BLUE PAPERS

Water & Heritage for Sustainable Development

Edited by Carola Hein, Matteo D'Agostino & Michele Tenzon

Leiden-Delft-Erasmus Universities

2026 (Vol. 5 No. 1)

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Editor-in-Chief
Carola Hein

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Journal Description

Blue Papers: Highlighting the Critical Role of Water and Heritage in Sustainable Development

Water in all its forms is key to human survival and well-being. Humans have created intricate and ingenious solutions to survive and thrive in difficult and complex territories and to adapt changes in social and environmental conditions. Remnants of past practices, structures and objects are still with us – in the built environment, in our institutions, in our ways of living and in our languages. Sometimes we call these objects and practices heritage, but more often they are so much a part of our everyday lives that we take them for granted.

As emphasized in the *UNESCO Thematic Indicators for Culture in the 2030 Agenda,*[1] culture is an important part of the Goals and Targets of the 2030 United Nations' Agenda for Sustainable Development. Stand-alone technological interventions cannot solve the complexities of the social, cultural and economic implications of climate change in the long term. New solutions require the engagement of local interested parties and local knowledge to address social and cultural dimensions of water and to create a new embedded water awareness in the built environment, in institutions and culture(s), so that we can preserve and protect our heritage, understand and learn from the past and activate history and heritage for future sustainable and inclusive living.

The biannual peer-reviewed journal *Blue Papers* explores the complex relationship between water, culture and heritage to assess lessons from the past, to protect heritage sites, to make use of water heritage and to contribute to the development of inclusive and sustainable future water systems. The past can help build a new platform for awareness of water and heritage, which involves shared methodologies and terminologies, policies and tools that bridge disparate fields and disciplines. To achieve this, we also need to rethink the role of water in the UN Sustainable Development Goals (SDGs). Water is not fully captured in *Goal 6: Ensure access to water and sanitation for all*; it is also an integral and inseparable key to all SDGs that carry us forward to a more sustainable future.

All issues of the journal will be loosely based on themes that link to water, culture and heritage, including (but not limited to):

- Transcending the nature-culture divide
- Tangible and intangible aspects

1. The UNESCO Thematic Indicators for Culture in the 2030 Agenda (UNESCO Culture|2030 Indicators), https://whc.unesco.org/en/culture2030indicators/.

- Integrated discourses and practices
- Capacity building for holistic systems
- Long-term (living) history perspectives for comprehensive understanding
- Preservation, protection and reuse of water-related (living) heritage
- Human and non-human stakeholders
- New practices and rituals for water awareness and engagement
- Strategies for inclusive sustainable development, including those drawing on heritage.

The launch of the open access, peer-reviewed journal *Blue Papers* has been led by the Chair History of Architecture and Urban Planning, Delft University of Technology; the UNESCO Chair Water, Ports and Historic Cities; and the LDE PortCityFutures Center. It was made possible thanks to financial support from the Ministry of Infrastructure and Water Management, the Netherlands; the Chair History of Architecture and Urban Planning, TU Delft and the LDE PortCityFutures Center. Setup and development of Blue Papers has been supported by ICOMOS NL, ICOMOS Germany, ICOMOS ISC Water, the Initiative for the Future of Great Rivers (IFGR), WAMU-NET, Waternet, Witteveen+Bos, and Stichting OpenAccess Platforms (SOAP). Over the years, colleagues from The University of Pennsylvania, Living Waters Museum, UNESCO Chair Heritage and Urban Regeneration and UNESCO Chair River Culture – Fleuves et Patrimoine have joined.

Cover image: River canal with traditional timber houses and stone embankment, Gujo Hachiman, Gifu Prefecture, Japan. Taken by Carola Hein. July 2025.

Publisher:
UNESCO Chair Water, Ports and Historic Cities

Open Access provider:`
SOAP | Stichting Open Access platforms
https://ror.org/01y7p7f26

ISBN/EAN:
978-94-93439-19-1

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Content


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10.58981/bluepapers.2026.1.wicon

Icons as a Tool to Connect Water Practices, Functions and Values across Space and Time: A Second Attempt

Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino

Humans have shaped water systems for millennia, creating complex networks of physical structures, institutions and cultural practices. These systems reflect locally embedded yet globally influenced values that evolve over time. From infrastructure and landscapes to rituals and laws, human engagement with water is both tangible and intangible, deeply influenced by societal preferences, climate conditions and historical choices. To better understand this diversity, we developed a set of icons to represent various water spaces, functions, practices and values. Rather than offering a fixed taxonomy, these icons are intended as tools for discussion – making visible the multiple dimensions of water and the meanings knowledge holders assign to it.

Originally introduced in 2022 (Hein et al. 2022), the icons were used by authors in our journal to highlight key themes in their work. While we envisioned them as a way to map specific water-related elements across time and geography, they also served as visual keywords, helping to reveal prominent aspects of water heritage and practice. This goal has guided our ongoing efforts to enhance the icons' interpretive and comparative value, stimulating deeper cross-contextual reflection (Hein et al. 2025). In our second attempt to build a taxonomy of water practices, functions and values, we have introduced new icons and revised others, notably by adding representations of aesthetic and economic aspects and refining examples.

Ultimately, these categories are suggestions – not exhaustive or mutually exclusive – designed to illuminate how water has been managed, valued and lived with across different times and places, and how the past continues to influence the present and shape our future.

As we make the water icons open source (CC-BY) available for download on the *Blue Papers* website, we invite readers to build on the current set and expand it to fit their own context. The goal is to foster a dialogue around water values, invite collaborative engagement and spur new insights.

To represent situations where multiple water functions, values, and practices are considered together, we use a circle to group the corresponding icons.

< Fig. 1 Water icons (Source: Carola Hein, Lea Kayrouz, Zuzanna Sliwinska and Matteo D'Agostino, 2025).

Tangible

Drinking Water
Access to and provision of fresh, potable water is a universal need. Humans employ many different techniques and infrastructures to transport, store, filter, pump, redistribute and use drinking water. Examples include the use of reservoirs and pipelines for storage and distribution, both above and under the ground, as well as filtration systems that ensure water quality meets safety standards.

Agriculture and Irrigation
A wide range of strategies and technologies are used to harness water for food production, such as by irrigating crops and providing water for livestock. Agriculture and irrigation practices vary across different contexts ranging from agroforestry to terrace farming, including techniques that leverage seasonal water changes like flood agriculture.

Drainage Water and Sanitation Systems
The removal of excess and sewage water, including rainwater, runoff, black water and gray water, requires extensive infrastructure and treatment systems. Sanitation systems are essential for public health and environmental sustainability. Examples include wastewater treatment plants that recycle water, formal and informal sewer networks, and waterless solutions such as composting toilets.

Protection of Human Settlements
Humans have created architectural, urban and landscape structures to adapt to their environments and address challenges posed by water, animals and enemies. Responses to rain, snow, floods and droughts include canals, dikes and moats. Water has also been used defensively through fortification walls and floodable landscapes designed to deter or delay potential threats.

Water and Health
Access to clean water is essential for human well-being, with water quality playing a critical role in individual, public and ecosystem health. The purification of water for human consumption, for example, through boiling, filtration or adding chemicals, has influenced the development of public health, planning and environmental policy and has sparked private and public interventions.

Energy and Industry
Water management systems play a critical role in supporting energy production and industrial processes, often facing challenges related to resource efficiency, environmental impact and sustainability. Examples include the use of dams for hydroelectric power generation, water-cooling systems in machinery and factories, and water-intensive industries like mining and breweries.

Shipping
Water bodies, including seas, rivers and canals, are vital for moving people and goods, supporting daily mobility, tourism and commerce. Natural and manmade waterways are linked to the boats and ships they serve. Specialized infrastructure such as quays, cranes, warehouses, ports and dredging operations enables navigation, transport and the storage of goods.

Places of Leisure
Water bodies, natural and man-made, serve leisure practices in multiple ways. The tangible aspect of water leisure focuses on physical spaces and infrastructure designed for recreational activities at the intersection of land and water. Examples include waterfront promenades, swimming pools, water parks and beaches, which serve as functional features that facilitate human interaction with water.

Sacred and Spiritual Spaces
Humans have long created sacred spaces to honor water, using it as a medium for spiritual connection or reverence for the divine. Religious architecture often includes elements like fountains, baptismal fonts, ablution facilities and temple tanks. These features not only symbolize purity and renewal but can also play a role in local water management.

