El Saladito in the department of Valle del Cauca. The workforce of the Montañuelas community is comprised of day labourers, domestic workers, gardeners, construction workers, private security personnel, and some skilled professionals. Many of these individuals have been displaced from other regions due to violence between armed groups and land disputes over ethnic divisions (Figure 4.1–4.3).

[2] According to Colombian regulations, these are the areas that must be permanently conserved with natural or artificial forests, in order to protect these same resources or other renewable natural resources (Ministerio de Ambiente de Colombia).

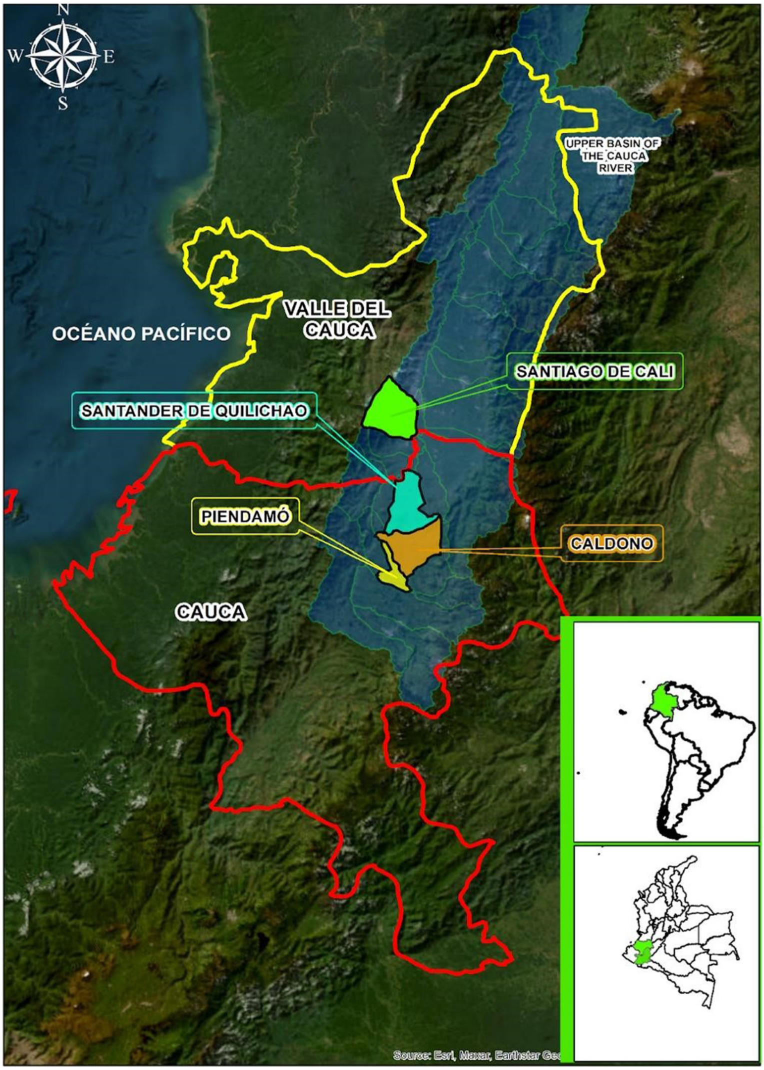

Figure 4.1 Map showing the location of the study areas. The community of Montañuelas is identified on the map with a yellow polygon. The rallanderías community is identified with a red polygon. Both communities are located in the Upper Cauca River Basin, in south-western Colombia. (Credit: Natalia Duque and Rocio Manzano Quintero).

Geographically, the community is situated in the national Cali River Protected Forest Reserve.[2] In the words of community leader and co-author Rocio Manzano, who has been a prominent figure in the area for over 20 years, 'The community's development faces limitations due to power relations and vested interests in the

Figure 4.2 Participatory workshops: (a) campesino community of Montañuelas, Cali, Valle and (b) the rallanderías community of North Cauca. (Credit: Natalia Duque and Rocio Manzano Quintero).

territory by capitalist communities. Consequently, the community's land tenure, access to water, and legitimacy within the area are affected.'

Meanwhile, the *rallanderías* community is located in the Quinamayó and Ovejas sub-basins:[3] Most of them are in Mondomo in Santander de Quilichao, with others in the Caldono and Piendamó municipalities in the department of Cauca. For over 100 years, the *rallanderías* have engaged in collaborative family traditions that involve producing cassava starch. Previously, production was largely undertaken manually by displaced women. Between 2019 and 2022, however, labour and raw materials (cassava) were scarce, and illicit coca cultivation was on the rise, which had an adverse impact on the industry (Aguirre & Manyoma, 2019). An adequate supply of water is needed for the optimal functioning of the *rallanderías*: the daily consumption of these agro-industries ranges from 50 m^3 (cubic litres) to 120 m^3.

One of the major issues faced by those working in cassava processing is waste disposal, which often goes untreated and is dumped into rivers and streams. According to co-author Natalia's doctoral research, the levels of organic matter pollution range from 3600 to 9000 mg/L Chemical Oxygen Demand and 1200 to 4000 mg/L Biochemical Oxygen Demand.[4] Additionally, residual cyanide is discharged in the range of 3 to 4.79 mg CN/L per plant in a working day. Such pollution levels can lead to severe damage to socio-ecosystems situated nearby (Figure 4.4).

[3] *Rallanderías* is the common name given to people who produce and participate in the elaboration of sour cassava starch in the north of the Cauca.

[4] Natalia's doctoral thesis has been developed in collaboration with cassava starch agro-industrialists; its general objective is to formulate a social-ecological strategy for the management of wastewater in cassava-processing plants, applied to the context of the Andean zone of the department of Cauca, Colombia.

Figure 4.3 Photographs of the diverse population of Montañuelas. (Credit: Natalia Duque and Rocio Manzano Quintero).

Methodology

A collaborative investigation was carried out using qualitative research with participatory methods, including participatory workshops, field visits, semi-structured interviews, and participant observation in both study areas. It is important to note that one of the authors, Rocio, is herself a community leader

Figure 4.4 Photographs of the campesinos of the rallanderías. (Credit: Natalia Duque and Rocio Manzano Quintero).

in the rural region of the Valle del Cauca, and thus experienced the social issues in the study area first-hand.

The authors of this spotlight have a long history of working in the study area; as such, they are familiar with the communities. The objective of this research is to analyse both communities' perception of water justice and their vision for the future. The authors used a participatory action research (PAR) methodology, collecting and analysing information with community members to address their problems and promote political and social changes. Emerging out of innovations in social sciences and the arts in 1970s Latin America (Bonilla *et al.*, 1972), PAR is based on the researcher inserting themselves into the community, analysing historical and social conditions, developing a level of consciousness among community members, and generally conducting research focused on problem-solving within the community or group.

We invited representatives from both communities (each of which is currently underrepresented in water security research and policy), to share their perceptions of justice related to water usage and management, alongside their current and future vision of and relationship to water. Opening with the guiding question 'What is justice?', we then aimed to spark a dialogue that went beyond a superficial response to the topic, resulting in a comprehensive examination of the vision of justice and its practical implications for the rural communities involved.

During the research process, it was established that negative impacts on water sources are not solely determined by technical factors, but also influenced by social and cultural components within the community's perspective on nature. These interrelational factors must be considered when addressing issues related to water preservation.

Individual and collective positions of communities on ownership, use, and tenure of water and soil

Elizabeth,[5] secretary of the Community Action Boards (Juntas de Acción Comunal [JAC]) in Montañuelas,[6] understands justice as the 'equality of opportunities for human rights'. When discussing its relationship to water, she highlighted the lack of such justice, stating 'There is no drinking water, which generates problems with the government', before adding, 'the state does not fulfil its duty to supply this liquid, which could be solved if the community were taken into account, but we are invisible to the government'.

For her part, Teresa (co-owner of a *rallandería*, where cassava starch is produced), emphasised the issue of representation, contending, like Elizabeth, that she does not see herself represented in governmental policies: 'Within the community, we are seen as micro-entrepreneurs who provide employment, while the government only sees us as a source of tax revenue.'

[5] Names have been changed to protect the identities of the accompanying communities.
[6] Juntas de Acción Comunal (Community Action Boards) are responsible for ensuring the fulfilment of human rights with the municipal and departmental authorities, as well as contributing to the integral and sustainable development of a community. They are elected by popular vote and their area of action is determined by neighbourhood or village.

Pedro (owner of another *rallandería*), not only called for recognition, but also stressed the importance of co-constructing political processes that consider socio-ecological context: 'I call on state entities to approach us so that we can build a better life, and also do our best for these watersheds, which we want to do, but it's not just those of us who live here who are part of the problem.'

Elizabeth, Teresa, and Pedro noted that justice based on the neoliberal capitalist model frequently fails to take into account the communities and ontologies present in rural Colombia, leading to ongoing conflicts, decontextualised regulations, human displacement, and overexploitation of nature. *Campesino* communities specifically prioritise their culture's collective and individual interests, which are closely tied to their relationship with the natural world.

Ignorance and a lack of contextualised representation have resulted in numerous longstanding injustices against the Colombian rural population. One such example is the ongoing situation in Montañuelas, where the fight for access to drinking water has been fought on various fronts, including the legal system. Community leaders such as Rocio have played a pivotal role. In 2018, they won a popular action,[7] according to which the local government of Cali was compelled to provide access to drinking water. But as of December 2023, the community was still without said drinking water. Carmenza, the president of the JAC of Montañuelas, expressed outrage that no action that been taken since the community's victory in August 2018, and further pointed out that this inaction violated human rights. As such, she emphasised the need for urgent action, exclaiming: 'We have the right to water! But in reality, we don't have water, we don't even have raw [untreated] water! As I told you: we have to fill jars to have water, we wait for water from the sky, from the rain.' Similarly, Milton (a community leader in Montañuelas) commented: 'Others of us bring jars of water for human consumption from Cali.'

Concerning the unfair allocation of water, Ana Judith, a 57-year-old inhabitant of Montañuelas, stated:

> 'I was born in my village … When we were children, we had to carry water from far-away places … This is unfairness of the social classes; those who have money have the right to water, those of us who are poorer do not have the right to water; if people were sensitive, if there were equity in society, this bias would not exist.'

Article 665 of the Colombian Civil Code states that 'real rights' encompass ownership, inheritance, usufruct,[8] use or habitation, and similar rights. These rights should lead to concrete actions, as demonstrated by the recent

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[7] In procedural law, a popular action is the legal action by which the public authorities and, in general, any citizen are legitimised to erase the action of the administration of justice in defence of collective or diffuse interests (National Constituent Assembly of Colombia, 1991).

[8] The Oxford English Dictionary defines usufruct as 'the right to enjoy the use and advantages of another's property short of the destruction or waste of its substance'.

successful popular action. Nevertheless, the hierarchical nature of human rights enforcement undermines justice, as Milton observed:

> 'Although we have the right to clean water, there is no guarantee that we will have access to it, and my community is currently at risk of displacement. The state, through police action, plans to evict us by force, alleging that we are an inadequate settlement in a forested region that endangers our surroundings, compelling us to vacate the area and depart under legal duress.'

From all of this, we see that the current focus lies in land ownership, instead of water.

Unlike the situation facing Montañuelas farmers, the issue for cassava agro-industrialists in Cauca does not concern water supply. Teresa from Piendamó (Cauca) stated, 'We have not suffered water shortages.' Similarly, Leonardo (co-owner of a *rallandería*) affirmed that 'the quantity and quality of water is sufficient, which allows for personal and community development.' However, water is unequally distributed, which makes for injustice, increasingly felt during the dry season. According to an independent *rallandería* worker named Alejandra, conflicts arise between *campesino* and indigenous communities over water during prolonged dry periods, and *rallandería* owners tend to overuse water, limiting its availability for other purposes.

Authorities often expect strict adherence to laws, but when these laws are formulated without taking into account the socio-ecological context of rural populations, they can create significant challenges. These communities often struggle to understand and comply with the laws, which is compounded by their difficulty accessing even basic resources. This is particularly challenging for cassava farmers, who must follow wastewater regulations that do not take their specific circumstances into account. These farmers generally lack technical assistance, while also navigating different regulations among state and local entities. Samuel (owner of a *rallandería*) highlights the sentiments of cassava processors:

> 'Look, I have done everything I know how to do in terms of water management, I don't know what else to do. The environmental authorities or anyone else involved in the matter only exert police pressure, but the support from them is almost nil and it seems as if they [the cassava processors] are talking to deaf people.'

Given the tensions that exist in both communities, it is clear that the current justice model in Colombia does not comprehend the contextual complexities in the territories. As argued by Yaka (2019), justice cannot exist in isolation from social struggles. To include the relational character of human and non-human life, our conception of justice needs to be expanded. Accordingly, nature should be framed as an integral part of the social world, rather than being viewed as a separate entity. In these two specific cases, the communities do not express their relationship with the natural world directly. However, evidence of this relationship is apparent, not only due to the *campesinos*' cultural tradition of a close bond with nature, but also because their primary concerns relate to the accessibility, distribution, and utilisation of water and land.

We furthermore noted that although the communities that participated in the project did not directly refer to SEJ, they were aware of its principles, or rather, they were aware of the need for a different kind of justice. Judith from Montañuelas said: 'If people were sensitive to each other and to nature, if there was justice in society, there would not be so many prejudices.' Carmenza added: 'Yes, we have learned to be animals of habit, to get used to things, today in my house the reuse of water predominates, not only for my benefit but also because the river deserves to flow.'

On the previous point, Mauricio (owner of a *rallandería*) commented:

> 'I have the responsibility to use water well, to minimise its impact on the environment and to contribute to its conservation through the reclamation and reforestation of land, not only for myself and the rest of the community, but also because I want the river to live again, but my efforts are useless because the government has forgotten us.'

SEJ aims to transcend the dichotomy between social and ecological justice by situating justice within a relational ontology between social and ecological phenomena. The concept of 'humans in nature' involves recognising the interconnectedness between humans and their environment – and in turn protecting the rights and interests of both parties so that they can coexist and flourish without harm or degradation (Yaka, 2019). SEJ prioritises diversity and contextualised justice, where the 'how' of a policy depends on the 'who' (Pope *et al*., 2021). This would enable fair and appropriate decision-making processes that consider the needs and perspectives of the *campesinos* in the study areas.

Predictions from the hidden campesino voices of the Montañuelas and the rallanderías on water security in 40 years

Recognising the communities' feelings about the relationship between water, community, and state in the previous section allowed us to explore the participants' vision of water in the future. The following is a summary of the impressions gathered.

Milton said:

> 'Firstly, we all have to have it [water] because now we defend ourselves with what they [the state] leave us; in order to have water and water quality in 40 years, we all have to do our part so that the water is not affected by pollution and the bad use we make of the rivers by throwing waste into them. We must take care of the headwaters and water sources that are essential for life.'

For her part, Ana Judith (Montañuelas) suggested that 'the government should create clear public policies, we should continue to take care of the streams by planting trees'. Maria (Montañuelas) added: 'The future is complex, and as we consider the planet, it is crucial to take care of it as it is a vital part of us; while there are extensive regulations and talk about the rights of nature, the truth is that nature is weakened.' Both expressed that fair community participation is the key to ensuring access to water for future generations.

The rural communities in Cauca acknowledge the ecological and social issues arising from water usage. As Alejandra (part of the *rallanderías* community) warned, 'I think that in about 10 years we will begin to suffer all the damage we have done to the planet.' Jeronimo stated: 'Everything must change, and what needs to change the most is education, which should be relevant to our culture, territory, and the diversity and richness of our ecosystems.' We must alter people's attitudes towards water, teaching them to value it more since it is crucial for sustenance. Likewise, Teresa said: 'Presently we are in a critical phase as decisions related to this essential resource will have far-reaching effects. To ensure the conservation of this vital resource, it is imperative for the government to enforce the existing regulations.' Abelardo (owner of a *rallandería*) added: 'I see the future as complicated … as water usage increases in both economic and social sectors. Population growth leads to diminished forest areas, which directly impacts water.' Furthermore, Alejandra wondered whether 'the future use of water may be plentiful in quantity but poor in quality, as rivers may be converted to pipes'.

It is evident that the participating communities see themselves as an interconnected component of their environment. Their responses indicate that their own livelihoods depend on the preservation of nature and that they as individuals see themselves as sharing a joint responsibility with the government to do so. However, this model falls apart somewhat, as the government's support for these individuals is generally disjointed, insufficient, and intermittent. Antonio (owner of a *rallandería*) confirms this: 'First of all, it is rare for the government to intervene and when it does it is ineffective and sporadic. The training we receive is basic, they play games and force you to fill in a form to get paid. All of this is of no practical use.' Likewise, the state has provided little support in Montañuelas in relation to water demands: a commission has been authorised to monitor compliance, but thus far very little action has been taken. It is worth recalling Carmenza's statement that the community's case was won in August 2018, but in 2023 residents were still boiling and filtering water to ensure access to clean water.

These stories demonstrate that looking after nature and one's own well-being can intersect, provided that communities interpret themselves as part of their non-human surroundings, owing to their relational character (Yaka, 2019). This notion remains ambiguous in the studied communities. Although they share an ancient heritage of harmonious coexistence with nature, in recent decades neoliberal capitalism has influenced a change in their thinking that has brought them into alignment with neoliberal economic visions. We hope, however, that the present system's inadequacies and the significant injustices it inflicts upon Colombian *campesinos* have increased their awareness and encouraged them to return to feeling a connection with nature. Interviews conducted in both communities provide evidence of this, as the pursuit of justice for themselves is inseparable from their demands for justice for the water systems and the non-human life that rely upon them.

Conclusion

These case studies highlight the continuous political struggle between rural communities and the Colombian state, characterised by centralised processes and challenges related to redistribution, representation, and recognition. These challenges overlook the region's social-ecological context, complex interrelationships, and diverse worldviews. Attempts by capitalist-orientated states to homogenise socio-ecosystems are common, perpetuating bottom-up homogenisation and causing losses in social and ecological biodiversity. Frequent struggles to defend the rights of communities and nature expose community leaders and put ancestral knowledge at risk.

Justice based on the neoliberal capitalist model not only disregards the *campesinos* in the Montañuelas and *rallanderías* communities, but also the natural environment. This detrimentally affects rural areas in Colombia, which is globally acknowledged for its exceptional diversity of flora and fauna, particularly in the Pacific region, where the communities in this study are situated: this region is unparalleled in terms of biodiversity compared with similar regions worldwide (Rangel-Ch, 2015). Our analysis of these communities demonstrates that while many individuals continue to see themselves as connected to the natural environment, neoliberalism has become ingrained throughout society, creating a dissonance between their conceptualisation of justice and their traditional ontologies that SEJ seeks to overcome.

In conclusion, SEJ allows us to address the issues that exist in Colombia's rural areas more effectively. In light of this, a substantial change in policy is needed, which can facilitate genuine support for communities, while taking into account their socio-ecological requirements. As illustrated in both communities, conventional justice falls short and results in disputes and inequities, especially in Montañuelas where state-forced displacement has taken place. In this instance, purported environmental protection pushes out peasant communities, and subsequently, these lands are allotted to influential economic interests that partake in activities that were once restricted.

4.2 POLITICAL LEADERSHIP OF WOMEN IN THE UPPER CAUCA RIVER BASIN, COLOMBIA

Federico Pinzón, Carolina Salcedo, Carolina Blanco Moreno, Natalia Duque

> 'Our River Cauca has been an example of resilience in the face of all that it had to suffer during the armed conflict.'
>
> Nelly Guapacha (2023)

The Cauca River is in a process of gradual deterioration, suffering changes in its water quality, riparian ecosystems (i.e. wetlands, madreviejas,[9] and lagoons),

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[9] A madrevieja is a still body of water formed by the erosion of a river in one of its sharp bends (Ramírez *et al.*, 2000). Separated from the main stream, it has a characteristic crescent shape and usually receives water during the rainy season through surface tributaries of the river, other drainages and the water table (Flores and Mondragón, cited in Ramírez *et al.*, 2000).

and ecosystem services. This is due to the sum of anthropogenic stressors such as dams, canalisation of tributaries, construction of irrigation canals, eutrophication, point and diffuse pollution discharges, mining, illicit crops, urbanisation processes, and sugar cane agro-industry (Galvis, 2017), in addition to the impacts generated by natural phenomena such as the El Niño-Southern Oscillation (ENSO),[10] aggravated by the climate change crisis (González-López & Carvajal-Escobar, 2020).

Colombia is a country that has been riven by armed conflict for more than 50 years, impacting human lives, memories, identities, and descendants, as well as ecosystems and nature (Pérez-Rincón *et al.*, 2022). Following the signing of a peace agreement between the Government of Colombia and the guerrilla Revolutionary Armed Forces of Colombia in 2016, the country saw some progress in terms of reparation and reconciliation, such as the restitution of land to victims of forced displacement (Law 1448, 2011) and the recognition of the ecosystemic impact on natural resources (Rajland *et al.*, 2023). Since the beginning of the war, the Cauca River has been a dumping ground for mining chemicals and illicit crops, as well as a mass grave of armed conflict and violence. For this reason, the Special Jurisdiction for Peace named the Cauca River as a victim of the armed conflict in Colombia (Jurisdicción Especial para la Paz, JEP, 2023).

The riparian communities of the Upper Cauca River Basin, mostly afro-descendants, have been recognised by the Colombian Political Constitution since Law 70 of 1993; this, under Decree 1745 of 1995, allowed for the creation of community councils as the ethnic authority in charge of administering the collective territories of black, afro-colombian, raizal (an ethnic group from the Archipelago of San Andrés, Providencia and Santa Catalina, off of Colombia's Caribbean coast) and palenquero (descendants of enslaved Africans who sought refuge in territories along the north coast of Colombia) communities (Unidad de Restitución de Tierras, URT, 2016). Community councils are the owners of the collective territories awarded to them, and it is their right to administer them according to their organisational policies, cultural traditions, and life projects (community goals). It is also their duty to safeguard their ecosystems and develop the traditional land use practices responsibly, ensuring that the territories are used sustainably. In this way, the community councils have led historical struggles for the conservation of water bodies and the life of their communities, integrating their bio-cultural values into ecosystems such as the Cauca River.

Under this premise, and recognising that black communities have historically experienced processes of marginalisation, violence, and displacement, as well as the non-inclusion of their leaders in land use planning processes, which forces people to fight for justice in their lives and territories, we highlight the perspectives of two women leaders: Dany Mileidy from the community of Bocas

[10] ENSO is one of the most important climatic events in Colombia. There are two variations: El Niño, characterised by high temperatures and extreme droughts; and La Niña, characterised by low temperatures and extreme rain.

del Palo and Nelly Guapacha from the community of Hormiguero. Both are afro-descendant women who fight for the conservation of their territories, ecosystems, and the Cauca River.[11] The video shown here highlights the challenges affecting the territories of these two women leaders, which can be extrapolated to the reality of many riverside communities in Colombia. We have pulled out some key quotations from Dany and Nelly as follows:

> 'The great challenges that we have faced as leaders and as mourners of our territory have been the sugar cane guilds. I think that these guilds have been the white elephants that have deteriorated all those ecosystems that we have within our territory.'
>
> 'Apart from the state's neglect of the municipality, Jamundí is a municipality that has been badly mismanaged at a territorial level. And what has caused this? What has been directly impacting the community councils? Expansion zones. These expansion zones not only change our culture, they change our mobility. They change and alter everything that has to do with our territory.'
>
> Dany Mileidy (2023)

> 'The sugar cane guilds are causing erosion because they're located very near the River Cauca, where the trees and bamboo used to be, holding the land. They no longer exist. And if you go upstream, it's terrifying. The sugar cane? How the riverbanks are falling, being eaten away by the river.'
>
> 'We did a tour of the River Cauca and we could see how the river has been channelled, how the river is eroding. They're built on wetlands, Bochalema and Ciudad Pacifica [expansion zones of Cali] are on wetlands.'
>
> Nelly Guapacha (2023)

We consider the role of afro-descendant women in the community councils in defence of nature and their bio-cultural legacy to be an expression of SEJ in the riverside territories of the Cauca River. The sense of justice and ethics of care, expressed in the political leadership of these two women, reveals a different relationship with nature as an entity that deserves to be respected. This alternative vision separates itself from an instrumental perspective of nature, based on the nature's utility as a source of resources, presenting instead an ontological dimension. They recognise that nature is a subject that

[11] With thanks to Alex Mauricio Villegas and Mariela Garcia.

suffers injustices, that responds according to the actions of human beings – consequently, they advance a vision of fair conditions in the territories that can only be achieved when the intrinsic rights of nature are recognised.

4.3 THE KISGÓ COMMUNITY, COLOMBIA: ORIGINS AND PRACTICES IN WATER

Vicky Azucena Muelas, Rachael Maysels

For many indigenous cultures, there is no separation between the well-being of their community and the territories in which they live. For the members of an indigenous community of Kisgó in south-western Colombia, their connection with nature goes beyond instrumental value: it is a kinship based on respect and reciprocity, in which the Kisweños consider themselves to be 'children of water'. Thus, when ecological injustices occur, they occur not just to the land, but to the community itself.

The Kisgó reservation is located in the Andean region of the department of Cauca, with about 4000 inhabitants living in the hydrologically lush (there are over 500 springs!) and biodiverse territory. During their centuries-long struggle for autonomy, recognition, and cultural preservation, the community and territory have faced many injustices, from displacement, land-grabbing, land exploitation, and impoverishment, to violent conflict (which has taken both human and more-than-human victims). Yet despite the intersectional challenges that the Kisweños face, they are actively working towards territorial sovereignty for themselves and non-human beings through practising and recovering indigenous, ancestral knowledge, which has primarily been transmitted orally for generations (Figure 4.5).

Figure 4.5 Illustrations depicting the Kisgó community origin story. (Credit: Vicky Azucena Muelas).

In this spotlight on SEJ, we present two videos in which the interconnectedness between the Kisweños and their territory, as well as their efforts with regard to justice, are told through the voice of the Kisgó people themselves.

In the first video, Kisgó community leader Vicky Azucena Muelas beautifully tells us the origin story of her people as descendants from the Kisgó lake. She introduces the video with the following words:

> 'What I want to tell today is not a story or a fable; what I am writing today is what my father and mother taught me. My name is Vicky Azucena Muelas, I am indigenous from the Kisgó people (in Cauca, Colombia), and I am proud to write about my territory. To understand what is going to be written here, it is necessary to leave academia and the conception of science that proves everything. The origins of the community of Kisgó comes from being and feeling the world – for the Kisweño that beginning of being comes from the water, that is to say 'we are children of the water and of the woman of the lake', the woman who with wisdom guided the path of a people that was dominated by Catholicism, blinded by the path already established by the ancestors. Before continuing, it is important to tell our history. The mapping of memory is the way in which we conceive our origin.'

The second video introduces the ancestral practice of sowing water, which the Kisgó community utilised to recover the sacred Kisgó lake. This is a practice rooted in ancestral knowledge and a profound relationship with the land, showcasing the deep ties between humans and nature; we learn that our foundational well-being depends on that of the natural world that surrounds us and on which we depend. It is significant to point out that the practice of sowing water is customarily led by the women of the Kisgó community. As Vicky Azucena Muelas notes:

> 'The Kisgó community has established that the Kisweño women are leaders when it comes to caring for and protecting their culture and territory, because it is them who carry the seed in their wombs. Just as the lake gave birth to the great Kiwa cacique, each Kisweño who arrives on Earth must continue to care for the water as the main foundation of life, culture,

and identity, as well as of the great Kisweño territory. The leadership of women has been so fruitful that today we young people do take care of the spiritual being that runs through our territory. Just as blood flows through the body and keeps us alive, water does the same; that is why the children of the water take care of our mother in order to survive.'

The Kisweño people show us that justices and injustices are driven by values and beliefs; how we relate to people and the natural world is foundational for our behaviours and decisions. These messages invite us to reflect on our relationship with the water that sustains us, as well as on how we can offer gratitude and well-being to water itself.

REFERENCES

Aguirre E. and Manyoma P. (2019). Agricultural supply chains prioritization for development of affected areas by the Colombian conflict. In: Advanced Studies in Multi-Criteria Decision Making, S. B. Amor, A. T. D. Almeida, J. L. D. Miranda and E. Aktas (eds.), Chapman and Hall/CRC, New York, US, 111–121, https://doi.org/10.1201/9781315181363-6

Bonilla V., Castillo G., Libreros A. and Fals Borda O. (1972). Causa Popular, Ciencia Popular (Popular Cause, Popular Science). Publicaciones de La Rosca, Bogotá, Colombia.

Cauca Chamber of Commerce. (2006). Agenda Interna del Cauca (Internal Agenda of Cauca). Colciencias, Popayan, Colombia. https://repositorio.ccc.org.co/entities/publication/2f9549cb-d971-4005-a7f0-0c531cdd8ccb (accessed 5 June 2024)

Comisión Económica para América Latina y el Caribe (CEPAL)(Economic Commission for Latin Amercia and the Caribbean). (2018). Economic Survey of Latin America and the Caribbean 2018. Evolution of Investment in Latin America and the Caribbean: Stylized Facts, Determinants and Policy Challenges. https://www.cepal.org/en/publications/43965-economic-survey-latin-america-and-caribbean-2018-evolution-investment-latin (accessed 25 April 2024)

Departamento Administrativo Nacional de Estadística (DANE)(National Administrative Department of Statistics). (2019). Resultados Censo Nacional de Población Y Vivienda 2018; Popayán, Cauca (Results of the 2018 National Population and Housing Census; Popayan, Cauca). Government of Colombia. https://www.dane.gov.co/files/censo2018/informacion-tecnica/presentaciones-territorio/190814-CNPV-presentacion-Resultados-generales-Cauca.pdf (accessed 25 April 2024)

Galvis A. (2017). Estado del Arte Sobre la Calidad del río Cauca. Foro Nacional E Internacional Recuperación del río Cauca: Toma de Decisiones Oportunas Para el Abastecimiento de Agua en la Región (State of the art on the Quality of the Cauca River. National and International Forum for the Recovery of the Cauca River: Making Timely Decisions for the Water Supply in the Region). Universidad del Valle, Instituto Cinara, Santiago de Cali, Colombia.

Gamarra Vergara J. R. (2007). La Economía del Departamento del Cauca: Concentración de Tierras Y Pobreza (The Economy of the Department of Cauca: Land Concentration and Poverty). No. 95, Banco de la Republica, Centro de Estudios Económicos Regionales, Cartagena, Colombia. https://www.banrep.gov.co/sites/default/files/publicaciones/archivos/DTSER-95.pdf (accessed 25 April 2024)

González-López N. and Carvajal-Escobar Y. (2020). *Caracterización de sequías hidrológicas en el río Cauca en su valle alto* (characterization of hydrological drought in the Cauca river high valley). *Tecnología Y Ciencias del Agua*, **11**(1), 235–265, https://doi.org/10.24850/j-tyca-2020-01-06

Jurisdicción Especial para la Paz (JEP)(Special Jurisdiction for Peace). (2023). La JEP Acredita Como Víctima al Río Cauca en el Caso 05 (JEP Credits the Cauca River as A Victim in Case 05). Comunicado 080, Bogotá, Colombia. https://www.jep.gov.co/Sala-de-Prensa/Paginas/-la-jep-acredita-como-victima-al-rio-cauca-en-el-caso-05.aspx (accessed 25 April 2024)

National Constituent Assembly of Colombia. (1991). Constitución Política de Colombia (Political Constitution of Colombia). Bogotá, Colombia, https://www.corteconstitucional.gov.co/inicio/Constitucion-Politica-Colombia-1991.pdf (accessed 5 June 2024)

Pérez-Rincón M., Peralta Ardila M. D. P., Méndez F. and Vélez-Torres I. (2022). *Conflicto armado interno y ambiente en Colombia: Análisis desde los conflictos ecológicos, 1960–2016* (Internal armed conflict and environment in Colombia: analysis from ecological conflicts, 1960–2016). *Journal of Political Ecology*, **29**(1), 672–703, https://doi.org/10.2458/jpe.2901

Pope K., Bonatti M. and Sieber S. (2021). The what, who and how of socio-ecological justice: tailoring a new justice model for earth system law. *Earth System Governance*, **10**, 100124, https://doi.org/10.1016/j.esg.2021.100124

Rajland B., Burgos Matamoros M. and Machado Fagundes L. (coords.) (2023). Derechos Humanos y Pensamientos Jurídicos Críticos Desde Nuestramérica (Human Rights and Critical Legal Thoughts From Our America), 1st edn. CLACSO, Ciudad Autónoma de Buenos Aires, Argentina. https://biblioteca-repositorio.clacso.edu.ar/bitstream/CLACSO/248285/1/Derechos-humanos-pensamientos-juridicos.pdf (accessed 25 April 2024)

Ramírez L. J., Vásquez G. L., Navarrete A. V., Vásquez C. M. and Orjuela Jorge J. E. (2000). Estado sucesional de los humedales Madrevieja Guarinó, Ciénaga La Guinea, Caño El Estero, Laguna Pacheco, Madrevieja Lili, Madrevieja Gota e Leche, Madrevieja Chiquique, Madrevieja La Herradura y Laguna Bocas de Tuluá. Localizados en los municipios de Cali, Jamundí, Bolívar y Tuluá, Departamento del Valle del Cauca (Successional status of the Madrevieja Guarinó wetlands, La Guinea Swamp, El Estero Creek, Pacheco Lagoon, Madrevieja Lili, Madrevieja Gota e Leche, Madrevieja Chiquique, Madrevieja La Herradura and Bocas de Tuluá Lagoon. Located in the municipalities of Cali, Jamundí, Bolívar and Tuluá, Department of Valle del Cauca). Corporación Autónoma Regional del Valle del Cauca, Santiago de Cali, Colombia.

Rangel-Ch J. O. (2015). La biodiversidad de Colombia: significado y distribución regional (Colombia's biodiversity: meaning and regional distribution). *Revista De La Academia Colombiana De Ciencias Exactas, Físicas Y Naturales*, **39**(151), 176–200, https://doi.org/10.18257/raccefyn.136

Saade Granados M. (ed.) (2020). Conceptualización del Campesinado en Colombia: Documento Técnico Para su Definición, Caracterización Y Medición (Conceptualisation of the Lower Class in Colombia: Technical Document for its Definition, Characterisation and Measurement). Instituto Colombiano de Antropología e Historia (ICANH), Bogotá, Colombia. https://publicaciones.icanh.gov.co/index.php/picanh/catalog/book/31 (accessed 25 April 2024)

Sánchez-Jiménez W., Passos-Blanco M., Salazar-Ríos J. H. and Rivas-Guzmán A. (2021). *Luchas y resistencias campesinas en Colombia* (Peasant struggles and resistance in Colombia). *Libre Empresa*, **18**(2), 63–90. https://revistas.unilibre.edu.co/index.php/libreempresa/article/view/9262 (accessed 25 April 2024)

Unidad de Restitución de Tierras (URT)(Land Restitution Unit). (2016). Los Derechos al Territorio, A la Identidad Cultural Y A la Restitución de las Comunidades Negras, Afrocolombianas, Raizales Y Palenqueras (The Rights to Territory, Cultural Identity and Restitution of the Black, Afro-Colombian, Raizal and Palenquera Communities). United Nations Refugee Agency, Bogotá, Colombia. https://www.acnur.org/fileadmin/Documentos/BDL/2017/11028.pdf (accessed 25 April 2024)

Yaka O. (2019). Rethinking justice: struggles for environmental commons and the notion of socio-ecological justice. *Antipode*, **51**(1), 353–372, https://doi.org/10.1111/anti.12422

doi: 10.2166/9781789062540_0099

Principle 1

Justice – conclusion

Victoria Anker, Rachael Maysels and Maria Valasia Peppa

The spotlights in the justice principle have showcased the need to recognise human and more-than-human injustices related to water insecurity, to include diverse values and voices, such as of those who are more affected by water insecurity, in decision-making, and to validate non-technocratic approaches towards water management systems.

These case studies from a range of different contexts indicate that similar intersectional injustices take place across the globe, including displacement (in both urban and rural settings), disproportionate impact on already impoverished people, a loss of territorial autonomy, and governmental neglect – and all of this is perpetuated and exacerbated by the neoliberal hegemonic powers that be. We have seen that social and ecological justices are enmeshed and therefore best approached via the lens of intersectionality.

However, while many of the groups – both human and more-than-human – featured in these spotlights still endure grave injustices, these case studies also highlight their innovation and resilience in the face of adversity, with the establishment of community water management associations in the Upper Cauca River Basin (Chapter 1.1), collaboration and collective action in Delhi (Chapter 2.1), and self-organised urban farming in Addis Ababa (Chapter 2.3). We have seen that historically marginalised communities such as the small-scale farmers in the Yamuna Basin (Chapter 2.2), indigenous, afro-descendant, and *campesino* communities in south-west Colombia (Chapter 4), and more-than-human peatland communities in the UK (Chapter 3.1) have boldly resisted the powers that be in defence of rivers for both human use as well as for the intrinsic value of the more-than-human world.[1]

[1] *Campesino:* while this term translates to 'peasants' in English, it encompasses a specific demographic of rural smallholder farmers in Latin America. As such, the Spanish term will be utilised throughout the book.

Drawing on Fraser's social justice framework, encompassing recognition, representation, and redistribution, we propose a more integrated approach towards socio-ecological justice (SEJ). In this, we are influenced by indigenous worldviews, according to which nature and people are not considered to be separate, but rather intertwined and interconnected. In light of this, we believe that justice should go beyond institutional action and be approached as a dynamic process that features a diversity of perspectives and takes shape according to the context in which it is applied, subject to monitoring and evaluation (Joshi, 2015).

In this section, we've learned that justice in relation to water security cannot be universally understood or applied, as it is inextricably tied to cultural practices, historical contexts, and local conditions – and therefore we must create processes and spaces in which those who are susceptible to injustices can participate in decision-making for water management. From planning processes, as we've seen in the case of Malaysia's water planning (Chapter 1.2), to decision-making tools, such as water use efficiency approaches in Colombia (Chapter 4) and Palestine (Chapter 1.3), to heritage infrastructure restoration (Chapter 3.2) there are many opportunities to make justice more prominent in water management.

In summary, we advocate for a more proactive approach towards water management that prioritises SEJ by considering the value of water beyond its instrumental value, actively including voices that have been excluded in planning and decision-making processes, examining the relationship between biophysical and social aspects of water systems, and recognising the knowledge and solutions that already exist throughout communities worldwide.

REFERENCE

Joshi D. (2015). Like water for justice. *Geoforum*, **61**, 111–121, https://doi.org/10.1016/j.geoforum.2015.02.020

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Principle 2

Knowledge – introduction

Maria Valasia Peppa, Carolina Montoya Pachongo and Andrés Fernando Toro Vélez

Our second principle is that, without knowledge, we cannot have inclusive water security. Through a series of spotlights, this section explores methods, tools, and frameworks to create an integrated knowledge base for a data-to-action approach.

SIGNIFICANCE OF PRINCIPLE

Knowledge has the ability to foster inclusion by ensuring accurate representation, fostering connections, and driving innovation. In its absence, and when gatekeepers enforce barriers, exclusion prevails: information becomes misrepresented or underrepresented, exists in silos, and stifles creativity. Therefore, knowledge is crucial in discussions on water security and sustainability. As Polaine *et al.* (2022) assert, 'water data is a foundation for an integrated understanding of the behaviour of water security.'

Reliable historic and up-to-date knowledge is indispensable for identifying water insecurity patterns and estimating potential risks to respond to hazards and inform decision-making. Knowledge in the first instance is generated either by the collection of primary data, raw observations, and/or the reuse of pre-existing resources, that is the so-called secondary data (Hox & Boeije, 2005). Primary and secondary data in the water security context include socio-economic, socio-cultural, and environmental information in a quantitative and/or qualitative format (Butte *et al.*, 2022). From the synthesis of such data, derived knowledge can provide a wide spectrum of information on topics such as water quantity, quality and sanitation infrastructure, socio-environmental pressures, ecological impacts, flood protection management, and so on (Polaine *et al.*, 2022; van Ginkel *et al.*, 2018). In our contemporary digital world, knowledge can also be enriched with the aid of open data, open and collaborative science, and artificial intelligence technologies via data-sharing and cloud computing platforms (IWA, 2021; Sugg, 2022; Walter, 2024).

Producing knowledge requires time, money, and resources, due to operational and labour-intensive procedures. Sometimes discovering knowledge via primary data collection is not feasible when, for example, in-situ water sampling is conducted in polluted environments. Hence, data scarcity can be prominent in low-resource and less-developed infrastructure contexts.

On the other hand, while the FAIR (findable, accessible, interoperable, reusable) principles, initially introduced by Wilkinson *et al.* (2016) and later advanced by the GO FAIR initiative (GO FAIR, 2021), have set compulsory standards for scientific data management, secondary data can be hidden behind governmental and institutional stakeholders (Jensen & Wu, 2018; Sugg, 2022). For example, government agents might impose fees on the public for data access (Sugg, 2022) or might make 'some data' available only to researchers and not to everyone (Jensen & Wu, 2018) – and certainly not beyond a nation's borders (Cory & Dascoli, 2021).

Even in the case of recorded secondary water data, which is findable via existing open data-sharing and/or -storing platforms, retrieved knowledge is often not interoperable or reusable, as data can be inconsistent, due to, for example, (i) dysfunctional in-situ hydrological sensors thanks to lack of maintenance and infrastructure (Donauer *et al.*, 2020), and (ii) data gaps due to internet restrictions imposed by governments (Shanahan & Bezuidenhout, 2022). In addition, data can be of suboptimal quality, hence inadequate for informing further decisions, for example due to lack of standardised data cleaning routines. Finally, metadata can be absent, because of limited capacity building across the institutional stakeholders (Sugg, 2022). To that end, even though we live in the era of 'digital water' (Walter, 2024), we still suffer from data scarcity, inaccessibility, and non-credibility; the latter in particular leads to the 'data rich but information poor' syndrome (Ward *et al.*, 1986).

PARTIAL AND ONE-SIDED INFORMATION

As explained in Polaine *et al.* (2022), a one-sided framework is completely inadequate to capture the multidimensional aspects of water security challenges. For example, water pollution, a sub-system of water security (Polaine *et al.*, 2022), is an inherently complex issue, stemming from variations across geographic contexts (spatial domain) and time (temporal domain), types of aquatic ecosystems and contaminants, and impacts on different parts of society and ecosystems. In order to understand water pollution, we need at least a four-question framework of 'why, how, what, and where', integrated with an understanding of the hydro-social cycle of water (Lu *et al.*, 2016), including the ecological element (hydro-eco-social cycle). In this instance, we would be looking for answers to questions such as: why is water polluted; how contaminated is water; what are the impacts of water pollution and where; and what are the actions to avoid or remediate water pollution.

To take just one of these elements – the question of how contaminated water is – researchers and practitioners have been developing water quality indices to aggregate several physicochemical and/or biological parameters, calculated from data collected at the point of wastewater discharges or directly in water bodies to produce one dimensionless value (Ndatimana *et al.*, 2023; Octavianti & Staddon, 2021). Such a value shows the current state of the water quality, according to the specific type of water and intended use (Manna & Biswas, 2023). Indices in general serve as standard assessment thresholds that can be used to regulate the performance of water utility providers (Jensen & Wu, 2018). For example, the World Health Organization (WHO) guidelines have well-established national regulations for acceptable contaminated levels of drinking water (WHO, 2017).

However, sometimes country-level water quality indices provide contradictory information, implying that more knowledge is required to get a holistic overview of water insecurity. For instance, the World Bank has produced a global water quality index (Damania *et al.*, 2019) using historical records from 2000 to 2010, showing that the most critical conditions of water pollution are in densely populated areas across the globe (examples include North America, both Western and Eastern Europe, and parts of Australia, East Asia, and South Africa).

On the other hand, the 2022 Environmental Performance Index (Wolf *et al.*, 2022), based on the disability-adjusted life years lost (DALYs) per 100 000 persons exposed to unsafe drinking water, provides a different picture. North America, Europe, and Australia are the regions that score the lowest in terms of DALYs and which therefore have the least contaminated drinking water – despite regions in these countries having a high risk of water pollution based on the aforementioned World Bank index. This contradiction may indicate that such countries have access to innovative treatment technologies that other countries do not. The two indices coincide only in regions of South Africa and India, which have low water quality based on the World Bank index and highly contaminated drinking water based on their relatively low DALYs score. For a detailed data visualisation of the two indices, you can refer to Damania *et al.* (2019), Wolf *et al.* (2022), and World Population Review (2023). However, we must stipulate that these indices still provide only a partial truth, as it becomes obvious that they follow current development models, dominated by short-term and reductionist approaches to globalisation, economic growth, and socio-economic inequalities across the globe.

Furthermore, as water quality is heavily dependent on the particular hydro-social conditions of a geographic location, such aforementioned indices provide solely area-specific information (Manna & Biswas, 2023), not always reflecting dynamic temporal changes (Jensen & Wu, 2018). As a result, they can offer limited knowledge for proactive decision-making. The United States Agency for International Development (USAID) has recently introduced new guidelines in an endeavour to improve knowledge dissemination: these aim to make the water data process more seamless (USAID, 2020), addressing varying spatial scales with the inclusion of satellite remote-sensing data to complement in-situ discrete measurements. USAID also advocates for using WHO's drinking water guidelines as a starting point for an understanding of water quality. Even so, this initiative has its blind spots, focusing on data-driven analysis and big data technology and neglecting data related to cultural local knowledge of water. It is not clear whether social data types other than standard questionnaires as described in Carroll *et al.* (2020) were considered in these guidelines (USAID, 2020).

Similarly, to address the question of what actions can remediate water pollution, if we look solely at technology-centric initiatives, technology has indeed progressed to treat water and make it safe for humans and ecosystems (Coccia & Bontempi, 2023; Shannon *et al.*, 2008). However, technology alone cannot be the sole way to approach water pollution complexity. For example, the emergence of new water pollutants is occurring at a faster rate than the current technological capacity to upgrade water treatment systems. What's worse, water treatment systems can cause secondary environmental impacts due to high energy and chemical demands. Current evidence shows that emerging contaminants are not removed efficiently in conventional drinking and wastewater treatment systems (Radwan *et al.*, 2023) – and it is even challenging to monitor them effectively because they appear in water at low concentrations, while the cost of analysing them in a laboratory is high (Shannon *et al.*, 2008). This highlights that there is a pressing need to continuously upgrade technology – in conjunction with current global commitments (e.g. Sustainable Development Goal 6), this puts pressure on governments and private industry to deliver and promote innovative water-related solutions (Mvulirwenande & Wehn, 2020).

Furthermore, while digital innovation has indeed increased the transparency of data resources, reduced the gap between data accessibility and sharing, and supported suppliers in engaging with water consumers via, for example, interactive digital apps (Walter, 2024), there are still several outstanding questions when it comes to proactively addressing water insecurities. These include (examples taken from Mvulirwenande & Wehn, 2020): should we focus on developing new, innovative digital solutions? Should we continuously upgrade current technologies? How would this work in low-resource and less-developed infrastructure contexts where public money would be required? How can low-cost, existing innovative technologies remediate health impacts on those contexts (examples of low-cost water treatment technologies in Chaúque *et al.*, 2023)? How does innovation incorporate the social aspects of water perception, use, and behaviours from local communities?

Overall, these examples demonstrate the current 'digital water' (Walter, 2024) and 'water innovation' (Mvulirwenande & Wehn, 2020) landscape, showing a number of digital water data processes (USAID, 2020) and standards (GO FAIR, 2021). All of the above gives us a glimpse of how to reduce water pollution, improve health outcomes, and promote seamless digital sharing platforms for a more inclusive way to address water insecurities. Nonetheless, these trends and frameworks have their limitations, as they are not always produced by diverse voices (including data practitioners or managers, individual water users, local communities, policymakers, etc.) in a joint process. In order to achieve this, we need a more mindful approach to data gathering, as spearheaded by recent theories such as CARE (collective benefit, authority to control, responsibility, and ethics), set out by Carroll *et al.* (2020), which includes indigenous voices in the process. Still, when developing a data-information-usage pipeline of water knowledge that can lead to decision-making, such principles with transdisciplinary types of voices and local knowledge are yet in their very infancy. We hope to further this approach in the course of this section.

AUTHOR CONTRIBUTIONS

The spotlights that sit in this section are united by the theme of knowledge while showcasing different applications of rigorous methodologies and information integration. We feature case studies from Colombia, Ethiopia, India, Malaysia, and the UK.

In Chapter 5, Data Collection, authors Yady Tatiana Solano-Correa, Rixia Zan, Maria Valasia Peppa, and David Chaquea-Romero highlight how collecting multifarious data provides crucial information at different spatial levels, from remotely sensed water quantity in a basin, to in-situ microbiological water quality, to people's water use behaviours in a household setting. While the first spotlight leverages freely available satellite imagery, the second spotlight leverages the latest portable equipment technology. Tatiana demonstrates how to estimate temporal changes across two water bodies in the Upper Cauca River Basin, Colombia, which can then be used to provide early warnings to local communities about potential flooding or drought. Rixia and Maria then demonstrate how to facilitate water quality diagnostics with the use of a smart suitcase laboratory that eliminates the need for expertise and expedites in-situ knowledge. This smart technology has now been rolled out to 150 researchers across Africa, Southeast Asia, and South America. Finally, in contrast to the first two spotlights that present quantitative datasets, David demonstrates the design of qualitative data acquisition to analyse human water use behaviours, particularly with regard to showering. The design firstly explores the diversity of people's ways of showering and is then scaled up to cover the municipality of Cali, Colombia. David adopts a methodology that, while widely used in social studies, is relatively unknown in residential water demand research. Overall, these spotlights show that data gathering, the first step in generating knowledge, is a process that should proceed in line with communities' needs and peoples' practices. They also demonstrate that, on the one hand, technology can expedite data capture, but on the other, advanced methods can be transferred from other disciplines to provide meaningful knowledge.

In Chapter 6, Databases, authors Ermias Teferi, Greg O'Donnell, and Zulfaqar Sa'adi address the challenges of data scarcity in relation to water resource management in the Abbay River Basin, Ethiopia and in the Johor River Basin, Malaysia. With fragmented, inconsistent, and inaccessible in-situ hydrometric and meteorological data of limited spatial coverage, proactive water resource management cannot be applied. Ermias discusses the establishment of a national-level data repository (CAMELS-Eth) that allows free access to hydrometric data of various spatio-temporal scales and visualisation tools. Data includes historical flows, hydrologic metrics, remotely sensed open-source hydrometeorological data, and geospatial information of 122 catchments in the Abbay River Basin. While addressing the same challenges, Zulfaqar specifically highlights the role of global open-source meteorological data in enhancing understanding of climate variability and demonstrates rigorous best practices for analysis and validation. He also draws attention to the lack of awareness of and familiarity with global open-source datasets, and regulatory non-compliance at constitutional levels. Overall, the two spotlights are examples of how data can be democratised and innovative methods can be adopted in data-sparse regions.

In Chapter 7, Data Modelling, Dinesh Kumar and Wegayehu Asfaw demonstrate the necessity of modelling data in different ways to understand, simulate, and predict water resource dynamics for improved decision-making. Dinesh discusses the implementation of the widely used Water Evaluation and Planning model in Delhi, India, incorporating knowledge from a variety of active players, stakeholders, and policymakers. The model provides future scenarios for a robust and sustainable water resource management system that can address challenges such as urban growth, climate change, and growing water demand and water distribution losses. Subsequently, Wegayehu predicts urban flood susceptibility in the Akaki catchment, Ethiopia. This spotlight highlights how state-of-the-art machine learning methods can be applied with a plethora of multi-modal observations to map the likelihood of flooding in a way that a human expert would not be able to produce so accurately and/or quickly. Machine learning in this context can support the proactive management of urban and real estate development, infrastructure, public health planning, emergency disaster response, and flood risk alleviation. Overall, both spotlights present knowledge that is generated via data model approaches, leveraging advanced technology to better inform policy decisions.

In Data Integration, the final chapter in this principle, the spotlights demonstrate how transdisciplinary voices can be integrated into the data-knowledge production pipeline. Diana Marcela Ruiz Ordóñez, Carolina Salcedo Portilla, and Samy Mafla Noguera present an understanding of water quality and ecosystem services in the Upper Cauca River Basin, Colombia, derived via social cartography with geospatial ethnographic practices and continuous interaction with local communities. By mapping the socio-ecological relationships between local communities and water use, supply, demand, and values, it is possible to understand socio-economic and political drivers that might influence ecosystem services and potentially lead to water quality degradation in the region. Such practices are unique to Latin America, providing a different perspective of data integration beyond a solely technological solution, safeguarding water resource management of indigenous communities, and promoting the CARE principles (Carroll *et al.*, 2020). Then, Jemila Mohammed Kassa demonstrates how universities, institutes, water management, and sewerage agencies in Ethiopia and the United Kingdom can join forces to educate, exchange knowledge, and monitor water contamination in the Akaki catchment, Ethiopia, with the ultimate aim of improving public health. The spotlight expands on the use of innovative portable suitcase labs, as introduced in Chapter 5, to address health issues: Jemila highlights how integrated efforts from both public and private sectors to scale up and develop scientific knowledge using this smart technology can help various downstream catchment communities better understand and manage potential water pollution and health impacts.

REFERENCES

Butte G., Solano-Correa Y. T., Peppa M. V., Ruíz-Ordóñez D. M., Maysels R., Tuqan N., Polaine X., Montoya Pachongo C., Walsh C. and Curtis T. (2022). A framework for water security data gathering strategies. *Water*, **14**(18), 2907, https://doi.org/10.3390/w14182907

Carroll S. R., Garba I., Figueroa-Rodríguez O. L., Holbrook J., Lovett R., Materechera S., Parsons M., Raseroka K., Rodriguez-Lonebear D., Rowe R., Sara R., Walker J. D., Anderson J. and Hudson M. (2020). The CARE principles for indigenous data governance. *Data Science Journal*, **19**(1), 43, https://doi.org/10.5334/DSJ-2020-043

Chaúque B. J. M., Issufo M., Benitez G. B., Cossa V. C., Chaúque L. G. H., Stauber C. E., Benetti A. D. and Rott M. B. (2023). Why do low-cost point-of-use water treatment technologies succeed or fail in combating waterborne diseases in the field? A systematic review. *Journal of Environmental Chemical Engineering*, **11**(5), 110575, https://doi.org/10.1016/j.jece.2023.110575

Coccia M. and Bontempi E. (2023). New trajectories of technologies for the removal of pollutants and emerging contaminants in the environment. *Environmental Research*, **229**, 115938, https://doi.org/10.1016/j.envres.2023.115938

Cory N. and Dascoli L. (2021). How Barriers to Cross-Border Data Flows Are Spreading Globally, What They Cost, and How to Address Them. Information Technology and Innovation Foundation. https://itif.org/publications/2021/07/19/how-barriers-cross-border-data-flows-are-spreading-globally-what-they-cost/ (accessed 11 April 2024)

Damania R., Desbureaux S., Rodella A.-S., Russ J. D. and Zaveri E. D. (2019). Quality Unknown: The Invisible Water Crisis (English). The World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/537481566459193718/quality-unknown-the-invisible-water-crisis (accessed 11 April 2024)

Donauer T., Haile A. T., Goshime D. W., Siegfried T. and Ragettli S. (2020). Gap and opportunity analysis of hydrological monitoring in the Ziway-Shala Sub-basin, Ethiopia. IWMI Working Paper 192, https://doi.org/10.5337/2020.210

GO FAIR. (2021). FAIR Principles. https://www.go-fair.org/fair-principles/ (accessed 11 April 2024)

Hox J. J. and Boeije H. R. (2005). Data collection, primary vs. secondary. In: Encyclopedia of Social Measurement, K. Kempf-Leonard (ed.), Elsevier, Netherlands, 593–599, https://doi.org/10.1016/B0-12-369398-5/00041-4

International Water Association (IWA). (2021). Digital Water. https://iwa-network.org/programs/digital-water/ (accessed 11 April 2024)

Jensen O. and Wu H. (2018). Urban water security indicators: development and pilot. *Environmental Science & Policy*, **83**, 33–45, https://doi.org/10.1016/j.envsci.2018.02.003

Lu S., Zhang X., Bao H. and Skitmore M. (2016). Review of social water cycle research in a changing environment. *Renewable and Sustainable Energy Reviews*, **63**, 132–140, https://doi.org/10.1016/j.rser.2016.04.071

Manna A. and Biswas D. (2023). Assessment of drinking water quality using water quality index: a review. *Water Conservation Science and Engineering*, **8**(1), 6, https://doi.org/10.1007/s41101-023-00185-0

Mvulirwenande S. and Wehn U. (2020). Dynamics of water innovation in African cities: insights from Kenya, Ghana and Mozambique. *Environmental Science & Policy*, **114**, 96–108, https://doi.org/10.1016/j.envsci.2020.07.024

Ndatimana G., Nantege D. and Arimoro F. O. (2023). A review of the application of the macroinvertebrate-based multimetric indices (MMIs) for water quality monitoring in lakes. *Environmental Science and Pollution Research*, **30**, 73098–73115, https://doi.org/10.1007/s11356-023-27559-0

Octavianti T. and Staddon C. (2021). A review of 80 assessment tools measuring water security. *WIREs Water*, **8**(3), e1516, https://doi.org/10.1002/wat2.1516

Polaine X. K., Dawson R., Walsh C. L., Amezaga J., Peña-Varón M., Lee C. and Rao S. (2022). Systems thinking for water security. *Civil Engineering and Environmental Systems*, **39**(3), 205–223, https://doi.org/10.1080/10286608.2022.2108806

Radwan E. K., Abdel Ghafar H. H., Ibrahim M. B. M. and Moursy A. S. (2023). Recent trends in treatment technologies of emerging contaminants. *Environmental Quality Management*, **32**(3), 7–25, https://doi.org/10.1002/tqem.21877

Shanahan H. and Bezuidenhout L. (2022). Rethinking the A in FAIR data: issues of data access and accessibility in research. *Frontiers in Research Metrics and Analytics*, **7**, 912456, https://doi.org/10.3389/frma.2022.912456

Shannon M. A., Bohn P. W., Elimelech M., Georgiadis J. G., Mariñas B. J. and Mayes A. M. (2008). Science and technology for water purification in the coming decades. *Nature*, **452**, 301–310, https://doi.org/10.1038/nature06599

Sugg Z. (2022). Social barriers to open (water) data. *WIREs Water*, **9**(1), e1564, https://doi.org/10.1002/wat2.1564

United States Agency for International Development (USAID). (2020). Data for Water Security: Improving Water Data Access and Use. USAID in partnership with Tetra Tech, the International Union for the Conservation of Nature, the Stockholm Environment Institute and the World Resources Institute. https://www.globalwaters.org/sites/default/files/swp-data-ws-8-24-2020.pdf (accessed 11 April 2024)

van Ginkel K. C. H, Hoekstra A. Y., Buurman J. and Hogeboom R. J. (2018). Urban water security dashboard: systems approach to characterizing the water security of cities. *Journal of Water Resources Planning and Management*, **144**(12), 04018075, https://doi.org/10.1061/(ASCE)WR.1943-5452.00009

Walter C. (2024). Digital technologies for the future of the water sector? Examining the discourse on digital water. *Geoforum*, **148**, 103918, https://doi.org/10.1016/j.geoforum.2023.103918

Ward R. C., Loftis J. C. and McBride G. B. (1986). The 'data-rich but information-poor' syndrome in water quality monitoring. *Environmental Management*, **10**, 291–297, https://doi.org/10.1007/BF01867251

Wilkinson M. D., Dumontier M., Aalbersberg I. J., Appleton G., Axton M., Baak A., Blomberg N., Boiten J-W., da Silva Santos L. B., Bourne P. E., Bouwman J., Brookes A. J., Clark T., Crosas M., Dillo I., Dumon O., Edmunds S., Evelo C. T., Finkers R., Gonzalez-Beltran A., Gray A. J. G., Groth P., Goble C., Grethe J. S., Heringa J., 't Hoen P. A. C., Hooft R., Kuhn T., Kok R., Kok J., Lusher S. J., Martone M. E., Mons A., Packer A. L., Persson B., Rocca-Serra P., Roos M., van Schaik R., Sansone S.-A., Schultes E., Sengstag T., Slater T., Strawn G., Swertz M. A., Thompson M., van der Lei J., van Mulligen E., Velterop J., Waagmeester A., Wittenburg P., Wolstencroft K., Zhao J. and Mons B. (2016). The FAIR guiding principles for scientific data management and stewardship. *Scientific Data*, **3**, 160018, https://doi.org/10.1038/sdata.2016.18

Wolf M. J., Emerson J. W., Esty D. C., de Sherbinin A. and Wendling Z. A. (2022). 2022 Environmental Performance Index (EPI) Results. Yale Center for Environmental Law & Policy, New Haven, Connecticut, USA. https://epi.yale.edu/epi-results/2022/component/epi (accessed 11 April 2024)

World Health Organization (WHO). (2017). Guidelines for Drinking-water Quality. 4th edition incorporating the 1st addendum. https://www.who.int/publications/i/item/9789241549950 (accessed 11 April 2024)

World Population Review. (2023). Water Quality by Country 2024. https://worldpopulationreview.com/country-rankings/water-quality-by-country (accessed 11 April 2024)

doi: 10.2166/9781789062540_0109

Chapter 5

Data collection

Yady Tatiana Solano-Correa, Rixia Zan, Maria Valasia Peppa and David Chaquea-Romero

Data gathering, the first step in generating knowledge, is a process that must proceed in line with communities' needs and peoples' practices. In this chapter, authors present case studies showing how technology can expedite data capture in Colombia and across the globe, as well as demonstrating how advanced methods can be transferred from other disciplines to provide meaningful knowledge in Colombia.

5.1 MULTITEMPORAL ANALYSIS FOR WATER MONITORING, MANAGEMENT, AND SECURITY FROM A REMOTE-SENSING PERSPECTIVE IN COLOMBIA

Yady Tatiana Solano-Correa

One of the most important external events to affect water in Colombia and the Upper Cauca River Basin (UCRB) is El Niño Southern Oscillation (ENSO) in its two variations: El Niño, characterised by high temperatures and extreme droughts (reducing water availability); and La Niña, characterised by low temperatures and extreme rain (increasing water levels, sedimentation, and risk of rivers overflowing). The effects of climate change have enhanced ENSO characteristics, causing widespread problems for Colombia in the past few decades. For instance, the La Niña period that occurred in 2010–11 led to considerable civil and economic losses and has been named one of the worst natural disasters in Colombian history (Vargas *et al.* (2018) and Hoyos *et al.* (2013).

Managing the consequences of ENSO events is of great relevance to both lives and livelihoods. It requires constant monitoring of water quantity and quality, and of land use surrounding different water sources. Such monitoring can be carried out in several ways, including through use of remote-sensing techniques. Remote sensing allows us to observe the Earth continuously, without coming into physical contact with it: remote sensors are located on aerial platforms and satellites, capturing information across the electromagnetic spectrum (optical and microwave) so that we can characterise the Earth's surface features and land cover.[1] This is possible thanks to the fact that everything in nature has its own distribution of reflected, absorbed, or emitted energy (Chuvieco, 1990).

Use of remote-sensing techniques makes it possible to obtain a detailed characterisation of water bodies without the need to embark on expensive, time-consuming and potentially dangerous field campaigns, where conflicts can make the collection of in-situ data difficult (Chawla *et al*., 2020). Existing optical remote-sensing studies are commonly performed in areas with (i) ideal weather conditions that allow for high-frequency acquisitions of data (i.e. without much obstruction by clouds in the area) or (ii) with large extensions of water that are easier to analyse with freely available data (Du *et al*., 2016). Nevertheless, these conditions are not fully satisfied for areas in Colombia, making the use of freely available optical remote-sensing data less common as a solution to water security problems. Therefore, there is a clear need to develop methodologies for optical and microwave satellite imagery that are able to work with freely available data and in areas with high cloud coverage.

Remote-sensing framework in the Upper Cauca River Basin

This case study presents a multitemporal image analysis of the surface area variations of two water bodies, correlated with water quality, located in the UCRB in Colombia (see Figure 5.1). The UCRB represents an important natural, cultural, social, and economic resource in Colombia, where water sources face continuous deterioration, which itself limits water use for human consumption (Sánchez Torres *et al*., 2022).

The left panel of Figure 5.1 shows Salvajina Reservoir (SR) and the right panel shows Sonso Lake (SL). SR is located in the department of Cauca (right before the Cauca River crosses into the Valle del Cauca) and is a difficult-to-access area due to armed conflict. SR is used for various purposes, including to support (i) the Cauca River flow, (ii) dilution of pollutants, and (iii) production of electrical energy. SL, on the other hand, is located in Valle del Cauca (right after the Cauca River has passed through Cali), and is a wetland, decreed a nature reserve since 1978, that varies the distribution of its water mirror throughout the year due to aquatic plants. Each of these bodies of water is a good example of an area with a specific context that offers only limited options with regard to implementing an effective method to assess their water security directly. It is for this reason that they have been selected for the present analysis.

[1] Optical remote sensing operates in red, green, blue, near-infrared, mid-infrared, and shortwave infrared wavelengths, while microwave remote sensing operates in microwave wavelengths, with the latter not being affected by atmospheric conditions (i.e. clouds, rain, fog, etc.).

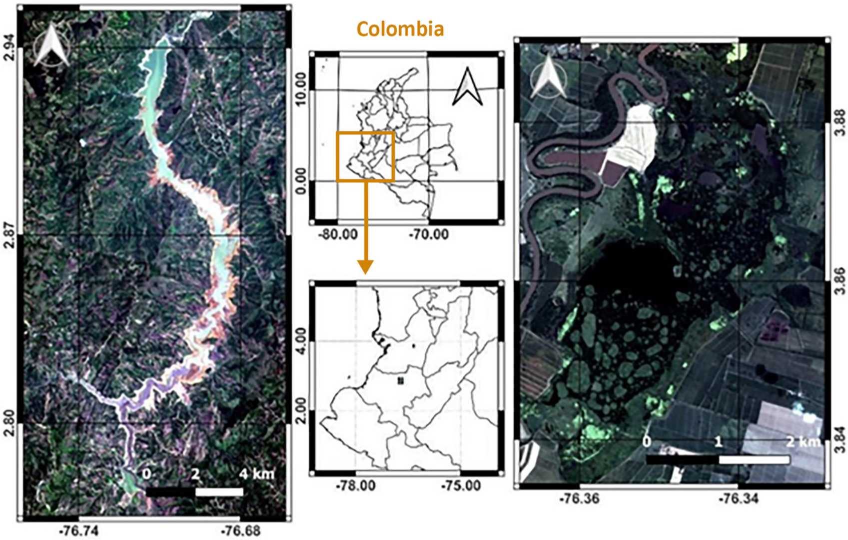


Figure 5.1 True colour satellite images of two water bodies in the UCRB: (left) Salvajina Reservoir; (right) Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

To overcome the existing remote-sensing challenges in the UCRB, a simple, yet effective, framework for monitoring water bodies through remote sensing is presented in Figure 5.2. The proposed method uses freely available data on the Google Earth Engine platform, which allows the researcher to clip out satellite images of the given area of interest (step 1). The framework's second step involves filtering the data, selecting only cloud-free images and/or those with the lowest percentage of clouds over the area of interest. Once data has been filtered out and downloaded, the third step sees the researcher extract radiometric indices and band ratios that help to better highlight water bodies.

Several satellite remote-sensing methods, such as image classification, linear unmixing, single-band thresholding, and water indexing, are available for the study of water bodies (Du *et al.*, 2014; Ji *et al.*, 2009). The Normalized Difference Water Index (NDWI) is one of the most used water indices to detect open surface water bodies. It was first created by the green (G) and near-infrared (NIR) spectral bands of Landsat TM (Özelkan, 2019), and benefits from the high reflectance in NIR of vegetation and soil features (Ko *et al.*, 2015). Other normalised indices exist to detect water bodies (such as the Modified NDWI); however, their results depend strongly on the colour, content, and depth of the water body under investigation, varying greatly from one region to another and therefore not allowing for a standardised comparison (Fisher *et al.*, 2016). For these and other reasons, the NDWI was used in this study to allow for the generic identification of water bodies.

With a proper feature extracted, the framework's fourth step segments the water bodies by three different methods: (i) Otsu's thresholding method

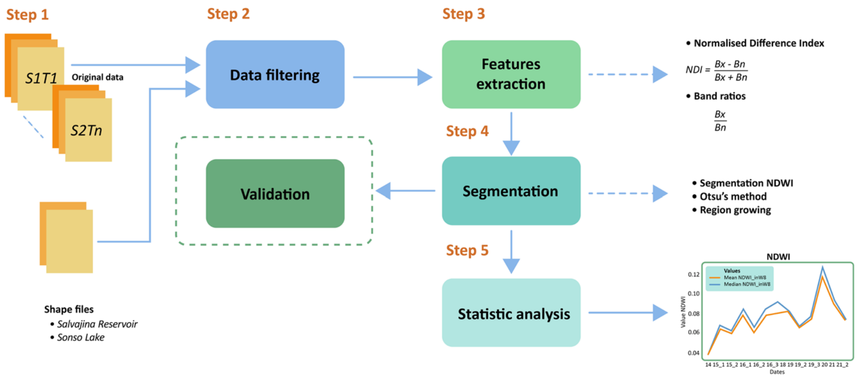


Figure 5.2 General block scheme of the proposed methodology for performing multitemporal analysis of water bodies. (Credit: rootsandwings.design).

(Yousefi, 2011), (ii) region growing (Fan & Lee, 2015), and (iii) segmentation by applying the physical meaning of the NDWI (Özelkan, 2019). These methods are applied to the NDWI images obtained for each water body. The fifth and final step performs a multitemporal statistical analysis of the images to correlate different variables such as area, water quality, and climate change variables. The analysis of these correlations should help decision-makers to better manage water bodies (see further explanation below).

Characterisation of two inland water bodies in the Upper Cauca River Basin

By making use of multitemporal information, it is possible to see how the water bodies' behaviour changes over different periods. Figure 5.3, for example, shows analysis of SR and SL over periods of seven and two

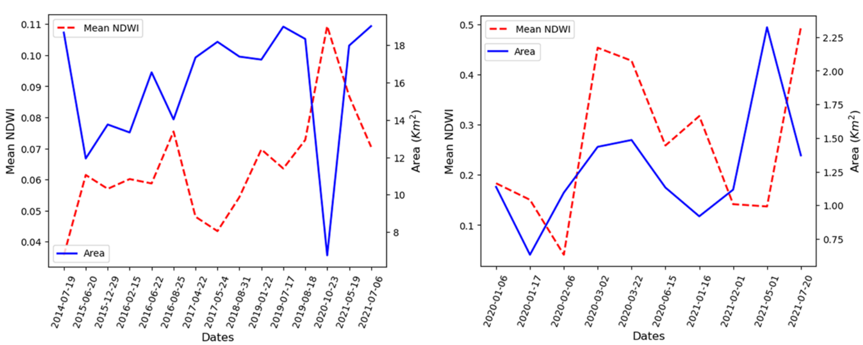


Figure 5.3 Characterisation of two inland water bodies in the UCRB: (a) Salvajina Reservoir; and (b) Sonso Lake: with regard to NDWI index and water body's area. (Credit: Yady Tatiana Solano-Correa).

years, respectively. Without the use of remote sensing, it would have been impossible to obtain such an analysis, since these areas generally do not use proper data acquisition protocols to keeps track of variables such as area/extension, contaminants, precipitation, or temperature, among others. Figure 5.3 shows the correlation between the temporal variable, the NDWI, and area/extension of SR and SL. An inverse correlation is found between these two values in SR (Figure 5.3a). This is because of the reflectance values of the water (Özelkan, 2019), which indicates the presence or absence of sediments and contaminants in the water body, with their proportion increasing when the water mirror (area) is smaller. A similar phenomenon occurs at SL (Figure 5.3b), but the inverse correlation is not as strong, perhaps because of aquatic plants on the water's surface (since this is a wetland). This information, together with meteorological data, can be used by decision-makers and communities to implement measurements about how to use the water for human consumption. Understanding if the increase/decrease of contaminants is related to climate conditions or human ones is also highly important for water security management.

Conclusion

Information from optical remote-sensing experiments such as this can be used (and is used) by communities and decision-makers to improve quality of life in the studied regions, all while guaranteeing water security. Remote-sensing techniques inform proactive decisions (e.g. by offering real-time information on the water bodies' conditions, area, and water quality) to safeguard water supplies before a water security risk emerges, rather than forcing locals to react after an event has occurred. For example, if weather conditions are such that a flood might occur, analysing the water body will provide more detailed information on this possible event, allowing an informed decision to be made about evacuating the area. The opposite is also true: during an extended period without rain, multitemporal information will show when the water levels are decreasing (by a decrease in area/extension of the water body), signalling the need to conserve water to reduce the risk of drought. And while the analysis we have presented demonstrates the success of an optical remote-sensing approach, which relies on clear atmospheric conditions, similar analysis can, in fact, be provided with microwave remote-sensing techniques, which are not influenced by weather.

Remote sensing has the advantage of providing a broader view of a system in its entirety, thus providing complementary information (to in-situ data) for proactive management. Remote-sensing information is often seen as too technical, but researchers can easily teach users how to read the derived information (such as multitemporal statistical analysis), thus supporting them to make their own decisions while being proactive about the management of the territory. In this way, communities, not just experts, can take control and act when risks arise.

Click on the following images to see timelapses of chlorophyll and segmentation in both water bodies (Figures 5.4–5.7).

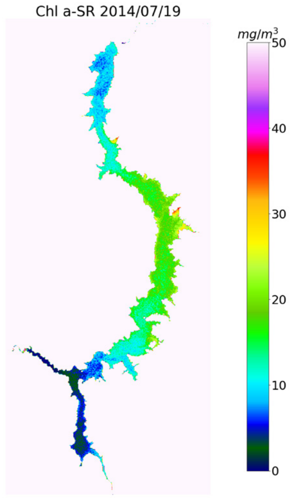


Figure 5.4 Chlorophyll in Salvajina Reservoir. (Credit: Yady Tatiana Solano-Correa).

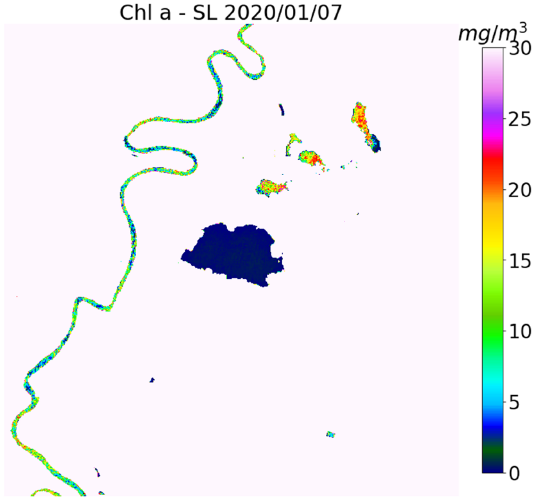


Figure 5.5 Chlorophyll in Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

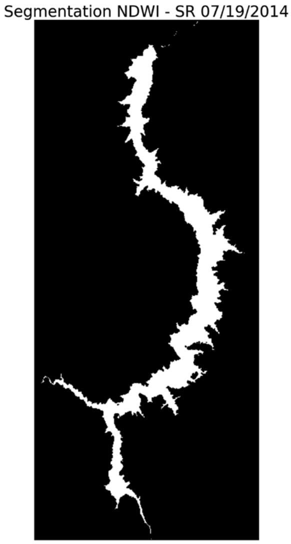


Figure 5.6 Segmentation in Salvajina Reservoir. (Credit: Yady Tatiana Solano-Correa).

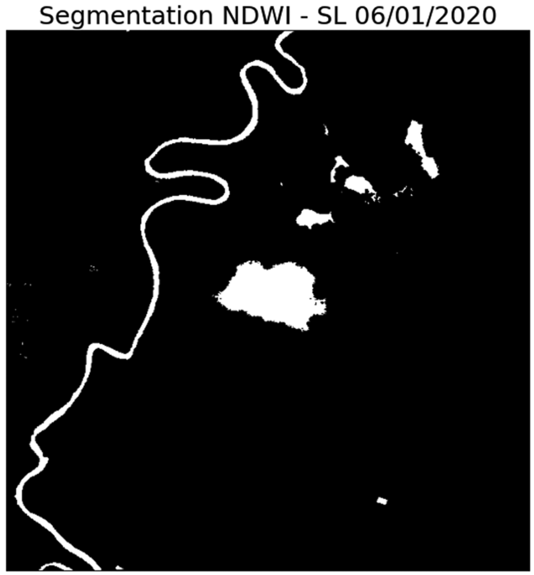


Figure 5.7 Segmentation in Sonso Lake. (Credit: Yady Tatiana Solano-Correa).

5.2 INNOVATIVE MOLECULAR MICROBIOLOGY METHOD FOR WATER QUALITY TESTING AND FAECAL POLLUTION SOURCE TRACKING: CASES FROM THE UK AND GLOBALLY

Rixia Zan and Maria Valasia Peppa

The COVID-19 pandemic has shown how powerful DNA/RNA-based diagnostics can be for hazard monitoring to protect public health (Diamond *et al.*, 2022). DNA/RNA-based diagnostics, also known as molecular diagnostics, examine sequences within the genetic code that can potentially serve as an indicator of specific diseases. Applying molecular microbiology to water quality monitoring could help with pollution source tracking and public health risk assessment. However, molecular microbiology-based methods usually are too expensive for low- to lower-middle-income countries. They also require a lot of investment in laboratory and professional skills. But it should be said that the problem of accessible water quality data is not unique to low- and lower-middle-income countries: for example, the UK sees high levels of sewage pollution in its rivers due to overflows and a lack of microbial water quality data. This challenge has become a top priority for the Environmental Audit Committee of the UK government (EAC, 2022).

Water can be rapidly screened for potentially hazardous microorganisms anywhere in the world, thanks to the development of an innovative and affordable suitcase laboratory (Acharya *et al.*, 2020; Halla *et al.*, 2022; Hiruy *et al.*, 2022; Pantha *et al.*, 2021). Conventional culture-based methods require 18 to 24 hours of incubation to produce results. In addition, they cannot tell if the faecal pollution source is from warm-blooded animals or humans. But the innovative suitcase laboratory, developed by Newcastle University, can obtain results in just three hours and can also identify specifically human sewage in a water body (Zan *et al.*, 2022) – which is crucial for rapid decision-making. What's more, it simplifies traditional molecular microbiology methods: while it's usually difficult to interpret complicated bio-information, especially for non-specialists, the suitcase laboratory primarily consists of user-friendly tools and state-of-the-art handheld devices to facilitate ease of use. Not to mention the fact that it's cost-effective, which is particularly crucial for low- and lower-middle-income countries, where people still lack access to clean water and sanitation. In short, the suitcase laboratory allows any microbial hazards in water to be identified quickly, easily, and cheaply (see Figure 5.8).

How to assemble the suitcase laboratory

Conventional quantitative polymerase chain reaction (qPCR) machines for specific genetic quantification and the next-generation sequencing instruments for comprehensive characterisation of genetic material in water are heavy and expensive.[2] Instead, the suitcase laboratory includes a speaker-sized qPCR instrument from Quantabio (Beverly, USA) and a pocket-sized sequencing

[2] qPCR is a molecular microbiology method to detect and measure specific genes.

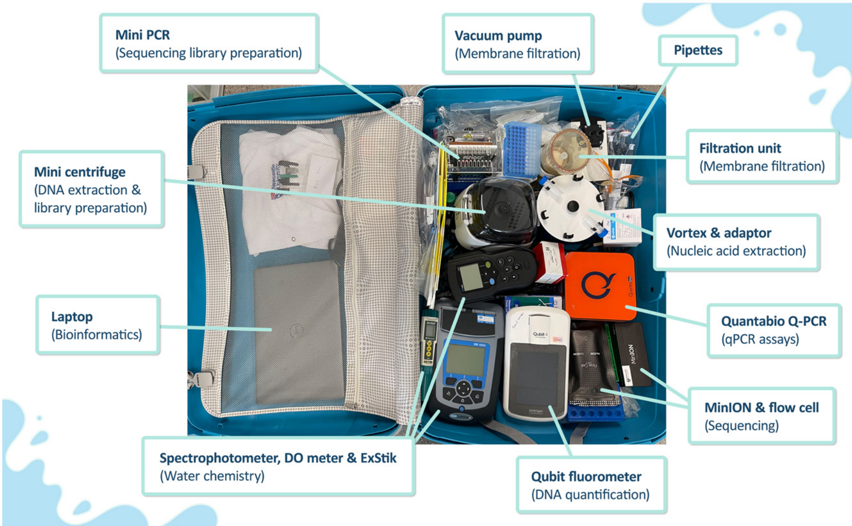


Figure 5.8 The latest edition of the suitcase laboratory. (Credit: Livia Douse).

device, MinION, from Oxford Nanopore Technologies (Oxford, UK). Aside from these two equipment items, it includes all the portable equipment needed for environmental DNA extraction from water, quantification, and amplification. In addition, a powerful laptop for sequencing data analysis and interpretation is included. All these equipment items readily fit into checkable luggage (Figure 5.9).

A suitcase laboratory for sequencing and water chemistry costs about $13 000; adding a qPCR machine to the mix brings the cost to $26 000, according to 2024 prices. Overall, this portable equipment allows for an 87% reduction in weight and an 85% reduction in cost.

What's more, while molecular microbiology is 2.6 times costlier than conventional microbiology, it provides detailed pollution source identification and helps with risk assessment and decision-making (Zan *et al.*, 2023). Although using the suitcase laboratory would require some knowledge of molecular microbiology, undergraduate students and local researchers can be trained in its application with a one-week training workshop. The main challenge is to get molecular microbiology consumables supplied to low-resource settings.

Case study

In our recent UK-based study (Zan *et al.*, 2022), we validated a methodology with portable laboratory equipment items that produced results which closely tallied with those obtained with conventional laboratory equipment items. We were able to identify human host-associated *bacteroides* in storm drain effluents and the Ouseburn River by using the portable instruments on site (in the back of a van) within three hours of sampling. The comprehensive

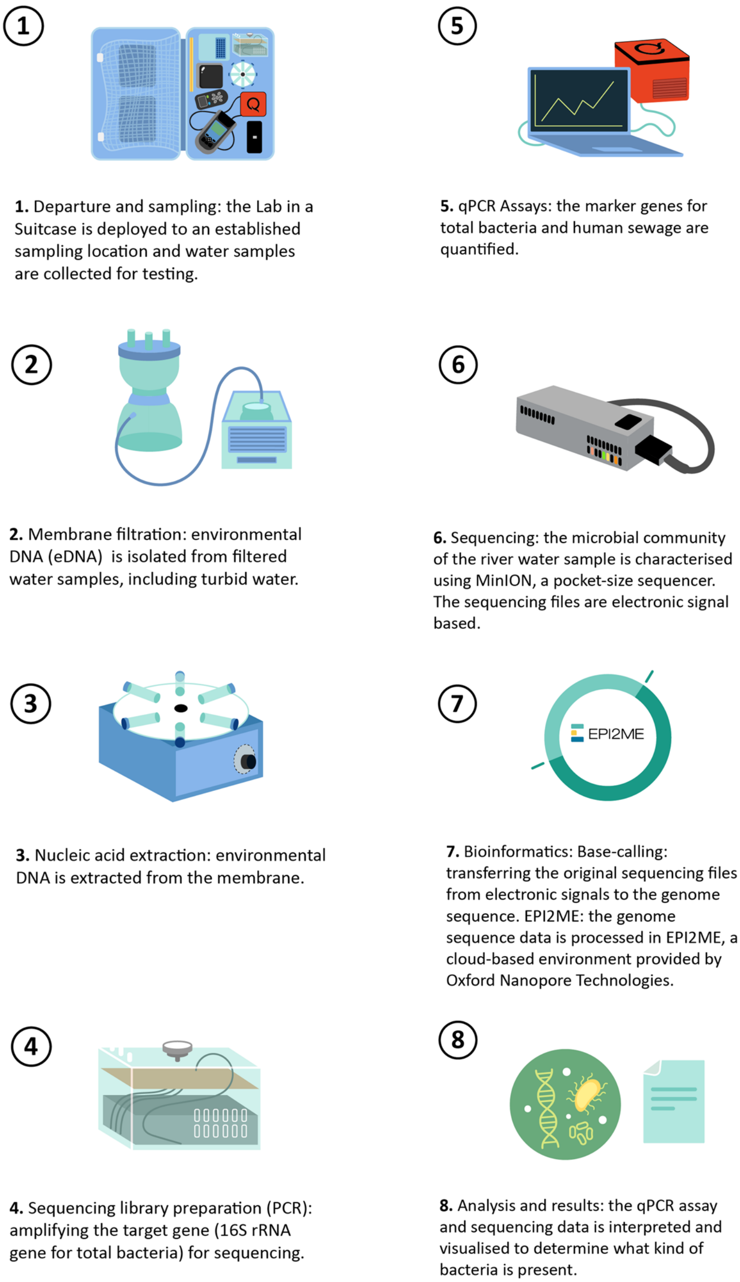


Figure 5.9 The process for assembling the suitcase laboratory. (Credit: rootsandwings. design).

Figure 5.10 Photographs of sampling along the Ouseburn River. (Credit: David Werner).

physicochemical and microbial water quality data showed faecal pollution from misconnections in the discharge of a surface water drain. The data also showed how stormwater retention in a pond produced effluent characteristics, like those seen in receiving river water, when compared with the water quality of discharges from two storm drains (Figure 5.10).

Global impact

The innovative suitcase laboratory for molecular microbiology water quality diagnostics enables faecal pollution source tracking and quantitative microbial risk assessment (Halla *et al.*, 2022; Zan *et al.*, 2023). This technology can also be applied to identify organisms such as protozoa (giardia and crypto) and antimicrobial resistance traits.

The application of the suitcase laboratory does require certain skills. But, as this video shows, we can train less experienced local researchers in applying state-of-the-art microbiology and related risk assessment methods with the help of the suitcase laboratory. Through this hands-on practice, participants learn about the importance of environmental monitoring, and wastewater collection and treatment.

Figure 5.11 Portable molecular diagnostics for on-site water quality monitoring workshops: (a) Kality Wastewater Treatment Plant, Addis Abba, Ethiopia; (b and c) Kung Krabaen Bay Royal Development Study Centre, Chanthaburi Province, Thailand; and (d) Mamiraua Institute for Sustainable Development, Amazon, Brazil. (Credit: Rixia Zan).

So far, we have used the suitcase laboratory in the UK, Brazil, Thailand, Cambodia, Malaysia, Ethiopia, and Tanzania. Trainees from Thailand, Brazil, and Ethiopia have applied the technology to their research (Figure 5.11). And since we started delivering the water quality workshops in 2021, over 150 researchers and water professionals have been trained in how to use the suitcase laboratory. We have built relationships with universities and institutions in Africa, Southeast Asia, and South America. We have also helped less experienced researchers develop their own microbiology laboratories and have collected comprehensive water quality data from all over the world. These workshops have allowed us to transfer our skills to others.

For example, our trainees from Newcastle University Medicine (NUMed) Malaysia attended a water quality workshop in August 2022. Then, they successfully helped us to deliver hands-on training in Ethiopia and Thailand in 2023. They also independently delivered the training to their own partner organisations in Cambodia, Thailand, and Indonesia. The attendees in Ethiopia are now using the suitcase laboratory to investigate bacterial hazards in the Akaki catchment (Hiruy *et al.*, 2022). Since several of our trainees have now become academics, they can pass on the skills they have gained to others. In Thailand, we provided hands-on training to the staff in Kung Karabean Bay Royal Development Study Centre in Chanthaburi province. Ten researchers from the study centre attended the practical lab session, while researchers from Thai universities and the Department of Fisheries in Chanthaburi attended the discussion session, after which a participant said, 'we can now better understand how the microorganisms affect the fishery products throughout the molecular microbiology technologies we learnt from this workshop.' Currently, NUMed (Malaysia), Addis Ababa Water and Sewage Authority (Ethiopia), King Mongkut's University of Technology Thonburi (Thailand), and Federal University of Minas Gerais (Brazil) are all using the suitcase laboratory. This year, we will deliver more workshops to colleagues from Colombia and Ukraine, increasing our global impact (Figure 5.11).

Conclusion

Water quality can be assessed via different approaches that are complementary to each other; we've mentioned just two of them in this spotlight.

Firstly, technological development makes water monitoring more efficient, allowing for the detection of microbial indicators of faecal contamination and bacteria resistant to antibiotics.

We have also, however, highlighted the importance of the social aspect, as democratising access to information and knowledge promotes community and participatory water quality data management (including collection, processing, and analysis). This helps to strengthen social cohesion and facilitate more informed decision-making to promote water security.

We also assert that the role of the academic institutions in these case studies is fundamental. For this reason, continuing to promote universities' social function, capacity building, and knowledge generation (especially in issues related to water security) is key to incorporating these concerns into political agendas and inter-institutional work.

Finally, it is essential to empower communities through the development of varied methodologies, tools, and socio-technical innovations. Decisions should not just be made by rulers or experts with a top-down approach, whereby communities are reduced to an object of study or response variable; even the most vulnerable communities can contribute to follow-up, monitoring, and generating new solutions for water security with a bottom-up approach.

5.3 EXPLORATORY MIXED METHODS DESIGN IN PRACTICE-CENTRED RESEARCH: SHOWERING IN CALI, COLOMBIA

David Chaquea-Romero

Residential water demand is connected to various aspects of water utility operations, such as pricing strategies, conservation initiatives, and customer engagement programmes. By analysing residential water demand trends, utility companies can implement targeted conservation efforts and incentivise efficient water use among consumers. Residential water demand research is mainly rooted in psychological and economic studies into the water consumption phenomenon (Darnton *et al.*, 2011; Shove, 2010, 2012). This approach is grounded in a positivist and causal understanding of household water consumption, where people are considered to be rational decision-makers whose behaviour is based on informed choices (Browne *et al.*, 2015; Shove, 2010; Sofoulis, 2011). As such, domestic water management focuses on providing knowledge and promoting water and/or pro-environmental values to encourage individuals to choose 'better' behaviours (Watson, 2012). This has created a top-down dynamic when it comes to determining 'best practices' for

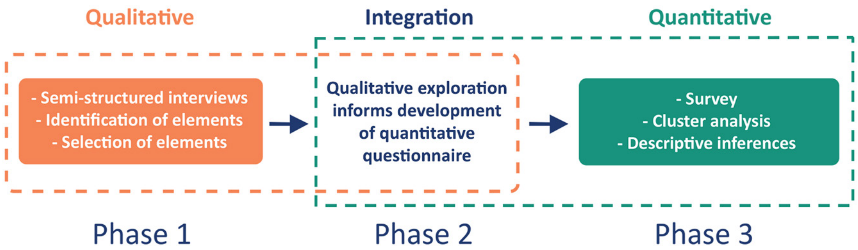


Figure 5.12 Scheme of the exploratory mixed methods design. Adapted from Plano Clark *et al.* (2008). (Credit: rootsandwings.design).

water users, where politicians, academics, water utilities, and water experts dictate how people should utilise water in their homes (Sofoulis, 2011: 805).

In contrast, when taken from the sociological perspective of practice theory (PT), visions of residential water demand are derived from the practices carried out by people in their everyday life (Browne *et al.*, 2015; Rinkinen *et al.*, 2021). Practices are what people actually do – like eating, sleeping, driving, working, or studying. They represent 'correct', 'appropriate', or 'acceptable' ways to behave under certain circumstances, which are socially accepted and do not need fully conscious or rational evaluation (Reckwitz, 2002; Shove *et al.*, 2012). As an outcome of practices, water demand is constantly and actively reproduced through people's performances (Rinkinen *et al.*, 2021); therefore, changing current consumption patterns lies in a better understanding of the configuration of water use practices (Figure 5.12).

Practice-centred research: mixed methodologies

Practice-centred approaches should play a crucial role in informing alternative water demand management, but they are underrepresented in the current policymaking framework (Hampton & Adams, 2018; Shove, 2010). While behavioural perspectives are predominant in domestic water consumption research and management, the translation of PT into intervention strategies is a work in progress (Kurz *et al.*, 2015: 123).

PT is not currently well represented in policymaking, because of the difficulty associated with characterising water use practices in large populations and scaling up their results (Hampton & Adams, 2018). Qualitative methods focusing on a small number of cases have traditionally been used in practice-centred research; quantitative methods, meanwhile, have been sidelined (Gram-Hanssen, 2015; Spaargaren *et al.*, 2016). However, quantitative methods can be used to address the situated and context-dependent characteristics and dynamics of practices, since they do not only evidence causality but also describe social phenomena (Browne *et al.*, 2014).

Some authors have claimed that quantitative approaches could be mistakenly applied in studying practices if they are used in the absence of a qualitative counterpart (e.g. Schatzki, 2012; Sofoulis, 2011). Consequently, mixed methods have been applied to characterise use practices (e.g. Eon *et al.*, 2018; Gram-Hanssen *et al.*, 2020; Pullinger *et al.*, 2013; van Tienoven *et al.*, 2017). These mixed methods have been mainly *explanatory*, where quantitative data is collected first and qualitative data is subsequently used to explain the findings (Creswell & Plano Clark, 2018). Here, it is assumed that the researchers are already very familiar with the object of study.

However, in cases like the one presented here, a lack of knowledge about what showering is (or means), demanded the implementation of an *exploratory* mixed methods design. We carried out a qualitative stage first to understand what made sense for people when they shower (Røpke, 2009). This prevented top-down impositions of researchers' preconceptions that did not necessarily align with people's actual ways of showering. Then, based on qualitative findings, a 'substantive, relevant, and culturally sensitive' questionnaire was designed (Creswell & Plano Clark, 2018: 86), which was capable of capturing the fuzzy composition of showering; finally, this was implemented quantitatively so that its findings could be scaled up to a larger population.

Practice-centred research: the case of showering in Cali

The research was conducted in Cali, the third-largest city in Colombia with a population of approximately 2.3 million people, and certainly the most important city in the Pacific region. It is culturally diverse because it has historically been a focus of migration from rural areas and other cities of the country. The city has the highest urban water demand in the UCRB, and its residential water demand is tackled through traditional, punitive economic measures and environmental education.

The three phases of the applied exploratory mixed methods design to characterise showering practice are presented below:

- Phase 1: We conducted 91 semi-structured interviews with people from 31 households in different parts of Cali, to identify the elements of showering based on the classification proposed by Shove *et al.* (2012): materials, competences, and meanings (Figure 5.13).[3]
- Phase 2: In the integration stage, the questionnaire was designed to collect data on the composition of people's performances in a larger sample, by measuring the presence or absence of the elements of the practice.[4] Even though showering is a 'habitual' practice (Shove, 2012), it is not performed in the same way every time: some elements are either integrated or not integrated in certain performances. Therefore, the measurement was carried out through four degrees of recurrence: 'always', 'most of the time', 'rarely', and 'never' (Figure 5.14).
- Phase 3: In the quantitative stage, we carried out the Domestic Water Use Practices Survey in a representative sample at the city level of 245 households; 597 people participated overall. Subsequent statistical

[3] Shove *et al.*'s three elements have been widely applied in empirical studies of practices.
[4] Here the concept of measuring does not represent the reduction of the practice to numerical values. Rather, it is used as 'the process of linking abstract concepts to empirical indicators' (Hernández Sampieri *et al.*, 2010: 199).