Aesthetic Water Sites
Physical spaces and structures, whether permanent or temporary, serve as tangible manifestations of cultural and artistic connections to water, often becoming sites of community significance. Examples include architectural interventions such as squares and fountains, as well as the urban design of coastlines, waterfront parks and promenades that celebrate water and encourage interaction with it.

Food from Water Bodies
Natural and artificial water bodies, such as rivers, lakes, seas and ponds, support diverse ecosystems and provide vital food sources through a wide variety of traditional and modern practices, from seashell collection to large-scale aquaculture and industrial fishing. These waters are home to a wide range of plant and animal species, sustaining local livelihoods and global food systems.

Intangible

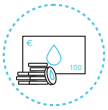
Daily Water Practices
Daily water practices are fundamental to human well-being, woven into routines that sustain health and hygiene. These include sourcing water for cooking and drinking, communal laundry, bathing and showering practices. Such everyday habits highlight water's essential role in both practical needs and sociocultural practices across communities.

Preservation, Adaptation, Reuse
Diverse traditional and contemporary practices aim at preserving or strategically changing water bodies, related ecosystems and the social customs connected to them. Examples include the use of local knowledge in cultural heritage protection, wetland conservation, modern techniques of river restoration and community efforts to maintain traditions, rituals and structures tied to water.

Knowledge Systems and Capacity Building
Socialization and education are key to healthy and sustainable living with water. This can occur through community engagement, school curricula, capacity-building initiatives, the preservation of traditional wisdom about local water systems and sustainable practices, and all initiatives aimed at exchanging or transmitting knowledge and raising water awareness.

Laws, Policies and Planning
Water management, access and use have long been regulated through governmental policies, customary law and land use planning. These frameworks, implemented by state, corporate or traditional authorities, determine rights and responsibilities through tools like zoning regulations, land ownership policies and infrastructure planning that affect how water is distributed, accessed and controlled.

Language and Idioms
People's connection to water is expressed through diverse cultural and artistic forms, reflecting its deep symbolic and practical importance. This shapes how communities understand and relate to water. For example, language often includes words and proverbs about water, embedding traditional wisdom and values that arise from close daily interaction with water in different environments.



Economic Value of Water
The economic value of water is often realized through its exploitation for agriculture, industry and energy production, such as intensive irrigation in agribusiness, dam-based hydropower, and mining operations that rely heavily on water access. These practices can generate significant income and infrastructure but also raise questions about equity, environmental impact and long-term resilience.

Institutions, Organizations and Governance
Water management involves diverse institutions and governance structures across local, national and cross-border levels. Formal entities like ministries and water boards, informal groups such as activist movements and community alliances, and customary bodies like traditional councils all play key roles. They set and enforce rules, guide social behavior and enable public participation in water governance.

Leisure Practices
Water-related leisure practices encompass activities and traditions that highlight the interaction between land and water. Examples include water sports, cultural events like fishing festivals, seasonal celebrations, informal gatherings for picnics or swimming at local rivers and recreational practices that bring communities together at waterfronts.

Rites, Rituals and Ceremonies
Water holds deep cultural, religious and spiritual significance, reflected in many practices and traditions. These include purification rites, blessings, baptisms, water festivals, and rituals that commemorate historic water events or celebrate the opening of new water structures. Such ceremonies highlight water's vital role in faith, community identity and cultural heritage across societies.

Music, Arts and Dance
Various cultural and artistic forms reflect the deep symbolic and practical importance of water. Examples include dance, spoken and written words, music, visual arts and other creative expressions. These forms offer insights into how communities relate to and understand landscapes shaped by water, highlighting its central role in human life and culture.

Water Access and Equity
Water infrastructures serve different users in different ways, with their social, environmental and economic impacts varying widely across contexts. These variations often reflect deeper inequalities of gender, ethnicity or economic background, which are at the heart of water justice and the power dynamics shaping access to and control over water.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 6–7
10.58981/bluepapers.2026.1.pref

Preface

Water as a Continuum: Bridging Freshwater, Ocean and Heritage

Niccolò Bassan
Intergovernmental Oceanographic Commission (IOC) of UNESCO

Water (in both its 'fresh' and 'salty' forms) shapes landscapes, societies, and cultures across time, linking ocean, rivers, coasts, and inland waters into a continuous and dynamic system. Managing water is therefore an inherently complex task, one that draws on long-standing practices while requiring new forms of knowledge and governance in response to climate change, environmental degradation, and growing social inequality. Whether as natural systems, engineered infrastructures, or cultural spaces, water environments embody collective memory and inherited relationships between people and their 'liquid' surroundings.

For much of history, communities have developed adaptive ways of living with water, informed by deep environmental knowledge and cultural practices tailored to local conditions. Over time, however, large-scale and centralized water management approaches, often driven by economic, political, or technological priorities, have reshaped these relationships. While such systems enabled development and security, they also over-simplified ecological processes and marginalized local knowledge, leaving enduring legacies that continue to influence vulnerability and resilience today.

International frameworks and global climate and disaster risk reduction agreements increasingly recognize the need for integrated approaches that connect freshwater and marine systems, science and society, and past experience and heritage with future action. These agendas call for governance models that are inclusive, adaptive, and grounded in place-based understanding, acknowledging that ocean sustainability depends on what happens upstream, and that heritage plays a key role in shaping how societies respond to change.

In this context, heritage is not only something to be preserved, but also a living resource for learning, adaptation, and transformation. Climate change challenges conventional approaches to conservation by introducing uncertainty, loss, and the need for continual adjustment. Responding to these pressures requires balancing continuity with change, technical expertise with cultural values, and centralized planning with community participation.

Editorial Issue 1/2026
Water and Heritage: From Centralized Legacies to Integrated Futures

Michele Tenzon, Carola Hein and Matteo D'Agostino

Debates on sustainability and climate adaptation bring together a broad range of perspectives that are often treated as opposites: historic practices versus future-oriented interventions, technological fixes versus nature- or culture-based approaches, top-down and large-scale systems versus bottom-up and community-based interventions. These distinctions can be useful as a heuristic, but they can easily slip into a familiar rhetoric of opposing extremes. In practice, approaches overlap, depend on one another, and frequently coexist within the same landscape.

The distinctive perspective that history and heritage bring to water makes this overlapping particularly visible. It invites us to take seriously the fact that water flows are shaped at the intersection of nature, culture, and technology, not along a simple line of opposition. Water is governed through institutions and infrastructures and, at the same time, experienced through everyday practices and contested values. Thinking about water from a long-term perspective, that is in historical terms, encourages scepticism toward monocausal explanations. It reveals that societies have managed water through an inextricable entanglement of technological capacities, forms of political control, and the values embedded in governance tools.

A historical gaze also shows that the difficulty of resisting the pull of easy dichotomies is not unique to our time. Over the last two centuries, and especially through the rhetoric and tools of what has been described as the era of hydraulic modernity, the need to engage with natural systems seemed to fade as technological knowledge and capacity increased. The growth of state apparatuses and the globalisation of financial control led, albeit through different geographies and timelines, to the construction of large centralized infrastructures such as dams, canals, pumping networks, and flood defences, conceived to regulate water at scale. These served agricultural and urban expansion, secured supplies, consolidated political authority over territory, and materialized a philosophy of human–water interaction grounded in measurement, predictability, and control. They were not only technical achievements. They were also powerful symbols of modernisation and progress, whose material legacies endured beyond their technical lifespans, reshaping landscapes and collective memory.

Yet it is equally clear that the benefits of centralised systems have often come with simplifications. Large infrastructures have reorganized social relations while marginalizing local forms of management. They have reduced ecological complexity to measurable and manageable variables

and, in doing so, obscured other forms of hydrological knowledge. Recognizing these shortcomings and their implications is a major outcome of what we might call a hydraulic post-modernity.

In recent decades, water management has increasingly drawn on logics that challenge the idea of control as the dominant mode of human–water interaction. Integrated and nature- and culture-based approaches foreground adaptation, temporality, and ecological interdependence, reflecting an epistemology that values dynamic balances with nature, society, and culture over their mastery. They seek to work with rather than against natural processes while emphasizing ecological restoration, social participation, and the incorporation of traditional and local knowledge.