Figure 5.13 The elements of practice. Based on Shove *et al.* (2012) and Spurling *et al.* (2013). (Credit: rootsandwings.design).

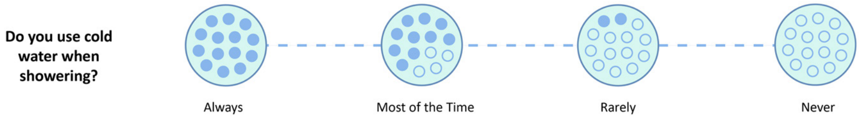
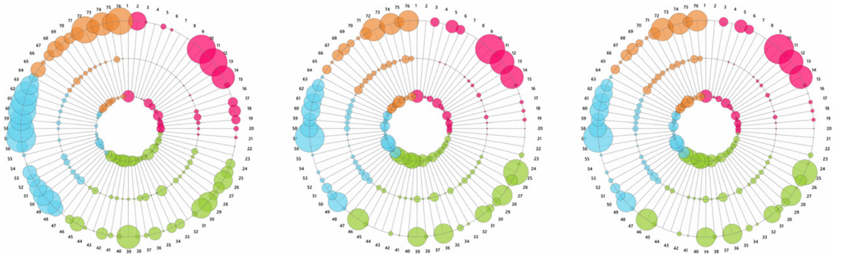


Figure 5.14 Example of the measurement of recurrence, using cold water in showering. (Credit: David Chaquea-Romero).

analysis consisted of the application of the k-means clustering method to identify patterns of response across the survey participants, by grouping cases whose content was as similar as it was different from other groups (Xu & Wunsch, 2009). Clusters or 'variants' of showering practice were identified based on the elements that people integrate always, most of the time, rarely, or never in their performances.

The variants of showering practice in Cali

The variants were named based on their characteristic elements: 'restoration showering', 'mixed simple showering', and 'simple readiness showering'. Each of them represents a particular understanding of the 'appropriate' way to perform the showering (Figure 5.15).



Restoration Showering (27.8%) | Mixed Simple Showering (40.36%) | Simple Readiness Showering (31.82%)

Figure 5.15 The practice of showering represented through an RRD. (Credit: David Chaquea-Romero).

Restoration showering

This pattern of performance revolves around restoring an individual's ideal physical and mental state. In this variant, the reasons and expectations of the practice are complementary. People always carry out the practice because:

- they feel cold or hot – and want to refresh themselves;
- they feel sweaty or they feel their body or hair is dirty – and want to feel clean;
- they feel odourful – and want to smell good;
- they feel tired or painful – and want to feel relaxed and energised, or to improve their mood.

The rings of recurrence diagram (RRD)

The RRD visualises differences between variants of showering practice. It consists of three rings: outer (representing the recurrence: 'always'), middle (representing the recurrence: 'most of the time'), and inner (representing the recurrence: 'rarely'). The recurrence 'never' is not included.

The RRD also visualises the types of elements in showering practice. It consists of four colours: red represents materials, green represents competences, blue represents meanings, and orange represents positions (i.e. actions before or after the practice is performed).

Participants' responses are distributed across the diagram in the intersection between a vector (element) and ring (recurrence). When the responses of two or more participants happen in an intersection (e.g. 'cold water' and 'always'), they are added to each other, and this value is represented by the diameter of the circle whose centre is in the respective intersection. Circle size therefore correlates to the number of coincidences in participants' responses.

Restoration showering has two faces in this pattern of performance: recovery and readiness. Recovery is related to performing the practice after activities that require physical activity (sports or household chores). Restoration showering is also carried out after returning home, and as such relates to feelings of weariness, the sensation of warmth, or ridding oneself of environmental pollution. On the other hand, readiness implies returning the body to a neutral state, in advance of activities to be carried out in the immediate future: before breakfast, leaving home, working or studying at home, being visited by someone, or dating at night.

It is not surprising that the daily frequency of restoration showering is twice a day, occasionally increasing to three, or decreasing to one (e.g. on weekends). Here, the distinction between body and hair is also crucial, which is reflected in using different consumables and in rinsing twice or more times. Because of this composition, people who carry out restoration showering frequently consider the practice to be of long duration.

Mixed simple showering

The mixed simple showering variant is configured on the minimum conditions that deem the performance appropriate around three main meanings: comfort, cleanliness, and care. This variant is considered 'mixed' because people's performances are more flexible in this variant compared with restoration showering, which means that, depending on the circumstances, they could adopt a relaxing, smelling good, or caring for the body/hair configuration. This variant is labelled as 'simple' because its composing elements are not essential but frequent; therefore, the standards of comfort, cleanliness, and care are not as meticulous as in restoration showering. Time spent showering is considered short, which could be associated with the fact that this pattern is often carried out in households with only one bathroom. Long showers are taken rarely, which could be related to the fact that people performing this type of showering are often in a hurry (e.g. before work on a weekday).

Simple readiness showering

While mixed simple showering is still strongly tied to comfort, cleanliness, and care, simple readiness showering is characterised by the position it occupies in relation to other practices. This pattern of performance is usually a pre-requisite for other activities: showering is performed before leaving home, before working or studying at home, and before dating at night. These positions are not essential, but they are frequently integrated into showering performances. Simple readiness showering could be considered the minimum standard to achieve before leaving home or carrying out practices that are traditionally associated with leaving it but are carried out inside (working or studying). In contrast to mixed simple showering, people who carry out this variant often live in households with two or more bathrooms; nonetheless, the practice is usually performed in the 'family bathroom'.

Conclusion

The variants of showering were consistent with the meanings of showering found by Hand *et al.* (2005) and Shove (2003) in their qualitative historical analysis of the practice, as well as with the variants of showering identified by Pullinger *et al*. (2013) in their explanatory mixed methods design applied to characterise water use practices in southern England. This proves that the implementation of an exploratory mixed methods approach is suitable for studying water use practices and (cautiously) scaling up their results. Methodological designs like the one outlined above challenge the traditional top-down approach to water consumption, by enabling people to speak about what makes sense for them in domestic water use from a bottom-up, culturally sensitive perspective.

The implementation of mixed methods – and particularly exploratory designs – could also boost the inclusion of practice-centred approaches in the policymaking arena, since descriptive inferences can be drawn in larger populations. This opens up a wider spectrum of intervention possibilities from within practices, rather than from external impositions (Jack, 2013).

In the specific case of showering in Cali, the identification of three variants provided evidence that materials, competences, and meanings are arranged and bound together through a routinised and daily reproduction, not from people's rational choices (Shove, 2010). Therefore, changes in peoples' water use cannot only be achieved through increased water prices, information campaigns, or environmental awareness. Research in local communities in Australia (Allon & Sofoulis, 2006; Fam *et al*., 2015; Fam & Mellick Lopes, 2015) shows that interventions centred on practices can be more effective, emerging from and fitting in current ways of water use. Findings in the presented spotlight contest the effectiveness of the one-size-fits-all strategies that are traditionally implemented in water demand management: such strategies neglect the fact that water is entangled in practices that are internally differentiated (i.e. variants of practice), which must be addressed and targeted from a holistic perspective.

To the knowledge of the author, practice-centred approaches are almost entirely unknown in residential water demand research and management at the local and national levels, which rely mainly on punitive economic measures, environmental education, or metering improvements. Further involvement of PT in residential water demand policymaking requires more research into the relationship between water consumption and the constitution of practices – which represents a further avenue to explore and improve for the approach presented here. Based on this, domestic water consumption could be addressed as a complex social phenomenon, beyond the exclusive engineering, economic, and psychological domains.

REFERENCES

Acharya K., Blackburn A., Mohammed J., Haile A. T., Hiruy A. M. and Werner D. (2020). Metagenomic water quality monitoring with a portable laboratory. *Water Research*, **184**, 116112, https://doi.org/10.1016/j.watres.2020.116112

Allon F. and Sofoulis Z. (2006). Everyday water: cultures in transition. *Australian Geographer*, **37**(1), 45–55, https://doi.org/10.1080/00049180500511962

Browne A., Pullinger M., Medd W. and Anderson B. (2014). Patterns of practice: a reflection on the development of quantitative/mixed methodologies capturing everyday life related to water consumption in the UK. *International Journal of Social Research Methodology*, **17**(1), 27–43, https://doi.org/10.1080/13645579.2014.854012

Browne A., Medd W., Anderson B. and Pullinger M. (2015). Method as intervention: intervening practices through quantitative and mixed methodologies. In: Social Practices, Intervention and Sustainability, Y. Strengers and C. Maller (eds.), Routledge, Abingdon, Oxfordshire, UK, pp. 1–207, https://doi.org/10.4324/9781315816494

Chawla I., Karthikeyan L. and Mishra A. K. (2020). A review of remote sensing applications for water security: quantity, quality, and extremes. *Journal of Hydrology*, **585**, 124826, https://doi.org/10.1016/j.jhydrol.2020.124826

Chuvieco E. (1990). Fundamentos de Teledetección Espacial. (Fundamentals of Satellite Remote Sensing), RIALP, Madrid.

Creswell J. W. and Plano Clark V. L. (2018). Designing and Collecting Mixed Methods Research, 3rd edn. SAGE Publications, California, US. https://us.sagepub.com/en-us/nam/designing-and-conducting-mixed-methods-research/book241842 (accessed 11 April 2024)

Darnton A., Verplanken B., White P. and Whitmarsh L. (2011). Habits, Routines and Sustainable Lifestyles: Summary Report. Department for Environment, Food and Rural Affairs (Defra), London, UK. https://uploads-ssl.webflow.com/5a9898f92fa8fa00017acfa3/5c63e1094387ae65504374ae_HabitsRoutinesSustainableLifestylesEVO502FinalSummaryReportNov20112.pdf (accessed 5 June 2024)

Diamond M. B., Keshaviah A., Bento A. I., Conroy-Ben O., Driver E. M., Ensor K. B., Halden R. U., Hopkins L. P., Kuhn K. G., Moe C. L., Rouchka E. C., Smith T., Stevenson B. S., Susswein Z., Vogel J. R., Wolfe M. K., Stadler L. B. and Scarpino S. V. (2022). Wastewater surveillance of pathogens can inform public health responses. *Nature Medicine*, **28**(10), 1992–1995, https://doi.org/10.1038/s41591-022-01940-x

Du Z., Li W., Zhou D., Tian L., Ling F., Wang H., Gui Y. and Sun B. (2014). Analysis of Landsat-8 OLI imagery for land surface water mapping. *Remote Sensing Letters*, **5**(7), 672–681, https://doi.org/10.1080/2150704X.2014.960606

Du Y., Zhang Y., Ling F., Wang Q., Li W. and Li X. (2016). Water bodies' mapping from Sentinel-2 imagery with modified normalized difference water index at 10-m spatial resolution produced by sharpening the SWIR band. *Remote Sensing*, **8**(4), 354, https://doi.org/10.3390/rs8040354

Environmental Audit Committee (EAC). (2022). Water quality in rivers. Fourth Report of Session 2021–22, HC 74, House of Commons, UK Parliament, London, p. 137. https://publications.parliament.uk/pa/cm5802/cmselect/cmenvaud/74/report.html (accessed 11 April 2024)

Eon C., Breadsell J. K., Morrison G. M. and Byrne J. (2018). The home as a system of practice and its implications for energy and water metabolism. *Sustainable Production and Consumption*, **13**, 48–59, https://doi.org/10.1016/j.spc.2017.12.001

Fam D. and Mellick Lopes A. (2015). Designing for system change: innovation, practice and everyday water. *ACME: An International Journal for Critical Geographies*, **14**(3), 751–764. https://acme-journal.org/index.php/acme/article/view/1231 (accessed 5 June 2024)

Fam D., Lahiri-Dutt K. and Sofoulis Z. (2015). Scaling down: researching household water practices. *ACME: An International Journal for Critical Geographies*, **14**(3), 639–651. https://acme-journal.org/index.php/acme/article/view/1224 (accessed 5 June 2024)

Fan M. and Lee T. (2015). Variants of seeded region growing. *IET Image Processing*, **9**(6), 478–485, https://doi.org/10.1049/iet-ipr.2014.0490

Fisher A., Flood N. and Danaher T. (2016). Comparing Landsat water index methods for automated water classification in eastern Australia. *Remote Sensing of Environment*, **175**, 167–182, https://doi.org/10.1016/j.rse.2015.12.055

Gram-Hanssen K. (2015). Structure and agency in understanding and researching practices. In: Practices, the Built Environments & Sustainability – Responses to the Thinking Note Collection, C. Foulds, J. Charlotte Louise, S. Blue and R. Morosanu (eds.), GSI, DIST, BSA, CCSG, Cambridge, Copenhagen, London, 9–10. https://vbn.aau.dk/ws/portalfiles/portal/209609495/responses_to_pbes_thinking_note_collection.pdf (accessed 11 April 2024)

Gram-Hanssen K., Christensen T. H. and Madsen L. V. and do Carmo C. (2020). Sequence of practices in personal and societal rhythms – showering as a case. *Time & Society*, **29**(1), 256–281, https://doi.org/10.1177/0961463X18820749

Halla F. F., Massawa S. M., Joseph E. K., Acharya K., Sabai S. M., Mgana S. M. and Werner D. (2022). Attenuation of bacterial hazard indicators in the subsurface of an informal settlement and their application in quantitative microbial risk assessment. *Environment International*, **167**, 107429, https://doi.org/10.1016/j.envint.2022.107429

Hampton S. and Adams R. (2018). Behavioural economics vs social practice theory: perspectives from inside the United Kingdom government. *Energy Research & Social Science*, **46**, 214–224, https://doi.org/10.1016/j.erss.2018.07.023

Hand M., Shove E. and Southerton D. (2005). Explaining showering: a discussion of the material, conventional, and temporal dimensions of practice. *Sociological Research Online*, **10**(2), 101–113, https://doi.org/10.5153/sro.1100

Hernández Sampieri R., Fernández Collado C. and Baptista Lucio P. (2010). Metodología de la Investigación (Investigation Methodology), 6th edn. McGrawHill Education, México. https://archive.org/details/hernandezetal.metodologiadelainvestigacion (accessed 5 June 2024)

Hiruy A. M., Mohammed J., Haileselassie M. M., Acharya K., Butte G., Haile A. T., Walsh C. and Werner D. (2022). Spatiotemporal variation in urban wastewater pollution impacts on river microbiomes and associated hazards in the Akaki catchment, Addis Ababa, Ethiopia. *Science of the Total Environment*, **826**, 153912, https://doi.org/10.1016/j.scitotenv.2022.153912

Hoyos N., Escobar J., Restrepo J. C., Arango A.M. and Ortiz J. C. (2013). Impact of the 2010–2011 La Niña phenomenon in Colombia, South America: The human toll of an extreme weather event. *Applied Geography*, **39**, pp. 16–25, https://doi.org/10.1016/j.apgeog.2012.11.018

Jack T. (2013). Nobody was dirty: intervening in inconspicuous consumption of laundry routines. *Journal of Consumer Culture*, **13**(3), 406–421, https://doi.org/10.1177/1469540513485272

Ji L., Zhang L. and Wylie B. (2009). Analysis of dynamic thresholds for the normalized difference water index. *Photogrammetric Engineering & Remote Sensing*, **11**, 1307–1317, https://doi.org/10.14358/PERS.75.11.1307

Ko B. C., Kim H. H. and Nam J. Y. (2015). Classification of potential water bodies using Landsat 8 OLI and a combination of two boosted random forest classifiers. *Sensors*, **15**(6), 13763–13777, https://doi.org/10.3390/s150613763

Kurz T., Gardner B., Veplanken B. and Abraham C. (2015). Habitual behaviours or patterns of practice? Explaining and changing repetitive climate-relevant actions. *WIREs Climate Change*, **6**(1), 113–128, https://doi.org/10.1002/wcc.327

Özelkan E. (2019). Water body detection analysis using NDWI indices derived from Landsat-8 OLI. *Polish Journal of Environmental Studies*, **29**(2), 1759–1769, https://doi.org/10.15244/pjoes/110447

Pantha K., Acharya K., Mohapatra S., Khanal S., Amatya N., Ospina-Betancourth C., Butte G., Shrestha S. D., Rajbhandari P. and Werner D. (2021). Faecal pollution source tracking in the holy Bagmati River by portable 16S rRNA gene sequencing. *npj Clean Water*, **4**(1), 12, https://doi.org/10.1038/s41545-021-00099-1

Plano Clark V. L., Huddleston-Casas C. A., Churchill S. L., O'Neil Green D. and Garret A. L. (2008). Mixed methods approaches in family science research. *Journal of Family Issues*, **29**(11), 1543–1566, https://doi.org/10.1177/0192513X08318251

Pullinger M., Browne A. L., Anderson B. and Medd W. (2013). Patterns of Water: The Water Related Practices of Households in Southern England, and Their Influence on Water Consumption and Demand Management, University of Manchester, Lancaster, UK. https://pure.manchester.ac.uk/ws/portalfiles/portal/38493062/FULL_TEXT.pdf (accessed 11 April 2024)

Reckwitz A. (2002). Toward a theory of social practices: a development in culturalist theorizing. *European Journal of Social Theory*, **5**(2), 243–263, https://doi.org/10.1177/13684310222225432

Rinkinen J., Shove E. and Mardsen G. (2021). Conceptualising Demand: A Distinctive Approach to Consumption and Practice. Routledge, New York, https://doi.org/10.4324/9781003029113

Røpke I. (2009). Theories of practice – new inspiration for ecological economic studies on consumption. *Ecological Economics*, **68**(10), 2490–2497, https://doi.org/10.1016/j.ecolecon.2009.05.015

Sánchez Torres L. D., Galvis Castaño A., Gandini M. A., Almario G., Montero M. V. and Vergara M. V. (2022). Commission for the upper Cauca river basin recovery, collaborative governance for sustainability and water security. *Frontiers in Water*, **4**, 782164, https://doi.org/10.3389/frwa.2022.782164

Schatzki T. (2012). A primer on practices: theory and research. In: Practice-Based Education. Perspective and Strategies, J. Higgs, R. Barnett, S. Billet, M. Hutchings and F. Trede (eds.), Sense Publishers, Rotterdam, pp. 13–26, https://doi.org/10.1007/978-94-6209-128-3_2

Shove E. (2003). Comfort, Cleanliness and Convenience: The Social Organization of Normality. Berg, Oxford, UK, https://doi.org/10.1023/A:1026362829781

Shove E. (2010). Beyond the ABC: climate change policy and theories of social change. *Environmental and Planning A: Economy and Space*, **42**(6), 1273–1285, https://doi.org/10.1068/a42282

Shove E. (2012). Habits and their creatures. In: The Habits of Consumption, A. Warde and D. Southerton (eds.), Helsinki Collegium of Advanced Studies, University of Helsinki, Helsinki, Finland, pp. 100–113. https://researchportal.helsinki.fi/en/publications/the-habits-of-consumption (accessed 5 June 2024)

Shove E., Pantzar M. and Watson M. (2012). The Dynamics of Social Practices: Everyday Life and How it Changes. SAGE Publications, London. https://us.sagepub.com/en-us/nam/the-dynamics-of-social-practice/book235021 (accessed 11 April 2024)

Sofoulis Z. (2011). Skirting complexity: the retarding quest for the average water user. *Continuum: Journal of Media & Cultural Studies*, **25**(6), 795–810, https://doi.org/10.1080/10304312.2011.617874

Spaargaren G., Lamers M. and Weenink D. (2016). Introduction: using practice theory to research social life. In: Practice Theory and Research – Exploring the Dynamics of Social Life, G. Spaargaren, D. Weenink and M. A. J. Lamers (eds.), Routledge, London, UK, pp. 3–27, https://doi.org/10.4324/978131565690

Spurling N., McMeekin A., Shove E., Southerton D. and Welch D. (2013). Interventions in Practice: Re-Framing Policy Approaches to Consumer Behavior. Sustainable Practices Research Group, University of Manchester. https://pure.manchester.ac.uk/ws/portalfiles/portal/32468813/FULL_TEXT.PDF (accessed 11 April 2024)

van Tienoven T. P., Glorieux I. and Minnen J. (2017). Exploring the stable practices of everyday life: a multi-day time-diary approach. *The Sociological Review*, **65**(4), 745–762, https://doi.org/10.1177/0038026116674886

Vargas G., Hernández Y. and Pabón J. D. (2018). La Niña Event 2010–2011: Hydroclimatic Effects and Socioeconomic Impacts in Colombia. In: Climate Change, Extreme Events and Disaster Risk Reduction, S. Mal, R. Singh, C. Huggel (eds.), Springer International Publishing, Switzerland, pp. 217–232 https://doi.org/10.1007/978-3-319-56469-2_15

Watson S. (2012). How theories of practice can inform transition to a decarbonised transport system. *Journal of Transport Geography*, **24**, 488–496, https://doi.org/10.1016/j.jtrangeo.2012.04.002

Xu R. and Wunsch D. C. (2009). Clustering. IEEE Press, John Wiley & Sons, Hoboken, New Jersey, US, https://doi.org/10.1002/9780470382776

Yousefi J. (2011). Image Binarization Using Otsu Thresholding Algorithm. University of Guelph, Ontario, Canada, https://doi.org/10.13140/RG.2.1.4758.9284

Zan R., Acharya K., Blackburn A., Kilsby C. G. and Werner D. (2022). A mobile laboratory enables fecal pollution source tracking in catchments using onsite qPCR assays. *Water*, **14**(8), 1224, https://doi.org/10.3390/w14081224

Zan R., Blackburn A., Plaimart J., Acharya K., Walsh C., Stirling R., Kilsby C. G. and Werner D. (2023). Environmental DNA clarifies impacts of combined sewer overflows on the bacteriology of an urban river and resulting risks to public health. *Science of the Total Environment*, **889**, 164282, https://doi.org/10.1016/j.scitotenv.2023.164282

doi: 10.2166/9781789062540_0131

Chapter 6

Databases

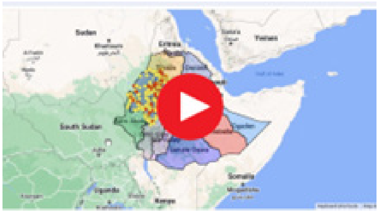
Ermias Teferi, Greg O'Donnell and Zulfaqar Sa'adi

With water scarcity and climate change threatening water security in multiple ways, accurate information can help us understand risks and formulate responses. Improved data and understanding are required to ensure that decision-making is effective and equitable. In the following case studies, the authors show how rigorous research methods and appropriate database tools, including the FAIR principles (see Principle 2. Knowledge – Introduction), can be implemented by active players to tackle water management challenges in Ethiopia's Abbay Basin and the Johor River Basin in Malaysia.

6.1 CAMELS-ETH EXPLORER: HYDROMETEOROLOGICAL AND GEOSPATIAL INTERACTIVE DATABASE TO SUPPORT WATER RESOURCE MANAGEMENT IN ETHIOPIA

Ermias Teferi and Greg O'Donnell

Ethiopia strives to use its available water resources efficiently, equitably, and optimally, to support socio-economic development on a sustainable basis (MoWIE, 2013). This requires a solid knowledge base for better decision-making. However, the governance of hydrometric data has historically been fragmented across agencies, with a lack of coordination impeding data sharing. Relevant stakeholders, including national ministries, local authorities, academic institutions, and non-governmental organisations, have limited capacity to access and utilise the hydrometric data that underpins a diverse range of practical and research activities. To achieve national goals when it comes to water resource management, stakeholders need transparent access to data and visualisation tools that capture key hydrometeorological and geospatial characteristics of river catchments.



To address this issue, the CAMELS-Eth Explorer (catchment attributes and meteorology for large-sample studies) has been established as a consolidated, national-level repository. This video offers a short virtual tour of the CAMELS-Eth Explorer, a dynamic web application through which the unified CAMELS-Eth database can be accessed.

Compilation of the CAMELS-Eth database

CAMELS-Eth draws together in-situ and remotely sensed hydrometeorological and geospatial datasets to provide a unified database that will enable better water resource management. Key activities performed include (Figure 6.1):

- Bringing together historical flow datasets and performing rigorous quality control;
- Calculating hydrologic metrics that characterise the dynamic behaviour of streamflow;
- Processing state-of-the-art remotely sensed rainfall, temperature, and evaporation datasets to augment the spatially limited in-situ monitoring network;
- Characterising topography, climate, soils, geology, hydrogeology, land cover, and anthropogenic influences;

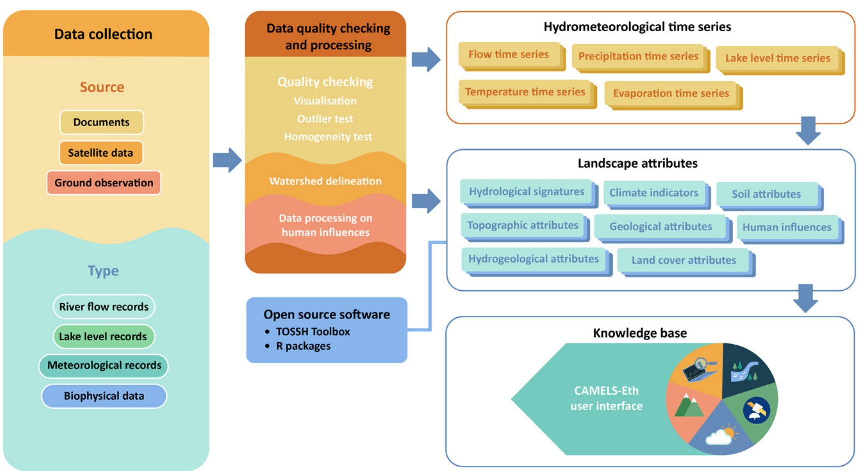


Figure 6.1 Workflow for the compilation of CAMELS-Eth. (Credit: rootsandwings.design).

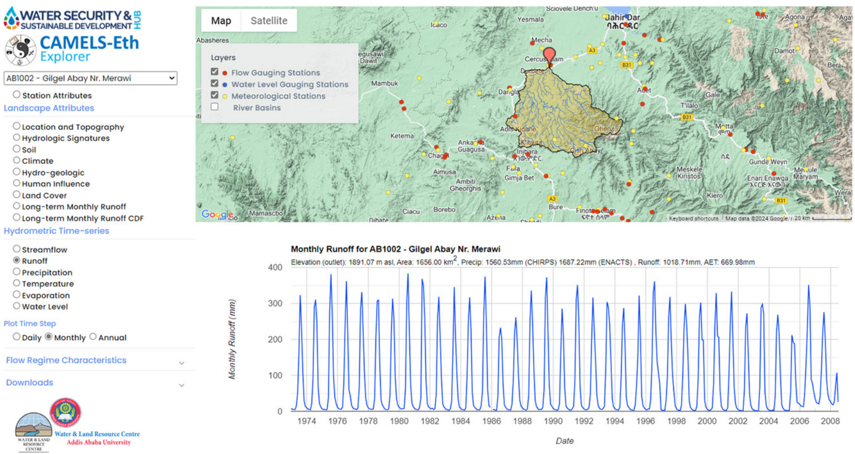


Figure 6.2 CAMELS-Eth Explorer web interface. (Credit: Ermias Teferi).

- Investigating the hydrological fluxes into and out of the catchment to support water resource development and management;
- Producing Ethiopia's first map-based user interface for hydrometric data (Figure 6.2).

Currently, CAMELS-Eth consists of datasets for 122 gauged catchments in the Abbay River Basin, which contributes about 50% of the country's total annual surface runoff.

Significance of CAMELS-Eth

- *Better data administration and governance*: The CAMELS-Eth Explorer is a dynamic web application that provides a unifying data portal to enable better data administration and governance. The CAMELS-Eth Explorer has also partnered with various academic institutes, including Mekdelamba University, Debre Birhan University, Debre Tabor University, and Addis Ababa University, empowering Ethiopian researchers to explore future water resource sustainability.
- *Comparative assessments*: The 122 catchments compiled under the CAMELS-Eth initiative exhibit considerable diversity in geophysical and hydrometeorological attributes. This variability, combined with the large number of catchments, makes the CAMELS-Eth dataset ideal for comparative assessments. For example, the classification and regionalisation of catchments can aid in the transfer of hydrological knowledge to catchments that have not been monitored.
- *Local versus global datasets*: Our primary goal in developing CAMELS-Eth was to use the best available datasets. Often local datasets provide the highest-quality information, but in their absence global datasets have been employed. By connecting international scientists to detailed,

Ethiopia-specific data, CAMELS-Eth Explorer helps overcome knowledge barriers and increases utilisation of valuable in-country insights, which external researchers might otherwise struggle to find and interpret.

- *Human activity on river flow*: CAMELS-Eth Explorer includes metrics on the extent of human activities relating to river flow and groundwater. Here, we have included information regarding river regulation, extent of urbanisation or man-made impervious surface, and population density. Knowledge of human activity is a prerequisite in understanding the partitioning of rainfall into evaporation, soil moisture, and runoff – which in turn allows us to quantify impacts on the dynamics of river flow and ecosystems. Additionally, this information can aid in the selection of relatively undisturbed 'benchmark catchments', suitable for the study of climatic variability and change.
- *Climate variability*: The data compiled in the CAMELS initiative has great potential to be utilised for analysing climate variability across different watersheds. It presents an important opportunity to comprehensively assess climate variability impacts on water in Ethiopia. The dataset facilitates robust hydro-climatic insights not possible from individual case studies.

Conclusion

Looking ahead, we envision many applications of the CAMELS-Eth database, including in water resource models to assess potential water resource development options; in studies of droughts, floods, and runoff generation; in planning in ungauged basins; and in assessments of environmental flows in relation to hydrologic alteration. CAMELS-Eth will continue to evolve as these new applications are developed and as users feed back as to what they need for more comprehensive hydrological systems analyses.

This initial work has focused on Ethiopia's Abbay River Basin, which is the country's most socially and economically vital basin, providing around 50% of Ethiopia's total annual surface runoff. We are currently preparing to expand to other river basins across Ethiopia, including the Awash Basin, where the capital city, Addis Ababa, is situated, and the Central Rift Valley River Basin, which is currently undergoing agricultural expansion informed by the CAMELS-Eth database and in line with the FAIR principles. We hope that the development of the first CAMELS dataset for Africa will provide a template for future endeavours in data-sparse regions that are experiencing water management challenges.

6.2 ENHANCING CLIMATE-BASED INFORMATION FOR JOHOR RIVER BASIN, MALAYSIA: ACCESSING DATA AND OVERCOMING BARRIERS

Zulfaqar Sa'adi

Water management in the Johor River Basin (JRB), Malaysia, faces multifaceted challenges that require the integration of diverse global open-source climate datasets (Giuliani *et al.*, 2017). However, entrenched conventional practices often hinder progress, highlighting the pressing need for a transformative shift towards accessible global open-source data to overcome prevailing barriers (Mondejar *et al.*, 2021). Government practitioners traditionally rely on conventional meteorological data, sourced from ground-based weather stations nationwide, to manage climate-based water resources. This data, encompassing rainfall, temperature, humidity, wind speed, and so forth, has been instrumental in analysing diverse climatic trends and their impacts on water resources (Fung *et al.*, 2022; Kang Ng *et al.*, 2020; Ng *et al.*, 2022).

This ground-based data, however, has limitations when it comes to spatial coverage, making it inadequate for the capture of microclimatic variations, which then leads to uncertainties around localised weather patterns and their water resource impacts. This data lacks consistency and homogeneity across stations due to variations in instrumentation, observation practices, and data quality control. Inhomogeneity and persistent missing data in meteorological datasets significantly impact climate assessments, as evidenced by the feasibility of only 24 out of 51 ground-based rainfall stations for extreme rainfall and drought assessments in the JRB (Sa'adi *et al.*, 2022, 2023a). Addressing missing data necessitates a rigorous data quality and imputation process (Sa'adi *et al.*, 2023b). For one thing, historical data may not align with the dynamics of climate change, often lacking the necessary long-term granularity to allow researchers to discern between the effects of short-term climate variability and long-term climate change (Ghil & Lucarini, 2020). Therefore, relying solely on conventional data sources limits our capacity to anticipate and respond to emerging climate change challenges, as well as hindering a comprehensive understanding of the complex relationships between climate, water resources, and human activities.

The benefits of global open-source climate datasets

By contrast, global open-source climate datasets combine ground-based observations, satellite measurements, and reanalysis models to achieve comprehensive coverage of the Earth's surface, including remote areas (Ayoub *et al.*, 2020). Global open-source climate datasets offer comprehensive, freely accessible collections of climate-related information, encompassing variables such as temperature, precipitation, humidity, wind speed, atmospheric pressure, and sea surface temperature across diverse spatial and temporal scales (Sun *et al.*, 2018). For instance, Figure 6.3 demonstrates the spatial advantages offered by Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) gridded rainfall datasets (CHIRPS, n.d.) compared with solely ground-based station datasets when assessing extreme rainfall in the JRB.

In the top array of Figure 6.3, extreme rainfall maps were created using ArcGIS by interpolating in-situ rainfall datasets from 24 stations situated within and in proximity to the JRB. The lower array of Figure 6.3 showcases extreme rainfall maps generated within the R environment, utilising 109 grid points extracted from CHIRPS data. This comparison reveals CHIRPS' superiority when it comes to capturing rainfall conditions, which could be attributed to its capacity to offer comprehensive and spatially contiguous assessment. This capability allows for a more accurate depiction of rainfall

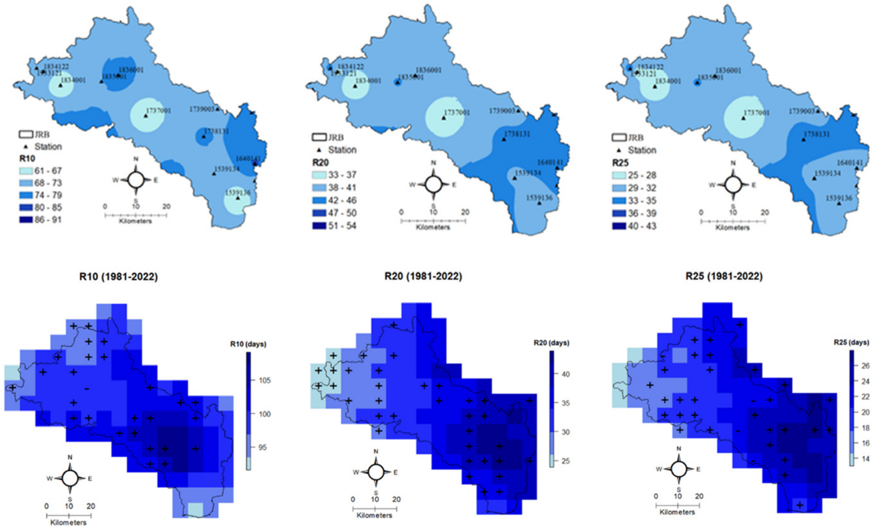


Figure 6.3 Comparison between extreme rainfall (number of heavy rainy days, R10; number of very heavy rainy days, R20; and number of extremely heavy rainy days, R25) assessments based on station data (Sa'adi *et al.*, 2022) (top array) and CHIRPS data (Sa'adi *et al.*, 2023c) (bottom array). Symbols '+' and '−' indicate positive and negative trends, respectively, under a statistical test at 95% significant level. (Credit: Zulfaqar Sa'adi).

across wider geographic areas, surpassing the limitations associated with station data, which often suffers from restricted coverage and spatial resolution. So, compared with others, CHIRPS offers distinct advantages for small-scale JRB basin rainfall assessment. With a spatial resolution of 0.05° and a historical record spanning over 42 years (since 1981), CHIRPS has been validated to adeptly capture variations in rainfall intensity and distribution in the JRB (Sa'adi *et al.*, 2023c). Incorporating both satellite and ground-based station data ensures reliability and consistency with near-real-time updates, essential for assessing historical trends and climate change impacts. Additionally, CHIRPS can fill data gaps in remote or data-sparse regions in the JRB, enhancing its utility for assessing basins with limited ground-based observations.

A wide array of global open-source climate datasets and simulation models is available, with the majority of users emanating from academic spheres rather than government agencies. There has been a move towards utilising the CHIRPS dataset in a number of recent academic climate assessments for drought (Sa'adi *et al.*, 2023c) and rainfall projection (Sa'adi *et al.*, 2024) in the JRB. Ayoub *et al.* (2020) evaluated CHIRPS data in Malaysia and found that, despite some slight overestimations, it effectively captured occurrences of high rainfall intensity. Additionally, Hashim *et al.* (2023) employed another freely available precipitation and evapotranspiration dataset to analyse changes in

JRB water yield.[1] Furthermore, Tan *et al.* (2021) utilised existing high-resolution global climate models to evaluate hydro-climatic change projections in the JRB (HRCM, n.d.). On a broader scale, Noor *et al.* (2021) compared the rainfall intensity estimations from four remotely sensed products from NASA and JAXA space agencies with those obtained using solely ground-based datasets at 80 stations in Peninsular Malaysia.[2] The authors concluded that the remotely sensed products required some correcting, due to biases relating to topography, cloud cover, and other climatic factors, but once these corrections had been made, one of the four products – JAXA's global product – significantly improved rainfall intensity estimations, making it suitable for hydrological analysis in regions without accessible in-situ rainfall data.

These examples demonstrate the extensive utilisation and validation of global datasets across Malaysian academia, benefiting from rigorous quality control and assimilation techniques that ensure reliability and enhance the robustness and consistency of climate analyses. Moreover, these datasets offer finer temporal resolution through reanalysis models and satellite observations, facilitating the detection and analysis of rapid climate variations and trends over shorter time scales. While conventional ground-based meteorological data is vital for local-scale analyses and forecasting, global open-source climate datasets offer a more comprehensive, consistent, continuous, and broader perspective on the Earth's climate system, enhancing our understanding of global climate variability and change. Therefore, both localised and global analysis should be conducted in a complementary manner, supplementing each other's temporal and spatial scales, especially in the case of ground-data scarcity.

Challenges to the adoption of global open-source climate datasets

Despite the wealth of information and accompanying benefits they offer in terms of policy- and decision-making, several factors contribute to the limited uptake of global open-source climate datasets by government entities. These include:

(1) Government agencies may lack awareness or familiarity with the existence and availability of global open-source climate datasets, as they often rely on traditional data sources from national meteorological agencies, potentially leading to a reluctance to explore alternative datasets.

(2) Reliability, consistency, and regulatory compliance in data sourcing is a priority for policy formulation and implementation. Even though global open-source climate datasets already undergo quality control,

[1] Between 1997 and 2015, the Tropical Rainfall Measuring Mission provided freely available critical precipitation measurements in tropical and subtropical regions (NASA, n.d.).

[2] (i) JAXA's global products for satellite mapping in near real time (GSMAP, n.d.); (ii) with some generated after gauge calibration; (iii) precipitation estimation from remotely sensed information using artificial neural networks (CHRS, n.d.); (iv) NASA's and JAXA's rainfall estimates from the Tropical Rainfall Measuring Mission.

some concerns may arise regarding data accuracy, consistency, and adherence to regulatory standards compared with traditional sources.

(3) There are technical and resource-related challenges in accessing, processing, and interpreting large-scale global open-source climate datasets.

(4) Integrating these datasets into existing systems and workflows may necessitate specialised expertise, infrastructure upgrades, and additional resource allocation, posing barriers to adoption and uptake.

(5) Specific data requirements and mandates may not be fully met by existing global open-source climate datasets, necessitating collaboration and customisation efforts for applications such as disaster risk management, infrastructure planning, and policy development.

So, wider adoption of global open-source climate datasets in governmental decision-making processes could be supported by greater collaboration between academic researchers and government agencies, among other things. The transition to global open-source climate data could involve initiatives to raise awareness, provide training and technical support, improve data accessibility and usability, and establish partnerships for co-development and customisation of datasets to meet specific governmental needs. Ensuring compatibility and interoperability between global open-source climate data and existing systems is vital for seamless integration into decision-making processes. Ultimately, the wealth of information contained in global open-source climate datasets has the potential to enhance evidence-based policymaking, improve resilience to climate change, and promote sustainable development at local, national, and global scales. By addressing these barriers to adoption, we can effectively unlock the potential of global open-source climate data for informed decision-making and climate resilience.

Conclusion

Global open-source climate datasets are invaluable resources for researchers, policymakers, and practitioners involved in climate-related studies and applications. They facilitate the analysis of past climate conditions, the monitoring of ongoing climate trends and variability, and the development of climate projections and scenarios for future climate change assessments. Additionally, these datasets support climate impact assessments, adaptation planning, and decision-making processes in sectors such as agriculture, water resources management, energy, and infrastructure development. Overall, global open-source climate datasets play a crucial role in advancing our understanding of the Earth's climate system, fostering collaboration and innovation in climate research and supporting efforts to address the challenges posed by climate change on a global scale. In conclusion, while traditional in-situ data sources continue to play a vital role in climate-based water management, the integration of global and gridded datasets offers significant opportunities to enhance decision-making and improve resilience to climate variability and change in areas like the JRB, especially when these regions lack in-situ data. By embracing diverse datasets and leveraging advanced technologies, practitioners can gain deeper insights into the complex dynamics of the climate–water system and develop more effective strategies for sustainable water management in the region.

REFERENCES

Ayoub A. B., Tangang F., Juneng L., Tan M. L. and Chung J. X. (2020). Evaluation of gridded precipitation datasets in Malaysia. *Remote Sensing*, **12**(04), 613, https://doi.org/10.3390/RS12040613

Center for Hydrometeorology and Remote Sensing (CHRS) (n.d.). Data Portal. https://chrsdata.eng.uci.edu/ (accessed 12 April 2024)

Climate Hazards Group Infrared Precipitation with Station Data (CHIRPS) (n.d.). CHIRPS: Rainfall Estimates From Rain Gauge and Satellite Observations. Climate Hazards Center, UC Santa Barbara. https://www.chc.ucsb.edu/data/chirps (accessed 12 April 2024).

Fung K. F., Chew K. S., Huang Y. F., Ahmed A. N., Teo F. Y., Ng J. L. and Elshafie A. (2022). Evaluation of spatial interpolation methods and spatiotemporal modeling of rainfall distribution in Peninsular Malaysia. *Ain Shams Engineering Journal*, **13**(02), 101571, https://doi.org/10.1016/J.ASEJ.2021.09.001

Ghil M. and Lucarini V. (2020). The physics of climate variability and climate change. *Reviews of Modern Physics*, **92**, 35002, https://doi.org/10.1103/RevModPhys.92.035002

Giuliani G., Nativi S., Obregon A., Beniston M. and Lehmann A. (2017). Spatially enabling the Global Framework for Climate Services: reviewing geospatial solutions to efficiently share and integrate climate data & information. *Climate Services*, **8**, 44–58, https://doi.org/10.1016/J.CLISER.2017.08.003

Global Satellite Mapping of Precipitation (GSMAP) (n.d.). Jaxa Global Rainfall Watch. https://sharaku.eorc.jaxa.jp/GSMaP/ (accessed 12 April 2024)

Hashim M., Baiya B., Mahmud M. R., Sani D. A., Chindo M. M., Leong T. M. and Pour A. B. (2023). Analysis of water yield changes in the Johor river basin, Peninsular Malaysia using remote sensing satellite imagery. *Remote Sensing*, **15**(13), 3432, https://doi.org/10.3390/RS15133432

High Resolution Climate Modelling group (HRCM) (n.d.). High Resolution Model Intercomparison Project (HighResMIP). https://hrcm.ceda.ac.uk/research/cmip6-highresmip/ (accessed 12 April 2024).

Kang Ng C., Lin Ng J., Feng Huang Y., Xun Tan Y. and Mirzaei M. (2020). Tropical rainfall trend and stationarity analysis. *Water Supply*, **20**(07), 2471–2483, https://doi.org/10.2166/WS.2020.143

Ministry of Water, Irrigation & Energy (MoWIE) (2013). Ethiopia's Climate-Resilient Green Economy – Climate Resilience Strategy: Water and Energy. Government of Ethiopia. https://www.mofed.gov.et/media/filer_public/05/cf/05cf1525-f484-4ff2-93dc-9ba0b8b7e060/water-and-energy_cr.pdf (accessed 12 April 2024)

Mondejar M. E., Avtar R., Diaz H. L. B., Dubey R. K., Esteban J., Gómez-Morales A., Hallam B., Mbungu N. T., Okolo C. C., Prasad K. A., She Q. and Garcia-Segura S. (2021). Digitalization to achieve sustainable development goals: steps towards a Smart Green Planet. *Science of The Total Environment*, **794**, 148539, https://doi.org/10.1016/J.SCITOTENV.2021.148539

NASA (n.d.). The Tropical Rainfall Measuring Mission. https://gpm.nasa.gov/missions/trmm (accessed 12 April 2024)

Ng C. Y., Jaafar W. Z. W., Mei Y., Othman F., Lai S. H. and Liew J. (2022). Assessing the changes of precipitation extremes in Peninsular Malaysia. *International Journal of Climatology*, **42**(15), 7914–7937, https://doi.org/10.1002/JOC.7684

Noor M., Ismail T., Shahid S., Asaduzzaman M. and Dewan A. (2021). Evaluating intensity-duration-frequency (IDF) curves of satellite-based precipitation datasets in Peninsular Malaysia. *Atmospheric Research*, **248**, 105203, https://doi.org/10.1016/J.ATMOSRES.2020.105203

Sa'adi Z., Yusop Z. and Alias N. E. (2022). Inter-comparison on the suitability of rain-based meteorological drought in Johor River Basin, Malaysia. *KSCE Journal of Civil Engineering*, **26**, 2519–2537, https://doi.org/10.1007/s12205-022-1481-7

Sa'adi Z., Yusop Z. and Alias N. E. (2023a). Long-term homogeneity and trend analysis of seasonality and extreme rainfall under the influence of climate change in Johor River Basin, Malaysia. *Natural Hazards*, **117**, 1813–1845, https://doi.org/10.1007/s11069-023-05930-1

Sa'adi Z., Yusop Z., Alias N. E., Chow M. F., Muhammad M. K. I., Ramli M. W. A., Iqbal Z., Shiru M. S., Rohmat F. I. W., Mohamad N. A. and Ahmad M. F. (2023b). Evaluating imputation methods for rainfall data under high variability in Johor River Basin, Malaysia. *Applied Computing and Geosciences*, **20**, 100145, https://doi.org/10.1016/J.ACAGS.2023.100145

Sa'adi Z., Yusop Z., Alias N. E., Shiru M. S., Muhammad M. K. I. and Ramli M. W. A. (2023c). Application of CHIRPS dataset in the selection of rain-based indices for drought assessments in Johor River Basin, Malaysia. *Science of The Total Environment*, **892**, 164471, https://doi.org/10.1016/J.SCITOTENV.2023.164471

Sa'adi Z., Alias N. E., Yusop Z., Iqbal Z., Houmsi M. R., Houmsi L. N., Ramli M. W. A. and Muhammad M. K. I. (2024). Application of relative importance metrics for CMIP6 models selection in projecting basin-scale rainfall over Johor River Basin, Malaysia. *Science of The Total Environment*, **912**, 169187, https://doi.org/10.1016/j.scitotenv.2023.169187

Sun Q., Miao C., Duan Q., Ashouri H., Sorooshian S. and Hsu K.-L. (2018). A review of global precipitation data sets: data sources, estimation, and intercomparisons. *Reviews of Geophysics*, **56**(1), 79–107, https://doi.org/10.1002/2017RG000574

Tan M. L., Liang J., Hawcroft M., Haywood J. M., Zhang F., Rainis R. and Ismail W. R. (2021). Resolution dependence of regional hydro-climatic projection: a case-study for the Johor River Basin, Malaysia. *Water*, **13**(22), 3158, https://doi.org/10.3390/W13223158

doi: 10.2166/9781789062540_0141

Chapter 7

Data modelling

Dinesh Kumar and Wegayehu Asfaw

Data is key to informing effective decision-making, institutional responses, and governance, particularly when informed governance supports future development while also reducing poverty and vulnerability. The rivers that run through both Delhi, India and Addis Ababa, Ethiopia (where these case studies are situated) cross key boundaries in a complex federal state, meaning it is often unclear who should shoulder responsibility for tackling water challenges and management. In the following case studies, the authors present knowledge that is generated via data model approaches, leveraging advanced technology orientated towards better informed policy decision-making.

7.1 UNDERSTANDING WATER SECURITY IN NCT DELHI, INDIA: USING QUALITATIVE AND QUANTITATIVE MODELLING

Dinesh Kumar

The National Capital Territory (NCT) of Delhi, the national capital of India, is at the forefront of grappling with the complex challenges of water security, as shown and detailed in Figure 7.1 (Jalsuraksha, n.d.). The city's rapid urbanisation, together with its ever-growing population and the impacts of climate change, has led to a pressing need for sustainable water management strategies. To address these challenges, a blend of qualitative and quantitative modelling approaches is being employed to assess and manage Delhi's water resources effectively (Bhave *et al.*, 2018). These approaches not only provide a comprehensive understanding of the current water system but also offer insights into the potential impacts of various management strategies under different future scenarios (Kumar *et al.*, 2022; Walsh *et al.*, 2013).

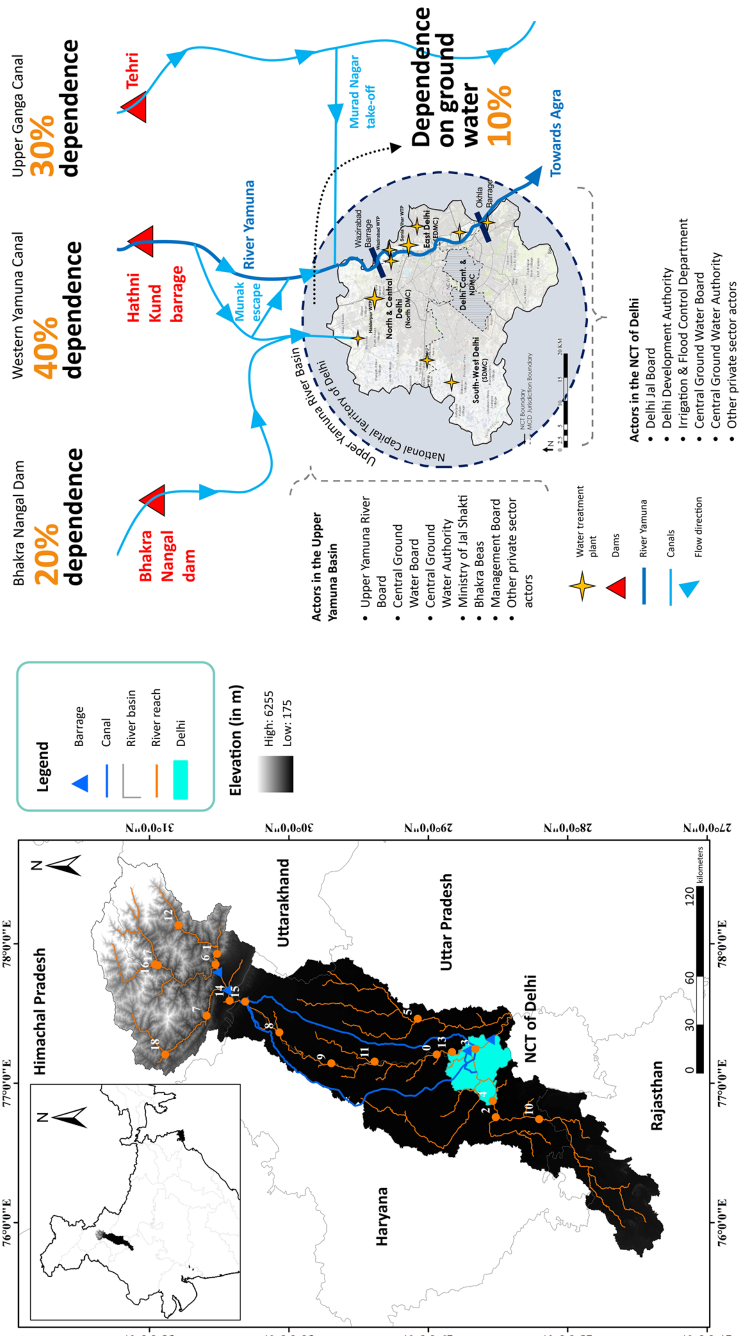


Figure 7.1 The study area of the NCT of Delhi: (a) location map of the NCT of Delhi; (b) water supply for the NCT of Delhi. (Credit: Dinesh Kumar).

Qualitative modelling in water resource management involves the use of conceptual frameworks and stakeholder engagement to understand the dynamics of the water system. This approach emphasises the importance of social, economic, and institutional factors in shaping water management practices. Indeed, stakeholder engagement has been a crucial aspect of qualitative modelling in Delhi, with the involvement of government agencies, non-governmental organisations (NGOs), academic institutions, and community groups (Loucks & van Beek, 2017). Through semi-structured interviews, workshops, and meetings, diverse perspectives and local knowledge are integrated into the water management framework, ensuring that the strategies developed are contextually relevant and socially acceptable. Additionally, qualitative modelling helps to identify key drivers of water demand and supply, as well as potential conflicts and synergies between different water uses and users.

Further quantitative modelling provides a more technical and data-driven approach to water resource management. The Water Evaluation and Planning (WEAP) model is one such tool that has been extensively used in Delhi to simulate the city's water system quantitatively. The WEAP model operates on the principle of water balance equations and incorporates various components of the water system, including supply sources, demand sites, and wastewater treatment plants. By inputting data on population growth, climate change projections, and socio-economic development, the model can predict the future availability of and demand for water under different scenarios. This allows policymakers and water managers to assess the potential impacts of various management options, such as the construction of new water treatment plants, implementation of water conservation measures, and changes in water pricing policies (Kwakkel & Haasnoot, 2019).

The integration of qualitative and quantitative modelling approaches (Bhave *et al.*, 2020) allows us to gain a holistic understanding of Delhi's water system. For instance, the qualitative insights gathered from stakeholder engagement can feed into the construction of the water system model and the development of scenarios and management options in th quantitative WEAP model. Conversely, the results from the WEAP model can be used to facilitate discussions among stakeholders, helping to identify priorities and build consensus on water management strategies. This iterative process ensures that the modelling outcomes are not only scientifically robust but also aligned with the social and economic realities of the city (Indian National Trust for Art and Cultural Heritage, 2017).

So, the combination of qualitative and quantitative modelling in water resource management offers a comprehensive and adaptable framework for addressing the complex challenges faced by Delhi. By leveraging the strengths of both approaches, policymakers and water managers can develop and implement strategies that are both effective and sustainable (Bhave *et al.*, 2022). This integrated approach is crucial for ensuring the long-term availability of water resources in Delhi, thereby promoting the well-being of people and the sustainable development of the city.

Methodology

The methodology employed in this study uses a blend of qualitative and quantitative approaches to assess Delhi's water supply and explore various water management scenarios. The qualitative aspect involves stakeholder engagement and conceptual framework development, while the quantitative aspect utilises the WEAP model for simulation. The methodology comprises the following steps:

(1) *Stakeholder engagement and data collection*: Engage with key stakeholders including the Delhi Jal Board (DJB), the National Mission for Clean Ganga (NMCG), NGOs, academic institutions, and community groups to gather relevant data and insights. Develop a comprehensive dashboard to provide public access to datasets related to urban water security in Delhi, facilitating stakeholder participation and data transparency.

(2) *Qualitative modelling and scenario development*: Conduct workshops and meetings with stakeholders to identify key drivers of water demand and supply, plus potential conflicts and synergies between different water uses and users. Develop conceptual frameworks to understand the social, economic, and institutional dynamics of Delhi's water system. Formulate scenarios based on qualitative insights, reflecting different plausible futures such as high socio-economic growth and climate change impacts.

(3) *WEAP model development and setup*: Create a conceptual WEAP model to simulate the business-as-usual scenario of Delhi's water system, incorporating data on water supply, sewage generation, and wastewater treatment. Set up the Delhi WEAP model with 11 water supply sources, demand sites, and wastewater treatment plants, using transmission links and return flows to represent the water flow dynamics.

(4) *Baseline establishment and water demand calculation*: Establish the baseline water system in WEAP with a simulation period from 2021 to 2050, using 2020 as the current year. Define water supply zones, population growth rates, and per capita water use rates. Calculate water demand for each site using the formula: total demand = total activity level x water use rate, accounting for transmission losses of 15–30% as per Indian National Trust for Art and Cultural Heritage (2017) data.

(5) *Quantitative scenario analysis*: Integrate the qualitative scenarios into the WEAP model for quantitative simulation. Assess the efficiency of various water management strategies under different scenarios, including demand management, infrastructure improvements, and policy interventions.

(6) *Iterative refinement and stakeholder feedback*: Use the results from the WEAP model to facilitate discussions among stakeholders, refining the scenarios and management strategies based on feedback. Iterate the modelling process to ensure alignment with the social and economic realities of Delhi, promoting a collaborative approach to water resource management.

This methodology provides a structured framework for evaluating Delhi's water supply system and exploring effective water management options to enhance urban water security.

Storyline-based scenarios

The storyline-based scenarios are explained below, and the identified water management options (Indian National Trust for Art and Cultural Heritage, 2017) are outlined in Table 7.1.

(1) *Scenario 1 – Business as usual*: In this scenario, Delhi continues to rely on its existing water treatment plants and demand sites, based on the city's current water supply and consumption patterns. This scenario serves as a baseline, illustrating a future where no significant changes are made to the water management system. But with the population projected to grow and climate challenges to persist, this path highlights the potential risks of sticking to the status quo, emphasising the need for proactive measures to ensure a sustainable water future.

Table 7.1 Water Management Options (WMOs). (Credit: Dinesh Kumar).

WMO No.	Type of Intervention	Relevant/ Aligned Scenarios	WMO Description	Assumptions of Model
1	Supply enhancement	Scenario 3	Increase in supply after the construction of a dam (Renuka Dam) in 2030, providing 275 MGD of water as per the 1994 Upper Yamuna River Board agreement.	Will reduce urban water demand by 275 MGD by 2050.
2		Scenarios 3 & 4	Groundwater recharging and rejuvenation through rehabilitating urban lakes by 2050.	Will reduce 50% of urban water demand by 2050.
3	Demand management	Scenario 4	By 2050, increase wastewater reuse for non-drinking purposes by 50% through decentralised wastewater treatment, community involvement, and shifting public perception.	Will reduce 50% of urban water demand by 2050.
4		Scenario 2	Better water pricing.	Will reduce 40% of urban water demand by 2050.
5		Scenario 2 & 4	Reduction of non-revenue water from 40% to 15%.	Will reduce 30% of urban water demand by 2050.

(2) *Scenario 2 – Intensification in urbanisation*: By 2030, Delhi's allure as an economic and political hub is expected to have intensified, drawing people from rural areas of neighbouring states – indeed, the city's population could burgeon at a rate of 3% annually, putting additional pressure on the city's water resources. This scenario, then, explores the challenges of managing water demand in a rapidly urbanising environment and underscores the importance of infrastructure development and efficient water use practices to cater to the growing populace.

(3) *Scenario 3 – Supply-side management*: The completion of the Renuka Dam in 2030 is expected to mark a turning point for Delhi's water supply. Providing an additional 275 million gallons per day (MGD), the dam should alleviate some of the city's water scarcity issues. This scenario also envisions increased utilisation of groundwater resources, offering a glimpse into a future where enhanced infrastructure and diversified water sources play a pivotal role in meeting the city's water needs.

(4) *Scenario 4 – Water-sensitive planning*: In this scenario, Delhi has transformed into a water-sensitive city by 2050, where wastewater reuse has surged by 50% due to decentralised treatment systems and active community acceptance. Thanks to a shift in public perception, locals have embraced the use of treated wastewater for non-drinking purposes, significantly reducing pollution in the Yamuna River and lessening the dependence on external water sources. This scenario paints a picture of a sustainable and resilient urban water system driven by innovative practices and a collective commitment to preserving precious water resources.

7.2 RESULTS

Stakeholder engagement

The development of the model and the formulation of scenarios were informed by extensive engagement with various stakeholders, including government agencies, water utilities, NGOs, academic institutions, and community groups (Figures 7.2 and 7.3). The DJB and the NMCG were key collaborators in the project, providing valuable data and insights into the city's water supply and wastewater management. Workshops and meetings were organised to gather input from these and other stakeholders, ensuring that the model accurately represented the current water system and future challenges. Furthermore, the online dashboard (Jalsuraksha, n.d.) established as part of the project facilitated ongoing stakeholder involvement by providing a platform for sharing information and updates related to Delhi's water security. This allowed for continuous feedback and refinement of the model based on real-time data and changing conditions. Overall, the modelling process was characterised by a high level of stakeholder participation, which was essential for capturing the complexities of Delhi's water system and developing realistic and effective management scenarios.

WEAP model development based on stakeholder engagement

Developing the WEAP model (Figure 7.4) served as a catalyst for consolidating datasets and stakeholder knowledge in the assessment of Delhi's WMOs. This

Figure 7.2 Photograph of stakeholders at the initial stakeholder meeting, 13 March 2020. (Credit: Dinesh Kumar).

Figure 7.3 Photograph of stakeholders at stakeholder meeting, 26 August 2022. (Credit: Dinesh Kumar).

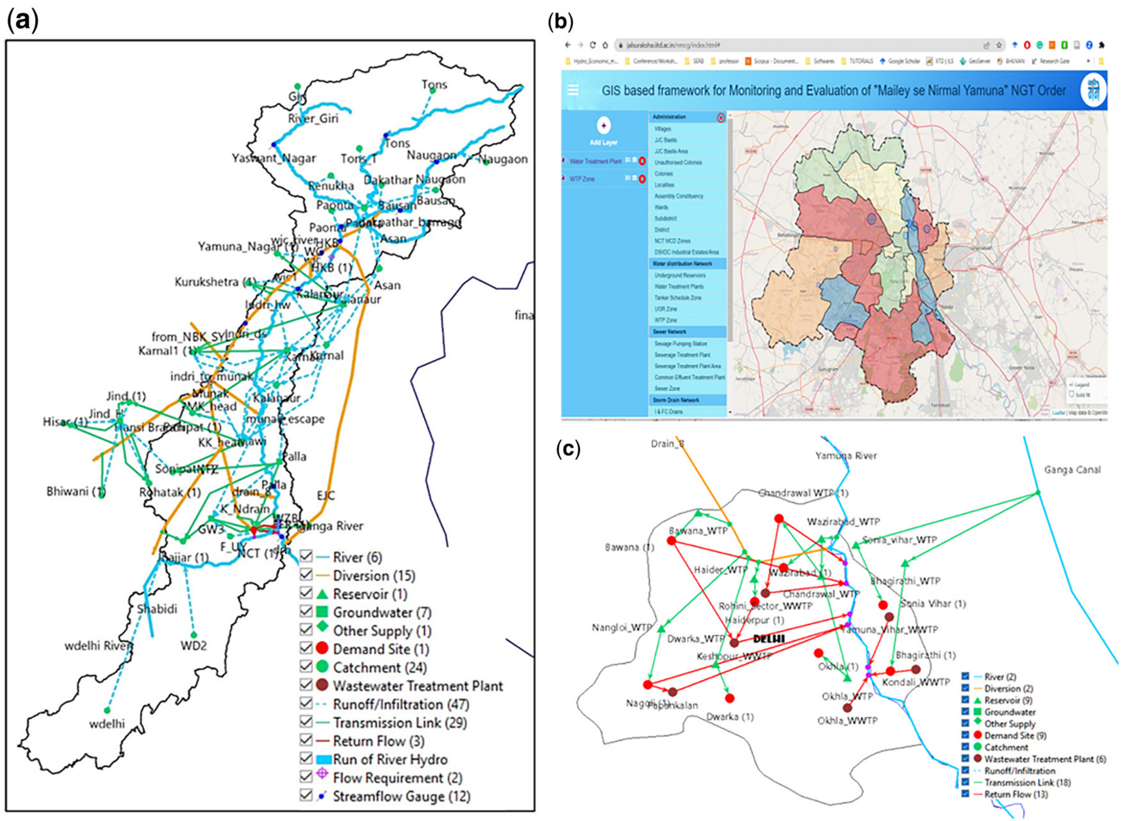


Figure 7.4 (a) The WEAP model of the Yamuna basin for initial stakeholder engagement; (b) the Jalsuraksha portal of the NCT of Delhi water and wastewater system; and (c) WEAP model of the NCT of Delhi. (Credit: Dinesh Kumar).

was facilitated through the establishment of a dashboard or web portal that acted as a one-stop platform for sharing and accessing information related to urban water security in Delhi. Collaboration between the DJB, the NMCG, and other stakeholders was central to this effort. The dashboard provided a user-friendly interface for visualising and analysing data on water supply, sewage generation, and wastewater treatment, enabling a more integrated approach to understanding and managing the city's water resources. The consolidation of datasets through the dashboard then helped us to represent Delhi's water system more comprehensively and accurately in the WEAP model. It allowed for rapid updates and adjustments to the model based on the latest information, ensuring that the scenarios and management strategies we developed were grounded in current realities.

Furthermore, the dashboard promoted knowledge sharing and collaboration among stakeholders. It provided a platform for exchanging ideas, discussing challenges, and exploring solutions aimed at improving water management in Delhi. By bringing together diverse perspectives and expertise, the dashboard enhanced our collective understanding of the city's water issues and fostered a more collaborative approach to addressing them. Overall, the WEAP model and the associated dashboard served as an impetus for consolidating datasets, knowledge, and collaboration, ultimately contributing to more informed and effective water management in Delhi.

Storyline-based scenario analysis

The results of the Delhi WEAP model suggest that a multifaceted approach is essential for a robust and effective solution to the challenges facing Delhi's water system. This approach should encompass demand management strategies, infrastructure enhancements, and policy interventions. One key element of this strategy is the construction of upstream dams (WMO-1, as shown in Figure 7.5): this will increase the reliability of the water supply by providing additional storage capacity and regulating the flow of water during periods of scarcity. However, demand management strategies need to be integrated to enhance the system's robustness further. Reducing non-revenue water (WMO-5) is one such strategy. By addressing leaks, illegal connections, and metering inaccuracies, this measure can decrease water losses and improve the efficiency of the water distribution system. Similarly, implementing water pricing mechanisms (WMO-4) is another crucial demand management strategy. By setting appropriate price signals, water pricing can incentivise conservation and reduce excessive consumption. This approach not only promotes more sustainable water use but also generates revenue that can be reinvested in the water system's infrastructure and maintenance.

In conclusion, the Delhi WEAP model underscores the importance of a comprehensive strategy that combines infrastructure development with demand management and policy measures. By adopting such an approach, Delhi can move towards a more sustainable and resilient water system that meets the needs of its growing population while safeguarding its precious water resources.

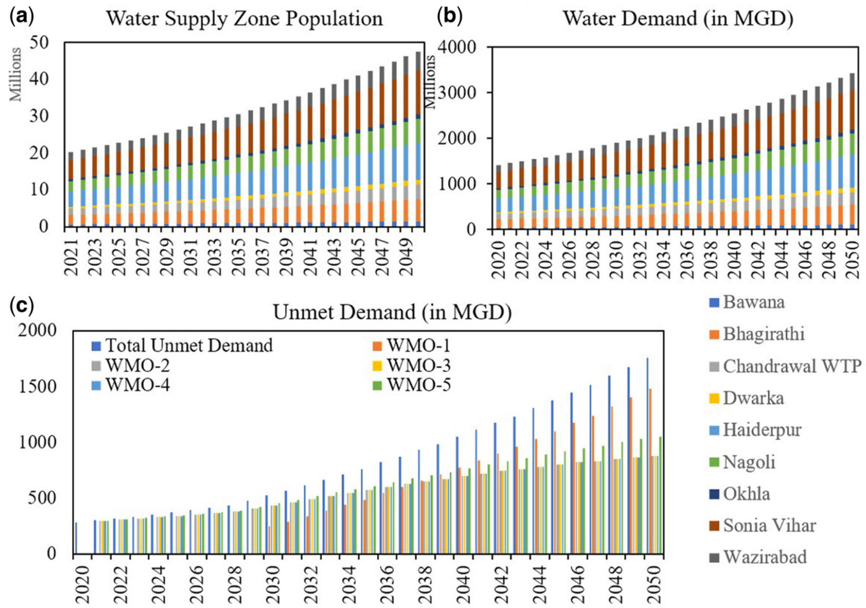


Figure 7.5 Results of the Delhi WEAP model: (a) total population projection; (b) total water demand; and (c) unmet water demand with and without implementing the WMOs. (Credit: Dinesh Kumar).

Conclusion

The findings from this study, underpinned by the WEAP model, highlight the growing challenge of meeting Delhi's water demand amid an expanding population and limited water resources. The construction of the Renuka Dam has been identified as a pivotal solution for mitigating water scarcity from 2025 to 2035, demonstrating the model's utility in strategic planning for water resource management. Additionally, the stakeholder engagement research emphasises the significance of fostering public awareness about water conservation practices, such as reuse and recycling, to cultivate sustainable water usage behaviours. The study reveals the critical role of policy interventions in the successful implementation of these strategies; it also shows that collaborative efforts among government agencies, private sector entities, and civil society organisations are imperative for driving change and ensuring the long-term sustainability of Delhi's water system.

In conclusion, the WEAP model has provided valuable insights into Delhi's water challenges through a comprehensive approach that combines supply-side and demand-side management, supported by robust policy frameworks.[1]

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[1] With thanks to Ajay Bhave, Asvhin Gosain, Dhanya C.T., and Greg O'Donnell.

7.3 LEVERAGING THE POWER OF AI FOR BUILDING PREDICTIVE MODELS ADAPTIVE TO FUTURE URBAN FLOODING IN ADDIS ABABA, ETHIOPIA

Wegayehu Asfaw

The severity of and damage caused by flood hazards are expected to increase in the near future (Seneviratne *et al*., 2021) due to the simultaneous effects of man-made and natural phenomena (Kam *et al*., 2021; Muis *et al*., 2015). At the local scale, rapid urban development and land use modifications have driven the expansion of impermeable surfaces, contributing to the generation of excess runoff. Added to this, global climate change is causing flooding to become more frequent (Kundzewicz *et al*., 2014; Tabari, 2020). Observations and model simulation outputs from recent studies illustrate the intensification of flood-induced extreme rainfall events, both in magnitude and intensity (Arnell & Gosling, 2016; Gu *et al*., 2022; He *et al*., 2022). What's worse, their impact is more pronounced in low- and lower-middle-income countries, where drainage infrastructure is inadequate, hydrological and meteorological monitoring is meagre, and flood forecasting systems are either unavailable or not well established. More efficient approaches are therefore needed to assess the problem of flooding at local, regional, and global scales, taking into account existing data gaps and local conditions.

Flooding is a dynamic, complex, and nonlinear event involving hydroclimatic, geomorphometric, anthropogenic, and other environmental causative factors. However, the connection between flooding and anthropogenic factors, as well as climate-related drivers, has not received much attention. We know that anthropogenic factors (population growth, urban expansion, and impervious infrastructure) and climatic factors (extreme rainfall events) are changing over time, but their impact on flooding is less known. Previous studies on the relationship between independent flood-causing factors and expected consequences have used physical-based models, such as hydraulic, hydrological, and hydrodynamic models (Guo *et al*., 2021); these models, however, require extensive input data in order to calibrate and accurately represent the study area's characteristics. It is a challenge to generate reliable model outputs for countries with limited data availability.

Recent years have seen promising advances with regard to understanding these complex interactions through machine learning models. Machine learning is a subset of artificial intelligence (AI) that uses automated techniques to learn from data and past experiences to identify patterns and make predictions with minimal human intervention (IBM, n.d.; MIT, n.d.). By utilising machine learning models, we can bridge the gap between studying how human activities contribute to flooding and understanding their implications for the future.

Overview

With recent advances in AI technology, machine learning models have evolved significantly: they are now able to produce flood susceptibility maps worldwide as they can handle a big volume of multifarious data. And this advanced learning approach is increasingly used alongside traditional physical-based flood prediction methods. Indeed, machine learning models are often trained on such physical models: they learn patterns from historical flood data, satellite imagery, and other relevant datasets, allowing them to adapt to the ever-changing urban landscapes. Machine learning allows multifarious geospatial data to be integrated with various conditional factors, producing a very different perspective of flood susceptibility predictions to those produced by traditional approaches. Machine learning models can also adapt and learn from new data, continuously improving their predictive capabilities and accommodating the dynamic nature of urban environments. While machine learning does generally heavily rely on historic data to produce accurate information for flood prediction, nowadays we are seeing advanced approaches (e.g. in Safonova *et al.*, 2023) that can be transferred from data-rich to data-scarce regions, providing a great potential route for knowledge creation in low-resource urban contexts.

Material

To create a flood susceptibility map for urban areas using machine learning, it is necessary to integrate a wide range of geospatial datasets, representing various factors that influence floods in cities. Such datasets include historical flood inventories, satellite images, land use and land cover maps, digital elevation models that represent the surface topography, geological maps, in-situ or remotely sensed meteorological datasets, among others.

Historical flood data is crucial for the machine learning model to learn and identify patterns and correlations between past events and the factors that trigger them. However, collecting this data manually on the ground is slow, expensive, and inefficient, especially for large areas. Satellite imagery can be a cost-effective alternative for near real-time extraction of flood data without spatial and time constraints. Likewise, land use and land cover data from satellite images are important for understanding the urban environment and assessing the impact of human activities on runoff generation. Elevation data, obtained from sources like digital elevation models, helps identify low-lying areas, river networks, drainage patterns, and potential flood pathways.[2] And then meteorological data, particularly rainfall, is essential for evaluating the climatic variables that influence flood susceptibility. Finally, all of the above can be incorporated with conditioning factors such as geology, soil, and other relevant environmental variables. The combination of these diverse datasets enables machine learning models to identify complex spatial relationships and patterns, resulting in more accurate and reliable flood susceptibility maps for urban areas.

Methods

Developing a flood susceptibility map for an urban area using machine learning involved a number of key steps. First things first, we had to select

[2] Digital elevation models are digital models or 3D representations of a terrain's surface created from terrain elevation data (ESDS, n.d.).

the appropriate machine learning algorithm based on data availability, the complexity of the issue, dataset size, and model interpretability. Then, we divided the flood inventory dataset into training and testing sets, typically in a 70%/30% ratio. The training set enabled the model to learn patterns and relationships, while the testing set evaluated its accuracy on an independent set of new data. During the model training, relationships between input and target variables were optimised to improve predictive capabilities and prevent overfitting. Once the model was trained, it was tested using the remaining 30% of the dataset to assess its predictive performance using metrics like accuracy, precision, recall, and F1 score (a machine learning evaluation metric). Lastly, we continuously monitored, updated, and validated the model with new data to enhance accuracy over time. This procedure can be used to train machine learning models and deploy them in areas lacking in-situ data to provide valuable flood predictions for decision-making of flood preparedness.

Application

Ethiopia has experienced numerous devastating floods in recent years, causing loss of life and property (Mamo *et al*., 2019). Many efforts have been made to study flooding in different areas of the country, mainly focusing on mapping the extent of historical flooding using satellite imagery (Bekele *et al*., 2022; Haile *et al*., 2023). However, the identification and prediction of hotspot areas to support proactive flood management have not yet received comparable attention. This case study addresses this lack, demonstrating how machine learning can be used to predict the susceptibility of the capital city of Ethiopia, Addis Ababa, to flooding.

In this example, a machine learning algorithm was trained and tested using two main types of data. Initially, various geospatial layers representing the factors contributing to flooding were examined. For the purposes of this study, these included attributes of precipitation, topographic and geomorphological variables, land cover, soil, and features that represent anthropogenic activities and interventions. Subsequently, a dataset containing locations that had either been inundated or not inundated in the past five years was extracted from flood extent maps.

The utilisation of these datasets in the model was not a straightforward process, beset by challenges ranging from data quality issues to inconsistent dataset formats, necessitating meticulous and time-consuming processing and analysis. Consequently, systematic methods were employed to enhance the dataset quality, including leveraging similar but alternative datasets and establishing workflows to ensure dataset consistency, in order to reach the final prediction outcomes. For instance, building footprints with different data formats from Google and Microsoft were accessed and processed to yield higher quality data. Similarly, multiple satellite estimates were blended to generate gridded rainfall data of enhanced quality for the study area (Asfaw *et al*., 2023). All in all, this case study involved gathering multi-dimensional data, which was then pre-processed and transformed into a suitable format to train and test the model; the model could subsequently be used to predict flood susceptibility across the city. As the model implemented in this example mainly used global databases to generate the

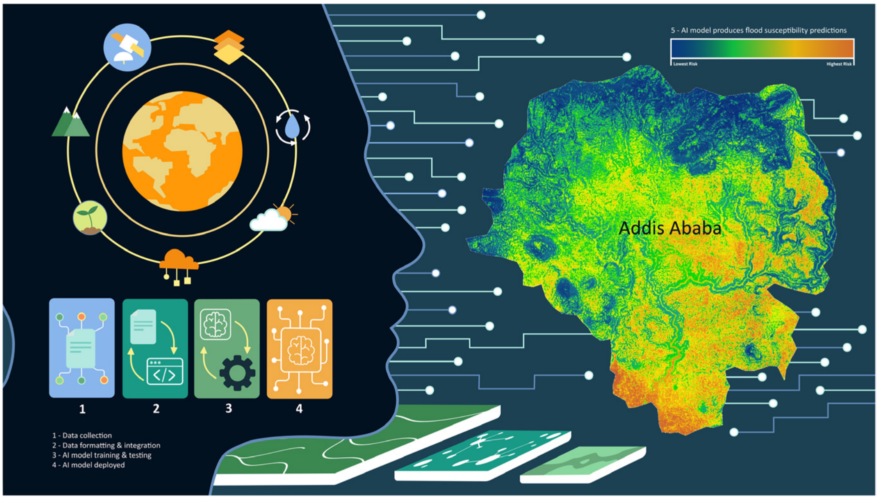

Figure 7.6 The workflow diagram shows the application of an AI-based approach, together with a cloud computing platform using a variety of Earth observation geospatial datasets, to predict urban areas' susceptibility to flooding in the city of Addis Ababa, Ethiopia. (Credit: rootsandwings.design).

necessary inputs, this workflow can be transferred, scaled, and applied to other data-poor areas, including parts of sub-Saharan Africa.

The output map (Figure 7.6) below visually represents the varying levels of flood susceptibility, as indicated by the colour gradient from low (blue and green) to higher (yellow and red) susceptibility. Based on the model's predictions, the northern region of the city, primarily encompassed by a mountain range, exhibits a minimal likelihood of flooding. Conversely, the central and southern areas, characterised by dense urban development, are highly prone to flooding, ranging from moderate to extremely high susceptibility. In general, the findings highlight the significant influence of factors such as slope, intense precipitation, land cover, population density, and the presence of road and drainage systems on the occurrence of frequent flooding in the given location.

The steps articulated in the figure are:

(1) Data collection
(2) Data formatting and integration
(3) AI model training and testing
(4) AI model deployed
(5) AI model produces flood susceptibility predictions

Conclusion

Machine learning models provide valuable prediction outputs that initiate and support the process of proactive flood mitigation strategies. These models have powerful computational capabilities and can effectively uncover hidden, complex, and nonlinear geospatial interactions among datasets. They are also adaptable, allowing for easy modifications and reproductions, along with the capability to seamlessly integrate new information. In general, machine learning models have the ability to produce reliable maps and predictions of the susceptibility of urban areas to flooding, which can help the following professionals in various fields by providing crucial information for planning, decision-making, and risk mitigation.

City planners and urban designers

Urban flood susceptibility maps play a crucial role in the development of resilient and sustainable urban infrastructure. By integrating such information into urban development plans, city planners can effectively guide the placement of critical infrastructure, residential areas, and green spaces. This proactive approach ensures that cities are better prepared to mitigate the effects of flooding and improves their overall resilience.

Emergency responders

Urban flood susceptibility maps can provide valuable information to emergency responders, helping to improve their preparedness and response to flood events. By using these maps, emergency responders can effectively identify high-risk areas, strategise evacuation routes, and allocate resources more efficiently during flood emergencies. As a result, they can better mitigate the effects of flooding and ensure the safety of potentially affected communities.

Insurance industry

The information provided by urban flood susceptibility maps is vital to the insurance industry, as it enables better assessment and management of risk. Using these maps, insurance companies can analyse the likelihood of flooding for individual properties and determine appropriate insurance rates. And this data plays a key role in improving the accuracy of risk assessment models.

Real estate developers and investors

Flood susceptibility maps provide vital information to property developers and investors, enabling them to make informed decisions about where to invest and develop. By using these maps, developers and investors can assess the flood risk associated with potential projects and ensure that new developments are strategically located in areas that are less prone to flooding. This proactive approach minimises the potential financial and environmental risks associated with flooding, ultimately safeguarding their investments and contributing to sustainable urban development.

Transportation planners

Urban flood susceptibility maps can greatly improve transport infrastructure planning: these maps provide valuable information that can be used to identify susceptible transport routes and critical nodes. Having identified these areas, planners can effectively implement measures to protect against flooding and maintain accessibility. This integration of susceptibility mapping into transport planning allows for a more comprehensive and proactive approach to mitigating the impact of flooding on transport systems.

Public health officials

Urban flood susceptibility maps have the potential to improve health risk evaluation in the occurrence of floods: through the utilisation of these maps, public health authorities can accurately identify regions that are at heightened risk of waterborne diseases during flooding and implement proactive measures to mitigate said risks.

Infrastructure maintenance and utilities management

Urban flood susceptibility maps have the potential to improve infrastructure maintenance and utility management, particularly when it comes to critical infrastructure. Managers of utilities such as water and sewage systems can use these maps to identify areas where maintenance should be prioritised due to increased flood risk.

REFERENCES

Arnell N. W. and Gosling S. N. (2016). The impacts of climate change on river flood risk at the global scale. *Climatic Change*, **134**(3), 387–401, https://doi.org/10.1007/s10584-014-1084-5

Asfaw W., Rientjes T. and Haile A. T. (2023). Blending high-resolution satellite rainfall estimates over urban catchment using Bayesian Model Averaging approach. *Journal of Hydrology: Regional Studies*, **45**, 101287, https://doi.org/10.1016/j.ejrh.2022.101287

Bekele T. W., Haile A. T., Trigg M. A. and Walsh C. L. (2022). Evaluating a new method of remote sensing for flood mapping in the urban and peri-urban areas: applied to Addis Ababa and the Akaki catchment in Ethiopia. *Natural Hazards Research*, **2**(2), 97–110, https://doi.org/10.1016/j.nhres.2022.03.001

Bhave A. G., Conway D., Dessai S. and Stainforth D. A. (2018). Water resource planning under future climate and socioeconomic uncertainty in the Cauvery River Basin in Karnataka, India. *Water Resources Research*, **54**(2), 708–728, https://doi.org/10.1002/2017WR020970

Bhave A. G., Bulcock L., Dessai S., Conway D., Jewitt G., Dougill A. J., Kolusu S. R. and Mkwambisi D. (2020). Lake Malawi's threshold behaviour: A stakeholder-informed model to simulate sensitivity to climate change. *Journal of Hydrology*, **584**, 124671, https://doi.org/10.1016/j.jhydrol.2020.124671

Bhave A. G., Conway D., Dessai S., Dougill A. J. and Mkwambisi D. (2022). Stress-testing development pathways under a changing climate: water-energy-food security in the lake Malawi-Shire river system. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **380**(2221), 20210134, https://doi.org/10.1098/rsta.2021.0134

Earth Science Data Systems (ESDS) (n.d.). Digital Elevation/Terrain Model (DEM). NASA. https://www.earthdata.nasa.gov/topics/land-surface/topography/terrain-elevation/digital-elevation-terrain-model-dem (accessed 12 April 2024)

Gu L., Chen J., Yin J., Slater L. J., Wang H.-M., Guo Q., Feng M., Qin H. and Zhao T. (2022). Global increases in compound flood-hot extreme hazards under climate warming. *Geophysical Research Letters*, **49**(8), e2022GL097726, https://doi.org/10.1029/2022GL097726

Guo K., Guan M. and Yu D. (2021). Urban surface water flood modelling – a comprehensive review of current models and future challenges. *Hydrology and Earth System Sciences*, **25**(5), 2843–2860, https://doi.org/10.5194/hess-25-2843-2021

Haile A. T., Bekele T. W. and Rientjes T. (2023). Interannual comparison of historical floods through flood detection using multi-temporal Sentinel-1 SAR images, Awash River Basin, Ethiopia. *International Journal of Applied Earth Observation and Geoinformation*, **124**, 103505, https://doi.org/10.1016/j.jag.2023.103505

He Y., Manful D., Warren R., Forstenhäusler N., Osborn T. J., Price J., Jenkins R., Wallace C. and Yamazaki D. (2022). Quantification of impacts between 1.5 and 4°C of global warming on flooding risks in six countries. *Climatic Change*, **170**(15), https://doi.org/10.1007/s10584-021-03289-5

IBM (n.d.). What Is Machine Learning (ML)? https://www.ibm.com/topics/machine-learning (accessed 12 April 2024)

Indian National Trust for Art and Cultural Heritage (2017). Water Policy for Delhi 2017. Government of the National Capital Territory of Delhi, India. https://faolex.fao.org/docs/pdf/IND222020.pdf (accessed 12 April 2024)

Jalsuraksha (n.d.). Water Security and Sustainable Development Hub. IIT Delhi India Collaboratory, Water Security and Sustainable Development in National Capital Territory of Delhi. https://jalsuraksha.iitd.ac.in/ (accessed 12 April 2024)

Kam P. M., Aznar-Siguan G., Schewe J., Milano L., Ginnetti J., Willner S., McCaughey J. W. and Bresch D. N. (2021). Global warming and population change both heighten future risk of human displacement due to river floods. *Environmental Research Letters*, **16**(4), 044026, https://doi.org/10.1088/1748-9326/abd26c

Kumar D., Dhanya C. T., Bhave A. G., Razavi S. and Gosain A. K. (2022). Assessing water management pathways for environmental flow management under uncertain futures in the Upper Yamuna Basin. AGU Fall Meeting 2022, 12–16 December 2022, Chicago, US, H42J–1407. https://agu.confex.com/agu/fm22/meetingapp.cgi/Paper/1126274 (accessed 12 April 2024)

Kundzewicz Z. W., Kanae S., Seneviratne S. I., Handmer J., Nicholls N., Peduzzi P., Mechler R., Bouwer L. M., Arnell N., Mach K., Muir-Wood R., Brakenridge G. R., Kron W., Benito G., Honda Y., Takahashi K. and Sherstyukov B. (2014). Flood risk and climate change: global and regional perspectives. *Hydrological Sciences Journal*, **59**(1), 1–28, https://doi.org/10.1080/02626667.2013.857411

Kwakkel J. H. and Haasnoot M. (2019). Supporting DMDU: A taxonomy of approaches and tools. In: Decision Making Under Deep Uncertainty: From Theory to Practice, V. A. W. J. Marchau, W. E. Walker, P. J. T. M. Bloemen and S. W. Popper (eds.), Springer International Publishing, Switzerland, pp. 355–374, https://doi.org/10.1007/978-3-030-05252-2_15

Loucks D. P. and van Beek E. (2017). Water resource systems modeling: Its role in planning and management. In: Water Resource Systems Planning and Management, D. P. Loucks and E. van Beek (eds.), Springer International Publishing, Switzerland, pp. 51–72, https://doi.org/10.1007/978-3-319-44234-1_2

Mamo S., Berhanu B. and Melesse A. M. (2019). Historical flood events and hydrological extremes in Ethiopia. In: Extreme Hydrology and Climate Variability: Monitoring, Modelling, Adaptation and Mitigation, A. M. Melesse, W. Abtew and G. Senay (eds.), Elsevier, Netherlands, pp. 379–384, https://doi.org/10.1016/B978-0-12-815998-9.00029-4

Massachusetts Institute of Technology (MIT) (n.d.). Machine Learning, Explained. MIT Management Sloan School. https://mitsloan.mit.edu/ideas-made-to-matter/machine-learning-explained (accessed 12 April 2024)

Muis S., Güneralp B., Jongman B., Aerts J. C. J. H. and Ward P. J. (2015). Flood risk and adaptation strategies under climate change and urban expansion: a probabilistic analysis using global data. *Science of The Total Environment*, **538**, 445–457, https://doi.org/10.1016/j.scitotenv.2015.08.068

Safonova A., Ghazaryan G., Stiller S., Main-Knorn M., Nendel C. and Ryo M. (2023). Ten deep learning techniques to address small data problems with remote sensing. *International Journal of Applied Earth Observation and Geoinformation*, **125**, 103569, https://doi.org/10.1016/j.jag.2023.103569

Seneviratne S. I., Zhang X., Adnan M., Badi W., Dereczynski C., Di Luca A., Ghosh S., Iskandar I., Kossin J., Lewis S., Otto F., Pinto I., Satoh M., Vicente-Serrano S. M., Wehner M. and Zhou B. (2021). Weather and climate extreme events in a changing climate. In: Climate Change 2021 – The Physical Science Basis, V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, Y. Chen, L. Goldfarb, M. I. Gomis, J. B. R. Matthews, S. Berger, M. Huang, O. Yelekçi, R. Yu, B. Zhou, E. Lonnoy, T. K. Maycock, T. Waterfield, K. Leitzell and N. Caud (eds.), Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1513–1766, https://doi.org/10.1017/9781009157896.013

Tabari H. (2020). Climate change impact on flood and extreme precipitation increases with water availability. *Scientific Reports*, **10**(1), 13768, https://doi.org/10.1038/s41598-020-70816-2

Walsh C. L., Roberts D., Dawson R. J., Hall J. W., Nickson A. and Hounsome R. (2013). Experiences of integrated assessment of climate impacts, adaptation and mitigation modelling in London and Durban. *Environment & Urbanization*, **25**(2), 361–380, https://doi.org/10.1177/0956247813501121

doi: 10.2166/9781789062540_0159

Chapter 8

Data integration

Diana Marcela Ruiz Ordóñez, Carolina Salcedo Portilla, Samy Mafla Noguera and Jemila Mohammed Kassa

One of the biggest barriers to water security is a lack of integrated data, both quantitative and qualitative. The spotlights in this chapter seek to address this by drawing on a range of data sources to support integrated risk analysis of a range of issues, both as researchers and with stakeholders, and to facilitate an open dialogue with appropriate administrations, at all levels, to improve data for management of basins. From empirical and experiment-based research, we have found that integrating a plurality of values and voices results in policies and plans that address water insecurities in a more inclusive manner. In this chapter, authors present case studies from Colombia and Ethiopia that demonstrate how knowledge exchange, information sharing, and transnational collaboration ensure that structural/technical solutions are situated in – rather than divorced from – non-structural solutions.

8.1 CONNECTING SOCIO-ECOLOGICAL AND ECOSYSTEM SERVICES IN SOUTH-WESTERN COLOMBIA

Diana Marcela Ruiz Ordóñez, Carolina Salcedo Portilla and Samy Mafla Noguera

In south-western Colombia, water availability is limited due to the prioritisation of economic activities and drinking water supply for urban communities: this has led to a deepening of socio-economic differences and worsening of water management processes across urban and rural communities.

In this spotlight, we analyse these dynamics from a socio-ecological perspective, with a focus on ecosystem services (ES). According to Gallopín (2006), socio-ecological systems are defined as systems that incorporate social (human) and ecological (biophysical) subsystems across a range of different scales, from a small community or watershed to the whole of humanity. ES, meanwhile, are the ecosystem's direct or indirect contributions to human well-being, depending directly on the system's resilience (de Groot *et al.*, 2010).

We discuss these dynamics in four case studies from the Upper Cauca River Basin (UCRB), where we involved local communities in a co-creation process based on knowledge interchange and confidence building to better understand changes in water quality. This approach allowed us to jointly identify the river's problems and find shared solutions, generating effective water management strategies by pooling our technical know-how and the traditional knowledge of these communities.

First, we described the condition of the basins' socio-ecological systems. This is important because the ES are affected by changing land use and land cover (LULC). Then, through joint analysis of the ES, informed by scientific techniques, zoning, and the collating of community perceptions, we generated community water management strategies, identifying actions that benefit or harm the 'water that connects us' or the 'water that benefits us' as a space of co-responsibility.

Thus, adopting a socio-ecological approach that incorporates spatial analysis and ES allows us to understand the complex relationship between communities and their territories. Indeed, it is arguably only by linking the hidden voices of communities with land use patterns and assessing the provision of ES in the UCRB that we can effectively understand the factors that influence water quality.

The Upper Cauca River Basin

The altitude of the UCRB ranges from 4700 metres above sea level at the top of the Puracé volcano to 950 metres above sea level in the alluvial valley of the Cauca. Its length is an estimated 520 km, and its overall area is around 2 180 940 hectares (ha) (DNP, 2009).

The population of the UCRB amounts to 5.9 million people, of which 65% is concentrated in the department of Valle del Cauca, followed by 15.5% in the department of Cauca. Of the population in the basin, 75% is considered to be urban and 25% is rural; in terms of ethnic makeup, 80% of the population is either 'mestizo' or white, 10% is indigenous, and 10% is afro-descendant (Galvis, 2017; HUB Colombia Project, 2022; MADS, 2020).[1] In light of these broad socio-economic and biophysical characteristics, we chose to focus on four sub-basins that reflect the heterogeneity of the UCRB in the departments of Cauca and Valle del Cauca. They are: (i) Las Piedras, (ii) Río Claro, (iii) Guachal, and (iv) Mediacanoa (Figure 8.1).

Process

We took a mixed methods approach, integrating analysis of spatial information and descriptive-interpretative characteristics of ES by communities with

[1] 'Mestizo' is a term applied to those born from a union of two people of different ethnicities.