It can be tempting, therefore, to frame current debates as a shift from centralized control to integrated, nature-based management. But starting from that opposition risks forcing a superficial story in which "modern" stands against "traditional," or "techno-bureaucratic" against "ecological." As a matter of fact, the ideal of "working with nature" itself can become institutionalized in policy frameworks that reproduce centralized forms of decision-making, merely translated into ecological or participatory rhetoric. Integrated water management, as promoted in international development and conservation agendas, often relies on complex forms of expertise, planning, and coordination that mirror the bureaucratic logic of the very systems it seeks to transform. Ultimately, integrated strategies do not emerge in a vacuum. They build upon, reactivate, or contest the infrastructures and institutional frameworks of earlier eras.

A more productive starting point is to examine how inherited infrastructures and institutions are changed and changing under climate pressure, and how ecological and participatory agendas are being layered onto older hydraulic regimes. This matters because many of the most consequential interventions already operate in hybrid form. Flood protection may rely on levees, reservoirs, and forecasting systems, while also requiring space for water through restored floodplains. Ports may depend on dredging and engineered channels, while experimenting with sediment dynamics and ecological corridors. The issue, then, is not which model should prevail in the abstract, but how specific combinations of expertise, infrastructure, governance, and values shape water landscapes over time and what shared values can create future opportunities. Thinking across water, culture, heritage, and sustainable development, rather than in a compartmentalised way, is therefore not an optional added layer. It is a condition for building approaches that are realistic, comprehensive, and socially legible.

Heritage and historical perspectives can play a central role in this discussion as a critical lens that makes water governance historically legible. They reveal how water landscapes are shaped by path dependencies embedded in material systems and institutional routines, from dams and canals to regulatory standards, administrative practices, and settled expectations about what water should do and how it should behave. This perspective helps trace how such layers accumulate and how they constrain, enable, or redirect knowledge and contemporary interventions. At the same time, it shifts attention away from abstract models and toward the values and power relations that water management carries.

Centralized infrastructures and integrated approaches are not neutral toolkits. They encode assumptions about what counts as legitimate expertise, which scales of action matter, and whose agency is recognized in the governance of water. By linking material systems to collective memory, symbolism, and everyday practice, heritage and history bridge what is often separated: engineering and culture, infrastructure and identity, design and lived experience. They help explain why hydraulic works persist not only because they function, but because they are embedded in narratives of modernization, progress, and territorial control, and why reworking them is as much a cultural and political task as a technical one.

The place of heritage in a Climate-Challenged Future

If heritage helps us avoid the pitfalls of simplification and abstraction, water and its challenges, in turn, prompt us to reflect on, and renegotiate, the meaning of heritage itself. The specificities of water contexts, and the pressures they face, require a reconsideration of heritage's premises and practices. As argued in depth in issue 4.2. of *Blue Papers* (Sliwinska et al, 2025), climate change introduces a fundamentally different kind of challenge, one that exceeds the frameworks of conventional conservation. Climate change matters not only because it generates material and ecological risks, but also because it reshapes the values through which societies decide what is meaningful or worth sustaining. At the same time, climate pressures can elevate the significance of other forms of heritage, particularly those associated with resilience, adaptability, repair, and sustainable interaction with water. In water landscapes, heritage cannot be approached only as something to safeguard. It must also be understood as an active process through which meanings, uses, and responsibilities are continually redefined. In this way, climate change transforms both the material and cultural dimensions of heritage, affecting not only what is at risk but also what is recognized as heritage.

Unlike threats such as war, neglect, or modernization, climate change is systemic, long-term, and deeply intertwined with human–environment interactions. It compels societies to reconsider what is worth preserving, how preservation should be carried out, and which forms of knowledge, practice, and infrastructure can support resilience. Preservation under these conditions is not a matter of maintaining a static record of the past, but of negotiating continuity, adaptation, and transformation in response to new ecological realities and emergent cultural priorities. This calls for a more dynamic understanding of heritage, one that prioritizes flexibility, learning, and responsiveness over permanence. It invites us to consider heritage not only as a record of past achievements, but also as a resource for imagining future coexistence with water. Heritage practices can demonstrate ways of living in more balanced relation with the environment, yet reviving historical practices also has limits and must be approached critically rather than romantically.

This issue of *Blue Papers* brings these perspectives into dialogue through a set of contributions that connect historical analysis, heritage practices, and climate adaptation.

A first group of articles examines how engaging with history can inform future-oriented design and governance. **Elyze Storms-Smeets** opens the issue by asking what it means to learn from the past, exploring heritage country estates in the Netherlands as spatial and social ensemble connected to broader landscapes. **Georges Gharios** brings a complementary perspective from southern Lebanon, focusing on communal pools known as *birket* as hydro-cultural heritage and as locally governed water infrastructures. **Rizki Dwika Aprilian**, **Ricky Purbaya** and **Miktha Farid Alkadri** focus on harbourmaster towers in Java's port cities as maritime symbols of power, trade, and colonisation, and reflect on their contemporary trajectories between neglect and restoration. **Meg John** and **Estere Cvilikovska**, respectively, show how water management has been used to reinforce power and centralize state functions in Iraq and Turkmenistan, tracing into the long-term effects of decades of large-scale interventions that ultimately contributed to the ecological crisis.

A second set of articles explores the relationship between heritage and nature- and culture-based approaches in contexts shaped by climate change. River port cities stand out as an understudied terrain where shipping and urban life intersect, and where climate change-driven flooding and drought are likely to have significant impacts. **Noémi Mené**, **Avicenna Tanubrata** and **José Manuel Pagés Sànchez** examine the role of heritage in maintaining and fostering identity, integration and sustainable development across four river port cities worldwide. Their contribution connects to the methodological explorations and case studies in Part II, which investigates how resilience can be fostered and rebuilt. Restoring the historical socio-cultural connections between rivers and local communities is central to the landscape biography approach proposed by **Gökhan Okumuş**, **A. Güliz Bilgin Altınöz** and **Gerdy A.Verschuure-Stuip**. Reporting on research in the Menderes Delta, Turkey, they show how water can act as a catalyst to reconnect communities to their landscape while promoting holistic heritage conservation strategies. **Shreya Sen**, using an innovative mapping methodology, examines the resilience of traditional practices by revealing how religious water practices overlap with contaminated waters in post-mining landscapes along South Africa's Klip River.

Several contributions also address the consequences of extractive development and centralised water management that ignored ecological limits. **Estere Cvilikovska** examines the Soviet-era Karakum Canal in Turkmenistan, tracing how it enabled the cultivation of vast previously arid lands while contributing to the collapse of the Aral Sea ecosystem. **Rhoda Osei-Nkwantabisa** and **Martin Larbi** explore the case of the Azizakpe island community in Ghana and its coping strategies in response to sea-level rise and flooding. **Mahendranath Sudhindranath** and **John Bosco Lourdusamy** analyze the history of disastrous flooding in Kerala, India, linking contemporary vulnerability to colonial-era extractive practices and the long-term consequences of large-scale, environmentally insensitive interventions. **Georges Gharios** presents a mixed-methods survey of *birkets* in Lebanon, combining historical cartography, satellite imagery and oral histories. Returning to Java's port cities, **Rizki Dwika Aprilian**, **Ricky Purbaya** and **Miktha Farid Alkadri** also consider how colonial-era harbourmaster towers are threatened by environmental change and urban transformation, highlighting the challenges of preserving and adapting these structures while rethinking their role today.

The issue closes with three contributions that link analysis to tools and methods for future design. **João Camelo** presents an application of the value case approach, proposing an interactive online platform to foster resilient water use and raise awareness of consumption among citizens in Alfândega da Fé, Portugal. **Maarten Kleinhans**, **Silke Baltussen**, **Eise Nota**, **Jana Cox**, **Han Meijer** and **Jasper Hugtenburg** discuss experiments on natural sedimentation in the main waterway of the port of Rotterdam, suggesting how working with tidal dynamics and sediment processes can prove beneficial in the long-run. **Leonardo Zuccaro Marchi**, **Shubham Majumder** and **Sara Sabry** conclude Volume 5.1 by elaborating a design strategy for safeguarding the socio-ecological landscapes of the Ifugao terraces in the Philippines, grounded in resilient traditional practices amid depopulation and pressure from mass tourism and urbanisation.