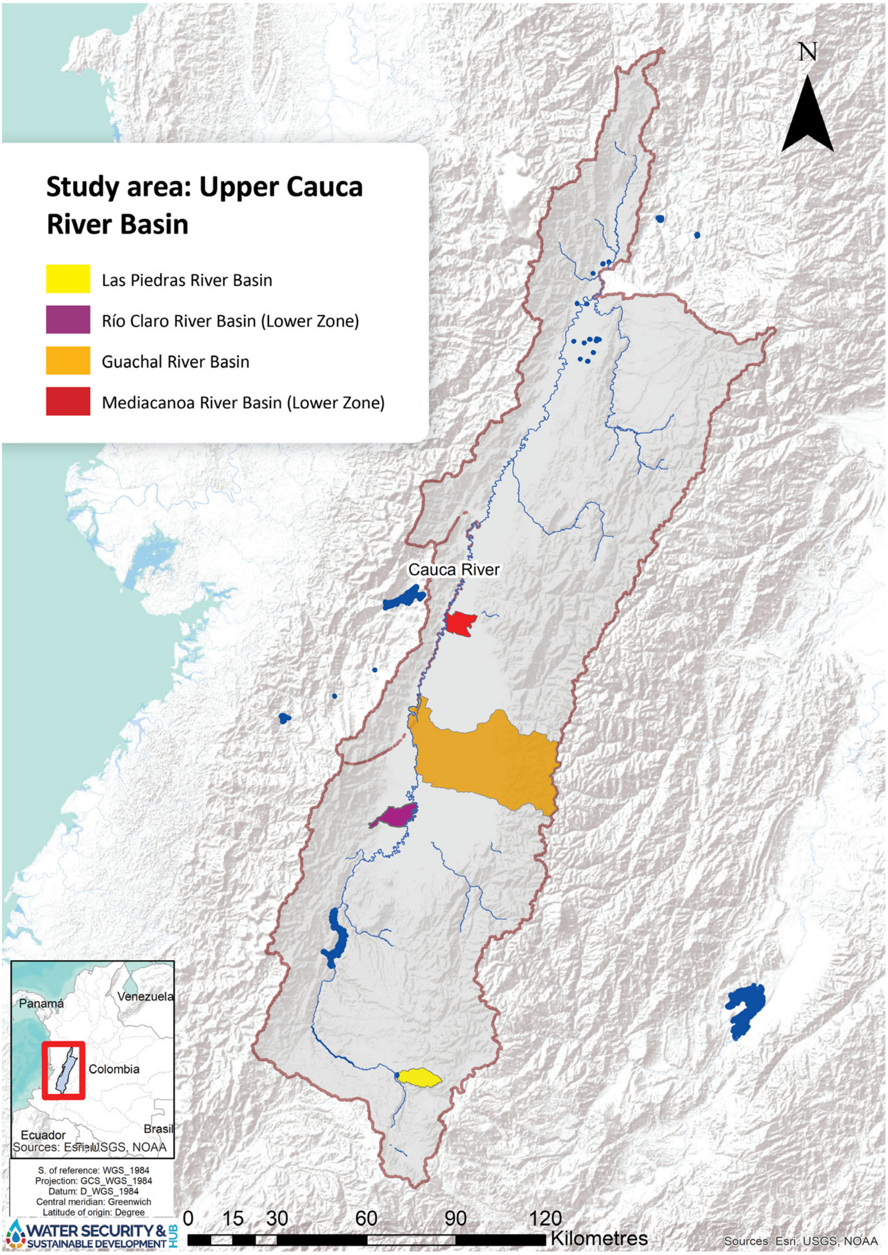

Figure 8.1 The study area in the UCRB. (Credit: Samy Mafla Noguera).

socio-ecological perspectives of ES. The methodology is based on three guiding steps: (i) socialisation and generation of trust in the communities; (ii) design of the workflow and validation of the instruments; and (iii) development and implementation based on focus and participatory group workshops, interviews, and field visits.

The ES and water quality were analysed through three iterative stages – diagnosis, perception, and analysis – which involved the identification and valuation of ES through different tools, including participatory identification, indirect identification with crucial actors, and spatial analysis.

The diagnostic phase presents the socio-ecological conditions of the case studies, based on spatial analysis, LULC, the relationship between water intakes and pollution, and the identification of main water ES using the Common International Classification of Ecosystem Services (CICES) framework (Haines-Young & Potschin, 2012). The second phase, perception, refers to the understanding of the current supply of ES in the sub-basins (adopting the CICES classification); this information was collected through social cartography and ethnographic studies implemented within community organisations and complemented by historical perspectives on ES transformations. Finally, in the analysis phase, we discuss the ES zoning and the interaction between LULC and drivers of change in the UCRB.

Case studies

We encourage readers to click on the images below to explore each of the four sub-basin case studies in detail (Figures 8.2–8.5).

- *Las Piedras River Basin (Cauca Department)*: Las Piedras River runs between the Popayán and Totoró municipalities. This basin is the primary water supply source of the city of Popayán, with hydrological strategic areas in the overlapping area of the Puracé National Natural Park.
- *Río Claro River Basin (Valle Department)*: The Río Claro River originates in the mountain range between the city limits of Buenaventura, Jamundí, and Cali in the Farallones de Cali National Natural Park. This river flows to the left of the UCRB, near the town of Paso de la Bolsa.
- *Guachal River Basin (Valle Department)*: The Guachal River is mainly formed by the confluence of the Párraga, Frayle, Bolo, and Palmira Rivers, which join before entering the Cauca River.
- *Mediacanoa River Basin (Valle Department)*: The Mediacanoa River is in the centre of the Department of Valle del Cauca, between the Yotoco and Cauca River basins.

Diagnosis

The land cover analysis reveals that the different regions have the following main characteristics:

- *Las Piedras*: significant presence of pastures (2408 ha), other crop areas (2878 ha), and water drainage areas (e.g. rivers) (146 ha);

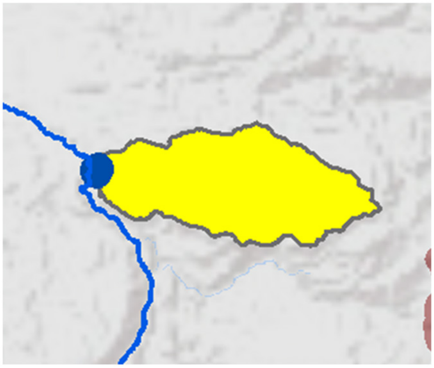

Figure 8.2 Las Piedras sub-basin. (Credit: Samy Mafla Noguera).

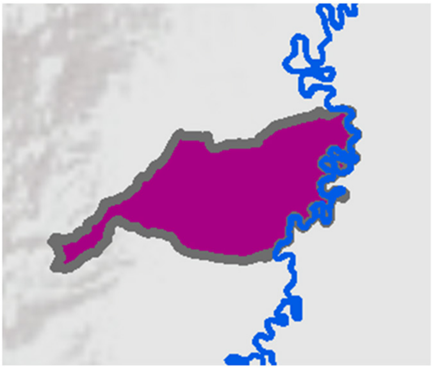

Figure 8.3 Río Claro sub-basin. (Credit: Samy Mafla Noguera).

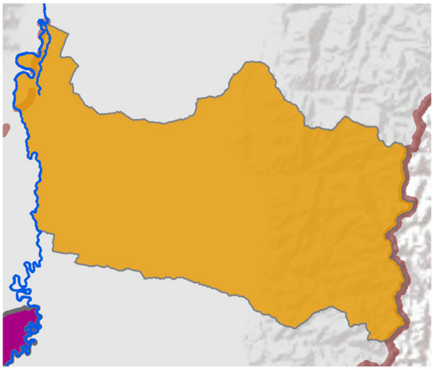

Figure 8.4 Guachal sub-basin. (Credit: Samy Mafla Noguera.

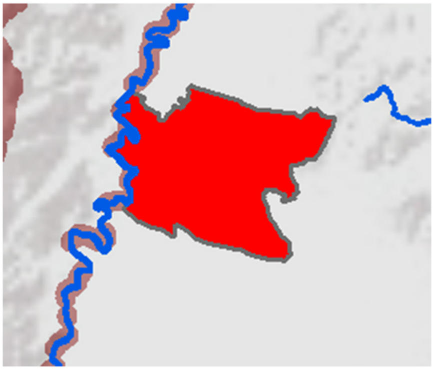

Figure 8.5 Mediacanoa sub-basin. (Credit: Samy Mafla Noguera).

- *Río Claro*: permanent crops (4076 ha), other crop areas (1308 ha), and natural areas (74 ha). The forests cover an area of 15 000 hectares;
- *Guachal*: extensive urban area (1657 ha) with industrial/commercial sites (1157 ha), significant presence of permanent crops (57 000 ha), other crop areas (17 580), and pastures (10 160 ha);
- *Mediacanoa*: predominantly covered by permanent crops (4620 ha), other crop and transient crop areas (965 ha), and pastures (264 ha). The lake covers an area of 1063 hectares.

One of the main demands in the UCRB is potable water for human consumption, together with agro-industrial activities, livestock, and fishing. Water supply infrastructure is often concentrated in the most densely populated areas of the region, such as the Popayán municipality, with a water flow demand of 800 L/s from Las Piedras River, a water flow rate of 3624 L/s in Guachal River, and a water flow rate of 745 L/s in Río Claro River. In Río Claro River Basin, meanwhile, the water supply is concentrated in communities with high socio-economic status, thus deepening the socio-economic gap. Either way, these water supply systems generally provide urban users with safe water; however, the inhabitants of the rural areas of Las Piedras, Guachal, and Río Claro have limited access to drinking water, a situation that exacerbates socio-economic tensions and fuels water conflicts.

Perception

With the aim of highlighting the hidden voices of the territories and showing interactions with and views of ES from the perspective of the communities and other actors, we present the specific ES identified and prioritised in each case study. These ES do not necessarily coincide with the CICES classification, but they accurately represent local views on ES in the territories.

Figure 8.6 shows that locals identified a significant number of regulating and cultural ES, when it comes to both biophysical changes and relevant aspects of their cultural forms and identity. Among the regulating ES, the migration of bird species, the life cycle and reproduction of fish species, the connotations of the Ramsar site at the Sonso Lake,[2] and the presence of aquatic ecosystems such as wetlands riparian vegetation stand out. In terms of cultural ES, expressions of art, traditional festivals, and local gastronomy have greater weight for the four basins.

In addition, thanks to the contribution of the different people/communities who supported this process, we also gained access to historic perceptions and valuations of ES, as preserved in local photographs that show daily life, values, and ES ratings, together with the experiences and narratives of the communities (Figures 8.7–8.10). We encourage readers to click on the images below to listen to each of the sonorous postcards.

Analysis

In Las Piedras River Basin, we found that changes in land use and the loss of ecosystem elements and cultural identity are the main drivers of ES transformation. This affects the ES for climate and hydrological regulation, particularly in the upper and middle part of the basin. We also established that socio-environmental conflicts arise between community stakeholders and institutions due to activities such as cattle grazing in steeply sloped areas, which are prone to erosion, combined with challenges related to sustainable production processes, marketing channels, and supply of organic products in regional markets.

[2] The Upper Cauca River Wetland Complex associated with the Sonso Lagoon is located at coordinates 3°55′N–76°19′W Colombia. It is Ramsar site number 2403 with an area of 5525 ha and was designated on 14 February 2017. This wetland complex is composed of 24 wetlands and is recognised as an ecosystem of great national and international importance due to its wide biological diversity. Official link: https://rsis.ramsar.org/ris/2403?language=en

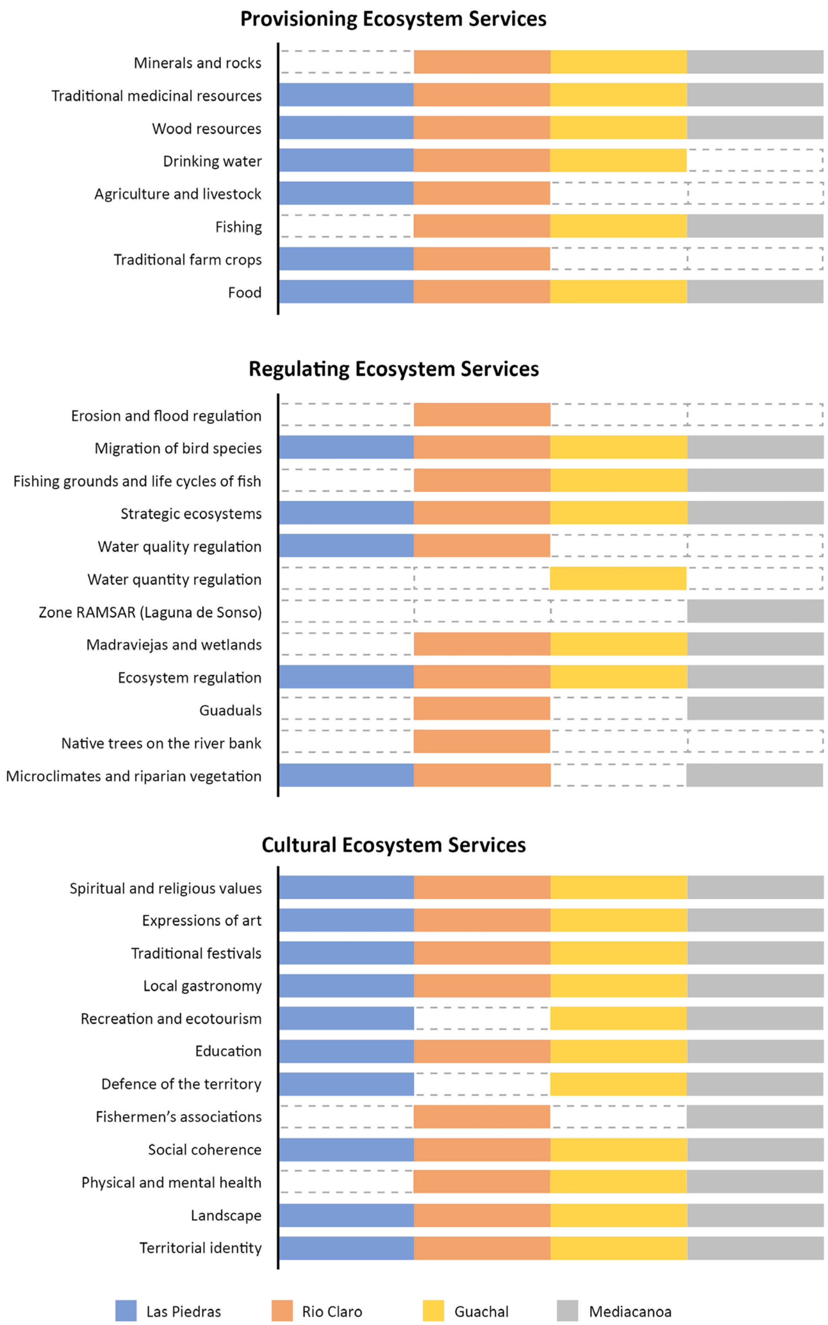

Figure 8.6 Perceptions of the presence/absence of the provision of ES in each sub-basin per category (adapted to authors' fieldwork 2018, 2022). (Credit: Livia Douse).

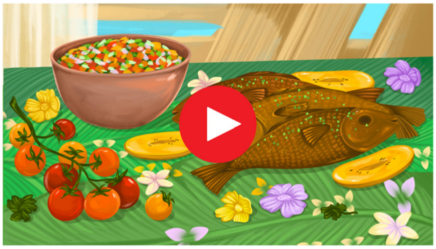

Figure 8.7 Omaira Balanta, environmental leader.

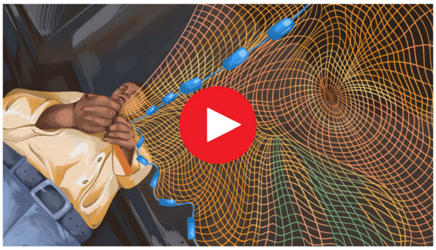

Figure 8.8 Jair Palacios, fisherman of Sonso Lagoon.

Figure 8.9 Las Piedras River community (1).

Figure 8.10 Las Piedras River community (2).

(Figures 8.7-8.10 credit: rootsandwings.design).

In the Río Claro River Basin, the main driver of overall transformation is changes in LULC related to the current demographic expansion in the department of Valle del Cauca.

ES and water regulation in the Guachal River Basin, meanwhile, are under pressure due to the expansion of sugar cane cultivation, agricultural frontier growth, and cattle ranching. These activities not only endanger water regulation and cultural relationships, but directly affect water quality, leading to significant pollution and environmental risks in the basin.

Finally, in the Mediacanoa River Basin, change is driven primarily by the monoculture of sugar cane and the installation of infrastructure for its production to improve economic sustainability.

Conclusion

Given water's critical role in the ecosystem and in human well-being, it is imperative to adopt an interdisciplinary lens to understand its complex interactions with its environment. Through this research approach and methodological proposal, we explore the intricate conditions that determine water quality from a multidimensional perspective. This is supported by an understanding of how socio-ecological factors shape dynamic transformations within the study cases, either hindering or enhancing the provision of ES. This involves considering different characteristics, changes, uses, and conflicts influenced by various socio-economic and political characteristics unique to each area.

Water pollution threatens the availability of water resources, which the inhabitants perceive as a threat throughout the sub-basins, since the riverbed is the axis along which socio-ecological dynamics are integrated. The emergence of wastewater-related conflicts and lack of basic sanitation aggravates this situation. What's more, there is also low institutional influence in the region, which in itself leads to the strengthening and consolidation of community management and administration processes, such as the network of reserves and field schools that are particularly prevalent in the lower zone of the sub-basin.

In turn, we see challenges arise relating to the division between entities/institutions that support this type of strategy, where some communities are directly involved in understanding water dynamics in relation to ES, and some are not. We argue that it is crucial for all institutions to articulate the physicochemical changes in the resources they govern, to show awareness of the community's connection to water with regard to identity, territory, and lifestyle, and to make the community members feel like they are part of the solution to improve their living conditions.

In this sense, addressing the socio-cultural relationship of ES together with the hydrological capacity of the basins to provide hydric ES strengthens the ability of communities to self-organise and manage their own water, which, alongside an institutional action plan that integrates management, restoration, and conservation of key areas, should contribute to improving both governance around water and water quality in the medium-term and long-term for rural communities.

8.2 UNDERSTANDING WATER POLLUTION AND MICROBIAL HAZARDS TO IMPROVE PUBLIC HEALTH IN ADDIS ABABA, ETHIOPIA

Jemila Mohammed Kassa

Addis Ababa is experiencing rapid urbanisation and population growth, leading to pollution of the rivers; this is putting the health of the city's five million inhabitants at risk from diseases caused by faecal and antimicrobial-resistant bacteria. Because of limited wastewater treatment capacity and weak monitoring and regulation, much of the city's domestic, commercial, industrial, and agricultural wastewater is discharged untreated into Akaki River. The Akaki River is the major water source of urban agriculture; the downstream communities depend on it for animal watering, vegetable cultivation, and other domestic purposes (Gashaye, 2020; Hiruy *et al.*, 2022). According to some estimates, around 60% of the city's agricultural produce is cultivated using river water, which presents a major public health concern (Woldetsadik *et al.*, 2017). Because of this diverse use of river water, many people are exposed to pollution hazards. Indeed, a major outbreak of acute watery diarrhoea in Addis Ababa in 2016 was attributed to open defecation, the discharge of untreated sewage, and consumption of food sources contaminated by faecally polluted river water (Dinede *et al.*, 2020).

We have seen several studies that have assessed water pollution issues, but very few have addressed emerging issues such as these. Therefore, the Water Security and Sustainable Development Hub, funded by Global Challenges Research Fund, decided to tackle these issues head-on by providing scientific evidence about the microbial community and level of drug resistance of the community in Akaki.

Microbial analysis

Baseline information regarding the occurrence and prevalence of antibiotics-resistant bacteria and pathogenic bacteria is essential to control the potential public health problem. However, the nature of the microbial hazards in the Akaki watershed was not well understood until quite recently, even though evidence suggests they are already causing significant disease outbreaks (Dinede *et al.*, 2020). Under the Water Security Hub umbrella, the International Water Management Institute (IWMI), in collaboration with Newcastle University and Addis Ababa Water and Sewerage Authority (AAWSA), conducted river pollution studies. First and foremost, this meant providing training to laboratory technicians to build capabilities and competencies in molecular water microbiology at AAWSA. The training focused on how to use an affordable suitcase laboratory for microbial community characterisation by 16S rRNA gene sequencing (Acharya *et al.*, 2020) (see also Chapter 5.2). Subsequently, two AAWSA staff members visited the microbiology laboratories at Newcastle University for further training on molecular analysis in the suitcase laboratory. This has enabled AAWSA staff to apply inexpensive and robust methods for near-real-time comprehensive water quality surveying using portable next-generation sequencing devices; in turn, this has led to the first ever in-depth survey of microbial water quality in the Akaki watershed.

By using next-generation sequencing, thousands of bacterial communities were detected for the first time in the Akaki River catchment. Worryingly, a number of potentially significant waterborne pathogens were found in this watershed, including *Arcobacter butzleri*, which appeared in abundance. The detection of *Vibrio cholerae* marker genes also gave cause for concern, as it provides strong evidence that *Vibrio cholerae* bacteria is originating from human sewage in the Akaki catchment (Acharya *et al.*, 2020; Hiruy *et al.*, 2022). Nearly 70 million people in Ethiopia are thought to be at risk of cholera, which can cause severe, life-threatening diarrhoea – there are already 275 221 estimated cases and 10 458 deaths per year (Ali *et al.*, 2015; Dinede *et al.*, 2020). In Addis Ababa, diarrheal diseases like cholera can be easily transmitted via the use of sewage-polluted river water for the irrigation of crops sold on the city markets (Dinede *et al.*, 2020).

In addition, one of the most difficult public health crises facing us today is the emergence of antibiotic-resistant microorganisms – and our study shows the Akaki River watershed has a high concentration of bacteria that are resistant to antibiotics (Hiruy *et al.*, 2022). This type of resistance is very concerning; it is expected to kill 10 million people annually by 2050 (Jampani *et al.*, 2022).

Still, now that the Water Security Hub has built microbial analysis capability at AAWSA, which has led to the recent inauguration of a wastewater laboratory, AAWSA is in a much better position to build an evidence base and understand the link between water pollution, poor sanitation, and health.

Enhanced collaboration

The Akaki River catchment in the city is highly affected by pollution. Both the public and private sectors are either directly or indirectly involved in managing this. Notable players include Addis Ababa Environmental Protection Authority, AAWSA, Addis Ababa Cleansing Management Agency, and the Ministry of Water and Energy, alongside universities and research institutes including IWMI, which contribute various research findings about water pollution in the Akaki River and its health impacts.

However, a lack of collaboration and data integration between stakeholders exacerbates water management issues. Hence, there is a need for academic and corporate/governmental stakeholders to collaborate to address challenges, bridge gaps, and search for solutions. We've already seen a number of positive developments on this front: for instance, AAWSA's collaboration with IWMI and Newcastle University has led to the establishment of the Addis Ababa Adaptation Network, which brings together experts from different fields to develop a co-produced approach. This network is now in the process of being widened out to facilitate greater collaboration between government stakeholders, researchers, and both financial and civil organisations involved in the Akaki Basin. We expect this iterative process to lead to more reliable, inclusive, and sustainable governance across the region when it comes to water pollution.

Conclusion

AAWSA benefited from the Water Security Hub's expertise, learning how to survey water quality in near real time using portable next-generation sequencing devices, plus how to collaborate effectively with different stakeholders. The research outputs from this study will inform future interventions regarding river pollution.

The Water Security Hub contributed to this achievement by providing financial and technical support, as well as consumables for the laboratory analysis, knowledge exchange through practical training, workshops, webinars, and technological innovations.

REFERENCES

Acharya K., Blackburn A., Mohammed J., Haile A. T., Hiruy A. M. and Werner D. (2020). Metagenomic water quality monitoring with a portable laboratory. *Water Research*, **184**, 116112, https://doi.org/10.1016/j.watres.2020.116112

Ali M., Nelson A. R., Lopez A. L. and Sack D. A. (2015). Updated global burden of cholera in endemic countries. *PLOS Neglected Tropical Diseases*, **9**(6), e00038, https://doi.org/10.1371/journal.pntd.0003832

de Groot R. S., Alkemade R., Braat L., Hein L. and Willemen L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, **7**(3), 260–272, https://doi.org/10.1016/j.ecocom.2009.10.006

Dinede G., Abagero A. and Tolosa T. (2020). Cholera outbreak in Addis Ababa, Ethiopia: a case-control study. *PLOS ONE*, **15**(7), e0235440, https://doi.org/10.1371/journal.pone.0235440

Gallopín G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*, **16**(3), 293–303, https://doi.org/10.1016/j.gloenvcha.2006.02.004

Galvis A. (2017). Estado del Arte Sobre la Calidad del río Cauca. Foro Nacional E Internacional Recuperación del río Cauca: Toma de Decisiones Oportunas Para el Abastecimiento de Agua en la Región. (The Quality of the Cauca River. National and International Forum for the Recovery of the Cauca River: Making Timely Decisions for the Water Supply in the Region). Universidad del Valle, Instituto Cinara, Santiago de Cali, Colombia.

Gashaye D. (2020). Wastewater-irrigated urban vegetable farming in Ethiopia: a review on their potential contamination and health effects. *Cogent Food & Agriculture*, **6**(1), 1772629, https://doi.org/10.1080/23311932.2020.1772629

Haines-Young R. and Potschin M. (2012). Common International Classification of Ecosystem Services (CICES) Version 4: Response to Consultation. Centre for Environmental Management, University of Nottingham, UK.

Hiruy A. M., Mohammed J., Haileselassie M. M., Acharya K., Butte G., Haile A. T., Walsh C. and Werner D. (2022). Spatiotemporal variation in urban wastewater pollution impacts on river microbiomes and associated hazards in the Akaki catchment, Addis Ababa, Ethiopia. *Science of the Total Environment*, **826**, 153912, https://doi.org/10.1016/j.scitotenv.2022.153912

HUB Colombia Project. (2022). Biophysical and Socio-Economic Characterisation of the Upper Cauca River Basin (UCRB). Universidad del Valle, Santiago de Cali, Colombia.

Jampani M., Gothwal R., Mateo-Sagasta J. and Langan S. (2022). Water quality modelling framework for evaluating antibiotic resistance in aquatic environments. *Journal of Hazardous Materials Letters*, **3**, 100056, https://doi.org/10.1016/j.hazl.2022.100056

Ministry of Environment and Sustainable Development (MADS). (2020). The Basin and its Basic Characteristics: Collaborative Platform 2 Upper Cauca River Basin. National Government of Colombia, Bogotá, Colombia.

National Planning Department (DNP). (2009). CONPES 3624: Programme for the Clean-Up, Management and Environmental Recovery of the Upper Basin of the River Cauca. National Government of Colombia, Bogotá, Colombia.

Woldetsadik D., Drechsel P., Keraita B., Itanna F., Erko B. and Gebrekidan H. (2017). Microbiological quality of lettuce (*Lactuca sativa*) irrigated with wastewater in Addis Ababa, Ethiopia and effect of green salads washing methods. *International Journal of Food Contamination*, **4**(3), https://doi.org/10.1186/s40550-017-0048-8

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Principle 2

Knowledge – conclusion

Victoria Anker, Rachael Maysels and Maria Valasia Peppa

The spotlights in the knowledge principle demonstrate examples of a data-information-usage-action approach to water insecurity issues in different infrastructure contexts in Colombia, Ethiopia, India, Malaysia, and the UK. In particular, the spotlights on the development and deployment of the suitcase laboratory (Chapters 5.2 and 8.2) show how smart technology can expedite in-situ data capture and microbial analysis, thereby contributing to better understanding of water pollution and the likelihood of emerging threats to public health, such as waterborne diseases. These spotlights also advocate for knowledge exchange and the democratisation of information via capacity building across different actors, including non-experts, young scientists, local communities, and members of different institutions in academia and industry throughout the world.

Other spotlights (Chapters 5.1 and 6.2) demonstrate that freely available, remotely sensed data of regional and global spatial coverage can successfully complement fragmented, limited, or even inaccessible pre-existing in-situ data, providing a more comprehensive view of existing pressures. For instance, optical satellite images can help monitor the water level and quantity of water bodies over time and correlate this with the presence or absence of contaminants (Chapter 5.1). Indeed, freely accessible information, once it has been subjected to appropriate data analysis and modelling, can provide near real-time understanding of sudden climate variations (Chapter 6.2), allowing for a proactive response to potential threats. Both of these spotlights promote open science, featuring rigorous methods that can be shared (e.g. via freely available cloud platforms) with non-experts, such as government agencies that might otherwise be unfamiliar with such open-source datasets. Chapter 7.2, meanwhile, describes how to leverage advanced articial intelligence methodologies to predict urban flood susceptibility, a challenging task for a human expert to complete in a timely manner, as it involves multifarious geospatial data modelling. By contrast, state-of-the-art machine learning methods can easily integrate datasets from different sources to predict hazards, generating knowledge even in data-scarce regions.

We have already seen that rigorous methodologies and tools are of paramount importance in modelling data and then translating it into meaningful information for sustainable solutions – which can be implemented to proactively manage water resources. For example, appropriate, well-established data modelling procedures can be used to evaluate solutions for future scenarios to better manage urban water resources in light of socio-economic pressures and climate variability (Chapter 7.1). We see that the active engagement of policymakers throughout the dynamic data modelling process helps reshape policies and revise plans in response to potential threats to water security. Similarly, Chapter 6.1 showcases how a unified database web platform can visualise and interpret a series of multifarious processed data with local and regional spatial context, with a potential to be extended nationwide. The database is set up using the FAIR principles (see Principle 2. Knowledge – Introduction), enabling free access to and reuse of meaningful information, and therefore supporting proactive decision-making for water resource management.

We further contend that meaningful information can only be generated with inclusive knowledge from multiple voices, and not just by adopting pure technocratic solutions without considering the socio-ecological context. Chapter 5.3 highlights the importance of understanding people's behaviours and designing qualitative data capture to explore complex social phenomena. Adopting the CARE principles (Carroll *et al*., 2020; see, again, Principle 2. Knowledge – Introduction), Chapter 8.1 demonstrates that building long-term relationships with local communities through geospatial ethnographic practices can provide meaningful information about land use in relation to water use and ecosystem status.

While technical expertise is a fundamental part of the process, especially when it comes to applying rigorous scientific methodology to model and translate data into impactful knowledge, the spotlights in this principle have shown that continuous participation, capacity building, active engagement, and mutual knowledge exchange between multiple actors are equally crucial for an effective pathway towards proactive water management.

REFERENCE

Carroll S. R., Garba I., Figueroa-Rodríguez O. L., Holbrook J., Lovett R., Materechera S., Parsons M., Raseroka K., Rodriguez-Lonebear D., Rowe R., Sara R., Walker J. D., Anderson J. and Hudson M. (2020). The CARE principles for indigenous data governance. *Data Science Journal*, **19**(43), 1–12, https://doi.org/10.5334/dsj-2020-043

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Principle 3

Collaboration – introduction

Victoria Anker, Maheshwari Gupta and Alejandro Figueroa

> 'We must pass the earth on in a better condition to the next generations. We have the legislation to do this; the implementation is the concern, across the globe. Academia, experts, scientists, administration must all work together.'
>
> Shri G. Ashok Kumar, Director General of the National Mission for Clean Ganga, India

Our third principle is that, without collaboration, we cannot have equitable water security. Through a series of spotlights, this section explores modes of participation and engagement that bolster capabilities.

SIGNIFICANCE OF PRINCIPLE

While water insecurity is prevalent around the world, it does not affect all people equally: in fact, it disproportionately impacts marginalised communities (Boelens *et al.*, 2018). Some regions endure extreme drought year-round, while others experience extended periods of drought and periods of severe rainfall (CRED & UNDRR, 2020). Climate change is exacerbating these conditions and resulting in an outpouring of climate refugees, often in areas facing intersectional socio-ecological issues such as conflict, extreme poverty, and food insecurity (Atapattu, 2020; Narayanaswamy *et al.*, 2023). Human-designed systems are also drivers of inequitable impacts of water insecurity. The infrastructure responsible for delivering safe and consistent water to people varies widely across the world in terms of coverage and effectiveness, often leaving those in worse socio-economic conditions without potable water and sanitation services (Romero Lankao, 2011). Inequitable access to water is also driven by 'water grabbing', which occurs when powerful actors mobilise to forcefully relocate water and seize control of land, negatively impacting those whose livelihoods, culture, and well-being depend on water and the ecosystem in which it is entangled (Matthews, 2012).

Throughout this principle, connections between the concepts of 'inequity' and 'governance' emerge. To achieve water security, water needs to be treated as 'first among equals' (Beck & Villarroel Walker, 2013: 627). A repatterning of water, along with other factors such as land, needs to reshape socio-ecological relations and power hierarchies. This is because water is deeply connected to other socio-natural resources (Franco *et al*., 2013). Thus, water security concerns contribute to multiple governance processes; the pluralistic nature of water values and the competing demands for this natural resource need to be articulated (Geleta *et al*., 2023) so that decision-makers can reconcile various considerations and trade-offs, with the aim of implementing sustainable water resource management.

Effective water management requires the seamless integration of policies and strategies, ensuring they complement and support each other. Policies set the overall framework for water management, while strategies provide specific solutions to achieve policy goals. Integration ensures that actions taken in water management align with broader objectives and maintain consistency across different sectors. Implementing water policies and strategies can be challenging due to conflicting interests, limited financial resources, and difficulties in coordinating between various sectors. Despite these challenges, there are opportunities for collaboration, cooperation, and capacity building to address complex water management issues effectively.

For example, in Colombia, researchers have contributed to the formation of the Commission for the Upper Cauca River Basin (UCRB) Recovery – a collective initiative that promotes action and collaboration between multiple stakeholders for sustainability and water security in the region. The Commission comprises public and private entities, and arose from the failure of the current model of water resource management in Colombia (Sánchez Torres *et al*., 2022). It operates through a Memorandum of Understanding between 28 institutions, centred on a shared vision between all actors involved, based on the concepts of biocultural diversity and the rights of nature. This facilitates collaborative governance, enabling the achievement of shared outcomes and benefits for all stakeholders with greater transparency and commitment. It also allows for connectivity between all relevant stakeholders and their ability to participate in and agree on actions to be taken in the short, medium, and long-term. Research, innovation, and development, alongside the roles, knowledge, and skills of all actors, are recognised as fundamental pillars of the recovery strategy for the benefit of humans and more-than-humans.

THEORY VS PRACTICE

Building equitable partnerships and emphasising the importance of relationships is key to collaboration. Collaboration brings together a range of stakeholders with different skills, knowledge, and experiences to work towards a common goal, despite their diverse values and perspectives. Multiple fields, from social sciences to ecology, are witnessing the rapid production of a body of literature in which different forms of collaboration are assessed and ranked (Ananga *et al.*, 2021; Bell & Reed, 2022; Hart-Fredeluces *et al.*, 2023; Wolff, 2021). However, these articles often leave little room for acknowledgement of the complexity of collaboration, which otherwise risks becoming homogenous, with cultural variations smoothed out and societal differences flattened. From contributing to democratic processes (Callahan, 2007) to crowdsourcing for data processing (Wolff, 2021), we posit that collaboration is relative and context dependent. It can, and indeed must, take different forms: as a global project tackling water security issues across different locations and contexts, we know how important it is that we work together, building cross-country relationships to share expertise.

We believe equitable collaboration has the potential to be the most effective route towards finding sustainable solutions. Cooperation is central to how our research programme was developed and delivered, through the creation of collaboratories (collaborative laboratories). A collaboratory provides a co-creative process for bringing together stakeholders from local communities (many of whom are marginalised groups), industry, government, regulators, professional bodies, and the third sector, alongside researchers (Muff, 2014). Each of the countries in which we work – Colombia, Ethiopia, India, and Malaysia – face different development transitions that illustrate the global challenges to sustainable water security. This is why we created our collaboratories; as spaces to explore water security issues, share ideas, formulate activities, reconcile trade-offs, and apply interventions according to their development needs.

However, it is important to note that these collaborative approaches have their limitations: we recognise their inability to address systemic injustices in areas such as governance structures and democratic participation. While inclusivity is the ideal, it is not always easy. For example, we use the term ‘citizen science’ to describe people taking part in activities such as data gathering, but ‘citizenship’ has a very different meaning – both for those denied it and across different disciplines. Collaboration is therefore a complicated concept: who defines it and who is allowed to take part? We have witnessed the active reluctance of some stakeholders to engage with those they perceive as marginalised, and we have seen the suspicion among those who are marginalised to engage with those they view as part of the establishment. Understanding the multiplicity of values and experiences, recognising the heterogeneity of those involved, and acknowledging subsets of power/authority are thus prerequisites to creating an enabling environment for collaboration.

Finally, building relationships and trust takes time and we must always be conscientious and alert to our own positionalities. This applies to both collaboration with our stakeholders and cooperation with our fellow researchers. While we, as researchers, are committed to rigorous and systematic research, it is important that we acknowledge our own biases within our problem-solving approaches and recognise the complexities of ensuring equitable engagement within international research partnerships (Narayanaswamy *et al.*, 2023). True interdisciplinary teams are hard to build. They require exposure to, and acceptance of, different cultures and ways of working, and an individual willingness to learn and grow. For us, we have found that we cannot meaningfully collaborate without first acknowledging the positionalities we hold in relation to each other.

AUTHOR CONTRIBUTIONS

The spotlights that sit in this section are united by the theme of collaboration, while also showcasing different forms of cooperation and engagement in order to achieve just water security. We feature case studies from Colombia, Ethiopia, India, and Malaysia.

In Chapter 9, Barriers to Collaboration, authors Nitin Singh, Savitri Kumari, and Shambhavi Gupta analyse the ways in which participation in decision-making processes can be hindered by, or limited to, those with real or perceived authority. Nitin and Savitri, in the opening spotlight, demonstrate how the complexity of the National Capital Territory (NCT) of Delhi's water governance limits the efficacy, efficiency, and equity of the city's water infrastructure. Through an analysis of different spatial scales and remits – from international to local – Nitin and Savitri expose the tensions among formal actors, and between formal and informal, private, and (sometimes) illegal actors. Acknowledging the colonial roots of this complex arrangement, Nitin and Savitri then demonstrate how the issue of water security affects those living within and outside planned developments, before highlighting the specific challenges of water insecurity for the most vulnerable.

In the spotlight that follows, Shambhavi continues the theme of exclusion, with a specific focus on Delhi's ballooning younger generation. Shambhavi argues that children and young people have the potential to transform Delhi's future but are often excluded from formal democratic routes to engagement due to the bureaucratic nature of decision-making in the city. By focusing on bottom-up approaches to youth engagement as well as the 'Main Bhi Dilli' ('I too am Delhi') campaign, Shambhavi shows how large-scale grassroots movements have the ability to realise democratic processes through public participation.

In the second chapter, Consultation, authors Neo Sau Mei and Adey Nigatu Mersha present spotlights in which researchers engage with stakeholders from a range of sectors to ensure a broad range of voices, knowledge, and experiences are included in the research process. Neo opens with a critique of the existing top-down governance structure of the Johor River Basin, which is typical of water management in Malaysia. However, there is growing recognition within government agencies and other 'powerful' stakeholders that these processes have neglected indigenous and local communities for whom the river is both home and source of income. Neo offers a practical case study of how researchers at the Universiti Teknologi Malaysia have sought to bridge this divide through multiple routes to engagement. Similarly, Adey, in the next spotlight, highlights how existing scenario modelling processes lack clear and transparent participatory processes. The spotlight provides a step-by-step breakdown of the methodological approach known as participatory scenario development, which enables a more holistic articulation of future scenarios through the integration and verification of stakeholder views.

In the third chapter, Citizen Science, authors Zulfaqar Sa'adi, Prabhakar Shukla, Likimyelesh Nigussie, and Tilaye Worku Bekele demonstrate how the process of citizen science creates multiple benefits – both for the citizen scientists themselves and those who subsequently use the citizen science-generated data.

Zulfaqar's spotlight showcases 'RainCrowd', an education-driven, crowd-based project that works with students in the local community to capture rainfall data. By articulating how the project was created and deployed, Zulfaqar shows how the project feeds into other initiatives in Johor that seek to engage citizen scientists in their environment. Next, Prabhakar details how an innovative new app uses a citizen science approach to gather crowdsourced data and real-time observations on urban flooding in NCT Delhi. The app allows users to engage directly in urban flooding reporting, facilitating not just the validation of the hydrological modelling, but also assisting government authorities with decision-making. Lastly, Likimyelesh and Tilaye show how the integration of citizen science into formal flood early warning systems improves local resilience to hydrological hazards, protecting livelihoods of at-risk communities.

In the fourth chapter, Co-Production, the spotlights highlight where communities and community organisations have driven the identification of problems and implementation of solutions in collaboration with researchers and non-governmental organisations. In the first spotlight, Renu Khosla speaks from her perspective as Director of CURE, a non-profit organisation established in 2023 to empower and aid vulnerable populations living in informal settlements across Delhi. Renu discusses the need to help improve access to basic sanitation by co-creating a process to understand needs and identify solutions, while Sheilja Singh provides the situational context, explaining how poor sanitation provision has threatened the health and well-being of local communities. Meanwhile, in the second spotlight, our colleagues in Colombia show how co-creation, knowledge exchange, and mutual learning underpin their modus operandi, enabling them to implement projects – such as the one Federico Pinzón and Andrés Fernando Toro Vélez describe here – that are co-constructed with local communities and organisations. Nuestra Agua (Our Water) is a co-created community water information system that helps communities manage local water resources and monitor water use.

In Community Leadership, the final chapter in this principle, Catalina Trujillo Osorio presents a case study of stakeholders working together to revitalise their territory. United through concepts of care, these actors place water and the environment at the heart of sustainable solutions. Recalling criticisms of neoliberal approaches to water governance articulated in Chapters 1 and 4, Catalina explores the diversity of water values expressed by different people and cultures, management systems and regulations, and how these influence water security.

REFERENCES

Ananga E. O., Naiga R., Agong S. G., Njoh A. J. and Vickers H. P. (2021). Examining the contribution of community participation in water resource production and management: perspectives from developing countries. *SN Social Sciences*, **1**(37), https://doi.org/10.1007/s43545-020-00050-0

Atapattu S. (2020). Climate change and displacement: protecting 'climate refugees' within a framework of justice and human rights. *Journal of Human Rights and the Environment*, **11**(1), 86–113, https://doi.org/10.4337/jhre.2020.01.04

Beck M. B. and Villarroel Walker R. (2013). On water security, sustainability, and the water-food-energy-climate nexus. *Frontiers of Environmental Science & Engineering*, **7**, 626–639, https://doi.org/10.1007/s11783-013-0548-6

Bell K. and Reed M. (2022). The tree of participation: a new model for inclusive decision-making. *Community Development Journal*, **57**(4), 595–614, https://doi.org/10.1093/cdj/bsab018

Boelens R., Perreault T. and Vos J. (eds.) (2018). Water Justice. Cambridge University Press, Cambridge, UK, https://doi.org/10.1017/9781316831847

Callahan K. (2007). Citizen participation: models and methods. *International Journal of Public Administration*, **30**(11), 1179–1196, https://doi.org/10.1080/01900690701225366

Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR). (2020). The Human Cost of Disasters: An Overview of the Last 20 Years (2000–2019). UNDRR, Geneva, Switzerland. http://www.undrr.org/quick/50922 (accessed 6 June 2024)

Franco J., Mehta L. and Veldwisch G. J. (2013). The global politics of water grabbing. *Third World Quarterly*, **34**(9), 1651–1675, https://doi.org/10.1080/01436597.2013.843852

Geleta Y., Haileslassie A., Simane B., Assefa E. and Bantider A. (2023). Mapping community perception, synergy, and trade-off of multiple water values in the Central Rift Valley water system of Ethiopia. *Water*, **15**(16), 2986, https://doi.org/10.3390/w15162986

Hart-Fredeluces G. M., Burnham M., Eaton W. M., Brasier K. J., Church S. P. and Wildermuth G. (2023). Advancing the scholarship and practice of stakeholder engagement in working landscapes: identifying and responding to six key research gaps. *Socio-Ecological Practice Research*, **5**, 231–237, https://doi.org/10.1007/s42532-023-00162-w

Matthews N. (2012). Water grabbing in the Mekong Basin: an analysis of the winners and losers of Thailand's hydropower development in Lao PDR. *Water Alternatives*, **5**(2), 393–411. https://www.water-alternatives.org/index.php/volume5/v5issue2/176-a5-2-12/file (accessed 6 June 2024)

Muff F. (ed.) (2014). The Collaboratory. A Co-Creative Stakeholder Engagement Process for Solving Complex Problems. Routledge, London, UK. https://www.routledge.com/The-Collaboratory-A-Co-creative-Stakeholder-Engagement-Process-for-Solving/Muff/p/book/9781783531431 (access 03 February 2023)

Narayanaswamy L., Ferritto R., Hillesland M., Anker V., Singhal S., Maysels R. M., Bantider A., Charles K., Doss C., Kumar A., Mdee A., Neo S-M., Pinzón F. and Mengistu B. T. (2023). Why a feminist ethics of care and socio-ecological justice lens matter for global, interdisciplinary research on water security. *Frontiers in Human Dynamics*, **5**, 1212188, https://doi.org/10.3389/fhumd.2023.1212188

Romero Lankao P. (2011). Missing the multiple dimensions of water? Neoliberal modernization in Mexico City and Buenos Aires. *Policy and Society*, **30**(4), 267–283, https://doi.org/10.1016/j.polsoc.2011.10.007

Sánchez Torres L. D., Galvis Castaño A., Gandini M. A., Almario G., Montero M. V. and Vergara M. V. (2022). Commission for the upper Cauca river basin recovery, collaborative governance for sustainability and water security. *Frontiers in Water*, **4**, 782164, https://doi.org/10.3389/frwa.2022.782164

Wolff W. (2021). The promise of a 'people-centred' approach to floods: types of participation in the global literature of citizen science and community-based flood risk reduction in the context of the Sendai Framework. *Progress in Disaster Science*, **10**, 100171, https://doi.org/10.1016/j.pdisas.2021.100171

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Chapter 9

Barriers to collaboration

Nitin Singh, Savitri Kumari and Shambhavi Gupta

Collaboration requires the engagement of a variety of different actors. As we saw in our first principle, justice, certain actors are often excluded thanks to a lack of representation in processes, a lack of recognition in frameworks, or the unjust distribution of resources: when viewed on Arnstein's (1969) classical scale, the involvement of such parties therefore oscillates between non-participation and tokenism. And this leads to ineffective engagement, which reinforces inequitable outcomes. To add to this, the participation process is power-driven and deeply rooted in bureaucratic governance channels. As the two following case studies demonstrate, the complexity of water governance systems makes it challenging to address inequity: there are structural barriers in place that allow some people to engage and others to not.

9.1 EXPLORING THE COMPLEXITY OF COLLABORATION FOR WATER GOVERNANCE IN NCT DELHI, INDIA

Nitin Singh and Savitri Kumari

The National Capital Territory (NCT) of Delhi, the capital of India, is projected to become the world's largest urban agglomeration by 2030 (United Nations, 2018).[1] Such rapid population growth and urbanisation is set to exacerbate the existing water demand–supply gap, deepening the 'spaces of inequity created by water' to the detriment of the city's many citizens who live in slums or informal and unauthorised settlements (Sarkar, 2021).

[1] Delhi's last census was in 2011 and the 2021 census was postponed. Estimates for the city's current population vary between 20 million people (Government of Delhi, 2023) and 33 million (World Population Review, n.d.).

Delhi is located in a small sub-basin of the Yamuna River, the only major river that runs through the city's administrative boundary. Delhi's present water demand is around 1200 million gallons per day (MGD), of which only 950 MGD can be produced, leaving a water demand–supply gap of 250 MGD. Furthermore, out of this 950 MGD, only 10% of the water is sourced internally (e.g. from aquifers and groundwater): Delhi is reliant on external sources for 90% of its water (Government of NCT of Delhi, 2023).

As a result of the 69th Constitutional Amendment Act, 1991, Delhi is simultaneously a city, union territory, and state. Delhi's water governance is multi-sectoral and multi-scalar, involving formal and informal actors and institutions at multiple different levels (Kumari & Biswas, 2022). The two most important agencies responsible for Delhi's water are the Delhi Jal Board (DJB), the nodal agency for water supply, drainage, and sewage services, and the Delhi Development Authority (DDA), the planning, development, and construction agency. However, the intertwined and complex nature of Delhi's water governance limits its efficacy, efficiency, and equity, privileging the upper and middle classes who reside in spaces served by the city's formal water infrastructure (Kumar *et al.*, 2021). Those living in unplanned developments, however, often do not receive adequate water provision, giving rise to informal actors with their own political and financial motives, which fill the water demand–supply gap (Birkinshaw, 2018).

Mapping Delhi's water governance

The spectrum of actors involved in Delhi's water governance span several spatial scales and multiple remits. At a supranational level, intergovernmental institutions, international financial organisations, and donor countries influence policymaking and water narratives in India (Kumari & Biswas, 2022). At a national level, the planning and management of water as a *national* resource sits with the Ministry of Jal Shakti (and its attendant departments and regulators), including interstate and transboundary water issues. However, under the Indian constitution, water is a *state* subject and thus the responsibility of each individual state. As a result, a tension exists between national-level policy, such as the National Water Policy, and the delivery/implementation of such policies at a state level (Pandit & Biswas, 2019).