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Carola Hein is Professor History of Architecture and Urban Planning at Delft University of Technology, Professor at Leiden and Erasmus University, and UNESCO Chair Water, Ports and Historic Cities and serves as director of the PortCityFutures Center. She has published and lectured widely on topics in contemporary and historical architectural, urban and planning history and has tied historical analysis to contemporary development. Among other major grants, she received a Guggenheim and an Alexander von Humboldt fellowship. Her recent books include: *Hustle and Bustle: The Vibrant Cultures of Port Cities* (2024), *Port City Atlas* (2023), *Oil Spaces* (2021), *Urbanisation of the Sea* (2020), *Adaptive Strategies for Water Heritage* (2020), *The Routledge Planning History Handbook* (2018) and *Port Cities: Dynamic Landscapes and Global Networks* (2011).

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Matteo D'Agostino is a researcher at the Delft University of Technology, a member of the PortCityFutures research group, and currently affiliated with the UNESCO Chair for Water, Ports and Historic Cities. Matteo is a cultural anthropologist experienced in the analysis of perceptions and relational dynamics between public and private actors. His research focuses on understanding multiple structural, spatial and socio-economic factors as the basis for spatial planning and social interventions. Other interests include policy implementation for granting access to basic resources, such as water, and the strategic reinterpretation of heritage by institutional and activist organizations.

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Michele Tenzon teaches and conducts research in architecture and architectural history. His publications focus on the history of global architecture, with particular attention to the ecological transformations produced by the direct and indirect, tangible and intangible actions of imperialism, as well as by postcolonial relations and conditions. He recently authored the short book *Designing the Rural-Urban Continuum* (LetteraVentidue, 2024) and co-authored *Architecture, Empire, and Trade* (Bloomsbury, 2025).

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Carlien Donkor is a PhD candidate at the African Studies Centre Leiden (ASCL), interested in traditional ingenuity and historical practices of living on and with water, and their positioning in inclusive development frameworks. Her experience as an architect and project manager combines research, design and construction for climate-resilient and context-sensitive solutions. She was among the winners of the EU Sparks hackathon in which The Nettuniani proposal was awarded the best solution for climate adaptation. Other interests include community collaborations and multimedia installations.

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PART I Challenges, Concepts and New Approaches

Blue Papers 2026 (Vol. 5 No. 1), pp. 20–31
10.58981/bluepapers.2026.1.01
Received 24.04.2025; Received in revised form 22.06.2025; Accepted 28.10.2025

Understanding the Historical Geography of Water Use in Estate Landscapes: Learning from the Past to Address Present-Day Water Challenges

Elyze Storms-Smeets

Abstract
In the Netherlands, climate change has brought longer periods of drought alongside short periods of more intense rain, prompting planning and heritage professionals to explore new approaches to water management. One promising method is "learning from the past." Landscape history studies can reveal continuity and change in hydrological practices, offering knowledge, inspiration and potential solutions to today's water challenges. But what does it mean to learn from the past? Historic knowledge must go beyond simply identifying historic water structures in the landscape. This article focuses on country estates, analyzing these heritage sites as spatial and social ensembles in wider landscape systems. Tracing how water shaped the establishment and development of country houses and estates reveals important dynamics and principles. This deeper understanding of the historical geographical dynamics of water use can help present-day estate owners, governments and spatial planners foster more resilient estate landscapes.

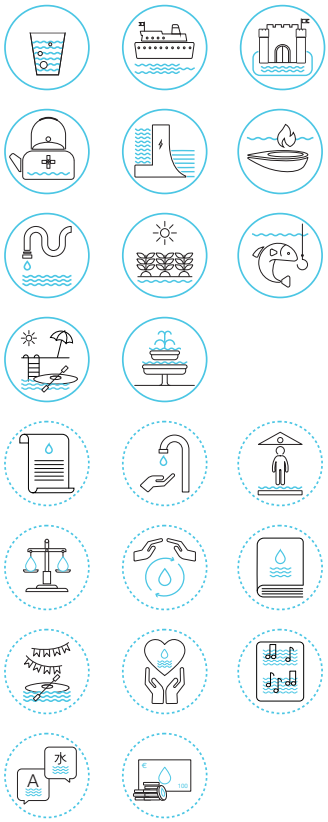
Policy Recommendations

- Policy leaders should apply the approach of 'learning from the past' to contemporary water challenges by analysing continuity and change in the long history of water use at heritage sites such as estates.
- Policy leaders and spatial planners, should consider estates as heritage ensembles within a broader system (estate landscape), rather than focus solely on the protected, monumental (parts of) estates.
- Decision makers should take into account both the spatial-functional and social cohesion of an estate (in the past and present), connecting spatial plans, long-term cooperation and participation.

KEYWORDS

drought
floods
country houses
estate landscapes
heritage

WATER VALUES



< Fig. 1 Sonsbeek estate in Arnhem, with the Sint Jansbeek stream. In the nineteenth and twentieth centuries, parts of the estate were sold off, enabling urban expansion (Source: MVOTV, 2021, CC BY-NC-ND; used with permission).

Introduction

In the Netherlands, a country house is a large house in the countryside, typically owned by a wealthy or aristocratic family, surrounded by an estate. In the Netherlands, country estates can be designated as national heritage sites. The National Heritage Agency of the Netherlands has listed over 550 such sites, with particular attention to the architectonic center of house and garden (Dessing and Holwerda 2024). This article draws on experiences of various country estate projects in the Dutch provinces of Gelderland and Limburg (Nijhuis, Storms-Smeets and Thissen 2023; Tomescu et al. 2021; Storms-Smeets 2023).

The regions are part of the High Netherlands, known for undulating, often sandy, landscapes. In recent years, heat waves and long dry periods have become the norm in the Netherlands (Inspectie Overheidsinformatie en Erfgoed 2020). Particularly in the east and south of the country, drought has resulted in low groundwater levels, with drastic consequences for estate landscapes (Nijhuis, Thissen and Storms-Smeets 2021; Provincie Gelderland 2022). Drought is considered "an assassin or silent killer" (Hartman 2019), because its effects are often only visible after a long time. It can lead to damage to the foundation of historical buildings, decay of historical water objects and structures, damage to green heritage and biodiversity and the impoverishment of agricultural land and forests.

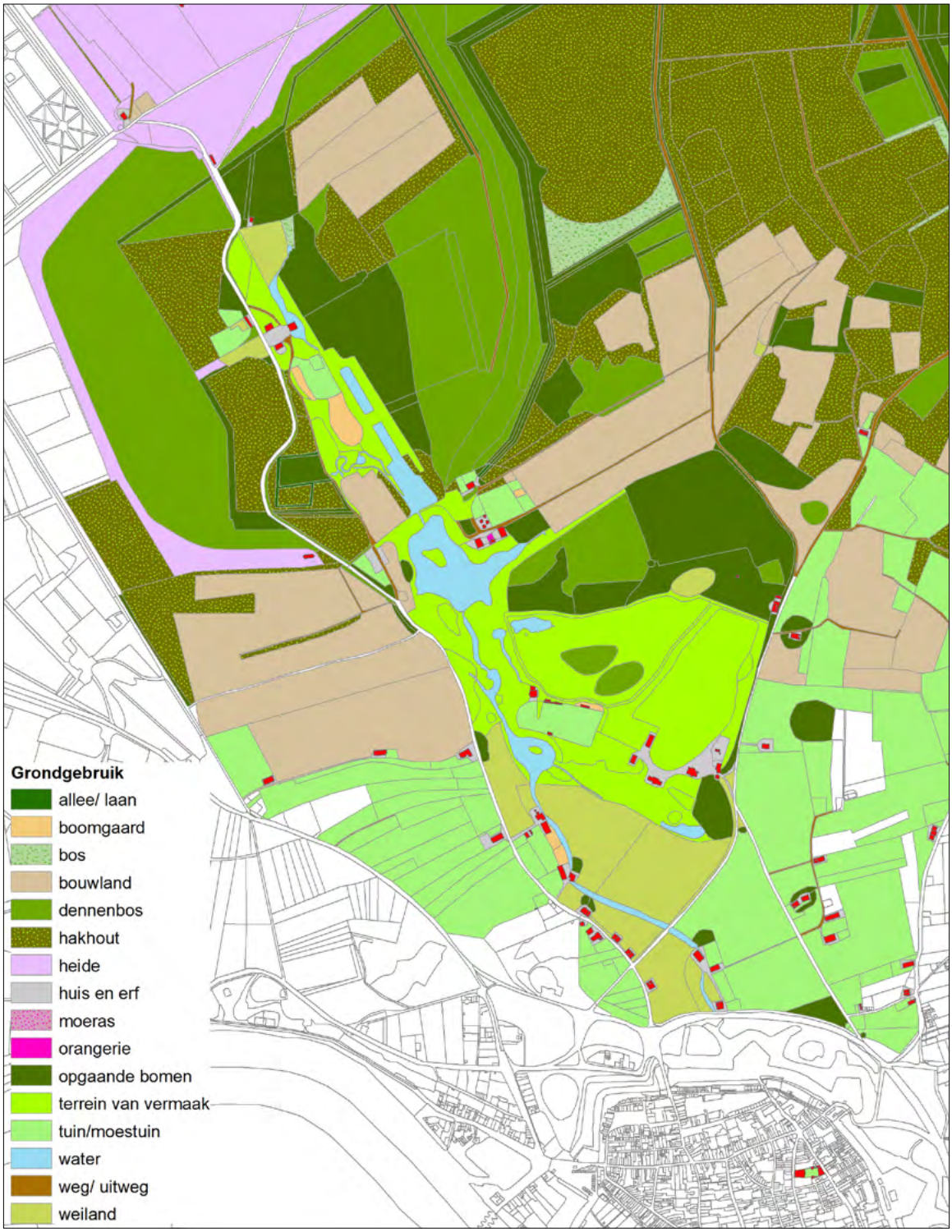
In contrast, damage caused by floods is often sudden and immediately visible (and tangible). Flooding can lead to water safety problems, damage and destruction to heritage (buildings, bridges, trees, landscapes, collections, etc.) and the loss of fertile soil and biodiversity. With the pattern of these climatic extremes (drought and floods), less rainwater infiltrates the soil. At the same time, faster drainage is occurring via sewers and rivers following increased urbanization, infrastructural expansion, surface hardening and excessive groundwater extractions.

When addressing present-day issues of drought and flooding in estate landscapes "a pure technological approach to water challenges is rarely sufficient" (Kolen 2022), but nonetheless remains dominant. As landscape archaeologist Jan Kolen stated at a 2022 conference on the Maas River:

> We need an intersectoral approach to issues and challenges in river landscapes. We need a long-term perspective on the history of the river, as people have always, continuously learned how to adapt. Actually, it's a long process of trial and error from which we can learn a lot. We should embrace the learning capacity of past communities.[1]

The adaptative skills of past societies are evident in resilient "socio-technical, cultural and environmental systems (SETs)" (Morató, Sánchez and Martin 2025). In recent years, a heritage-based approach for tackling water challenges has been promoted, motivating spatial planners to look "past forward" instead of "fast forward" (Van Paassen 2022; Vreenegoor and Kosian 2022; Janssen and Van Asseldonk 2023). Indeed, knowledge of heritage sites can help address water challenges – an effort that "isn't about protecting the past but using heritage to find solutions for the future" (Historic Environment Forum 2021).

1. See also the publication resulting from this conference (Caljé and N. Randeraad 2025).



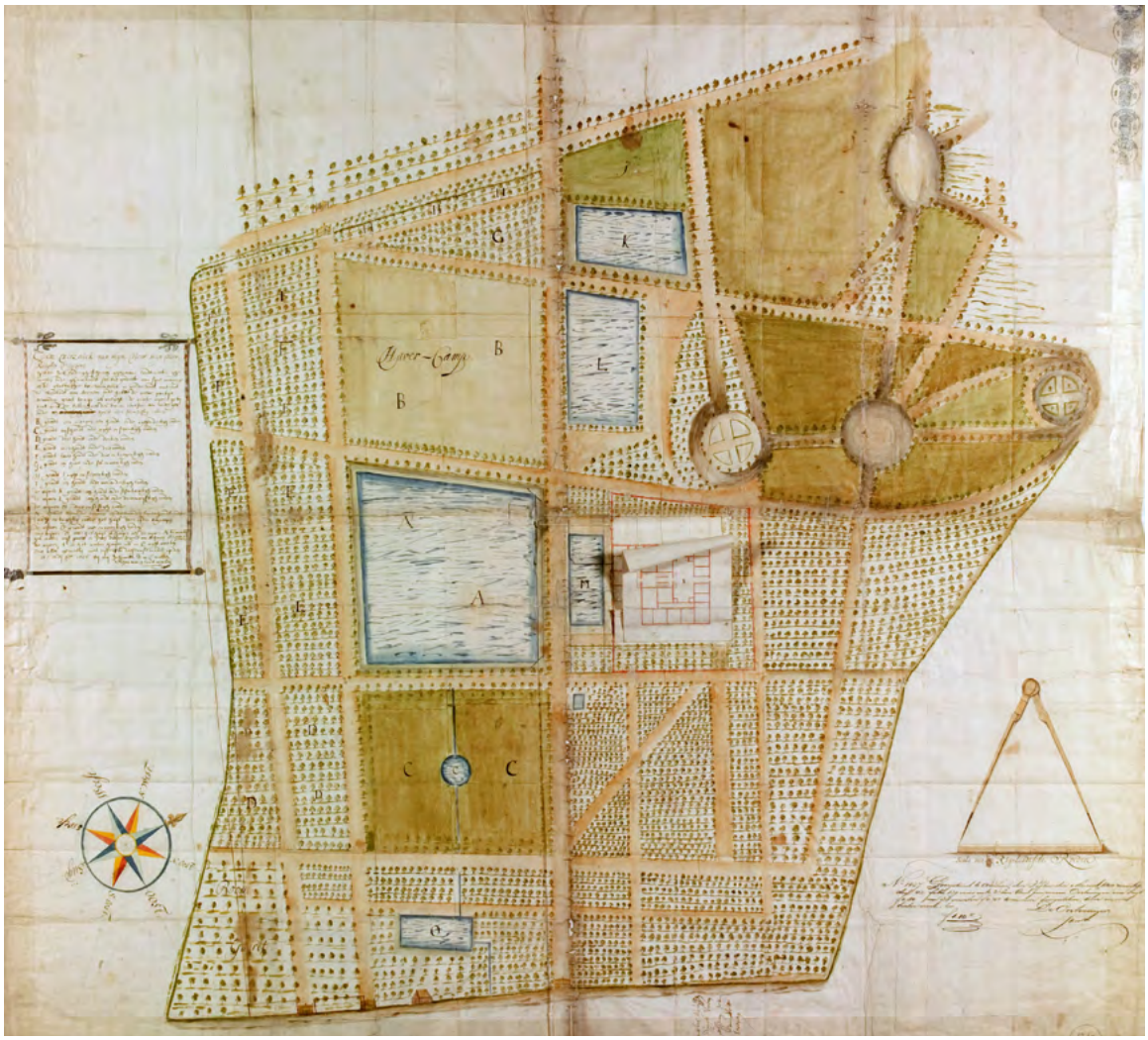
^ Fig. 2 Estates of Zypendaal (north) and Sonsbeek, circa 1832, showing multifunctional landscapes before the urban expansions of the late nineteenth century (Source: Elyze Storms-Smeets, 2025. Based on 1832 cadastral maps from HisGIS, Fryske Akademy © HisGIS open data, www.hisgis.nl).

Understanding Country Estates as Heritage Ensembles

When addressing water challenges at country estates, spatial planners generally tend to consider legally defined heritage sites. However, the number of 550 nationally listed country estates does not represent all country estates in the Netherlands. In the province of Gelderland, there are 120 nationally listed country estates, yet over 500 sites have been identified (Nijhuis, Storms-Smeets and Thissen 2023).

Furthermore, to really understand a country estate and its relation to water, we must look at the entire ensemble and not just at the core of country house with garden and park. This means taking account of the wider estate landscape with economically productive lands (vegetable garden, orchards, forests, agricultural fields, farms, water mills) and sometimes a church and village.