The boundary between national and state is further complicated by regional or interstate institutions such as the Upper Yamuna River Board (UYRB), which regulates the division of the Upper Yamuna's waters. As well as Delhi, state signatories to the UYRB include the upper riparian states of Uttar Pradesh, Uttarakhand, Haryana, Rajasthan, and Himachal Pradesh, which provide raw water to the capital. Other regional boards include the Bhakhra Beas Management Board, which regulates water and power supply to the states of Punjab, Haryana, Rajasthan, Himachal Pradesh, and Delhi.

At the state level, various agencies operate under the aegis of the Government of National Capital Territory of Delhi (GNCTD), including the DJB. Established by an act of the GNCTD in 1998, the DJB is the primary agency responsible for water supply, drainage, and sewage services in Delhi

(GNCTD, 1998). Other agencies under the GNCTD include the Irrigation and Flood Control Department (IFCD) and Delhi Pollution Control Committee. Central government agencies, including the DDA, also function at this state level. Established by an act of parliament in 1957, the DDA is responsible for the planning and development of the city through the master plans of Delhi, including infrastructure and utilities for water and sanitation services in new 'development areas' (Kumar *et al.*, 2021). The National Capital Regional Planning Board, which focuses on Delhi, is also involved in the city's growth and water governance.

In addition to these policy, planning, and delivery institutions, there are a range of judicial and statutory institutions at national and state levels, including the Supreme Court of India, the National Green Tribunal, and the High Court of Delhi. From supranational to state, the majority of actors and institutions at play here are formal.

However, at a local level, formal and informal actors operate simultaneously (Figure 9.1). The formal actors include Delhi's three municipal bodies.[2] The DJB is the nodal agency for water supply and sanitation, as well as wastewater treatment in the Municipal Corporation of Delhi (MCD); the MCD, meanwhile, functions as a byelaw enforcer. The DJB supplies water in bulk to the New Delhi Municipal Council and the Delhi Cantonment Board, which then take charge of distribution, but the DJB is responsible for wastewater treatment in these areas. Many planned settlements also have a Resident Welfare Association: this a voluntary organisation that represents their interests to the DJB and Members of the Legislative Assembly (MLAs). Other non-state (but to some degree, formalised) organisations include non-governmental organisations (NGOs) and civil society organisations (CSOs), which advocate and advise on water-related issues in Delhi, for example access to safe and affordable water, groundwater depletion, and pollution.

The DJB is not mandated to supply piped water to the unplanned developments in Delhi, including slums, unauthorised colonies, and urban villages. Consequently, there are also a range of informal, non-state actors who operate with varying degrees of authority and legality, including water tanker drivers (both contracted by the DJB and private), private water vendors, and individuals using illegal borewells and handpumps to meet their non-potable water demands. As Truelove (2021) notes, there is not always a clear distinction between 'state' and 'non-state' – some actors and modes of governance operate in the 'twilight' zone, blurring 'the boundary between state and society'.

Coordination for water equity

For some actors within this framework, cooperation and coordination are possible. While the DJB is responsible for water supply, sewage, and drainage in Delhi, multiple other stakeholders work in tandem in their efforts to bridge the water demand–supply gap. Public representatives like the MLAs and municipal

[2] These are the MCD, New Delhi Municipal Council, and Delhi Cantonment Board.

JURISDICTION	POLICYMAKING	PLANNING AND MANAGEMENT	SERVICE DELIVERY/ IMPLEMENTATION
Supranational	• United Nations • World Bank • Japan Bank for International Cooperation (JBIC) • Asian Development Bank		
National	• Parliament of India • Supreme Court of India	**Ministries:** • Ministry of Jal Shakti • Ministry of Housing and Urban Affairs • Ministry of Environment, Forest and Climate Change **Departments:** • Department of Drinking Water and Sanitation **Regulatory Authority:** • National Green Tribunal **Boards:** • Central Water Commission • Central Ground Water Board • Central Pollution Control Board	
Interstate/Regional	• State of Haryana: Irrigation and Water Resources Department • State of Uttar Pradesh: Jal Nigam	• Bhakhra Beas Management Board • Upper Yamuna River Board	
State	• Government of National Capital Territory of Delhi • Delhi Development Authority • National Capital Region Planning Board • Indian National Trust for Art and Cultural Heritage • National Institute of Urban Affairs	• Delhi Jal Board • Delhi Pollution Control Committee • Irrigation and Flood Control Department • Public Works Department	• Delhi Jal Board • Delhi Urban Arts Commission • Delhi State Industrial and Infrastructure Development • Corporation Ltd.
Local		• Delhi Jal Board	• Municipal Corporation of Delhi (North, South, East) • New Delhi Municipal Council • Delhi Cantonment Board • Resident Welfare Associations (RWAs) • NGOs and CSOs e.g. CURE, Water Aid

No authority is present

Figure 9.1 The range of formal actors involved in Delhi's water governance. Notably, this structure excludes a range of informal, private, and sometimes illegal actors. (Credit: rootsandwings.design).

councillors are an integral part of water governance processes at the local level, coordinating with DJB officials and releasing MLA funds to extend the local water supply infrastructure (mostly in informal areas). Civil bodies like Resident Welfare Associations and NGOs also play a pivotal role in ensuring that unauthorised colonies and slums have access to at least the bare minimum water supply by developing temporary groundwater supply systems and formal water tankers (with the DJB's knowledge). Coordination between these actors is a necessary part of trying to meet Delhi's water demand. A glimpse of these combined and coordinated efforts is shown in this video.

Challenges to water equity

It should be noted that the complex horizontal and vertical matrix of water governance in Delhi has its origins in the colonial period (Kumar *et al.*, 2021; Truelove, 2021). And this multi-level governance results in fragmentation and lack of convergence between actors. At a regional level, interstate water disputes between Delhi and its neighbouring upper riparian states are common, especially during summer. Such arguments should be dealt with by the UYRB, as the regional regulatory authority, but the DJB (a state agency) often bypasses the regulator, appealing to the Supreme Court (the national judiciary) instead (Dutta, 2022; PTI, 2018).

Within Delhi, the DJB and the DDA are the two most important state actors, but they do not coordinate effectively, which plagues the city's water governance. While the two agencies acknowledge that collaboration is a necessity (as evident in this video) and can articulate each other's process, role, and responsibilities in developing the city's water infrastructure, they fail to deliver the services collaboratively. To cite just one example, the DDA began developing the town of Dwarka (then named Papankalan) in the late 1980s/early 1990s. Designed for the middle and increasingly upper classes, the neighbourhood was built without an operational network of water infrastructure. Residents relied on water tanks provided by the DDA and private (illegal) groundwater borewells. It was only after resident protests and an intervention by the Delhi High Court that Dwarka finally began receiving piped water supply in spring 2015 when DJB took over distribution (Express News Service, 2015; Kumar *et al.*, 2021).

And if this example highlights how the current fractured system leads to inequitable access to water for those living *within* planned developments, the inequitable consequences for those living *outside* these residences are even starker. As we saw in Chapter 3, the DDA prioritises development over livelihoods, evicting farmers to rejuvenate floodplains. From the DDA's perspective, the 'illegal encroacher' has no right to public land (Singhal, 2024). Exclusionary and inequitable water distribution mechanisms have legal backing under the Delhi Jal Board Act, 1998, which excuses the DJB from providing water supply 'to any premises which have been constructed in contravention of any law' (GNCTD, 1998).

As a result, an estimated 45% of the city's population has been written out of the legal framework (MCD, 2009); in other words, it is legal to leave these residents out of the DJB's centralised piped water supply network. Due to political pressure, DJB does use water tankers to provide potable water to informal localities, but this is largely insufficient, leading to the rise of invisible and/or illegitimate actors and institutions who assume the role of state to meet the local water demand (Figueroa-Benitez *et al.*, 2023).

This informal network brings with it a number of challenges, including:

- Health risks – via the sale and consumption of contaminated water;
- Exclusionary water practices – communities are not homogenous: there are subsets of power and intersectional vulnerabilities within unplanned developments;
- Economic risk – private water costs more and constitutes a higher percentage of salaries;
- Protests and unrest – disruptive action tends to generate political attention, especially in the run-up to elections (Sarkar, 2021);
- Illegal modes and practices – including boreholes, handpumps, illegal tapping of the DJB network, and illegal sale of potable state water that is the water 'mafia' (Birkinshaw, 2018; Truelove, 2021);
- Above all, resource uncertainty.

Conclusion

Delhi has one of the world's most rapidly growing urban populations. If estimates are correct, it has already overtaken projections in the Master Plan Delhi (MPD) 2041, which expects the city's population to hit 28 million by 2041. Meeting the extra water demand will be a huge challenge, requiring the redistribution of power, changes in democratic control and citizen influence, and shifting accountability structures. The hydro-solidarity among regional actors like GNCTD and upper riparian states of Haryana, Punjab, Uttar Pradesh, Uttarakhand, and Himachal Pradesh is of utmost important to ensure uninterrupted raw water for Delhi. At the city level, coordination and convergence among various central and state-level institutions like the DDA, DJB, and IFCD is crucial for the design and implementation of water infrastructure that is fit for purpose. In addition, the effective public participation of citizens, as envisaged in national and local water policies, holds the key not just to Delhi's water equity, but its future water security as well.

9.2 YOUTH IN URBAN WATER FUTURE: PARTICIPATION, RECOGNITION, AND ACCOUNTABILITY IN NCT DELHI, INDIA

Shambhavi Gupta

In 2023, India overtook China as the world's most populous country according to United Nations population estimates (UNPFA, 2023). More than 40% of India's estimated 1.428 billion people are under 25 – equating to approximately 560 million children and young people (Silver *et al.*, 2023) – and every fourth child (27.4%) lives in an urban area (Dhar & Thakre, 2020). India, specifically its cities, is facing a youth bulge. It is predicted to have one of the youngest populations globally until 2030 (UNPFA, 2023).

It is this younger generation that will face the consequences of our current anthropogenic activities and bear the brunt of climate crisis-related destruction.

And notably, in one of the first large-scale surveys of young people (16–25 years) across the globe, 78% of youths living in India said that they were extremely or very worried about the impact of climate change (Hickman *et al.*, 2021).

Children and young people (0–19 years) constitute around 37% of Delhi's population (GNCTD, 2023). These children and young people will play a key role in future development; indeed, they have the potential to transform the city's socio-economic fortunes. At present, however, this potential is not fully utilised, as youth participation in city building is negligible, even if the interest and desire to engage are present (Ghafoor-Zadeh, 2023).

Youth participation in urban governance

Building child-friendly cities is not a new concept. The UNICEF-led Child Friendly Cities Initiative, launched in 1996, defines a child-friendly city as 'a city, town, municipality or any system of local governance committed to fulfilling child rights as articulated in the Convention on the Rights of the Child' (UNICEF, 2022). However, in their systemic literature review, Cordero-Vinueza *et al.* (2023) observed that the literature around the theme of 'right to the city' is limited in its translation for theory to practice, especially when participation and engagement in decision-making (particularly in urban planning) are strenuous.

This is a particular challenge in Delhi, where decision-making is rooted in multi-level, bureaucratic channels of governance. Public participation in metropolitan and local governance is mandated through the Delhi Development Act, 1957 (Kumar *et al.*, 2020). When it comes to urban planning however, statutory public participation usually only occurs after a draft plan has already been prepared (Kumar, 2017). Such is the case in Delhi: the DDA, a parastatal body, circulates draft master plans, inviting objections and suggestions, but the final documents may or may not incorporate those suggestions, as the final decision is based on the discretion of the authority.

During the drafting of the MPD 2041, the Delhi Commission for Protection of Child Rights called for the DDA to incorporate child-friendly spaces and services (Express News Service, 2021; Hindustan Times, 2019). However, in the absence of formal channels for children and youth consultation, other organisations have taken steps to facilitate youth participation in city planning and engagement in the urban environment.

These organisations include the Bernand van Leer Foundation (an international funder), the National Institute of Urban Affairs (NIUA) (a national research institute), Beyond Built Trust (a national NGO), Ankur Society for Alternative Education (ANKUR) (a local NGO), and City Sabha (a local CSO). Though they all focus on encouraging young people to engage with their urban environment and participate in governance mechanisms, the overall approaches of these organisations differ substantially. And it should be stated that their work is centred on various facets of urban sector, of which water is one of many. For instance, the Bernard van Leer Foundation and NIUA focus on building capacity among urban planners to design child-friendly cities through the provision of resources informed by NIUA's 'Urban Youth Unit', which acts as a forum for young people to engage in the processes of urban development (NIUA, n.d.). For their part, Beyond Built Trust – experts in landscape architecture, urban planning, and heritage conservation – and ANKUR – experts in experimental pedagogy in marginalised neighbourhoods – use storytelling and place-based engagement to contextualise urban spaces and develop a sense of ownership. Thus, they encourage children to develop an understanding of the themes of water and waste. Finally, City Sabha, with its focus on inclusive placemaking, works with young people to voice their concerns and visualise change.

The work of these organisations is commendable, although, notably, ANKUR is the only organisation where local partnership with children and young people is actually envisioned and implemented. Furthermore, while their work centres on enabling youth recognition in urban decision-making, these organisations exist outside of Delhi's governance system and so, despite their engagement and advocacy, their ability to affect policy in a meaningful way is limited. Nevertheless, advocacy organisations like City Sabha and the Mai Bhi Dilli campaign did successfully influence the MPD 2041 preparation and public hearings in 2021 (Figure 9.2).

Main Bhi Dilli: bottom-up planning

In order to build partnerships with the development authorities and agencies, the legal provision of objections and suggestions must be operationalised to its maximum. Recently, the public participation mandate was used by the 'Main Bhi Dilli' ('I too am Delhi') campaign – a people's campaign for an inclusive and equitable planning approach to Delhi (MainBhiDilli, n.d.). The campaign,

Figure 9.2 Excerpt of children's testimony about their environment following a workshop led by ANKUR. Translation: 'The rivulet flowing near the hilly squatters is black in colour. There is garbage and bricks and stones on the sides. All our friends play there.' (Credit: Shambhavi Gupta).

which launched in 2018, brought together a group of 40 organisations to engage citizens and historically excluded communities in the process of drafting the MPD 2041 through knowledge co-production. The campaign deliberately aimed to 'propositionally counter the top-down and technocratic approach of master planning' and position itself as 'as a source of data and knowledge about the city' that filled gaps in NIUA's understanding (Lall *et al.*, 2023). The wave of advocacy driven by the Main Bhi Dilli campaign – both in terms of driving citizen engagement and in opening discussions with the NIUA and the DDA – brings hope that bottom-up movements can inform and influence conventional urban planning processes (Lall *et al.*, 2023).

Envisioning an urban water future

The development authorities and service provision agencies need to make a proper effort to engage and educate young people, thus encouraging youth participation and rendering decision-making more inclusive. Most importantly, this will benefit communities residing in informal settlements, where access to water, water quality, and water rights are all in question (see Chapter 10). This is only possible if current efforts to build recognition of young people in decision-making with respect to urban development widen out to include water service provision. This animated doodle uses Arnstein's Ladder of Participation (Arnstein, 1969) to articulate the process.

The Main Bhi Dilli campaign undoubtedly pioneered a large-scale bottom-up movement in Delhi. However, attention also needs to be brought to the accountability of the public authorities and service provision agencies. For instance, the Main Bhi Dilli campaign simply supported the plan-making process in Delhi, never questioning why the mandated process of participation (as per the Delhi Development Act, 1957) did not include primary surveys, which haven't been undertaken since the second revision of the master plan.

The voices of young people must be incorporated into Delhi's planning system, in which civic surveys and public hearings can play significant roles. This should be supplemented by the work of organisations like ANKUR, Beyond Built Trust, City Sabha, and others. NIUA, in turn, can play a role as an enabler, ensuring capacity is built in the workforce across the service provision agencies and development authorities.

Youth participation is the key to securing the urban water future of Delhi, helping to design a system that is based on education, inclusive decision-making, and accountability on the part of the development authorities. The first, prerequisite step in this quest is to coherently integrate the development authority and other service provisioning agencies.

REFERENCES

Arnstein S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, **35**(4), 216–224, https://doi.org/10.1080/01944366908977225

Birkinshaw M. (2018). 'Water mafia' politics and unruly informality in Delhi's unauthorised colonies. In: Water, Creativity and Meaning, L. Roberts and K. Phillips (eds.), Routledge, London, pp. 188–203, https://doi.org/10.4324/9781315110356

Cordero-Vinueza V. A., Niekerk F. and van Dijk T. (2023). Making child-friendly cities: a socio-spatial literature review. *Cities*, **137**, 104248, https://doi.org/10.1016/j.cities.2023.104248

Dhar D. and Thakre M. (2020). No Child's Play: The Enduring Challenge of Creating Child-Friendly Cities. ORF Issue Brief No. 415, October 2020, Observer Research Foundation. https://www.orfonline.org/public/uploads/posts/pdf/20230515132401.pdf (accessed 16 April 2024)

Dutta S. (2022). 'Satyendar Jain calls out Haryana for not releasing 'Delhi's share of water', residents suffer'. *The Hindustan Times*, 17 May. https://www.hindustantimes.com/cities/delhi-news/minister-says-haryana-not-releasing-delhi-s-share-of-water-residents-suffer-101652782450511.html (accessed 16 April 2024)

Express News Service. (2015). 'Dwarka plant to supply water from March 16'. *The Indian Express*, 2 March. https://indianexpress.com/article/cities/delhi/dwarka-plant-to-supply-water-from-march-16/ (accessed 16 April 2024)

Express News Service. (2021). 'Delhi needs child-friendly master plan, says DCPCR'. *The New Indian Express*, 12 August. https://www.newindianexpress.com/cities/delhi/2021/Aug/12/delhi-needs-child-friendly-master-plan-says-dcpcr-2343655.html (accessed 16 April 2024)

Figueroa-Benitez A., Nagheeby M., Figueroa A. and Amezaga J. (2023). Disrupted water governance in the shadows: revealing the role of hidden actors in the Upper Cauca River Basin in Colombia. *Frontiers in Water*, **5**, 801171, https://doi.org/10.3389/frwa.2023.801171

Ghafoor-Zadeh D. (2023). Moving through, interacting with, and caring for the city: children's and young people's everyday experiences in smart cities. *Digital Geography and Society*, **4**, 100051, https://doi.org/10.1016/j.diggeo.2023.100051

Government of NCT of Delhi. (1998). The Delhi Water Board Act 1998. Department of Law, Justice & Legislative Affairs, Government of NCT of Delhi. No. F. 13(4)/98-LAD, 2 April 1998. https://delhijalboard.delhi.gov.in/sites/default/files/Jalboard/generic_multiple_files/delhi_jal_board_act_1998.pdf (accessed 16 April 2024)

Government of NCT of Delhi. (2023). Economic Survey of Delhi, 2022–23. Planning Department, Government of NCT of Delhi. https://delhiplanning.delhi.gov.in/planning/economic-survey-delhi-2022-23 (accessed 16 April 2024)

Hickman C., Marks E., Pihkala P., Clayton S., Lewandowski R. E., Mayall E. E., Wray B., Mellor C. and van Susteren L. (2021). Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. *The Lancet Planetary Health*, **5**(12), 863–873, https://doi.org/10.1016/s2542-5196(21)00278-3

Hindustan Times. (2019). 'Ensure Delhi child-friendly spaces in master plan draft: Rights body'. *The Hindustan Times*, 25 June. https://www.hindustantimes.com/delhi-news/ensure-child-friendly-spaces-in-master-plan-draft-rights-body/story-lUSIT7d75KvMhTCLvlS3pK.html (accessed 16 April 2024)

Kumar A. (2017). E-democracy in New Delhi Municipal Council: a case of smart city planning processes. In: E-Democracy for Smart Cities, T. M. Vinod Kumar (ed.), Springer, Singapore, pp. 121–142, https://doi.org/10.1007/978-981-10-4035-1_4

Kumar A., Vidyarthi S. and Prakash P. (2020). City Planning in India, 1947–2017, 1st edn. Routledge India, London, https://doi.org/10.4324/9781003055969

Kumar A., Singh N., Cooper S., Mdee A. and Singhal S. (2021). Infrastructural violence: five axes of inequities in water supply in Delhi, India. *Frontiers in Water*, **3**, 727368, https://doi.org/10.3389/frwa.2021.727368

Kumari S. and Biswas R. (2022). Decoding Delhi's water governance through multi-level governance approach. *H2Open Journal*, **5**(4), 722–734, https://doi.org/10.2166/h2oj.2022.048
Lall R., Mehra R. and Narayan M. (2023). Co-producing knowledge in action: reflecting from the Main Bhi Billi campaign for equitable planning in Delhi. Planning Theory, https://doi.org/10.1177/14730952231184339
MainBhiDilli. (n.d.). Main Bhi Dilli: Ab Sheher Saath Banayenge (I too am Delhi. Now we will make a city together). Campaign homepage. https://www.mainbhidilli.com/ (accessed 16 June 2024)
Municipal Corporation of Delhi (MCD). (2009). Fact Sheet. Slum and JJ Department, Delhi.
National Institute of Urban Affairs (NIUA). (n.d.). Urban Youth Unit. https://niua.in/youth-unit/ (accessed 16 April 2024)
Pandit C. and Biswas A. K. (2019). India's National Water Policy: 'Feel good' document, nothing more. *International Journal of Water Resources Development*, **35**(6), 1015–1028, https://doi.org/10.1080/07900627.2019.1576509
PTI. (2018). 'Delhi-Haryana water sharing: Supreme Court slams Upper Yamuna River Board'. *The Indian Express*, 11 May. https://indianexpress.com/article/cities/delhi/delhi-haryana-water-sharing-supreme-court-slams-upper-yamuna-river-board-5173240/ (accessed 16 April 2024)
Sarkar A. (2021). Everyday practices of urban poor to access water: evidence from Delhi slums. In: Reflections on 21st Century Human Habitats in India, M. S. Jaglan and Rajeshwari (eds.), Springer, Singapore, pp. 371–392, https://doi.org/10.1007/978-981-16-3100-9_15
Silver L., Huang C. and Clancy L. (2023). Key Facts as India Surpasses China as the World's Most Populous Country. Pew Research Center, 9 February. https://www.pewresearch.org/short-reads/2023/02/09/key-facts-as-india-surpasses-china-as-the-worlds-most-populous-country/ (accessed 16 April 2024)
Singhal S. (2024). Uncovering the Silences: Environmental Knowledges in the Floodplains of Yamuna, Delhi, Decolonial Subversions. http://decolonialsubversions.org/docs/pdfs/2024/6.1_Singhal.pdf (accessed 16 April 2024)
Truelove Y. (2021). Who is the state? Infrastructural power and everyday water governance in Delhi. *Environment and Planning C Politics and Space*, **39**(2), 282–299, https://doi.org/10.1177/2399654419897922
UNICEF. (2022). Guidance Note: The Child Friendly Cities Initiative. UNICEF, New York, US. https://www.unicef.org/media/133746/file/Child-Friendly_Cities_Initiative_Guidance_Note.pdf (accessed 16 April 2024)
United Nations. (2018). The World's Cities in 2018: Data Booklet. Department of Economic and Social Affairs, Population Division, United Nations. https://www.un.org/en/development/desa/population/publications/pdf/urbanization/the_worlds_cities_in_2018_data_booklet.pdf (accessed 16 April 2024)
United Nations Population Fund (UNPFA). (2023). State of World Population 2023: 8 Billion Lives, Infinite Possibilities. UNFPA Division for Communications and Strategic Partnerships, New York, US. https://www.unfpa.org/sites/default/files/swop23/SWOP2023-ENGLISH-230329-web.pdf (accessed 16 April 2024)
World Population Review. (n.d.). Delhi Population 2024. https://worldpopulationreview.com/world-cities/delhi-population (accessed 16 April 2024)

doi: 10.2166/9781789062540_0191

Chapter 10

Consultation

Neo Sau Mei and Adey Nigatu Mersha

Policymakers and practitioners in the water sector generally promote policies and plans that apparently support sustainable water resource management, but such plans and policies are often laid out without consultation with local communities (Berke & Conroy, 2000). This hinders effective development and implementation. Indeed, in some cases, decision-makers have already come up with a solution and merely seek to accommodate local people in the solution-seeking process as an afterthought, creating a deceptive picture of participation that doesn't tally with reality (Kumar *et al.*, 2020). In this chapter, however, authors present case studies in which stakeholder participation has been systematically embedded in policymaking processes through consultative and operational frameworks in Johor, Malaysia and Addis Ababa, Ethiopia, thus strengthening collective decision-making.

10.1 STAKEHOLDER ENGAGEMENT: EXPLORING MULTIPLICITY OF VALUES IN JOHOR RIVER BASIN, MALAYSIA

Neo Sau Mei

Water management and governance is a critical issue in Malaysia (Chan, 2009; Saimy & Yusof, 2013; Woodhouse & Muller, 2017). Malaysia provides water to 95% of its population at one of the most affordable rates globally (Chan, 2009). However, there are several aspects of water governance that need to be improved to achieve water security. Power is often overly held by government-controlled, centralised departments across the water sector, requiring stronger commitment to excellent services to ensure transparency, professionalism, and accountability (Chan, 2009; Saimy & Yusof, 2013).

At present, many documents and data are archived or 'classified' instead of being publicly available and accessible. Transparent information-sharing management is needed to promote accountability and build trust between the government and community or society. Furthermore, it should be stated that water management authorities often overlap both within and between federal and state governments. Unfortunately, these government agencies and other relevant stakeholders do not coordinate effectively, decreasing accountability and trust in water governance. The lack of diversity and social inclusivity in decision-making processes also leads to declining interest and trust in government (Chan, 2009).

The situation and significance of Johor River

The Johor River Basin (JRB) is located in the south-east of Peninsular Malaysia and occupies approximately 14% of Johor (Shafie, 2009). It is the main river in Johor State and an essential source of freshwater for Johor and Singapore (Obaid & Shahid, 2017). In 2016, Johor ranked in the top three among the states in Malaysia, generating an income of RM11,406 million (around $2435 million) through domestic and international tourism (Rahman & Ching, 2020). The district of Kota Tinggi is one of the most famous and frequently visited tourism areas in Johor (Saad *et al.*, 2023) – and it is a notable part of the JRB. In general, the area's rich ecosystem, waterfalls, firefly parks, historical tombs, museums, and royal history (as the birthplace of the Johor Dynasty) support a growing tourism industry (Hamzah *et al.*, 2012). Demographically speaking, the communities residing in the JRB include Malaysian, Chinese, Indian, and indigenous people. Many of them rely on the river for their livelihoods, working as fishers, farmers, and agricultural and oil palm estate workers. These communities are not homogenous – they hold different social, cultural, and economic values. This is particularly true of the basin's indigenous people, who continue traditional practices and ways of life; although they represent a comparatively minor group within the area, they have a long history in the JRB. Their beliefs and culture are mostly connected to the land and nature, and their traditions are celebrated through festivals, dance, and language.

Traditionally, Malaysia has implemented top-down governance in integrated water management (Khalid *et al.*, 2018). However, considering the diversity of values present in the JRB and the importance of the basin to a number of different communities, the water sector needs to more proactively engage, include, and listen to stakeholders and representatives from each of the communities, so as to achieve inclusivity and equality in water management decisions. The views and opinions of all these stakeholders are equally valuable in and necessary to water management in practice, ensuring that comprehensive and collective policies are proposed and executed. By considering diverse perspectives, we can practise and implement inclusive decision-making processes that lead to sustainable water management solutions and ensure our research and research impact is not removed from the realities and lived experiences of these historically marginalised communities (Choong & Neo, 2022).

Identifying stakeholders

As the first step in this process, the government needed to build relationships with communities and gain their trust, before integrating them into the planning and management process (Di Napoli *et al.*, 2019). Our research team initiated the engagement, acting as a bridge between community representatives and other stakeholders. As Universiti Teknologi Malaysia (UTM) is a public, government-backed university, engaging with stakeholders from government agencies and relevant government-linked industries was relatively straightforward, accomplished through meetings, emails, and regularly follow-ups on agreed actions. By comparison, establishing relationships with community representatives and non-governmental institutions was more complex, involving more thoughtful communication and the use of intermediaries. For example, it was necessary to first approach the Department of Orang Asli Development (JAKOA), a department under the Ministry of Rural and Regional Development of Malaysia that is responsible for the welfare of the indigenous people, before we could reach out to indigenous populations. Researchers from UTM then engaged in frequent visits, capacity building, and grassroot programmes, with the aim of empowering wider communities to engage in further participatory workshops and activities.

Only once we had studied the department, roles, and background (cultural, historical, and social) of all the relevant parties and formed a relationship with them through visits, meetings, interviews, and follow-up calls did we begin to bring stakeholders together. The pre-engagement stage process took time and resources, as it required nuanced coordination and management at multiple levels. But in due course, stakeholders were invited to workshops based on assessment criteria such as availability, experience, position, and background. Generally, the individual stakeholders were collated into specific categories such as government agencies, water management institutions, non-governmental organisations, community representatives, or industries. The diversity of categories allowed multiple perspectives to be captured in an effort to develop and co-create potential solutions.

Working together across sectors

We conducted a number of participatory workshops (Figure 10.1) with relevant stakeholders from the different categories, bringing together water management agencies, government institutions, local authorities, and community representatives to discuss existing and emerging water security issues in the JRB. We facilitated focused and topical discussions between various parties from various levels, exchanging thoughts, experiences, and ideas to improve the basin.

In addition, we hosted virtual coffees and catch-ups to provide an online platform for engagement during the COVID-19 pandemic, when movement and physical interaction were restricted. The virtual coffee concept is inspired by the World Café method (Brown & Isaacs, 2005), which has been widely adopted across multiple disciplines (Chang & Chen, 2015; Fouché & Light, 2010; Fullarton & Palermo, 2008; Ritch & Brennan, 2010): the rationale of this

Figure 10.1 Photographs of the stakeholder dialogues in Senai, Johor, 2019. (Credit: Neo Sau Mei).

method is to provide an opportunity for communities to express their views freely in a relaxed and comfortable virtual space. It represents an innovative engagement approach to build rapport and maintain trust between the research team and the communities.

Furthermore, community representatives from nine villages in the JRB, including indigenous villages, were invited to separate sessions to participate in a small-scale, focused discussion of water security challenges as well as of the potential solutions to these issues. These dialogues revealed the challenges facing communities living in the JRB, including but not limited to water pollution, loss of biodiversity, loss of food sources, and flash flooding. We also uncovered potential causes of these issues, such as outdated laws and regulations, overlapping power between governing institutions, weak enforcement by authorities, insufficient financial and human resources, and politicisation of the sector. While the water management authorities were likely already aware of some of these issues (e.g. the lack of staff to monitor water quality), these dialogues helped those 'in charge' to understand the impact and lived experiences of those for whom the river is both home and livelihood (Figure 10.2).

Conclusion

In conclusion, the stakeholder engagement process has provided more than just a platform for the communities to voice their concerns; it ensures their voices have been heard by those who have decision-making power. This process has empowered communities through collective and collaborative discussion so that their voices are integrated into strategic planning processes. Bringing community voices into dialogue with traditional top-down approaches to water management and governance has brought about a wider paradigm shift, as diverse perspectives have been incorporated into the decision-making process, influencing potential outcomes through the subsequent development of the strategic plan.

The strategic plan represents an important milestone in the evolution and adaptation from exploratory to action-based research. We still have a long way

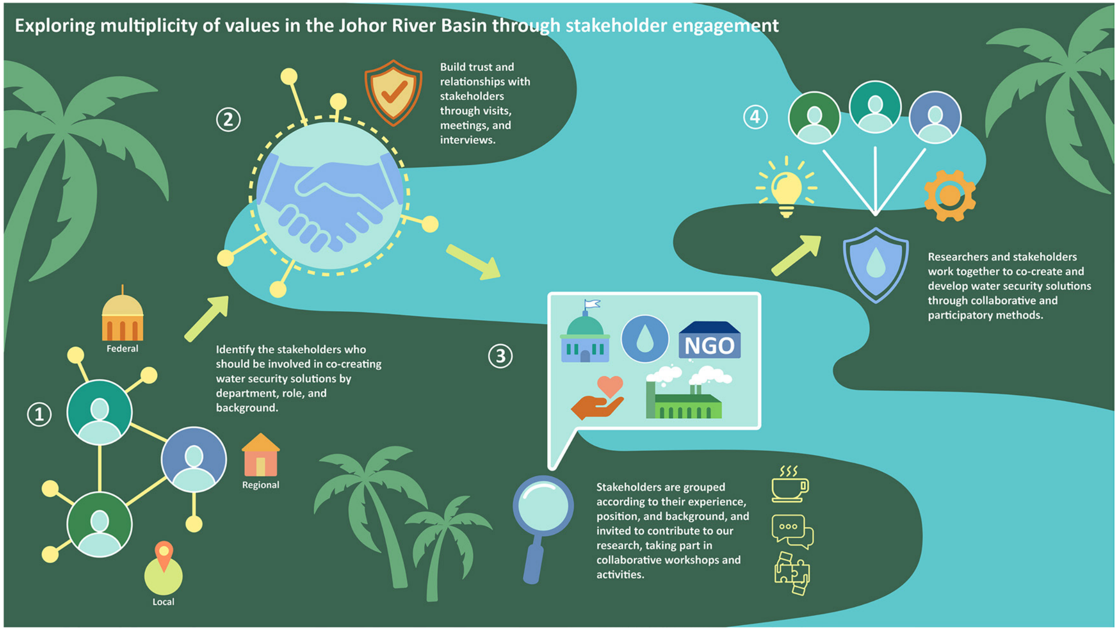

Figure 10.2 The process of connecting and engaging with stakeholders to co-create solutions during collaborative workshops and activities.[1] (Credit: rootsandwings.design).

[1] The steps articulated in the figure are as follows:

(1) Identify the stakeholders who should be involved in co-creating water security solutions by department, role, and background.
(2) Build trust and relationships with stakeholders through visits, meetings, and interviews.
(3) Stakeholders are grouped according to their experience, position, and background, and invited to contribute to our research, taking part in collaborative workshops and activities.
(4) Researchers and stakeholders work together to co-create and develop water security solutions through collaborative and participatory methods.

to go. However, these co-creation initiatives are crucial in creating the space for sustainable, long-term collaboration and maintaining momentum in the shift towards transparent, accountable, and inclusive water management. This ongoing collaboration in the JRB will also serve as a useful foundation and reference point for future engagement.

10.2 PARTICIPATORY SCENARIO DEVELOPMENT FOR WATER ALLOCATION MODELLING AND SUSTAINABLE WATER MANAGEMENT IN ETHIOPIA

Adey Nigatu Mersha

Global water demand is expected to continue rising, driven by population growth, socio-economic development, and changing consumption patterns (Huang *et al.*, 2021; van Vliet *et al.*, 2021). Recent United Nations reports indicate that the global freshwater demand will increase by about 30% by 2050, surpassing the available water supply by 40% by 2030 – and all of this will be exacerbated by the impact of climate change on water availability (UNEP, 2017). In short, the issue of water scarcity is expected to worsen. The greatest chance to improve water security lies in managing water demand across all sectors, but particularly in agriculture, which is the largest water user globally (Mekonnen & Gerbens-Leenes, 2020; UNEP, 2017).

Given how little we know at present about socio-ecological systems' potential responses to key stressors and management interventions, planners are increasingly using scenario-based simulations to support risk-based planning and establish proactive systems of water management (Dong *et al.*, 2013; Speed *et al.*, 2013). A range of simulation models can study water resource planning and management issues in river basins in a way that enables stakeholders to be actively involved in the planning and decision-making process. This study uses the Water Evaluation and Planning system (WEAP), as it simulates water systems and policies in a comprehensive and integrated manner, being designed as a comparative analysis tool. It has accordingly been referred to as a laboratory for examining and evaluating a full range of water development and management options (Yates *et al.*, 2005).

Although scenario methods have been widely applied in risk-based assessments of water resource systems, there has not been per se clear operational methodology or procedure defined on how the alternative scenarios are developed. Rather they are simply assumed, and the necessary participatory processes followed in their design are not clearly traceable (Mahmoud *et al.*, 2009). The need for a methodological guideline for participatory scenario development (PSD) is of a paramount importance in order to ensure a clear system definition and representation in modelling water resources systems. The practical methodological progress in scenarios representation should result from adaptive courses of action integrating enough flexibility to adapt models to diverse social, economic, and policy contexts, and ultimately result in a comprehensive suite of strategies and action pathways for sustainable water allocation and management.

Participatory scenario development

PSD is an interdisciplinary and operational process for crafting various narratives about what the future may hold with regard to water availability conditions and management requirements. PSD enables a clearer and collective understanding of water systems' key processes; it thus underpins the assessment of the impacts of development and changing natural conditions on the future availability of water resources. It also strengthens strategic decision-making, by supporting the development of a well-informed hydrological modelling tool, as a common platform to combine natural and biophysical elements of the water resource system with that of the socio-economic processes for a context-based reasoning tailored to specific local needs By representing the water system in a multivalent and holistic way, PSD explores issues related to water allocation and management, along with a set of plausible adaptation options for a practical representation of the systems dynamics in model-based analysis to guide water resources management in an equitable, efficient, and sustainable manner. The PSD process outlined in this study was informed by the views of stakeholders (see 'Case study' section), as well as by concepts and processes from previous related studies, such as Dong *et al.* (2013), Mahmoud *et al.* (2009), Ocampo-Melgar *et al.* (2022), Speed *et al.* (2013), and Weng *et al.* (2010).

Six key stages of the PSD process

Categorisation of scenarios

In defining and categorising scenarios for water allocation planning, four key questions first need to be answered: what do past trends show? How does the current situation perform? What is the likely future situation? How can we shape or inform the future situation?

From these questions, scenarios can be categorised as:

(I) The situation as it currently exists – representing the 'business-as-usual' scenario, assuming no major change is introduced into the current system. This is a reference setting or baseline scenario against which likely future situations are measured, compared, and evaluated.

(II) Intervention scenarios – these refer to future situations where there are changes in water use and management as well as availability conditions. Intervention scenarios are further categorised based on: (i) likely changes in socio-economic conditions for example policy changes, development plans and ambitions, population growth, and urbanisation; (ii) changing natural circumstances for example changing rainfall patterns and climate in general; and (iii) changing management practices for example efficiency measures, supply management, water transfers, and environmental goals.

The status quo and setting of objectives

Here, we define the context and characterise the water system in terms of biophysical and socio-economic processes. We define clear objectives for scenario development and for the overall water allocation planning process, considering context-relevant scopes and spatio-temporal boundary conditions.

Possible objectives of water allocation scenario analysis could include: to ensure sustainable water use and management; to enhance equitability and inclusivity; to serve ecological management and conservation; or to enhance water productivity. Goals, meanwhile, could be to enhance livelihoods, economic development, or community well-being as a whole.

The engagement of stakeholders

This stage systematically identifies relevant stakeholders to ensure that they are participating throughout the process. With this in mind, researchers will guide participation (through data acquisition and validation), co-develop knowledge and build capacity (through training, discussions, and idea exchange on key research processes and findings), and establish discussion platforms (such as focus groups, as well as consultative and dissemination workshops) aimed at including diverse perspectives and uncovering hidden voices related to water allocation.

Identification of major problems and drivers of change

This stage is aimed at developing a thorough characterisation of critical system gaps and their consequences in terms of water allocation and management as well as resource suitability. And having identified the problems, we can then collaboratively trace their sources (i.e. major drivers of change that have led to the identified water use and management issues) and classify them according to their degree of influence.

Analysis of possible intervention options (adaptation measures)

Next, we identify and prioritise possible intervention options to support equitable, efficient, and environmentally sustainable water use and management. The exploration and analysis of the management/adaptation options can be procedurally categorised into three major areas of action: (i) supply-side interventions; (ii) demand-side interventions; and (iii) policy-based interventions.

Scenario definition

The final step is to formulate cause-and-effect relationships between the different context-relevant drivers of change and their impact on future water availability, based on the various scenario storylines. To do this, the assumed changing circumstances will be organised along with their consequences and possible sets of responses to generate a set of plausible future scenario storylines perceivably representing a range of potential futures based on different combinations of the identified key driving forces. Thus, we can explore a spectrum of likely situations. The scenario narratives will then take shape as a sequence of events or a synopsis of a possible course of action or events collating the information examined in relevance with the identified problems, the drivers of changes, and possible ways to address anticipated risks. Figure 10.3 presents a framework delineating a step-by-step process for PSD that supports water resource planning and policymaking.

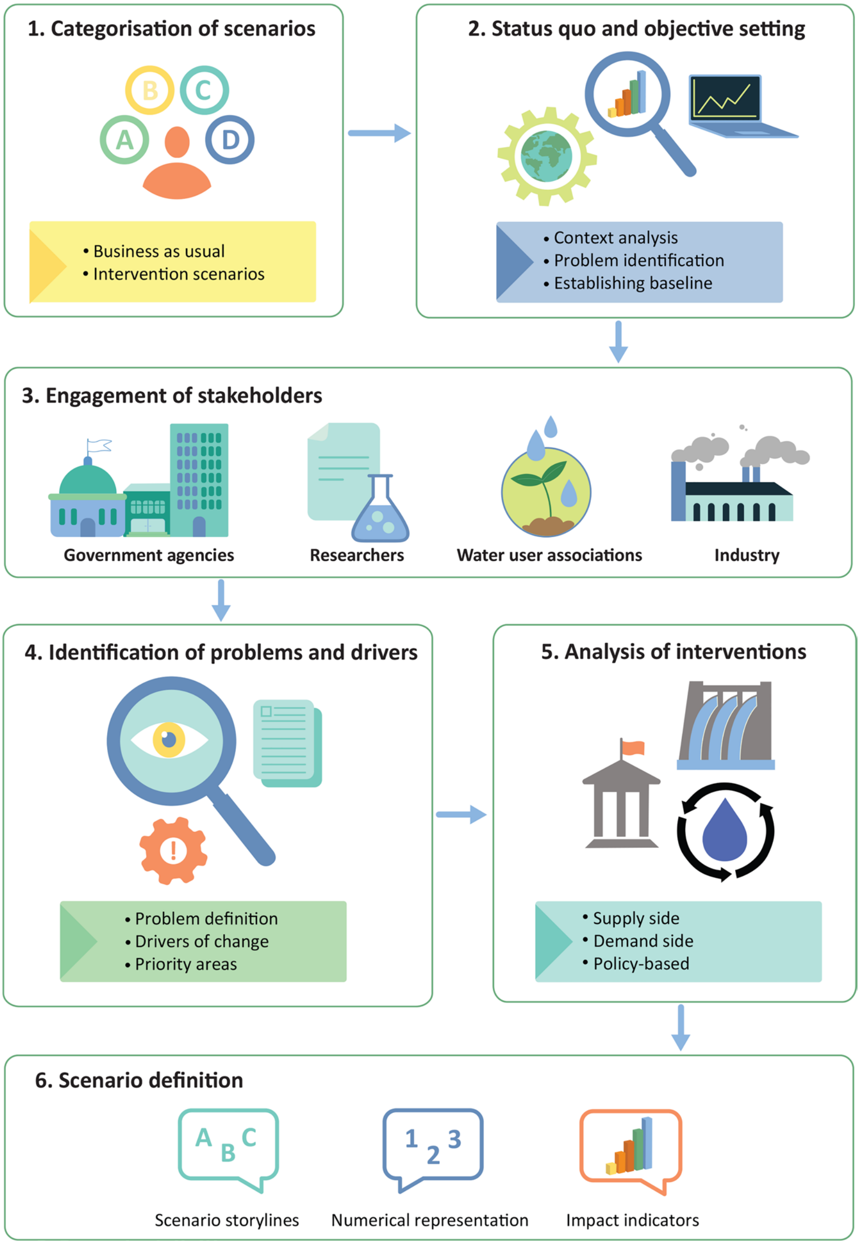

Figure 10.3 A step-by-step process for PSD. (Credit: rootsandwings.design).

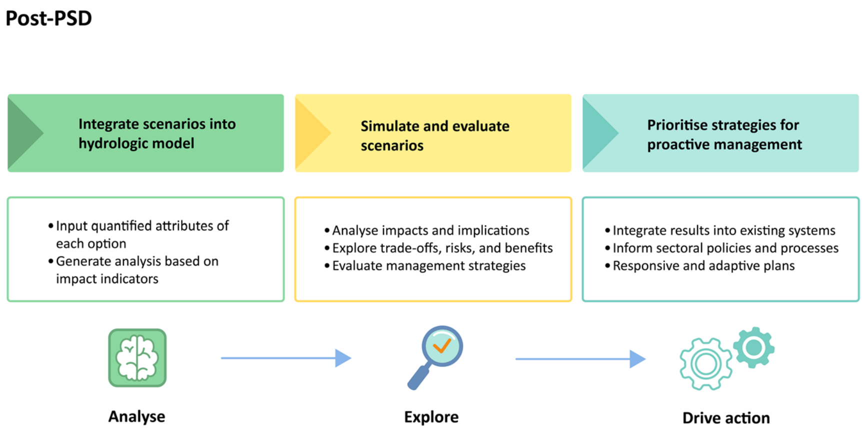

Figure 10.4 Post-PSD process: application of PSD for water resource planning. (Credit: rootsandwings.design).

Post-PSD: application of scenarios for strategic planning

Once the PSD process has enabled the definition of the scenarios, there are three further steps (Figure 10.4):

Scenario specification and quantification

Here, we assign indicative quantitative attributes for each set of scenario options and intervention measures to substantiate the proposed scenario storylines, before they are integrated into the numerical (hydrologic model-based) analysis in terms of their implications for water demand, water availability, socio-economic development, societal well-being, and general health of the ecosystem.

Scenario simulation and evaluation

Next, we integrate the quantified and qualified scenarios into the hypothetical catchment characterisation to project future trends concerning development and water availability conditions. This enables us to analyse the trade-offs, risks, and benefits associated with each of the options. Feedback sessions with relevant groups enable us to refine the outputs and scenarios and thereby enhance the relevance and precision of the scenarios analysis for effective risk-based planning.

Communicate results of scenario evaluation and systems analysis

Finally, we disseminate the results to key stakeholders including decision-makers, development planners, and local communities, with the aim of informing sectoral policies and water management strategies. This communication also helps to maintain stakeholder engagement, strengthening collaborative efforts in the service of proactive management. Ultimately, it is hoped that this will create a planning process that is responsive to changing circumstances, ensuring water security and sustainable development.

Case study

This methodological framework was developed and tested with the participation of diverse stakeholders in the Central Rift Valley sub-basin. The Central Rift Valley is one of the most hydrologically vulnerable areas of Ethiopia, located in the dynamic system of the Great East African Rift Valley (Bantider *et al.*, 2023; Mersha *et al.*, 2023).

In this context, a combination of methods was employed to build understanding and guide the PSD process, including desktop research, stakeholder mapping, participatory planning and data collection, and stakeholder consultations, interviews, and group discussions. In these group discussions and activities, researchers guided stakeholders in a step-by-step manner to explore the future situation in a realistic and policy-relevant way. Key drivers of change (categorised into natural and anthropogenic) as well as possible adaptation options were explored. And we made sure to discuss possible interventions and outcomes, allowing for socio-economic aspects of water management and allocation planning to be captured. Table 10.1 summarises the results of the

Table 10.1 Results of the PSD process: problems, drivers, and options. (Credit: Adey Nigatu Mersha).

Problem Definition	Drivers of Change	Adaptation Options	
Biodiversity degradation Climatic extremes Deforestation Inefficient water use Lack of ownership, awareness Lack of water prices Land degradation Limited data and information Pollution Salinity Sedimentation Soil erosion Water scarcity Water table depletion Waterborne diseases Wetlands encroachment	Climate change Hydrological hazards Industrialisation Irrigation expansion Lack of cross-sector collaboration Lack of land use plans and policies Policy and institutional gaps Pollution Population growth Rainfall shortages Overgrazing Urbanisation Mismanagement	Agronomic measures Climate-smart agriculture Climate-resilient green economy Conjunctive water use Enhanced awareness Environmental flows Groundwater recharge (artificial) Improved conveyance system Improved irrigation efficiency Improved management processes Precision agriculture Protection of wetlands, riverbanks, and buffer zones	Rainwater harvesting Spring development Storage structures/dams/reservoirs Stormwater management Stronger and more capable institutions Stronger licensing and regulations Stronger policies and plans Water harvesting and reuse Water pollution control Water pricing and tariffs Water rights recognised Watershed management Use of indigenous and local knowledge

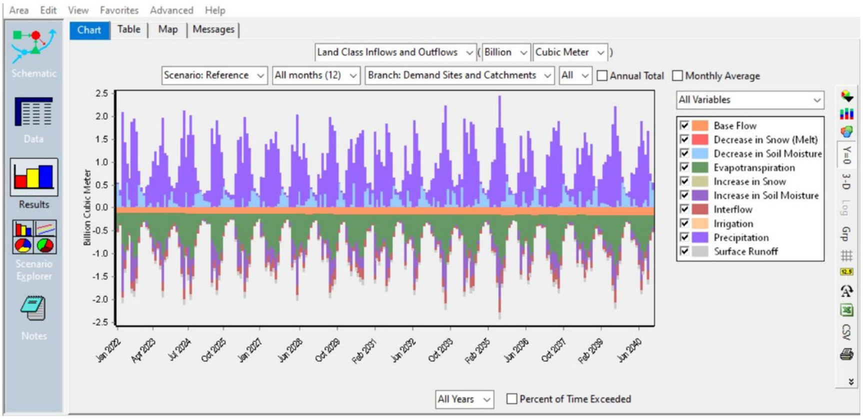

Figure 10.5 Results of the PSD process: scenarios in the WEAP model. (Credit: Adey Nigatu Mersha).

participatory scenario development process including the identification of key problems, the major drivers of change, and suggested adaptation options.

The results of the PSD were then applied in an ongoing water allocation modelling process for the sub-basin (Figure 10.5). The variables used to define metrics against the values of the different scenarios in the WEAP modelling platform include demand-side savings, loss and reuse, supply augmentation, and demand sites' priority for supply. Likewise, the set of evaluation criteria built in the WEAP model, such as water demand, supply delivered, unmet demand, and streamflow at selected stretches of the river, were set to measure the performance of scenarios and to prioritise accordingly.

The scenarios and test results were subsequently validated in another multi-stakeholder workshop (Figure 10.6). Researchers facilitated a feedback process through a series of active group discussions that took place in breakaway

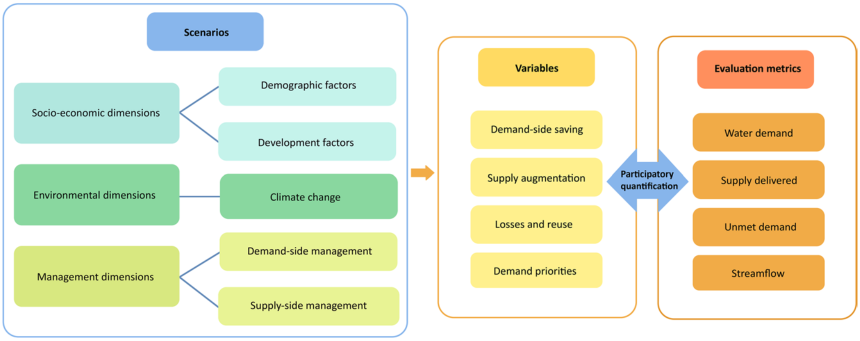

Figure 10.6 Results of the PSD process: validating scenarios through participatory quantification. (Credit: rootsandwings.design).

settings as well as reflection sessions, where we asked stakeholders to verify the plausibility of the applied framework for long-term water resource planning.

Conclusion

A methodical PSD approach and the integration of the resulting scenarios into hydrologic modelling tools enables risk-based assessment for a more holistic picture of water resource systems and the diverse implications of global change processes on multiple system variables. In the past, formulation of scenarios for representation of future development and adaptation options in hydrologic modelling operations for water demand–supply analysis and water allocation planning have often relied on top-down assumptions, without the participation of the target communities and stakeholders. This particular case study has shown that it is, in fact, crucial to include such stakeholders: water resource decision-making requires careful, meticulous, and participatory processes, such that planning contexts are well understood and the views and interests of diverse stakeholders are represented in the analysis and related basin-wide decisions. However, the limitations of this participatory process might be the required level of representation of the diverse stakeholders in a way that all voices are heard and that 'no one is left behind'. This requires a critical and comprehensive mapping of stakeholders, identifying the respective levels and stages of participation in the participatory systems modelling process as well as sufficient time and logistical arrangements.

REFERENCES

Bantider A., Tadesse B., Mersha A. N., Zeleke G., Alemayehu T., Nagheeby M. and Amezaga J. (2023). Voices in shaping water governance: exploring discourses in the Central Rift Valley, Ethiopia. *Water*, **15**(4), 803, https://doi.org/10.3390/w15040803

Berke P. and Conroy M. (2000). Are we planning for sustainable development?: An evaluation of 30 comprehensive plans. *Journal of the American Planning Association*, **66**(1), 21–33, https://doi.org/10.1080/01944360008976081

Brown J. and Isaacs D. (2005). The World Café: Shaping our Futures Through Conversations That Matter. Berrett-Koehler Publishers, San Francisco, California, US. https://www.bkconnection.com/books/title/the-world-cafe (accessed 6 June 2024)

Chan N. W. (2009). Issues and challenges in water governance in Malaysia. *Iranian Journal of Environmental Health Science & Engineering*, **6**(3), 143–152. https://www.bioline.org.br/pdf?se09022 (accessed 6 June 2024)

Chang W.-L. and Chen S.-T. (2015). The impact of World Café on entrepreneurial strategic planning capability. *Journal of Business Research*, **68**(6), 1283–1290, https://doi.org/10.1016/j.jbusres.2014.11.020

Choong W. W. and Neo S. M. (2022). From Exploratory Research to Action Research: Co-Creation Workshop to Resolve the Johor River-Related Issues Among the Stakeholders. Paper presentation, World Social Marketing Conference, 5–7 September, Brighton, UK.

Di Napoli I., Dolce P. and Arcidiacono C. (2019). Community trust: a social indicator related to community engagement. *Social Indicators Research*, **145**(2), 551–579, https://doi.org/10.1007/s11205-019-02114-y

Dong C., Schoups G. and van de Giesen N. (2013). Scenario development for water resource planning and management: A review. *Technological Forecasting and Social Change*, **80**(4), 749–761, https://doi.org/10.1016/j.techfore.2012.09.015
Fouché C. and Light G. (2010). An invitation to dialogue: 'The World Cafe' in social work research. *Qualitative Social Work*, **10**(1), 28–48, https://doi.org/10.1177/1473325010376016
Fullarton C. and Palermo J. (2008). Evaluation of a large group method in an educational institution: The World Café versus large group facilitation. *Journal of Institutional Research*, **14**(1), 109–117. https://files.eric.ed.gov/fulltext/EJ1055582.pdf (accessed 16 April 2024)
Hamzah J., Habibah A., Buang A., Jusoff K., Toriman M. E., Mohd Fuad M. J., Er A. C. and Azima A. M. (2012). Flood disaster, impacts and the tourism providers' responses: The Kota Tinggi experience. *Advances in Natural and Applied Sciences*, **6**(1), 26–32. https://www.aensiweb.com/old/anas/2012/26-32.pdf (accessed 16 April 2024)
Huang Z., Yuan X. and Liu X. (2021). The key drivers for the changes in global water scarcity: water withdrawal versus water availability. *Journal of Hydrology*, **601**, 126658, https://doi.org/10.1016/j.jhydrol.2021.126658
Khalid R. M., Mokhtar M. B., Jalil F., Ab Rahman S. and Spray C. (2018). Legal framing for achieving 'good ecological status' for Malaysian rivers: are there lessons to be learned from the EU Water Framework Directive? *Ecosystem Services*, **29**, part B, 251–259, https://doi.org/10.1016/j.ecoser.2017.06.015
Kumar A., Vidyarthi S. and Prakash P. (2020). City Planning in India, 1947–2017. 1st edn, Routledge India, London, https://doi.org/10.4324/9781003055969
Mahmoud M., Liu Y., Hartmann H., Stewart S., Wagener T., Semmens D., Stewart R., Gupta H., Dominguez D., Dominguez F., Hulse D., Letcher R., Rashleigh B., Smith C., Street R., Ticehurst J., Twery M., van Delden H., Waldick R., White D. and Winter L. (2009). A formal framework for scenario development in support of environmental decision-making. *Environmental Modelling & Software*, **24**(7), 798–808, https://doi.org/10.1016/j.envsoft.2008.11.010
Mekonnen M. M. and Gerbens-Leenes W. (2020). The water footprint of global food production. *Water*, **12**(10), 2696, https://doi.org/10.3390/w12102696
Mersha A. N., Bantider A., Alamirew T., Alemayehu T. and Zeleke G. (2023). Water Resources Management and Use in the Central Rift Valley Basin, Ethiopia. Working Paper No. 6, Water and Land Resources Centre, Addis Ababa University, Addis Ababa, Ethiopia. https://wlrc-eth.org/wp-content/uploads/2024/01/Water-Resources-Management-and-use-in-the-CRV.pdf (accessed 17 April 2024)
Obaid H. A. and Shahid S. (2017). Soil erosion susceptibility of Johor River basin. *Water and Environment Journal*, **31**(3), 367–374, https://doi.org/10.1111/wej.12252
Ocampo-Melgar A., Barría P., Chadwick C. and Rivas C. (2022). Cooperation under conflict: participatory hydrological modeling for science policy dialogues for the Aculeo Lake. *Hydrology and Earth System Sciences*, **26**(19), 5103–5118, https://doi.org/10.5194/hess-26-5103-2022
Rahman S. and Ching G. H. (2020). Tourism in Johor and its potential. In: Johor – Abode of Development?, F. E. Hutchinson and S. Rahman (eds.), ISEAS Publishing, Singapore, pp. 183–202, https://doi.org/10.1355/9789814881289-016
Ritch E. L. and Brennan C. (2010). Using World Café and drama to explore older people's experience of financial products and services. *International Journal of Consumer Studies*, **34**(4), 405–411, https://doi.org/10.1111/j.1470-6431.2010.00881.x
Saad M., Husin N. A., Rosman S. N. H., Husain R. and Abdul Latif @ Bapoo L. (2023). The nexus of community perception on turning idyllic Panchor town into a future

river tourism destination. *Cogent Social Sciences*, **9**(2), 2253021, https://doi.org/10.1080/23311886.2023.2253021

Saimy I. S. and Yusof N. A. M. (2013). The need for better water policy and governance in Malaysia. *Procedia – Social and Behavioral Sciences*, **81**, 371–375, https://doi.org/10.1016/j.sbspro.2013.06.445

Shafie A. (2009) Extreme Flood Event: A Case Study on Floods of 2006 and 2007 in Johor, Malaysia. Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado, US. https://www.engr.colostate.edu/~pierre/ce_old/Projects/linkfiles/Atikah%20Shafie%20Johor_final_121009.pdf (accessed 6 June 2024)

Speed R., Yuanyuan L., Le Quesne T., Pegram G. and Zhiwei Z. (2013). Basin Water Allocation Planning: Principles, Procedures and Approaches for Basin Allocation Planning. UNESCO, Paris. https://unesdoc.unesco.org/ark:/48223/pf0000220875 (accessed 6 June 2024)

UN Environment Programme (UNEP) (2017). UN Environment Annual Report 2017. https://www.unep.org/resources/un-environment-annual-report-2017 (accessed 17 April 2024)

van Vliet M. T., Jones E. R., Flörke M., Franssen W. H. P., Hanasaki N., Wada Y. and Yearsley J. R. (2021). Global water scarcity including surface water quality and expansions of clean water technologies. *Environmental Research Letters*, **16**(2), 024020, https://doi.org/10.1088/1748-9326/abbfc3

Weng S. Q., Huang G. H. and Li Y. P. (2010). An integrated scenario-based multi-criteria decision support system for water resources management and planning: a case study in the Haihe River Basin. *Expert Systems with Applications*, **37**(12), 8242–8254, https://doi.org/10.1016/j.eswa.2010.05.061

Woodhouse P. and Muller M. (2017). Water governance: an historical perspective on current debates. *World Development*, **92**, 225–241, https://doi.org/10.1016/j.worlddev.2016.11.014

Yates D., Sieber J., Purkey D. N. and Huber-Lee A. (2005). WEAP21: a demand-, priority-, and preference-driven water planning model. *Water International*, **30**(4), 487–500, https://doi.org/10.1080/02508060508691893

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Chapter 11

Citizen science

Zulfaqar Sa'adi, Prabhakar Shukla, Likimyelesh Nigussie and Tilaye Worku Bekele

Many water bodies around the world remain blighted by a lack of available information and regular monitoring, making it difficult to identify change and discover early signs of water-related hazards and threats to people's lives and livelihoods. Citizen science has a great potential to fill these data gaps (Babiso *et al*., 2023). Researchers can work with communities to enable citizens to collect and manage their own data, gaining important information for model validation while also empowering locals to engage in decisions about water management. In this chapter, authors present case studies that demonstrate the multiple benefits of citizen science, from enhancing community understanding of their environment to resolving data gaps for risk assessment and modelling, leading to better decision-making.[1]

11.1 EDUCATION-DRIVEN CROWD-BASED RAINFALL OBSERVATION IN JOHOR RIVER BASIN, MALAYSIA

Zulfaqar Sa'adi

In the context of Malaysia, the Johor River Basin (JRB) plays a pivotal role in supporting diverse ecosystems, agriculture, and urban centres (Sa'adi *et al*., 2024a). Given its significance, accurate and timely monitoring of rainfall in this region is essential for effective water resource management, flood prediction, and infrastructure planning (Fairudz Jamaluddin *et al*., 2022). Traditionally,

[1] There are many different levels of participation within different models of citizen science. We recommend Wolff (2021) for types of people-centred approaches to flood risk reduction, and Haklay (2013) for an overview and typology of participation.

meteorological data collection has been the domain of government agencies and meteorological stations, employing sophisticated instruments and advanced technologies. However, the limitations of these centralised systems, including sparse spatial coverage and high operational costs, have spurred the exploration of alternative methodologies. Crowd-based data collection, leveraging the ubiquity of smartphones and the enthusiasm of the public, presents an innovative way to overcome these limitations (Araujo *et al*., 2020; van Emmerik *et al*., 2020).

Crowd-based rainfall observations can complement existing monitoring networks and facilitate data collection in regions where data might otherwise be unavailable. To this end, we created the RainCrowd project. RainCrowd uses education and citizen science for continuous rainfall observations, capturing both qualitative and quantitative spatio-temporal information relating to rainfall events in the JRB. Physical sessions for this project were held at Recreational Forest located within the Universiti Teknologi Malaysia (UTM), involving 16 students and eight teachers, who collected data from January to March 2024. Then, various high schools, situated in the JRB, were carefully chosen to ensure the collected data aligned with the specific environmental context of the JRB. Involving the local community in this activity promotes engagement, empowerment, and education, giving students the valuable opportunity to learn about climate change, data collection, and citizen science processes.

Developing the module and resource

It is crucial to shore up the educational aspect of a citizen science project before embarking on data collection, because it ensures that participants have the necessary knowledge and skills to effectively contribute to scientific endeavours (Lüsse *et al*., 2022). RainCrowd, for example, aims to train students to become citizen scientists, who can play an important, long-term part in collecting rainfall data. To that end, we developed Sahabat Air, a learning module and educational resource. The citizen science monitoring method is introduced as a key part of the module, encouraging community involvement and ensuring participants understand the active role they can play in addressing climate change. This module was specifically prepared for high school students, but it is applicable to individuals of all ages. The theoretical component of the course was delivered online, while the practical component of the course was delivered offline, to ensure participants were confident in their ability to apply their knowledge and contribute to the citizen science rainfall monitoring process. The course was tailored to the conditions of the JRB, which experiences increasingly frequent, intense rainfall, with over 41% of days of rain annually (Sa'adi *et al*., 2024b) (Figure 11.1).

These courses enabled participants to enhance their understanding of the fundamental concepts and frameworks of climate change, facilitating more effective and informed engagement in subsequent citizen science activities. It was evident that certain terms commonly associated with climate change required clarification, such as the distinction between 'weather' and 'climate', the disparity between 'climate change' and 'climate change impact', and

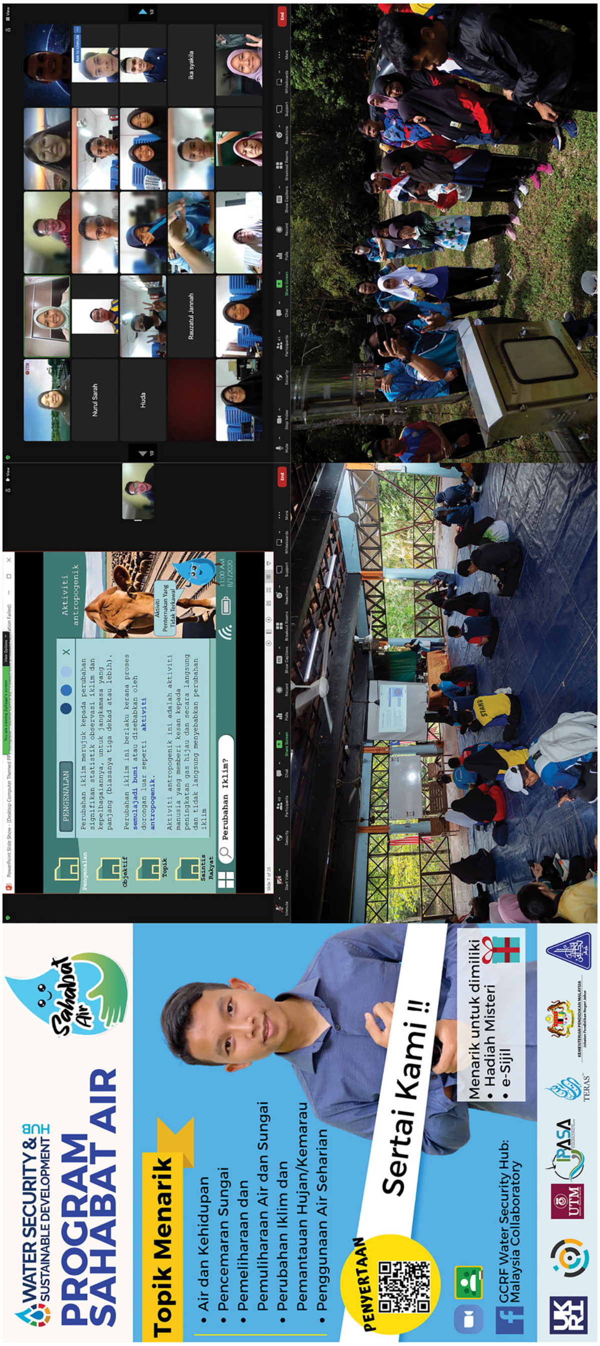

Figure 11.1 Educational activities delivered online and offline with participants from selected high schools. (Credit: Zulfaqar Sa'adi).

the connection between ‘global warming’ and ‘climate change’. Answering questions and clarifying key concepts during the course helped to prevent potential misinterpretation, ensuring participants shared a common baseline understanding. Consequently, this preparation not only enhanced the quality of data collection and interpretation but also fostered greater engagement with and deeper understanding of the project’s objectives and outcomes among participants. We also made sure to employ the Malay language across the educational and citizen science platforms to ensure accessibility, inclusivity, and cultural relevance for the local community, while also promoting the national language and identity.

The challenges of community-generated data

RainCrowd relies on data submitted by users and the community. However, users only have limited information on how to maximise the delivery of high-quality scientific observations: there is currently a lack of comprehensive guidance or strategies to help users optimise the accuracy and reliability of their contributions. This gap in information raises questions about how to effectively standardise data collection methods, validate observations, and minimise potential biases or inaccuracies inherent in citizen science initiatives.

In addition, it is crucial to involve and retain a wide range of citizen scientists for data collection, but this can also represent the biggest challenge for projects involving citizen scientists (Arienzo *et al.*, 2021). Recruiting a diverse, representative, yet qualified group of participants can be tricky, especially if the project requires specialised knowledge or skills. Additionally, maintaining participants’ interest and motivation over time may be difficult, particularly if the project is lengthy or if volunteers encounter obstacles or frustrations during data collection (Paul *et al.*, 2020). Furthermore, ensuring the data collected by citizen scientists is both high-quality and reliable can be a major challenge (Njue *et al.*, 2019). Without proper training, guidance, and support, participants may inadvertently introduce errors or biases into their observations, compromising the integrity of the data (Fraisl *et al.*, 2022). Added to this, without adequate mechanisms for validation and quality control, it can be challenging to assess the accuracy and consistency of citizen-generated data.

The benefits of community-generated data

As a result, the citizen science project in the JRB is closely tied to the Sahabat Air programme, which facilitates consistent and close participation of researchers at UTM alongside citizen scientists (who are themselves continuously trained to improve their data collection techniques). The citizen scientists are then empowered to collect and translate local rainfall data through the RainCrowd platform, which offers a plethora of beneficial features, particularly in enriching rainfall data and engaging its participants. Firstly, it provides continuous education about climate science and rainfall monitoring, enabling ongoing learning and knowledge dissemination in the community. Additionally, self-training online tutorials are available on the platform, equipping participants with the necessary skills and knowledge to contribute effectively to the project. One of RainCrowd's key strengths is its inclusivity, as it is accessible to individuals of all ages, encouraging diverse participation.

Moreover, the project collects both quantitative and qualitative data to enrich the understanding of local rainfall patterns. Qualitative data, like perceptions of rainfall events, including observations on intensity, timing, and impacts, complements numerical rainfall data, offering contextual insights into how rainfall events are experienced by the community. It also enables real-time reporting of rainfall observations, facilitating prompt responses and action if necessary.

Finally, RainCrowd supplements data from existing rain gauges, enhancing the accuracy and reliability of rainfall measurements – indeed, its data can be used for rainfall station validation. What's more, participants can contribute additional data such as the timing and frequency of rainfall, specific locations, and observations on wind, lightning, cloud cover, rainbows, and other meteorological phenomena, further enriching the dataset.

Conclusion

RainCrowd serves as a valuable platform for community engagement, education, and the collection of comprehensive rainfall data for various purposes, including quantitative and qualitative data collection, real-time flood reporting, enhanced understanding of rainfall events through individual perception, and validation of station data, as demonstrated by Figure 11.2. For the rainfall event described in this figure, multiple people in close proximity submitted observations, thus improving spatial coverage, validating local station data, and increasing confidence in the findings. With the option to make rainfall observations over a predetermined period ranging from one month to six months, citizen scientists can significantly contribute to enhancing the quality of rainfall data collected in their locality. This data can then complement and enrich existing datasets, ultimately serving the interests of relevant local stakeholders. The results of citizen science approaches to rainfall monitoring are encouraging, indicating that RainCrowd is a promising way to supplement existing observation networks and obtain valuable data.

The ongoing collaboration with the Johor Educational Department will also help to train additional citizen scientists from various educational levels, including primary school, high school, and tertiary institutions. This will facilitate broader citizen science data collection efforts nationwide. RainCrowd continues to evolve to support its own sustainability, now offering a new module designed to train the trainers themselves: this module will focus on equipping selected individuals with the necessary knowledge, skills, and resources to effectively train new participants in using RainCrowd for rainfall monitoring. Thus, the project empowers people to educate and support others in becoming citizen scientists.

As climate change increasingly impacts weather patterns, the need for decentralised and community-driven rainfall observation approaches is becoming ever more apparent. This is because such approaches focus on gathering localised data and insights, which are essential for understanding and responding to the evolving impacts of climate change at the community

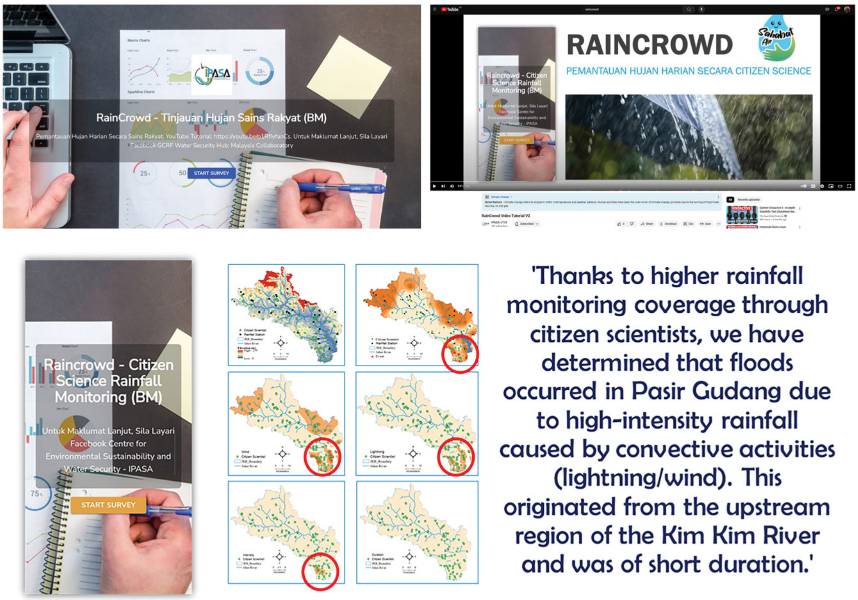

Figure 11.2 The RainCrowd interface, YouTube tutorial, and the output prompted from qualitative and quantitative rainfall monitoring based on citizen science in the JRB. (Credit: Zulfaqar Sa'adi).

level. RainCrowd's inclusion of a self-training element ensures the longevity of this approach, while also contributing to the growing body of literature on crowd-based rainfall monitoring. This underscores the potential synergy between education, public engagement, and scientific data collection, all of which are crucial aspects to consider when addressing the complex challenges of water resource management amid a changing climate.

11.2 LEVERAGING CITIZEN SCIENCE FOR URBAN FLOOD MANAGEMENT IN NCT DELHI, INDIA: THE AAB PRAHARI APP

Prabhakar Shukla

Urban flooding in the National Capital Territory (NCT) of Delhi is a multifaceted challenge impacted by rapid urbanisation, inadequate drainage systems, and the escalating effects of climate change (Kumar, 2023). The city's low-lying areas, often densely populated, are particularly vulnerable, experiencing frequent waterlogging and infrastructure damage during heavy rainfall events. And in the context of Delhi, the current approach to flooding revolves around reactive measures rather than proactive prevention. Authorities primarily focus on clearing drainage systems, desilting water bodies, and deploying pumps during heavy rainfall events – but this approach is insufficient due to several factors. Firstly, urbanisation and improper land use planning have led to increased surface runoff, exacerbating flooding risks. Compounding this, there is a lack of real-time data on rainfall intensity, water levels, and drainage capacity, hindering timely and effective decision-making. Without accurate and up-to-date information, authorities struggle to anticipate and respond promptly to flooding events, resulting in inadequate measures and inefficient resource allocation. In short, the absence of real-time data severely impacts the authorities' ability to mitigate flood impacts and safeguard the city's infrastructure and residents.

To address this complex issue, a comprehensive approach that integrates improved drainage infrastructure, sustainable urban planning practices, and citizen science for improved flood management strategies is needed. In response to this urgent need, we developed a pioneering mobile application called 'AAB Prahari' (DD News, 2022) that uses citizen observations and crowdsourced data to enhance existing datasets.

In the specific context of Delhi, citizen science plays a crucial role in water management due to the city's complex urban environment and the challenges it faces with regard to water quality, availability, and flooding. In creating a citizen science app, we aimed to leverage technology and public participation to address water issues (including urban flooding and solid waste management) effectively. This initiative is significant as it enables anyone with a smart phone to contribute to data collection, allowing for a more comprehensive understanding of the city's flooding dynamics, such as spatial distribution. The AAB Prahari app represents a novel approach to Delhi's water management landscape: for the data gatherer, through the integration of advanced technology and user-friendly features; and for the data analyser, through the creation of a centralised platform for data collection, integration, and processing.

The AAB Prahari app for real-time flood reporting was created through a collaboration between the Indian Institute of Technology Delhi (IITD) and the Delhi Jal Board, as an endeavour to bridge data gaps in official records, as existing data often fails to capture real-time information crucial for effective flood response. Alongside the app, we introduced awareness campaigns to engage citizen scientists: these campaigns aimed to provide information about the app's functionalities, its importance in flood monitoring, and how participation could contribute to improved flood management. Feedback from users was promising, indicating their willingness to engage with the app and their overall comprehension of the purpose of data collection. Subsequent efforts to enhance users' awareness of how their contributions directly influence flood response strategies are ongoing – this is essential for sustaining user engagement and ensuring the app's continued effectiveness in supplementing formal reporting to generate a timely flood response.

The app was officially launched in September 2022. Anyone can download the app, which uses a citizen science approach that encourages individuals to report real-time flooding incidents (Figure 11.3).

Through the app, users can capture and send detailed information, including photos and the depth of flooding at specific locations, with location data (latitude and longitude) automatically geotagged, to a central server. This

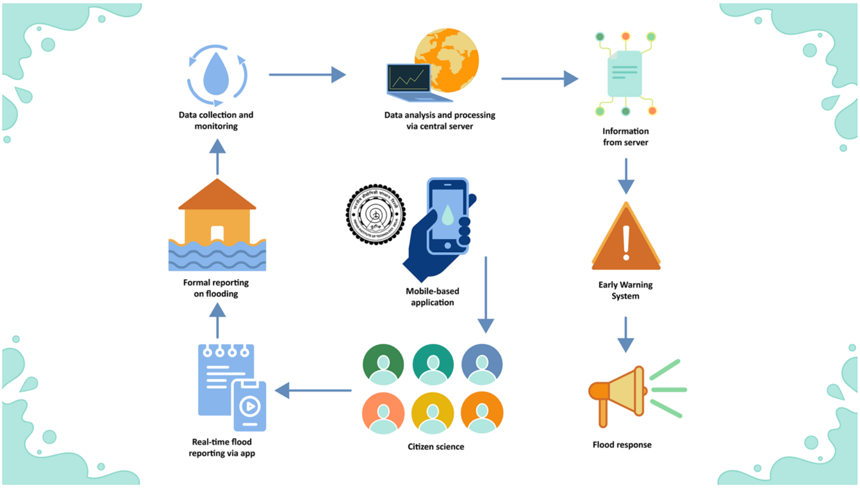

Figure 11.3 Flow diagram illustrating the AAB Prahari app. (Credit: rootsandwings.design).

crowdsourced data assists water authorities to develop and deploy an early warning system for urban floods through validation of IITD's hydraulic model. In addition, the citizen observations, comprising pictures and measurements on the Jalsuraksha server (Jalsuraksha, 2023), enable authorities to promptly assess the situation and implement effective response measures, such as improved drainage infrastructure through the deployment of pumps.

Figure 11.4 illustrates flooding incidents reported by users through the AAB Prahari app. Incidents were reported at over 100 locations, indicating that Delhi experienced numerous high-intensity rainy days in July (19.5 mm), August (18 mm), September (64.5 mm), and October (76 mm).

The AAB Prahari app represents a significant advancement in urban flood management, offering a platform for public participation and providing valuable insights into the frequency, severity, and location of flooding incidents. Engaging citizens in flood management efforts, as this app does, yields several benefits for different stakeholders.

Firstly, for app users, participation in flood management through citizen observations fosters greater awareness of their environment and helps them to understand flood risks. Secondly, for researchers, citizen science-generated data enriches research endeavours by providing real-time, ground-level insights into flooding patterns, impacts, and vulnerabilities. This crowdsourced data improves understanding of flood dynamics and informs the development of more effective mitigation strategies. Thirdly, for authorities, citizen engagement can improve flooding responses, as the information gathered via the app supplements official data to enable more comprehensive and timely decision-making, as well as better resource allocation, response effort prioritisation, and communication with affected areas, ultimately enhancing the overall effectiveness of flood management initiatives in Delhi.

Figure 11.4 An illustration of flooding incidents reported by citizens through the AAB Prahari app in Jalsuraksha server. (Credit: Prabhakar Shukla).

Various authorities, including the Irrigation and Flood Control Department and the Public Works Department of NCT Delhi alongside the Delhi Jal Board, have acknowledged the utility of the app in providing real-time data on flood incidents. They have subsequently committed to integrating it into their response protocols.

For those considering developing a citizen science-based flood reporting app for their city, key lessons from our experience creating the AAB Prahari app include that it's crucial to involve government agencies, researchers, and the local community from the outset, ensuring support and buy-in. Awareness campaigns are also essential to facilitate reliable data collection and promote community efforts. Technological features such as real-time data collection and GIS mapping enhance the app's effectiveness, while transparency and credibility build trust with authorities. Finally, customising solutions to the local context ensures relevance and applicability, ultimately contributing to more effective flood management strategies on a local and a global scale.[2]

11.3 COMMUNITY-BASED FLOOD EARLY WARNING SYSTEMS IN THE AKAKI CATCHMENT, ETHIOPIA

Likimyelesh Nigussie and Tilaye Worku Bekele

Floods were responsible for 44% of natural hazard-related disasters from 2000–2019. Floods impacted the highest number of people – 1.6 billion

[2] With thanks to Sandhya Rao.

globally (41% of the total number of people affected by disasters) – and are the most common type of disaster, averaging 163 events per year (CRED and UNDRR, 2020). Vulnerable populations are at the highest risk from floods due to socio-economic, political, and social inequalities, as well as a lack of effective adaptation measures (Ngcamu, 2023). As such, effective response to future flood disasters will rely on the implementation of strategies that focus on risk prevention, vulnerability reduction, and preparedness, particularly in vulnerable communities (IFRC, 2020).

Early warning systems (EWS) play a crucial role in disaster risk management, particularly in mitigating the impact of floods. The United Nations Office for Disaster Risk Reduction (UNDRR) defines EWS as a set of capacities, data, information, and knowledge that allows individuals and communities exposed to hazards to prepare and evacuate in an appropriate manner and in adequate time to reduce the likelihood of loss of life, personal injury, losses, and damages (UNDRR, 2009). According to the UNDRR Sendai Framework (UNDRR, 2015), EWS should have four complementary elements: risk knowledge, monitoring, communication of warnings, and response capability.

Communicating flood risk in the Akaki

The Akaki, a headwater catchment in Ethiopia's Awash Basin, is prone to flooding due to factors like low elevation, overcrowding, inadequate drainage systems, and rapid housing development (Feyissa *et al.*, 2018). At-risk communities, including low-income residents in informal settlements with poor conditions, face significant economic and social difficulties, including loss of life, property, livestock, and farmland, as well as related mental stress (Feyissa *et al.*, 2018).

Various government agencies implement formal flood EWS to protect at-risk communities from flood damage. Specifically, the Addis Ababa Water and Sewerage Authority (AAWSA) disseminates early warning information about the release of water from the Legedadi reservoir, while the Ethiopian Meteorology Institute (EMI) disseminates rainfall forecasts using one-way communication channels (such as radio and television). However, techno-centric, top-down EWS are often ineffective and fail to deliver reliable warning information to at-risk communities (Canwat, 2023). This is due to several reasons including (i) a lack of details regarding the timing and magnitude of potential flooding, (ii) insufficient communication and collaboration among stakeholders, and (iii) exclusion of local knowledge and activities in at-risk communities in the formal flood EWS.

To mitigate the issue, at-risk communities complement the formal flood EWS with their own informal communication channels. These include door-to-door visits, phone calls, text messages, whistles, and shouting to disseminate warning information. Formal flood EWS and informal community systems have their strengths and weaknesses. Formal flood EWS, despite their technological advancements, may not provide accurate or reliable information that is context-specific due to lack of local knowledge and resources (Parker & Handmer, 1998). On the other hand, informal flood EWS rely on local knowledge and practices but face limitations when it comes to technology, reliability, coordination, and adaptability (Parker & Handmer, 1998). As a result, the systems work in silos, decreasing the effectiveness of the overall system.

Integrating citizen science for flood risk management

The Sendai Framework encourages ‘a people-centered approach’ to flood risk (UNDRR, 2015). This has led to the rise of community-based flood early warning systems (CBFEWS), based on citizen science, low-cost technology, and timely dissemination of information. The aim of CBFEWS is to increase the awareness and preparedness of at-risk communities and decrease their vulnerability to natural hazards (Garcia *et al*., 2014). We used a citizen science approach to pilot and implement CBFEWS in the Akaki catchment (Figure 11.5).

Figure 11.5 A citizen scientist making notes about flooding in his logbook. (Credit: Tilaye Worku Bekele).

Figure 11.6 Citizen scientists out in the field. (Credit: Tilaye Worku Bekele).

To establish CBFEWS using citizen science, researchers from the International Water Management Institute, in collaboration with the at-risk communities, identified a total of 11 citizen scientists (six women and five men) from said communities to co-manage the system. The selection process was inclusive and representative, involving a diverse range of age groups and occupations, including farmers, sand miners, daily labourers, stay-at-home spouses, and football players. Citizen scientists expressed that they were drawn to CBFEWS because of their passion, as well as the networking and educational opportunities the initiative offered, but they were also wary of the substantial time, money, and energy commitment. Balancing dedication, benefits, and costs was crucial (Figure 11.6).

The piloted citizen science approach in CBFEWS integrates formal flood EWS with at-risk community activities, co-generating flood risk knowledge, facilitating transdisciplinary collaboration, and establishing a feedback mechanism.

As this video shows, a wide range of stakeholders are involved in CBFEWS, including at-risk communities, citizen scientists, staff from AAWSA and EMI, and researchers from the International Water Management Institute and

Addis Ababa University. CBFEWS stakeholders collaborate through direct communication, training programmes, and workshops. In addition, researchers and citizen scientists develop flood data collection guides to document and share causes and impacts of, as well as responses to, flooding in their localities, contributing to the field of flood research. Moreover, the Addis Ababa Adaptation Network platform promotes transdisciplinary collaboration and reliable information exchange.

Benefits and challenges of CBFEWS

The Akaki flood EWS has significantly improved due to the meaningful engagement of citizen scientists in CBFEWS and subsequent two-way communication. For example, the collaboration of citizen scientists, researchers, and Legedadi dam operators has generated valuable insights with regard to the correlation between water discharge from the Legedadi dam and the depth and extent of floods in Akaki. Among other things, this has enabled accurate water release timing, which has helped to reduce night-time flooding. To name another example, thanks to their collaboration with researchers and EMI rainfall forecasting experts, citizen scientists have been able to get improved access to rainfall forecast information and training to convert the information into flood warnings, fostering further knowledge co-generation on flood risk.

However, there have also been challenges in implementing CBFEWS using citizen science in the Akaki catchment. Firstly, due to the absence of institutional structures, CBFEWS relies heavily on specific personal connections, affecting the long-term sustainability of the pilot. Secondly, the citizen scientists' contribution and motivation vary widely depending on their age, gender, livelihood and so on., shaping how the overall system performs. Thirdly, insufficient resources to design and implement CBFEWS in a wider context hamstrings the initiative's ability to engage diverse social groups and/ or reach a wide audience with the resulting warning information.

Overall, our results show that the application of citizen science in CBFEWS improves local responsiveness and the performance of flood EWS. Specifically, it enhances collaboration among stakeholders, helping to empower communities, build trust, and instil ownership. However, limited institutional structures and capacities affect the long-term sustainability and performance of piloted CBFEWS. To address these challenges, we need to establish institutional structures and operational guidelines, allocate adequate resources, and consider further diverse engagement and incentive mechanisms at the local level.

REFERENCES

Araujo G., Legaspi C., Matthews K., Ponzo A., Chin A. and Manjaji-Matsumoto B. M. (2020). Citizen science sheds light on the cryptic ornate eagle ray *Aetomylaeus vespertilio*. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **30**(10), 2012–2018, https://doi.org/10.1002/aqc.3457

Arienzo M. M., Collins M. and Jennings K. S. (2021). Enhancing engagement of citizen scientists to monitor precipitation phase. *Frontiers in Earth Sciences*, **9**, 617594, https://doi.org/10.3389/feart.2021.617594

Babiso W. Z., Ayano K. K., Haile A. T., Keche D. D., Acharya K. and Werner D. (2023). Citizen science for water quality monitoring in the Meki River, Ethiopia: quality assurance and comparison with conventional methods. *Water*, **15**(2), 238, https://doi.org/10.3390/w15020238

Canwat V. (2023). Social innovations and drivers in flood early warning systems: a community-based transboundary perspective from Elegu flood plain in Northern Uganda. *Journal of Flood Risk Management*, **e12930**, https://doi.org/10.1111/jfr3.12930

Centre for Research on the Epidemiology of Disasters (CRED) and United Nations Office for Disaster Risk Reduction (UNDRR). (2020). The Human Cost of Disasters: An Overview of the Last 20 Years (2000–2019). UNDRR, Geneva, Switzerland. http://www.undrr.org/quick/50922 (accessed 6 June 2024)

DD News. (2022). *IITD AAB praharee mobail aip se jal bharaav kee vajahon ka pata lag sakega* ('IITD AAB Prahari' mobile app will help in finding out the causes of water logging). YouTube video, 13 September. https://www.youtube.com/watch?v=yZ-ZOrxlQe4 (accessed 17 April 2024)

Fairudz Jamaluddin A., IkmalNor Mustafa Kamal M. and Helmi Abdullah M. (2022). Comparison between satellite-derived rainfall and rain gauge observation over Peninsular Malaysia. *Sains Malaysiana*, **51**(1), 67–81, https://doi.org/10.17576/jsm-2022-5101-06

Feyissa G., Zeleke G., Gebremariam E. and Bewket W. (2018). GIS Based quantification and mapping of climate change vulnerability hotspots in Addis Ababa. *Geoenvironmental Disasters*, **5**(14), 1–17, https://doi.org/10.1186/s40677-018-0106-4

Fraisl D., Hager G., Bedessem B., Gold M., Hsing P.-Y., Danielsen F., Hitchcock C. B., Hulbert J. M., Piera J., Spiers H., Thiel M. and Haklay M. (2022). Citizen science in environmental and ecological sciences. *Natural Reviews Methods Primers*, **2**(64), https://doi.org/10.1038/s43586-022-00144-4

Garcia C., Frigerio S., Daehne A., Corsini A. and Sterlacchini S. (2014). The relevance of early-warning systems and evacuations plans for risk management. In: Mountain Risks: From Prediction to Management and Governance, T. Van Asch, J. Corominas, S. Greiving, J.-P. Malet and S. Sterlacchini (eds.), Springer, Dordrecht, Netherlands, Vol **34**, pp. 341–364, https://doi.org/10.1007/978-94-007-6769-0_13

Haklay M. (2013). Citizen science and volunteered geographic information: overview and typology of participation. In: Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice), D. Sui, S. Elwood and M. Goodchild (eds.), Springer, Dordrecht, Netherlands, pp. 105–122, https://doi.org/10.1007/978-94-007-4587-2_7

International Federation of Red Cross and Red Crescent Societies (IFRC). (2020). World Disasters Report 2020. Come Heat or High Water: Tackling the Humanitarian Impacts of the Climate Crisis Together. IFRC, Geneva, Switzerland. https://www.ifrc.org/document/world-disasters-report-2020 (accessed 6 June 2024)

Jalsuraksha. (2023). Waterlogging Locations Reported by Citizens Using 'IITD AAB Prahari' Mobile App. IIT Delhi India Collaboratory, Water Security and Sustainable Development in National Capital Territory of Delhi. https://jalsuraksha.iitd.ac.in/barapullah/aab_prahari/showwaterlogging.html (accessed 17 April 2024)

Kumar A. (2023). 'Development gone 'rogue' and the high flood in Delhi'. *The Wire*, 20 July. https://thewire.in/environment/development-rogue-flood-delhi (accessed 17 April 2024)

Lüsse M., Brockhage F., Beeken M. and Pietzner V. (2022). Citizen science and its potential for science education. *International Journal of Science Education*, **44**(7), 1120–1142, https://doi.org/10.1080/09500693.2022.2067365

Ngcamu B. S. (2023). Climate change effects on vulnerable populations in the Global South: a systematic review. *Natural Hazards*, **118**(2), 977–991, https://doi.org/10.1007/s11069-023-06070-2

Njue N., Stenfert Kroese J., Gräf J., Jacobs S. R., Weeser B., Breuer L. and Rufino M. C. (2019). Citizen science in hydrological monitoring and ecosystem services management: state of the art and future prospects. *Science of the Total Environment*, **693**, 133531, https://doi.org/10.1016/j.scitotenv.2019.07.337

Parker D. J. and Handmer J. W. (1998). The role of unofficial flood warning systems. *Journal of Contingencies and Crisis Management*, **6**(1), 45–60, https://doi.org/10.1111/1468-5973.00067

Paul J. D., Cieslik K., Sah N., Shakya P., Parajuli B. P., Paudel S., Dewulf A. and Buytaert W. (2020). Applying citizen science for sustainable development: rainfall monitoring in western Nepal. *Frontiers in Water*, **2**, 581375, https://doi.org/10.3389/frwa.2020.581375

Sa'adi Z., Alias N. E., Yusop Z., Iqbal Z., Houmsi M. R., Houmsi L. N., Ramli M. W. A. and Muhammad M. K. I. (2024a). Application of relative importance metrics for CMIP6 models selection in projecting basin-scale rainfall over Johor River Basin, Malaysia. *Science of the Total Environment*, **912**, 169187, https://doi.org/10.1016/j.scitotenv.2023.169187

Sa'adi Z., Alias N. E., Yusop Z., Ramli M. W. A. and Muhammad M. K. I. (2024b). CHIRPS Rainfall product application for analyzing rainfall concentration and seasonality in Johor River Basin, Malaysia. *Journal of Atmospheric and Solar-Terrestrial Physics*, **256**, 106203, https://doi.org/10.1016/j.jastp.2024.106203

United Nations Office for Disaster Risk Reduction (UNDRR). (2009). 2009 UNISDR Terminology on Disaster Risk Reduction. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland. http://www.undrr.org/quick/10973 (accessed 6 June 2024)

United Nations Office for Disaster Risk Reduction (UNDRR). (2015). Sendai Framework for Disaster Risk Reduction 2015–2030. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland. http://www.undrr.org/quick/11409 (accessed 6 June 2024)

van Emmerik T., Seibert J., Strobl B., Etter S., den Oudendammer T., Rutten M., bin Ab Razak M. S. and van Meerveld I. (2020). Crowd-based observations of riverine macroplastic pollution. *Frontiers in Earth Sciences*, **8**, 298, https://doi.org/10.3389/feart.2020.00298

Wolff W. (2021). The promise of a 'people-centred' approach to floods: types of participation in the global literature of citizen science and community-based flood risk reduction in the context of the Sendai Framework. *Progress in Disaster Science*, **10**, 100171, https://doi.org/10.1016/j.pdisas.2021.100171

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Chapter 12

Co-production

Renu Khosla, Carolina Montoya Pachongo, Sheilja Singh, Federico Pinzón and Andrés Fernando Toro Vélez

Co-production aims to increase community participation in identifying problems and creating solutions; it is therefore fundamental in enabling equitable, redistributive, and integrative water management. In resource-scarce settings, community-based solutions that reduce the risks associated with poor-quality drinking water, sanitation services, and hygiene are vital to ensuring sustainability of the interventions. In this chapter, authors present case studies from rural Colombia and Delhi, India that show how locals' involvement in participatory projects has allowed them to self-manage water, sanitation, and hygiene (WASH) services, helping to improve their general well-being.