Moreover, understanding the estate community of owners, staff, tenants and volunteers is



^ Fig. 3 Estate map depicting the former Monnikhuizen Monastery transformed into a regent country estate, incorporating existing waterways, ponds, and watermills, with additional features such as a fountain (Source: Johannes van Swieten, 1656. Public domain, via Gelders Archief, Inv. 70-0002).

equally important as country estates are spatial, functional and social ensembles (Storms-Smeets 2023). Each estate is part of a larger cultural landscape, often with adjacent estates that are spatially connected through natural or man-made waterways. Together, the various individual heritage ensembles form part of a larger system. By gaining a better understanding of the establishment, development, functioning, design and transformation of heritage ensembles over time, we also gain a better understanding of the possibilities and limitations of contemporary conservation and development of heritage in our greater living environment.

Key Properties of Water Use in Estate Landscapes

As multifunctional ensembles, country estates offer lessons for how we can learn from the past. A historical geographical analysis of country estates reveals three major periods of new estate building: castles and large landed estates for nobility (1000–1600), country estates for city regents (1600–1800), and the creation of villa-like country estates for a new elite of bankers, industrialists and lawyers (1800–1940) (Storms-Smeets 2021). The focus here is on the first two categories (the younger villa-like estates were often located on previously undesirable locations with little water at hand). This article explores historical geographic dynamics of estate landscapes and the use of water. The analysis draws on a wide range of historic sources, including topographical maps, manuscript estate maps, eyewitness descriptions, management records and pictorial sources like paintings, prints and photographs. Having studied hundreds of country estates in High Netherlands, particularly Gelderland and Limburg, several key properties can be identified.

^ Fig. 4 Map of the Klarenbeek estate, 1635 (Source: Nicolaas Geelkerken, 1635. Public domain, via Archives of the Klarenbeek house, Inv. 21).

^ Fig. 5 Boundary of the nationally listed country estate of Well (Limburg). The water board initially focused only on this part of the former estate, but through collaboration with heritage advisors and a long-term landscape analysis, more appropriate solutions emerged (Source: Cultural Heritage Agency of the Netherlands (RCE), 2024. CC BY-NC-ND).

The proximity to water was often decisive when choosing a location and many castles and country houses are built near a river, stream or canal. Most castles can be found close to rivers, for instance Maas (Well, Geijsteren, Blitterswijck), Geul (Schaloen, Genhoes), Rijn (Doorwerth, Rosande), IJssel (Middachten, Gelderse Toren) and Baakse Beek (Hackfort, Vorden, 't Medler, De Wildenborch) (Hupperetz, Olde Meierink and Rommes 2005; Jas et al. 2013). Together with early settlements, castle estates occupied prime riverside locations. The country homes of regents were established near cities, often making use of older farmsteads and monasteries located in smaller valleys with natural springs. For example, in the Gelders Arcadia region around the city of Arnhem, regent families took advantage of the dissolution of Catholic monasteries, creating their own country estates with the already existing arable fields, meadows, roads, lanes, brooks, ponds and watermills. Such regent estates include Mariëndaal and Klarenbeek (Storms-Smeets 2021). Castle estates were originally very large, ranging between 500 and several thousand hectares. Regent country estates were smaller, with approximately 100 to 500 hectares.

The use of water at country estates is varied and often the same water was used for various reasons. Corresponding with the "intangible and tangible water icons" (Hein et al. 2025) the following properties of water use at country estates have been identified, showing the interwovenness of multiple water functions, values and practices.

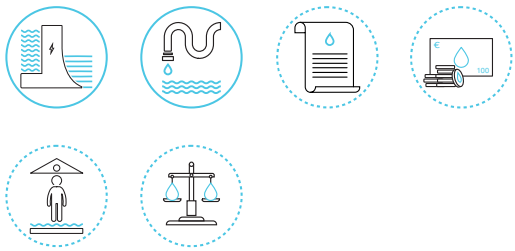
- Above all, water was (and is) a basis for life. Water was derived from natural springs, brooks, rivers and man-made water wells (collecting rainwater or groundwater). It was used as drinking water for humans and animals, for watering vegetable gardens, and in ponds for keeping fish and waterfowl. This corresponds with Hein et al. 'water icons' (Hein et al. 2025):

- Natural and man-made waterways have been the main transport routes in the Netherlands for centuries, and members

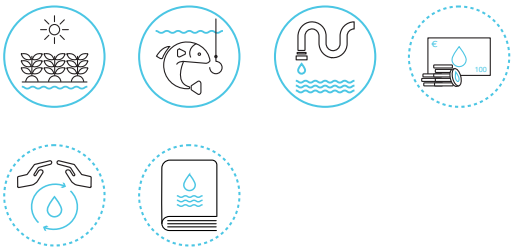
of the elite chose to build their castles and country homes close to these routes in order to move more easily and quickly between city and countryside. The location also included possibilities for ferries to cross the river and for the owners to collect tolls.

- Castles were surrounded by a (double) moat for defense reasons (both military and to stop thieves). If country houses of regents were moated, it was probably due to the older layout (e.g., the farm that existed there previously was moated) or for aesthetic reasons. The location had no military function, but a moat was still useful for keeping out thieves.

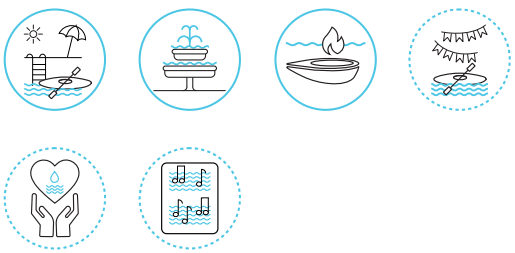
- Most castle estates would have one or more watermills. Younger country estates in spring valleys also had watermills; already in medieval times these springs had been dug out to feed man-made brooks (then as part of a monastery or farmstead). Each watermill had a mill pond (in Dutch: *wijer*), a weir (*stuw*), and surface waters (like streams, ditches and canals). The estate owners enjoyed manorial rights on the water, including the right to use water power for watermills. Originally watermills were primarily used for agricultural purposes (grinding grains into flour), but became more industrial as they were used to produce lumber, textiles and paper.



- Drought and floods are not new to this region. Inhabitants adapted the landscape or their practices to respond to changes in water availability. In Gelderland and Limburg, both castle estates and regent country estates had multifunctional landscapes with meadows, hay fields and ponds in the low-lying wet landscapes. Arable lands, orchards and vegetable gardens were situated on the higher lands close to the water, and woodlands and heathland on the steep, high and dry landscapes. In the Baakse Beek area, estate owners created water meadows and so-called rabbatten woodlands (coppice on ridges) in wetlands. The use of the landscape was based on local conditions of water, soil and relief in such a way to get the best results and create a resilient landscape. Thus, flooding was allowed (desired even) in the (water) meadows and hay fields because it increased fertility. Planting woodlands on steep hills prevented erosion. The landscape was designed to make water flow as effectively as possible (including rainwater streaming down the relief).



- Beginning in 1600, water became increasingly important in the aesthetic landscapes of gardens and parks, which included ponds, cascades, fountains and other waterworks. Famous water works can still be seen at Rosendael, Sonsbeek and Biljoen and Beekhuizen. Although in the seventeenth century, geometric designs represented one's status and power in society, the more romantic landscape style from about 1750 allowed owners to express their personal feelings and emotions (often in poems and songs, but also in the landscape). Statues of Greek and Roman water gods represented spirituality and symbolized the owner's position of power and status. Fountains, cascades and other aesthetic water sites represented life, beauty, art, transience and purity.



- Particularly in Catholic regions, like Limburg, water was (and is) important for religious practices and values. For instance, the Saint Gerlachus well at the St. Gerlach estate was known for its healing properties and became a pilgrimage site. At the castles of Schaloen and Genhoes (Oud-Valkenburg), yearly religious processions through the landscape also incorporate indicate the importance of water. The names of these wells, and their meaning, are still widely known in local communities.

Conclusion

The abundance and shortage of water resulting from climate change greatly affects the management of heritage sites like estate landscapes. This goes beyond the heritage field. Spatial planners, however, still tend to view heritage only as legally listed tangible monuments that need protection, and don't look at the wider ensemble and system. Viewing estates and estate landscapes as spatial, functional and social ensembles and systems helps find solutions to spatial problems, but also contributes to better cooperation and participation. Without social connection it would not be possible to execute spatial plans.

At country estates in Gelderland and Limburg, water has been used (and reused) for utility and beauty in the estate landscape, creating complex and integrated ensembles and systems. Analyzing continuity and change in the long history of estate ensembles gives us new knowledge and deeper understanding of the historical use of water and developments that can help with solutions for contemporary challenges. In the Baakse Beek area, for instance, the water board worked together with local governments and estate owners to deal with

^ Fig. 6 Preliminary climate-proof design for the Well estate using a "learning-from-the-past" approach (Source: Martijn Al, Veenenbos and Bosch Landscape Architects, 2024. CC BY-NC-ND).

drought by restoring historic water systems (including rabbatten woodlands, water meadows and castle moats). Their cooperative efforts were awarded with the Gelderland Spatial Quality Award in 2022 (Provincie Gelderland 2022). We should, more than before, learn from the past and find solutions in the preservation and improvement of the integral values (heritage, nature, social, economic, etc.) of our living environment.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein and Matteo D'Agostino.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 32–41
10.58981/bluepapers.2026.1.02
Received 14.05.2025; Received in revised form 02.09.2025; Accepted 26.11.2025

Sustainable Development and Indigenous Knowledge: The Role of Ancestral Communal Pools (*Birket*) in Southern Lebanon

Georges Gharios

Abstract
This article explores the pivotal role of ancestral communal pools, known as *birket*, in fostering sustainable water management, social resilience and climate adaptation in southern Lebanon. Rooted in centuries-old indigenous knowledge, these open-air reservoirs have historically enabled rural communities to manage scarce water resources through collective action and seasonal rituals. Despite the pressures of modernization, conflict and environmental degradation, many *birket* still exist – serving not only as functional infrastructure but also as vital symbols of cultural identity and solidarity. Based on a detailed survey and fieldwork in the historical region of Jabal Amel, this study highlights the practical and symbolic significance of *birket*, especially in border zones marked by displacement and ecological fragility. Examining their socio-ecological value and restoration potential, the article makes a case for integrating traditional water systems into national strategies for sustainable development and climate resilience – particularly in contexts where centralized infrastructure remains insufficient or ecologically unsound.

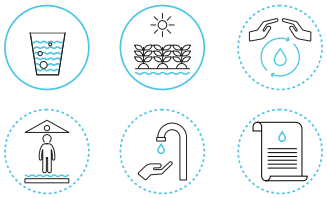
Policy Recommendations

- Recognize *birket* as heritage infrastructure in cultural/environmental registers and municipal plans.
- Fold *birket* into the next National Water Strategy update as decentralized, complementary storage.
- Embed *birket* in education: Add short case studies to national environmental toolkits (MEHE/UNESCO, 2025–2030).
- Create a hydro-cultural registry of water assets by 2026 to prevent ad-hoc conversion of key sites.

KEYWORDS

hydro-cultural heritage
legal pluralism
indigenous water knowledge
communal governance
nature-based solutions

WATER ICONS



< Fig. 1 Image from Le Pays d'Israel, a collection of 19th-century views of the Holy Land published in Paris (Source: Charles William Meredith van de Velde, 1857. Public domain, via Wikimedia Commons).

Introduction

Water, the most critical resource of the twenty-first century, has long shaped the social, political and ecological foundations of the Levant. Lebanon, a country often mythologized for its abundant springs and fertile valleys, paradoxically faces chronic challenges in managing its water resources sustainably (Catafago and Jaber 2001). These challenges are rooted in infrastructural and governance shortcomings as well as in the underappreciation of traditional and community-based water management systems that have proven resilient over centuries. In the southern rural regions of the country, particularly within the historical territory of Jabal Amel, water scarcity has long been a defining feature of life. Here, the scarcity of perennial watercourses has led to the development of intricate and adaptive water management systems, shaped by indigenous knowledge and deeply rooted in collective practice (Gharios 2022). Among the most prominent of these systems is the *birket* (fig. 2) – a communal rainwater harvesting pool that has served social, economic and ecological functions in the villages of southern Lebanon for generations.

Despite its functionality and symbolism, the *birket* has received scant attention in contemporary water policy and academic discourse. As Lebanon grapples with the compounded effects of climate change, political instability, infrastructural decay and regional displacement, the imperative to recognize, protect and include traditional water management systems in broader sustainability frameworks becomes urgent (Gharios 2022). Climate models for the eastern Mediterranean forecast a significant decrease in annual rainfall, a reduction in snow cover and more erratic seasonal precipitation – all of which threaten the reliability of conventional surface and groundwater systems (MoE 2016). In this context, ancestral systems such as the *birket* offer a buffer against environmental shocks and serve as living testimonies to the adaptive ingenuity of marginalized communities.

This article investigates the *birket* as both a physical infrastructure and a social institution. It argues that the *birket* functions as a vernacular hydro-technology that aligns with the principles of nature-based solutions, echoing recent international calls to embrace low-carbon, context-specific water infrastructure. The communal nature of these pools fosters collective responsibility, equitable water access and seasonal rituals of maintenance, repair and sharing – all of which contribute to a deeper sense of environmental stewardship and local empowerment. Unlike modern water infrastructure systems that often exclude users from governance and management, *birket* systems operate on shared norms and inherited rights, often articulated through customary law, oral tradition and village-level negotiation.

The study is situated within a broader scholarly effort to decolonize water knowledge by recognizing non-Western forms of expertise and practice (Gharios 2022). Much of Lebanon's legal and infrastructural water management architecture is modeled after French colonial precedents, themselves layered upon Ottoman and Islamic precedents. Yet underneath these formal systems lies an enduring matrix of customary practices that remain active in many rural settings. The *birket*, in this sense, offers an entry to understanding the palimpsestic nature of Lebanese water law and the cohabitation of codified and customary regimes of regulation. Through the lens of the *birket*, this article explores how indige-

^ Fig. 2 *Birket* of Taybeh, 1982 (Source: Photographer unknown; private collection of Abbas Kawsan, used with permission).

nous knowledge systems might contribute to climate adaptation, sustainable development and post-conflict rural recovery.

The argument advanced here is threefold. First, *birket* systems exemplify locally appropriate, environmentally sustainable and socially inclusive forms of water management that predate and, in some cases, outperform centralized modern systems. Second, the failure to incorporate *birket* in contemporary water strategies reflect broader patterns of epistemic marginalization that undervalue rural and indigenous knowledge systems. Third, the rehabilitation of these systems – when grounded in participatory frameworks and linked to development priorities – can serve as an effective tool for sustainable water governance, climate adaptation and rural revitalization.

By engaging with the *birket* as both a historical legacy and a practical resource, this article seeks to connect heritage with development, indigenous practice with modern planning and climate science with local action. The goal is to frame *birket* as living systems, not relics – recognizing them as a resilient hydro-cultural heritage that continues to shape landscapes, livelihoods and identities in southern Lebanon.

Historical Context

Water management in Lebanon reflects a complex and layered history shaped by successive civilizations, each contributing new legal, social and infrastructural systems to the governance of water. From Roman aqueducts to Islamic waqf institutions and Ottoman land law, Lebanon's hydraulic landscape is a palimpsest of traditions, shaped by centuries of adaptation to topographic, climatic and geopolitical realities (Gharios 2022). Within this intricate framework, the *birket* – a communal rainwater harvesting pool – emerged as one of the most enduring and contextually appropriate technologies, particularly in the rural highlands of southern Lebanon.

The roots of Lebanon's hydraulic culture lie in antiquity. Roman engineering, with its monumental aqueducts, canals and cisterns, introduced a culture of infrastructure building that persisted for centuries. The ruins of Roman waterworks across the Beqaa Valley and Mount Lebanon continue to testify to the importance of controlling water for both domestic and agricultural needs. During the Islamic Golden Age (8th to 13th centuries CE), new legal and social frameworks emerged around water governance, emphasizing equity, conservation and public accessibility. Under Islamic law (sharia), water was classified as a common good (*mubāḥ*) and thus not subject to private appropriation unless captured or diverted for beneficial use. This legal ethos was expressed through institutions such as the *sabil* (public fountains), *hima* (protected communal lands) and *waqf* (charitable endowments),

which collectively ensured that water remained a socially governed resource embedded in ethical and religious obligations (Caponera 1992; Mallat 2003).