12.1 COMMUNITY-BASED WASH SOLUTIONS IN NCT DELHI, INDIA

Renu Khosla, Carolina Montoya Pachongo and Sheilja Singh,

Poor water quality can significantly impact a community's socio-economic, ecological, and health conditions; as such, access to adequate sanitation and safe water is not only a fundamental human right, but also crucial for reducing poverty, promoting equality, and supporting socio-economic development.

When a community is exposed to low-quality water, especially when combined with inadequate sanitation facilities, it can lead to a wide range of health issues (Biswas & Gangwar, 2021; Lin *et al.*, 2022). These include: heavy metals from industry, which, when discharged into water bodies, affect flora and fauna and subsequently the humans consuming the fauna; and microbial contaminants in sewage, such as the bacteria Vibrio cholerae, which causes cholera, and Salmonella typhi, which causes typhoid fever, are major sources of waterborne diseases. All of this leads to increased healthcare costs and reduced quality of life. And in turn, poor water quality can also impact mental health, as having no access to clean water seriously compromises human well-being and development.

In the National Capital Territory of Delhi (NCT Delhi), both water supply volume and water quality vary considerably between districts, contributing to the ongoing water crisis (Biswas & Gangwar, 2021). Recent studies have concluded that the groundwater quality in central and south-east districts of NCT Delhi is substandard, highlighting the need to improve the water supply in the area (Bidhuri & Khan, 2020). As things stand, unregulated groundwater extraction and unauthorised construction hinder the groundwater's ability to recharge and contribute to declining groundwater levels across various parts of the city. In addition, despite various government programmes and initiatives, the quality of water is declining in multiple areas across the city, primarily because of pollution, shortages arising from development and infrastructure projects, and transboundary conflicts. These factors collectively impact the urban environment as well as the quality of life and human survival rate in NCT Delhi (Aijaz, 2020). How our cities are built directly contributes to economic and urban health outcomes; however, as we saw in Chapter 9, improving access to clean water, particularly in informal settlements, is a challenge due to the complex nature of water governance in NCT Delhi.

Access to a decent household toilet is key to improving physical and social well-being. But in overcrowded and dense informal settlements, vulnerable communities typically experience inadequate living conditions and rely on pit latrines, community toilets, or nearby public toilets for their daily basic needs. Life without a toilet is dirty, dangerous, and undignified, compromising the individual's right to water and sanitation as well as impacting public health. It should also be noted that having adequate toilet facilities also often drives improvements in gender equality, education, economics, and the environment.

In this video, Renu Khosla talks to Carolina Montoya Pachongo about her work with residents of the Safeda Basti in Geeta Colony, home to approximately 800 households, located on the western bank of the Yamuna River. In 2011, CURE worked with the community to co-design a simplified sewer line to connect the settlement to the main sewer. The simplified sewer has enabled over 60 households in one street to build individual toilets. This was part of a participatory development project, which was found to bring more than water and sanitation benefits: it led to physical upgrading of the household, increased safety for women and girls, and better access to education for children. The community then led an initiative to replicate the project in other settlements, demonstrating that such projects can empower vulnerable populations to self-manage water and sanitation solutions.

12.2 SOCIO-TECHNICAL INNOVATION FOR WATER QUALITY DATA: INFORMATION SYSTEMS FOR RURAL COMMUNITY WATER MANAGEMENT IN COLOMBIA

Federico Pinzón and Andrés Fernando Toro Vélez,

Currently, 161 million people in Latin America do not have adequate access to safe drinking water and 461 million do not have access to sanitation (ECLAC, 2022). The situation becomes even more complex when you consider the differences between urban and rural areas. In Colombia, the drinking water coverage for urban areas is 97%; for rural areas, by contrast, it is just 59% (Garcia *et al.*, 2015). And these aggregate figures at the national level also hide a class gap, as developed, wealthy communities mostly reside in urban areas, whereas vulnerable communities, including indigenous people and afro-descendants, often reside in rural areas (as well as some informal settlements in cities).

In rural areas of Latin America, the main providers of drinking water are community-based organisations (CBOs). At the end of the 20th century and start of the 21st, various empowerment processes among CBOs gave rise to second-tier regional associations, such as the Association of Community Organisations Providers of Public Services of Water and Sanitation of Colombia (Aquacol) and the Federation of Community Organisations Providers of Rural Residential Public Services of Valle del Cauca (FECOSER). Between them, the two organisations bring together 161 CBOs and 240 128 consumers (Blanco Moreno & Peña-Varón, 2023). The CBOs in Aquacol and FECOSER seek to share knowledge, support each other in solidarity, defend their rights, promote policies, and more. For information on their history, process of associativity, and advancements in recognition, please see Carolina Blanco Moreno's spotlight in Principle 1, Chapter 1.

Promoting associativity and sharing local knowledge is vital to democratise access to data and information, and subsequently make better community-based decisions concerning water supply. Currently, it is difficult for rural community water supply organisations (RCWSOs) to understand reports from the official national platforms because searching for the data is expensive, the interface is challenging to navigate, and these platforms do not offer helpful, locally appropriate information for water administrators and operators. RCWSOs are also expected to upload information to these platforms themselves, with the respective authorities sometimes imposing fines when the information is not uploaded on time. Addressing these challenges requires a two-fold approach, involving (i) the creation of alternative and locally appropriate information systems, and (ii) the transformation of existing technological platforms. Both issues can be more readily addressed by second-tier organisations like Aquacol and FECOSER, which can act as political advocates for RCWSOs as well as channels for technology transfer.

Participatory processes of co-creation

Since 2006, Aquacol has sought to develop a platform to record data related to water supply in a way that is useful and accessible to local community leaders – this essentially involves keeping structured records using basic information and communication technologies that make it easier to operate, maintain, and monitor water systems. But Aquacol has struggled to achieve this objective because the existing system was put in place by national government organisations and continues to serve their interests.

Faced with this situation, Aquacol and the Cinara Institute of the University of Valle have jointly undertaken a participatory process to co-create an innovative community water information system, working with the four RCWSOs in the region that have the highest number of users and that each use different technologies for water treatment (Table 12.1).

Table 12.1 Selection criteria for and technology of the four RCWSOs. (Credit: Andrés Fernando Toro Vélez).

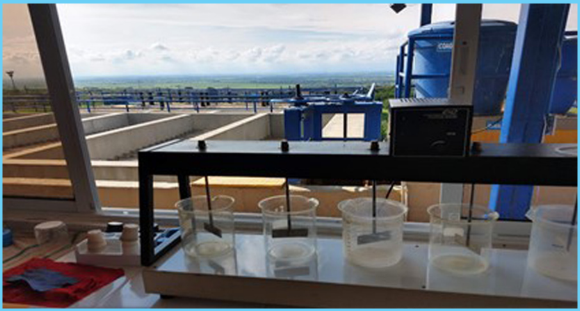
RCWSO Selection Criteria	Technology for Water Treatment
ACUAMONDOMO Number of users: 5000 Treated water flow (litres per second): 22 l/s Partial historical water quality data available GPS equipment available for geo-referencing structures All the information in blueprints	 **FiME** (*filtración multietapa*, Spanish acronym for multi-stage filtration)
ACUASUR Number of users: 17 000 Treated water flow: 40 l/s Hourly logging of water quality data in an analogous manner Willingness to designate operational personnel to oversee data management	 **Conventional water treatment plant** (coagulation, flocculation, sedimentation, and filtration)

Table 12.1 Selection criteria for and technology of the four RCWSOs. (Credit: Andrés Fernando Toro Vélez) (*Continued*) .

RCWSO selection criteria	Technology for water treatment
LA SIRENA Number of users: 5265 Treated water flow: 15 l/s Operators demonstrate profound knowledge of the water utility network structure Previous work in information modelling Connections with trainees from technical institutions	 **FiME** (*filtración multietapa*, Spanish acronym for multi-stage filtration)
ACUANARIÑO Number of users: 1049 Treated water flow: 15 l/s Existing hydraulic modelling process of scenarios for water management Advances in data organisation but high vulnerability in information security	 **OxFi** (*filtración de oxidación*, Spanish acronym for oxidation plus upflow gravel filtration for groundwater)

The co-creation process utilised GIS tools alongside participatory action research to define the gaps and requirements of the system, design a conceptual model, collect field data, perform quality assurance and quality control activities, and finally develop the technical module.[1] In this way, we developed

[1] This development was carried out with Environmental Services Research Institute (ESRI) technology, under ESRI's social responsibility agreement for non-profit organisations, which facilitated the acquisition of licences for Aquacol. GIS technology can be expensive, and hence difficult for some organisations to access and use, unless companies like ESRI are willing to offer it cheaply.

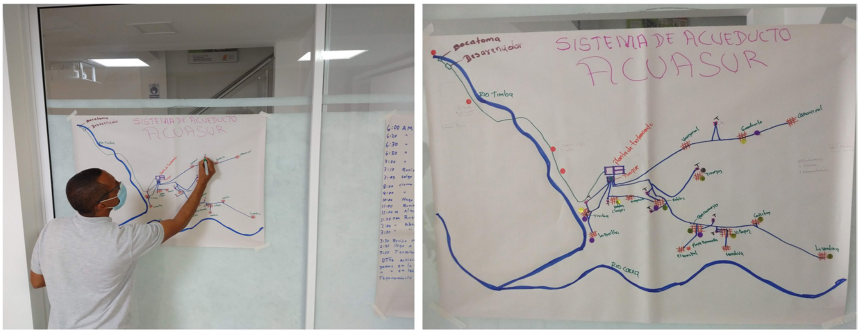


Figure 12.1 Workshop with RCWSOs to formulate the water information system. (Credit: Federico Pinzón).

a bespoke process and system that drew upon community perspectives and needs, thus differing fundamentally from existing official national platforms (Figure 12.1).

The resulting information system is called Nuestra Agua (Our Water). This video documents the challenges faced by RCWSOs and explores the process and benefits of Nuestra Agua for those involved in its creation. Nuestra Agua is a dynamic platform that allows and facilitates the collection, registration, and analysis of information related to RCWSOs.

Resulting outcomes

The co-construction of a community water information system as a socio-technical tool for innovation generated new capacities in both the communities and Aquacol (into which Nuestra Agua has been incorporated) when it comes to managing data and administering the information system. It is now possible for RCWSOs to log and access geo-referenced data at a convenient and detailed scale and to refer to historical data on critical variables for the operation of the water supply system. However, this has generated a new concern: data security. RCWSOs need to feel confident that their information is stored securely to stop sensitive data, for example, information about the structure of the water utility network (the technical cadastre), being used for clandestine or illegal activities.

RCWSOs have also found another unexpected – but perhaps more relevant – way to use this technological platform, besides monitoring the quality, quantity, and continuity of the drinking water system: Nuestra Agua is now being used to

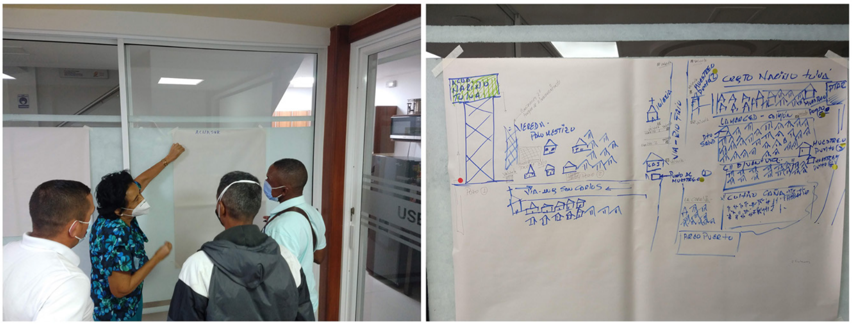


Figure 12.2 Co-creators of Nuestra Agua with Professor Mariela Garcia. (Credit: Federico Pinzón).

register the users of the RCWSO, their economic activities, and their relationship with water consumption, and to review inventories of materials used to repair and extend the networks. The evolution of this co-created tool has generated further ideas for new modules related to leakage management, communication, and reporting across users of the water system. The communities, together with the University of Valle, are now designing methods to monitor the state of the basin, which are to be implemented in the information system in the future.

Through GIS technology, it is possible to collect local and thematic data that the community needs to manage their water at the local level, in addition to providing analysis tools to support the decision-making process and operation of the water supply systems. As a result, communities can now make stronger, more informed decisions with data and information acquired through local technological platforms. This also strengthens the position of the local CBOs, which manage and guarantee their own systems' sustainability as well as ensuring water security in their territories.

All in all, this co-creative alliance between academia and CBOs through participatory action research has led to improvements in methodologies, data management, and local governance: indeed, this case study shows that co-creation processes generate new values related to governance, promoting horizontal relationships between institutions, minimising potential negative outcomes, and strengthening decision-making with high-quality technical information (Li & Tuunanen, 2022; Polo Peña *et al.*, 2014). We want to thank all the communities that participated in the construction of Nuestra Agua, as well as members of Aquacol and researchers at the Cinara Institute, University of Valle, especially Mariela Garcia (Figure 12.2).

REFERENCES

Aijaz R. (2020). Bridging Water Demand and Supply in Delhi: The Potential of Rainwater Harvesting. ORF Special Report 117, Observer Research Foundation, New Delhi, India. https://www.orfonline.org/wp-content/uploads/2020/08/ORF_SpecialReport_117_RainwaterHarvesting.pdf (accessed 19 April 2024)

Bidhuri S. and Khan M. M. A. (2020). Assessment of ground water quality of central and southeast districts of NCT of Delhi. *Journal of The Geological Society of India*, **95**, 95–103, https://doi.org/10.1007/s12594-020-1390-7

Biswas A. and Gangwar D. (2021). Studying the water crisis in Delhi due to rapid urbanisation and land use transformation. *International Journal of Urban Sustainable Development*, **13**(2), 199–213, https://doi.org/10.1080/19463138.2020.1858423

Blanco-Moreno C. and Peña-Varón M. (2023). Relationship between community water management, conceptions, and struggles for justice in Southwest Colombia. *Environmental Justice*, **16**(3), 230–243, https://doi.org/10.1089/env.2022.0065

Garcia M., Peña M. R., Toro A., Cerón V. A., Tamayo S. P., Mena-Aristizábal E., Orjuela V., Morales D., Bolaños S. I., Vidal-Gómez J. and Castro J. E. (2015). Democratisation of water and sanitation governance by means of socio-technical innovation – empowerment, resilience and sustainability: evaluation of an integrated water and sanitation system in a rural community in Colombia. *WATERLAT-GOBACIT Network Working Papers*, **2**(9), Research Projects Series SPIDES – DESAFIO Project, Newcastle upon Tyne, UK and Santiago de Cali, Colombia, https://doi.org/10.13140/RG.2.1.1361.6244

Li M. and Tuunanen T. (2022). Information technology-supported value co-creation and co-destruction via social interaction and resource integration in service systems. *The Journal of Strategic Information Systems*, **31**(2), 101719, https://doi.org/10.1016/j.jsis.2022.101719

Lin L., Yang H. and Xu X. (2022). Effects of water pollution on human health and disease heterogeneity: A review. *Frontiers in Environmental Sciences*, **10**, 880246, https://doi.org/10.3389/fenvs.2022.880246

Polo Peña A. I., Frías Jamilena D. M. and Rodríguez Molina MÁ (2014). Value co-creation via information and communications technology. *The Service Industries Journal*, **34**(13), 1043–1059, https://doi.org/10.1080/02642069.2014.939641

United Nations Economic Commission for Latin America and the Caribbean (ECLAC) (2022). A Transformative Recovery in Latin America and the Caribbean with Basic Drinking Water and Electricity Services as Key Sectors. Briefing note, 18 December. https://www.cepal.org/en/notes/transformative-recovery-latin-america-and-caribbean-basic-drinking-water-and-electricity (accessed 17 April 2024)

doi: 10.2166/9781789062540_0231

Chapter 13

Community leadership

Catalina Trujillo Osorio

We – as individuals and society – need to move away from 'utilitarian environmentalism' approaches to sustainability, that is protecting the environment because of the social and economic benefits we derive from it (Muradian & Gómez-Baggethun, 2021). As we saw in Chapter 3, proponents of ecological justice hold that more-than-human nature has intrinsic value and moral standing in its own right (Washington *et al.*, 2018; Wienhues, 2020). Building on this, the case study in this chapter offers an example of how collaboration centred around an ethics of care can bring about 'transformational change' (Muradian & Gómez-Baggethun, 2021; Narayanaswamy *et al.*, 2023).

13.1 NETWORKS OF COLLECTIVE CARE: COOPERATION FOR CONSERVATION IN A COLOMBIAN WATERSHED

Catalina Trujillo Osorio

In Colombia, water and sanitation coverage has historically been deficient and inequitable at social and environmental levels. For example, although 73% of households currently have drinking water services, only 17% have sanitation coverage (The World Bank, 2020). Additionally, only 5% of the water used for consumption and agricultural production receives any treatment and 60% of the country's rivers present some signs of contamination (IDEAM, 2019), showing the shortcomings of Colombian water infrastructure (Figueroa-Benitez *et al.*, 2023; Nagheeby *et al.*, 2023).

This situation has been exacerbated by the integrated water resources management (IWRM) model adopted at a national level, which is based on neoliberal and hegemonic values that prioritise economic growth and efficiency (MMAVDT, 2010). Thus, Colombian water policy defines the resource by instrumental, vertical, and exclusionary characteristics, which fail to reflect the real value water holds for diverse social groups around the country (Correa, 2015). The IWRM model, which is oriented solely from the top-down perspective, similarly does not recognise the existence of valuable social networks around water governance and does not make space for local actors who have been historically excluded from water governance – but who actively attend to water care, at watersheds and at the basin level.

Alternative frameworks for water management

In the Upper Meléndez River Basin (in Cali, the capital of the Valle del Cauca department), the inhabitants, water users, institutional environmental actors, such as the Farallones National Natural Park, Río Meléndez National Protective Forest Reserves, and local social groups, have formed a hydrosocial network around the care of water and its attendant ecosystems, with the aim of protecting the basin from degradation. This water care network is a collective practice, whereby all members of the network work together to promote the preservation of the area, as well as jointly developing sustainable ways to use the river, soil, forest resources, and water in the basin. Through this process, the network stakeholders have developed an alternative relationship with water that is based on shared social values of recognition, respect, cooperation, and gratefulness – which apply to the river, the community, and the territory as a whole (Trujillo Osorio *et al.*, 2023).

Through a participatory social learning process and social network analysis methods, we identified 35 types of actors in this hydrosocial network, connected by intertwined relationships and collaborative water care values. In this network (Figure 13.1), three categories of actors stand out: private (*Actores Privados*), collective (*Actores Colectivos*), and state (*Actores Estatales*), each with distinct roles inside the network, as well as water relations, water uses, and care practices.

Private actors are associated with economic sectors such as livestock, agriculture, tourism, and services like transportation and restaurants. Collective actors, meanwhile, are generally community-based social groups that promote social and collective processes and work for socio-ecological welfare, such as popular action boards, community councils, basin foundations, and other actors like the local green agro-ecological market, Mercado de la Montaña (Mountain Market), that seek collective well-being at a social and environmental level. Finally, state actors are the state-level institutions that provide social and environmental services; in this case, such actors include the national park, forest reservations, rural deputies, environmental agencies, and others engaged in the environmental conservation and regulation of the basin.

As seen in Figure 13.2, the basin actors are all connected: the lines indicate the relationships between actors. The blue lines represent relationships of care, protection, control, respect, and cooperation between actors caring for water and ecosystems, while the black lines represent relationships related to production, extraction, and trade, among others.

Collective care and cooperation

At the network's core, we find a group of 31 actors united by conceptions of care and care practices, and also sharing values relating to respect and admiration

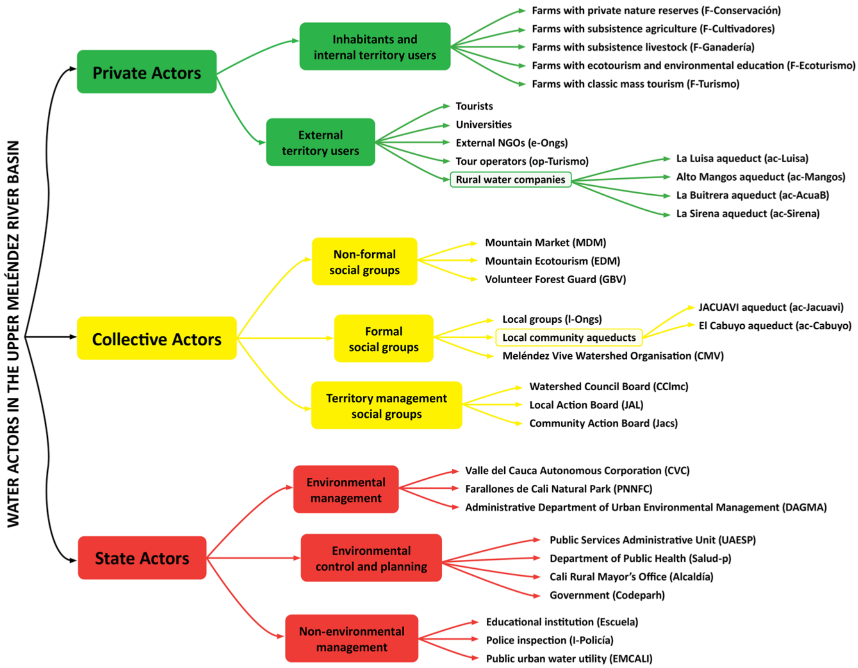


Figure 13.1 Water-related actors from Meléndez Basin: actor-mapping workshop (Trujillo Osorio *et al.*, 2023). (Credit: Catalina Trujillo Osorio).

for water. They carry out joint, quotidian actions to defend and care for the river and the territory, such as permanent reforestation days, water harvesting, spring care, cleaning of rivers and streams, local seed planting, and other shared actions related to water and basin care.

In addition, actors not linked to the care network, such as safety officers, rural water companies, tourism agencies, tourists visiting the basin, and the public water utility company of Cali, are still encouraged to adopt a vision of water that is oriented towards instrumental, extractive, efficient, and caring values: these shared values, actions, and practices are essential for forging long-term relationships at the local, regional, and city levels. Indeed, their utility as political instruments for water management should not be overlooked.

This water care network, then, highlights the role of cooperation in water security and how it pays to establish robust care links between water actors in the basin (see also Narayanaswamy *et al.* 2023). In turn, such networks beget further connection, fostering the development of collective social processes related to water care practices, such as Mercado de la Montaña and a volunteer scheme in the forest, among others. Shared care values act as a bridge through which different actors can integrate, form networks, multiply their values, and formulate visions around care and water security (Figure 13.3).

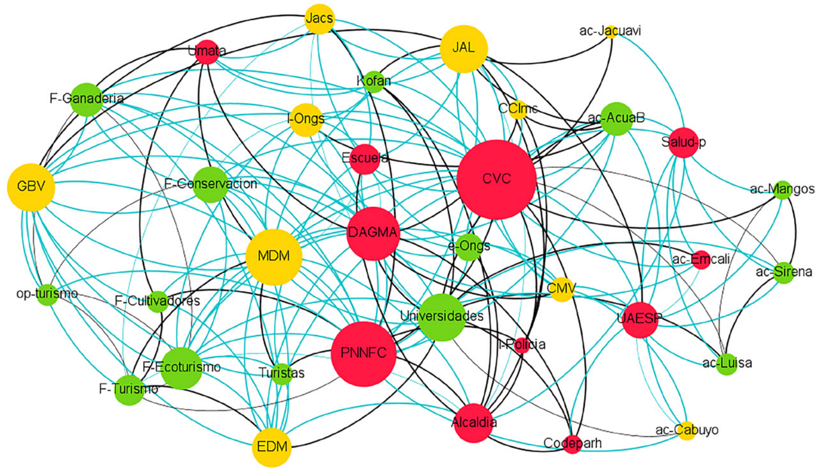


Figure 13.2 Composition and structure of Meléndez Basin Actors (Trujillo Osorio *et al.*, 2023). (Credit: Catalina Trujillo Osorio).

A new water management model

This case study from the Upper Meléndez River Basin highlights the value of networks that prioritise water and environmental care over economic growth, supply, and efficiency. Through participatory workshops, we established a local definition of water security as 'the process of collective care for water, forest, and mountain, which fosters the capability to conserve the abundance of water for life, beauty, fauna, and the forest as a whole community' (see Figure 13.4 for original Spanish and direct English translation).

Figure 13.3 Mercado de la Montaña (Mountain Market), a local green agro-ecological market. (Credit: Catalina Trujillo Osorio).

Figure 13.4 Local understanding of water security, as expressed during workshops. *Translation:* 'What does water security mean to you? It means: caring for the ecosystem with awareness, knowledge, respect, and gratitude; to conserve the abundance of water for life, biodiversity, and everything as a unit.' (Credit: rootsandwings.design).

For these reasons, the Upper Meléndez River Basin has been held up as a territorial management blueprint for other basins in the region. These other basins are currently beginning to form environmental care networks of their own, such as via local and collective agro-ecological markets, in an effort to forge shared care values and protection practices in everyday life.

REFERENCES

Correa G. (2015). *Gobernabilidad del agua en Colombia: dimensiones y contexto* (Water governance in Colombia: dimensions and context). Revista Educación y Desarrollo Social, **9**(2), 124–135. https://doi.org/10.18359/reds.950

Figueroa-Benitez A., Nagheeby M., Figueroa A. and Amezaga J. (2023). Disrupted water governance in the shadows: revealing the role of hidden actors in the Upper Cauca River Basin in Colombia. *Frontiers in Water*, **5**, 801171. https://doi.org/10.3389/frwa.2023.801171

Institute of Hydrology, Meteorology and Environment Studies (IDEAM) (2019). Estudio Nacional del Agua 2018 (National Water Study 2018). IDEAM, Bogotá, Colombia. http://www.andi.com.co/Uploads/ENA_2018-comprimido.pdf (accessed 17 April 2024)

Ministry of Environment, Housing and Territorial Development (MMAVDT) (2010). Política Nacional para la Gestión Integral del Recurso Hídrico (National Policy for the Comprehensive Management of Water Resources). MMAVDT, Vol. **1**, Bogotá, Colombia. https://www.minambiente.gov.co/wp-content/uploads/2021/11/Politica-Nacional-para-la-Gestion-Integral-del-Recurso-Hidrico.pdf (accessed 6 June 2024)

Muradian R. and Gómez-Baggethun E. (2021). Beyond ecosystem services and nature's contributions: Is it time to leave utilitarian environmentalism behind?, *Ecological Economics*, **185**, 107038, 10.1016/j.ecolecon.2021.107038

Nagheeby M., Amezaga J. and Mdee A. (eds.) (2023). Critical Water Governance: Contextualising Water Security in Colombia, Ethiopia, India and Malaysia. July 2023 Joint Report, Water Security and Sustainable Development Hub, UK Research and Innovation. https://eprints.ncl.ac.uk/file_store/production/294534/341330FD-D5B7-46A9-99CF-B7716E9C2004.pdf (accessed 17 April 2024).

Narayanaswamy L., Ferritto R., Hillesland M., Anker V., Singhal S., Maysels R. M., Bantider A., Charles K., Doss C., Kumar A., Mdee A., Neo S-M., Pinzón F. and Mengistu B. T. (2023). Why a feminist ethics of care and socio-ecological justice lens matter for global, interdisciplinary research on water security. *Frontiers in Human Dynamics*, **5**, 1212188. https://doi.org/10.3389/fhumd.2023.1212188

The World Bank (2020). Colombia: Turning the Tide. Water Security for Recovery and Sustainable Growth. Policy Brief, International Bank for Reconstruction and Development/The World Bank, Washington DC, US. https://thedocs.worldbank.org/en/doc/148581599058364514-0090022020/render/TurningtheTideBriefENAugust3020.pdf (accessed 17 April 2024)

Trujillo Osorio C., Peña-Varón M. and Revelo-Osorio L. (2023). *Aportes al estudio de las redes hidrosociales desde los métodos de análisis de redes sociales ARS: estudio de caso en la cuenca alta del Río Meléndez-Colombia* (Contributions to the study of hydrosocial networks from ARS social network analysis methods: case study in the upper basin of the Meléndez River in Colombia). *INTER-LEGERE*, **6**(36), 38, https://doi.org/10.21680/1982-1662.2023v6n36

Washington H., Chapron G., Kopnina H., Curry P., Gray J. and Piccolo J. J. (2018). Foregrounding ecojustice in conservation. *Biological Conservation*, **228**, 367–374. https://doi.org/10.1016/j.biocon.2018.09.011

Wienhues A. (2020). Ecological Justice and the Extinction Crisis. 1st edn, Bristol University Press, Bristol, UK. https://doi.org/10.2307/j.ctv16t671c

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Principle 3

Collaboration – conclusion

Victoria Anker, Rachael Maysels and Maria Valasia Peppa

The spotlights in the collaboration principle highlight the different ways in which we – particularly as researchers – have engaged and worked with stakeholders to address water insecurity in different socio-cultural and socio-ecological contexts from Colombia, Ethiopia, India, and Malaysia. In particular, the spotlights emphasise the diverse, non-hierarchical ways in which collaboration can manifest, while recognising the limitations of these collaborative approaches and their inability to redress systemic injustices in areas such as governance structures and democratic participation. Likewise, while we are committed to rigorous and systematic research, we acknowledge our own biases in our problem-solving approaches and recognise the complexities of ensuring equitable engagement within big international research partnerships (Narayanaswamy *et al.*, 2023).

Collaboration is often complex as it involves actors from diverse backgrounds, cultures, and institutional systems. This complexity was described in Chapter 9.1, where we mapped the multi-level institutional structure of Delhi's water governance in India, showing its fragmented nature, according to which different levels struggle to coordinate and citizens are unable to participate. Looking back in history, this structure was once suited to the city's previous population and colonial political conditions. Today, however, with rapid urban growth, the structure does not promote water equity, nor safeguard water security, as we define it here. To enable change, we need to educate young people, helping them to understand the difficulties of the past so that they do not repeat them in the present and instead create a brighter future. Chapter 9.2 demonstrates how international, national, and local charity organisations have initiated youth participation in urban planning, heritage conservation, and decision-making, applying pressure to the public authorities in India to include all voices in every aspect of urban/water management. Obviously, rigorous changes will take time to be accepted in this political and geographic context; however, such initiatives give a sense of hope, as they plant the seed of recognising and including youth voices in the cycle of proactive management.

Practical steps forward, allowing us to move from fragmentation to continuous dialogue and engagement, are established in Chapter 10. The first spotlight demonstrates the importance of building long-term relationships between local community members (e.g. fishers and farmers) and governmental actors in Johor River Basin, Malaysia. To establish such relationships, many informal dialogues (e.g. virtual coffees during the COVID-19 pandemic) have been organised by the Universiti Teknologi Malaysia (UTM) over the past four years. The UTM research team now understands community needs in relation to water resource management and can bridge the gap between governmental actors and local voices. Likewise, the second spotlight articulates a clear methodology to highlight the various access points for stakeholders to engage with research – from context analysis, to qualitative input into numerical configurations, through to scenario quantification and validation. This continual engagement ensures the scenarios being modelled are appropriate and relevant for stakeholders, generating actionable and realistic solutions for the proactive management of water resources in the Central Rift Valley.

We have already seen that environmental and climate education are innately tied to environmental and climate justice. Citizen science can, at its most basic, fill data gaps created by the absence of regular monitoring, which otherwise hampers understanding of water quality, water-related risks, and risks to people's health and livelihoods. However, as the spotlights in Chapter 11 demonstrate, citizen science generates more than just accurate and reliable data. It helps communities enhance their understanding of their environment and enables them to better engage in discussions about water management and inform adaptation strategies. Chapter 11.3 shows how establishing a link between the Legedadi reservoir operators (such as the Addis Ababa Water and Sewerage Authority) and downstream communities – who are negatively impacted by the operators' practices – has led to exchange of valuable information and creation of early warning notifications, thus reducing damage caused by reservoir operations.

In this section, we've also explored how communities work with researchers, non-governmental organisations, and other stakeholders to co-produce, co-create, and lead the identification of problems and solutions. Chapters 12.2 and 13.1 highlight the interconnectedness of water supply, water quality, floods, soil erosion, and ecosystem health. The Andean communities of Cauca are diverse across a number of factors, including (but not limited to) gender, ethnicity, and disability. As such, working with and being guided by local communities is an important aspect of how our Colombian colleagues have generated equitable, redistributive, and integrative actions to address issues of water insecurity. In summary, the spotlights in this principle have shown that while collaboration can be challenging, it plays a fundamental role in ensuring no one and nothing is left behind in the pathway towards proactive water management.

REFERENCE

Narayanaswamy L., Ferritto R., Hillesland M., Anker V., Singhal S., Maysels R. M., Bantider A., Charles K., Doss C., Kumar A., Mdee A., Neo S-M., Pinzón F. and Mengistu B. T. (2023). Why a feminist ethics of care and socio-ecological justice lens matter for global, interdisciplinary research on water security. *Frontiers in Human Dynamics*, **5**, 1212188. https://doi.org/10.3389/fhumd.2023.1212188

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Conclusion

Victoria Anker, Rachael Maysels, Maria Valasia Peppa, Anna Murgatroyd and Adey Nigatu Mersha

This volume has shown that pushing the paradigm of global water security requires an approach rooted in principles of justice for humans and more-than-humans; knowledge that is pluralistic, accessible, and fair; and collaboration across sectors and communities, as well as geographical, hydrological, and political borders. We have shown that water security is dependent on a multitude of factors. For example, biophysical factors, such as the climate and weather, impact the quality and quantity of water supply. Anthropogenic factors, such as sectoral water abstraction, water infrastructure, and the built environment, control the availability and quality of water resources and the distribution of water to consumers to support socio-economic developments. Finally, policies, institutions, and laws influence who gets water and how often, as well as guiding whether water as a resource is managed in an equitable, efficient, and sustainable manner.

The co-production and just distribution of knowledge of the factors that influence water security is crucial when determining how we identify solutions to address current and future development injustices in water security. Collaborative analysis of diverse sets of biophysical, anthropogenic, socio-environmental, and policy scenarios can offer insights into how water systems might look in the future. Furthermore, shared evaluation of responses to water security threats between social actors, marginalised voices, resource managers, and policymakers can help to control the known factors that impact water security. This all works in theory. However, in practice, how do we, as academics, activists, and advocates for fair and equitable access to safe and secure water, successfully plan for sustainable water security in the future?

PROACTIVE MANAGEMENT FOR SUSTAINABLE WATER SECURITY

Proactive management is not a commonly used term when planning for water security. In spite of this, many components of proactive management are observed in everyday water system operations and water use. Simply defined, proactive management for water security involves planning for potential threats to safe water supplies, which we argue should be situated within broader socio-ecological systems. It is an approach that focuses primarily on preventive (proactive) measures to manage water risks and ensure sustainable water security, instead of responsive (reactive) measures to deal with water-related crises (Madani, 2014) (Figure C.1).

A proactive management paradigm recognises the complexity of water systems and their associated uncertainties, as well as the ways in which the water sector relates to other sectors. By better understanding how water systems behave at different scales, and how threats arise, this paradigm tackles the root of problems in a holistic and progressive manner, rather than treating the symptoms as they occur. In doing so, a proactive management approach manages water rather than controlling it. Such an approach should explore a broad range of possible solution pathways that include input from a multitude of actors and make good use of non-structural solutions related to policies, legislation, and institutional arrangements, as well as various structural

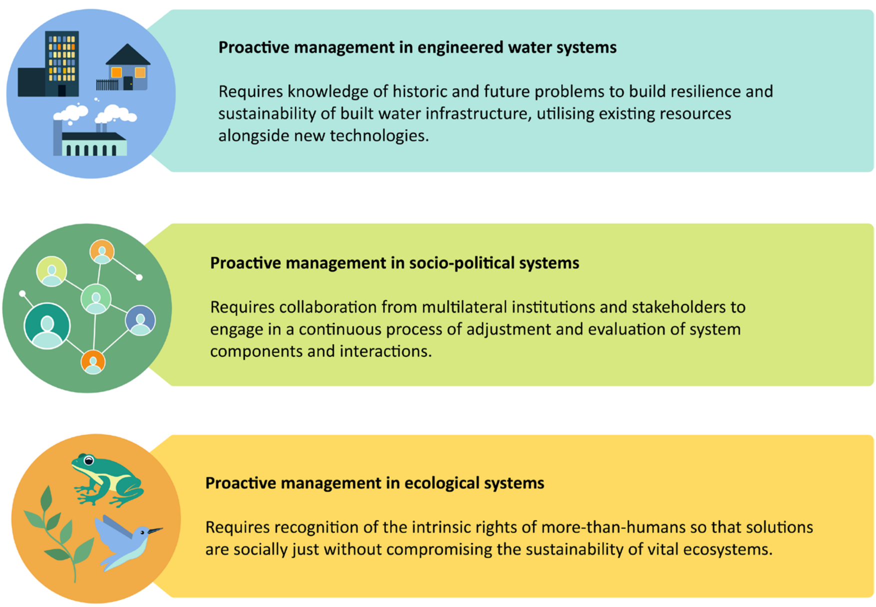

Figure C.1 Proactive management for sustainable water security. (Credit: rootsandwings.design) solutions such as storage systems, diversions, water supply augmentation, water distribution networks, and development systems (Cooper, 2016; Madani, 2014).

In order to develop effective, equitable systems of proactive water management, we require replicable, adaptable, and cost-effective solutions from a variety of epistemologies. Water resource-related challenges pose a threat to human and more-than-human well-being, but a proactive approach to managing these challenges can significantly minimise risks and promote coordinated action in a world of uncertainty. Through continuous, interdisciplinary monitoring of socio-ecological systems (including natural and biophysical processes, as well as socio-economic trends), proactive management foresees possible water crisis situations and applies appropriate measures before the real effects of water insecurity become apparent.

A PROACTIVE MANAGEMENT PATHWAY

Here, we present a proactive management pathway for water security, setting out how water can be managed holistically. This framework takes into account injustices in water systems and knowledge of current and future risks, while encouraging collaboration and equitable partnerships. The figure below describes seven stages to guide sustainable decision-making for the next generation. A key element of this approach is the ongoing review of the state of the water system and continual reassessment of emerging or potential threats before they materialise, hence the circular design of the pathway (Figure C.2).

DETECT ***existing and future threats to water security***: Justice involves empowering communities as the primary source of detection, with institutions supporting their ongoing activities. This means ensuring that detection and data-sharing platforms are open and accessible to the public, particularly the vulnerable, and implementing a participatory and transparent process for context analysis to understand the issues faced by these communities. Local knowledge is crucial, and so communities should be trained to aid in detection processes. Understanding current scenarios and existing conditions in an integrative, timely manner is also essential for identifying existing and future threats. This requires real-time, integrated, and open data sharing and forecasting, supported by rigorous systems, tools, and methods such as modelling, projections, and assessment of vulnerabilities and socio-ecological settings. Collaboration is key to identifying enablers and barriers and determining the best ways to work together in the service of mitigation and adaptation. Effective data sharing among all relevant stakeholders is vital for the quick and accurate detection of pressures, both present and future: sharing mechanisms that normalise communication between institutions, communities, and industries are necessary to facilitate this collaboration.

ESTIMATE ***the likelihood of water insecurity occurring***: In a just society, everyone would have access to the same information, enabling well-informed predictions and fostering an equitable and empowered community. This entails creating comprehensive, user-friendly open platforms for disaster forecasting. Knowledge is a powerful tool for predicting the future; thus, accessible, representative, and integrated data should be made available to local people, not

Figure C.2 A proactive management pathway for water security. (Credit: rootsandwings.design)

just those in positions of authority. Emphasising citizen science and pluralistic knowledge systems, comprehensive data can help identify trends through predictions, modelling, multicriteria analysis, and participatory scenario analysis. In order to mark hazard hotspots, we also need to understand the causes of vulnerability and the factors that alleviate or elevate it. To access this information, collaboration is crucial, involving local people and data from a variety of sources to integrate indigenous knowledge with technical and scientific data. Effective data sharing among all relevant stakeholders ensures that all potential scenarios are thoroughly considered.

CALCULATE ***the multifaceted impact on water security***: Justice requires us to take an intersectional approach to risk, recognising who is vulnerable and how different groups are affected. It is essential to include all voices in risk calculations, considering not just infrastructure and services, but also the environment and vulnerable populations. By calculating risk inclusively, we can identify who will be most impacted by water security issues. Generating this knowledge involves the demarcation of eco-sensitive zones and the use of modelling and visualisation. It is important to remember that calculating risk is not solely a quantitative exercise; qualitative assessments and the consideration of indigenous and experiential knowledge of risk impact are crucial. Various stakeholders' perspectives should be incorporated into the risk calculation process and different approaches to calculating risk should also be integrated. Building the capacity of stakeholders to effectively calculate risk is also necessary for comprehensive and accurate assessments.

IDENTIFY *and* EVALUATE *equitable and sustainable solutions*: Justice is an inherent part of equitable solutions, which balance human and more-than-human needs. These solutions must be fair, inclusive, affordable, and user-friendly, promoting co-living between nature, biodiverse creatures, and people. In terms of knowledge, it is essential to clarify what is included in the water system to identify equitable and sustainable solutions. Nature-based solutions are crucial for ecosystem protection, alongside modern technological solutions, including structural measures. Building capacity based on local and indigenous knowledge can strengthen nature-based solutions, and identifying vulnerable sites, infrastructure, and people in close cooperation with the target community is essential for sustainable solutions. Effective collaboration means developing a participatory process for identification and evaluation, ensuring that solutions benefit different groups equitably. Water systems encompass a range of sectors, such as agriculture and industry, and so solutions need to benefit all these sectors, while also accepting some trade-offs.

RESHAPE *policies and* REVISE *plans*: Justice requires decision-makers, academics, and water experts to acknowledge that they are not omnipotent authorities dictating how the world should function. Policies and plans must account for uncertainty, variabilities, and context-specific factors. Without justice, such policies and plans are meaningless. It is crucial to systematically and structurally involve marginalised voices in decision-making processes, ensuring that equity, diversity, and inclusion are considered. The information shaping these policies must be accessible to everyone, enabling democratic participation in their formation. In addition, socio-ecological justice is not an optional extra but a fundamental necessity.

It is important to develop a wide range of methods and processes to collect and make accessible the evidence behind decisions. Qualitative evidence, such as local values, is just as important as quantitative evidence. Decisions should be supported by all types of knowledge, including local, technical, and scientific. Collaboration is essential in encouraging buy-in to plans and policies, fostering a sense of ownership and belonging with regard to decisions. This also helps stakeholders understand the risks faced by others, leading to a more cohesive approach. Policies should be multi-sectoral, synchronised, comprehensive, and inclusive, with bottom-up strategies prioritising vulnerable communities and nature. Recognising and addressing power asymmetries in policymaking and planning is crucial for justice. Additionally, collaboration is necessary for effective knowledge sharing.

IMPLEMENT ***solutions and*** **MONITOR** ***progress***: Considering justice means co-producing solutions that can be operated, repaired, adjusted, and modified by those who face the problems in real life. Monitoring must ensure environmental justice, not just human benefits, and while compromises will be necessary, solutions should not exacerbate existing inequities or injustices. These solutions should align with local values, beliefs, culture, and practices, and establish feedback mechanisms to check progress against inclusivity, equity, and efficiency considerations. Prioritising knowledge entails real-time monitoring and capacity building to enhance implementation and monitoring effectiveness. Citizen science empowers people to learn and contribute to knowledge generation, and data sharing across agencies allows progress to be monitored and best practices to be shared. Knowledge transfer to different groups also helps standardise monitoring processes and generate further innovations in both structural and non-structural designs. In order to promote this collaboration, community members once again need to be trained to monitor progress; in time, this leads to community-owned and -managed solutions, which foster a sense of ownership. All implementation processes should involve communities actively, rather than being imposed on them. Participation creates a sense of belonging and collaboration between stakeholders with different expertise ensures effective realisation of solutions.

RESPOND ***to potential threats to water security***: Justice is essential in ensuring that we aid the most vulnerable and in need first, while also maintaining fairness to ecosystems. This means identifying marginalised groups and ensuring their access to safety procedures. And we must adopt a longitudinal perspective to mitigating threats, recognising that this is not a fixed goal, but rather an evolving process. Knowledge, though always incomplete and scarce compared with reality, must be managed effectively. Integrated, real-time data is crucial for effective response and prioritisation of actions. Finally, collaboration demands that we coordinate responses that are multi-agency by nature, facilitated by effective communication and dissemination platforms.

CONCLUDING REMARKS

Throughout this book, we have sought to highlight the critical importance of water security amidst growing global challenges such as conflict, pollution, and climate change. We have emphasised the need for a comprehensive and proactive approach, drawing upon diverse perspectives and experiences from around the world. The book features the voices of a variety of stakeholders, including early career researchers, non-governmental organisations, indigenous communities, and government agencies. Through community-directed videos, sonorous postcards, and visual stories, we have created forms of expression accessible to a broad readership beyond the traditional academic audience.

We have highlighted a methodology of transnational cooperation, interdisciplinary collaboration, and diagnostic problem-solving, rejecting reductionist approaches to addressing water security. In academia, research is often siloed by disciplines and researchers are put in competition with one another for funding, promotions, and jobs. As a multi-cultural network of early career researchers with vastly different backgrounds and expertise, we have shown that international, interdisciplinary collaboration is indeed possible. The process of creating this anthology has not been a straightforward linear progression, but an illuminating learning experience in which interdisciplinarity has been cooperatively formulated and applied into practice, enabling many possibilities for future work and methodologies.

Collectively, in order to shift the current technocratic and anthropocentric paradigm of water security, we advocate for the recognition of the interconnectedness of environmental conservation, social stability, and economic vitality. We call for solutions rooted in socio-ecological justice that look beyond physical boundaries and borders and integrate pluralistic knowledge systems, driving change through collaboration and partnerships. This is how we achieve a water secure future.

REFERENCES

Cooper M. (2016). Conclusions: The future of sustainable water management. In: Sustainable Water Management: New Perspectives, Design, and Practices, K. Nakagami, J. Kubota and B. I. Setiawan (eds.), Springer, Singapore, pp. 175–185. https://doi.org/10.1007/978-981-10-1204-4_12

Madani K. (2014). Water management in Iran: What is causing the looming crisis? *Journal of Environmental Studies and Sciences*, **4**, 315–328. https://doi.org/10.1007/s13412-014-0182-z

This book brings together early career researchers, non-governmental organisations and industry practitioners, indigenous and local communities, and government agency workers to interrogate the concept of water security. By collating multicultural perspectives, diverse contributions, and illustrative media, we challenge the current anthropocentric, technocratic narrative of water security, according to which: water security is solely for humans; development initiatives and interventions are driven by neocolonial and neoliberal ideologies; the socio-cultural approach to water security is secondary to a technical, engineering-based approach; and interdisciplinarity is not practical in its application.

Presented here is an amalgamation of our personal and professional efforts to address these challenges. The nuance of this book is in our methodology: transnational cooperation, collaboration across disciplines, and diagnostic problem-solving. While we do not promise a single solution (there is no such thing as 'one size fits all'), we believe this timely contribution broadens the discussion around water security through its firm rejection of reductionist approaches to this most complex of 'wicked problems'.

Most notably, we push for the radical acceptance of the indivisibility of environmental conservation, social stability, and economic vitality. We resist the temptation of 'green growth', recognising it as little more than neoliberalism in disguise. The brilliance, innovation, and recall to tradition that emerge through this book demonstrate the importance of solutions that are informed by a plurality of knowledge types (from scientific and technical to indigenous and local) and generated through collaboration and partnerships to support the attainment of socio-ecological justice.

Essential reading for water practitioners, policy makers, and multilateral organisations in the development sector, it is also a must-read for doctoral and master's students working at intersections of water, and undergraduates who want to challenge their subject-specific perspectives on water and push disciplinary boundaries.

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