The Ottoman Empire further codified water management through the 1858 Land Code and subsequent regulatory instruments that shaped property rights and water access. In Ottoman Lebanon, communal tenure systems such as *musha'* (shared agricultural land) were prevalent, and these often coexisted with customary rules around water use. These informal norms, referred to as *'urf*, governed everything from irrigation schedules to maintenance obligations. They were passed down orally and were often enforced by local elders or village notables rather than imperial officials. Following the collapse of the Ottoman Empire and the establishment of the French Mandate in 1920, a new layer of statutory water law was imposed. Drawing on French civil law traditions, the colonial administration introduced technical planning agencies and centralized oversight, which gradually eroded the authority of customary arrangements. However, these formal structures rarely reached the rural peripheries, where ancestral practices persisted out of necessity (Gharios 2022).

What emerges from this history is a form of legal pluralism, in which statutory, religious and customary laws have overlapped and competed over time. In the absence of strong state infrastructure – especially in Southern Lebanon, historically marginalized by geography and politics – communities continued to rely on inherited social systems to manage their limited water resources. Within this context, the *birket* evolved as both a hydrological solution and a governance institution. Unlike private cisterns or state-engineered dams, *birket* were typically communally constructed, maintained and managed. They served multiple purposes: irrigation of crops, watering of livestock, provision of domestic water, and more recently, recreational and construction-related uses.

The social life of the *birket* was as important as its utilitarian function. Positioned at the edge of villages, often in natural depressions or at springs, *birket* were gathering spaces that hosted seasonal rituals, labor-sharing events, and dispute resolution processes (fig. 1). Their upkeep – typically carried out in the dry autumn months – was a community affair involving men and women of all ages. Silt was manually removed, walls were reinforced with local stone or clay, and irrigation gates were calibrated according to crop schedules and rainfall expectations. This collective labor reinforced social cohesion and affirmed local ecological knowledge, especially in regions where state presence was minimal or absent.

In the Jabal Amel region, which comprises much of southern Lebanon, these pools became integral to village identity. Families took pride in the size, clarity and volume of their *birket*, and oral histories often referenced the circumstances of their construction or expansion. As rainfall patterns fluctuated and spring flows diminished – especially during the long, dry summers – these reservoirs became critical buffers, allowing villages to irrigate tobacco fields, water herds and maintain subsistence agriculture. Their existence was not static: Many were expanded or replicated as village populations grew. In some cases, smaller satellite *birket* were added in outlying farmlands to serve seasonal workers or herders.

With the turn of the twenty-first century, the relevance of *birket* systems began to wane under the pressure of urbanization, war-related destruction and the expansion of centralized

water infrastructure. Many pools were filled in, repurposed or abandoned. Yet others persisted, sustained by the same communal norms and adaptive practices that had supported them for centuries. In villages like Marwaheen, the *birket* was reclaimed and restored through a combination of municipal initiative and donor support, offering a contemporary illustration of how ancestral practices can be integrated into modern water and development planning.

What makes the *birket* particularly relevant today is not just its historical legacy, but its alignment with current global priorities around sustainability, decentralization and resilience. The United Nations' emphasis on nature-based solutions, participatory water governance and climate adaptation provides a policy framework within which *birket* systems can be valorized and scaled. They exemplify low-tech, high-impact infrastructure that can be maintained locally with minimal external inputs. Moreover, they offer a living example of how heritage and innovation can coexist: By recognizing and investing in such systems, policymakers can foster environmental sustainability as well as cultural continuity and rural agency.

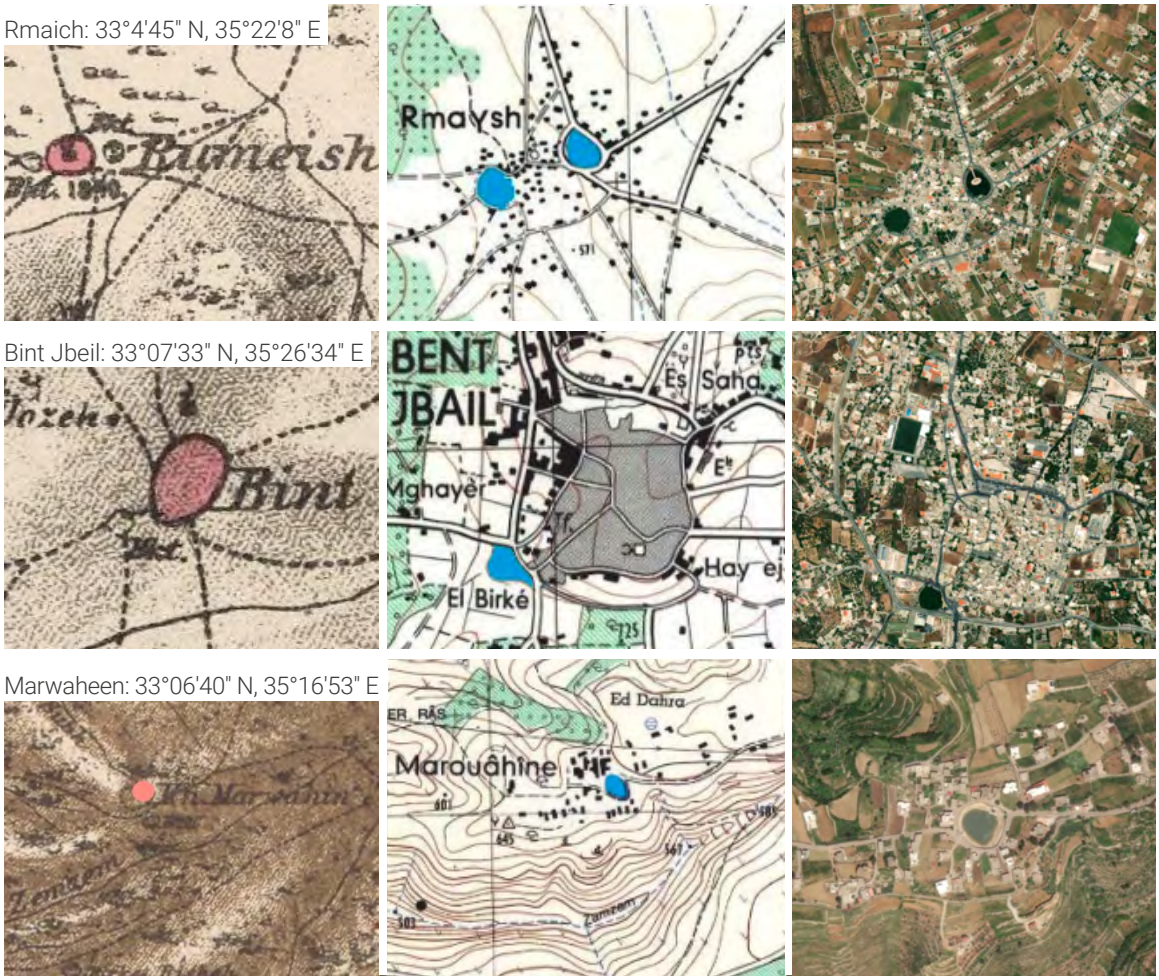
In summary, Lebanon's water history reveals the persistence and adaptability of indigenous systems amid shifting legal and political orders. The *birket* represents a particularly illustrative example of this resilience. As a technology, it reflects the ecological intelligence of communities who learned to store rainwater in arid and semi-arid contexts. As a social institution, it embodies a culture of cooperation, stewardship and collective memory. With a proper understanding of this historical context, it is possible to safeguard the *birket* as heritage and use it to reimagine a sustainable water future.

Methodology and Case Studies

This study adopts a multidisciplinary and multi-scalar methodology combining spatial analysis, historical documentation, oral history and ethnographic fieldwork. The aim is to understand the physical distribution and status of ancestral *birket* (communal water pools) in southern Lebanon, as well as their functional, social and symbolic roles over time. As a research object, the *birket* is both material and cultural: It is part of the physical landscape while simultaneously anchored in social practices, local governance traditions and collective memory. Empirically, the article draws on multi-scalar research conducted across 86 villages in southern Lebanon, where over 100 historical *birket* sites were surveyed using a combination of remote sensing, historical cartography, oral history and field observation. The case of Marwaheen, a village once deeply impacted by Israeli occupation and later revitalized through the restoration of its abandoned *birket*, serves as a key case study. The Marwaheen project restored a water infrastructure asset and catalyzed local agricultural innovation, renewing interest in indigenous forms of environmental management.

1. Research Design

The research began with an extensive literature review covering the evolution of water law and governance in Lebanon and the wider Levant. Key sources included legal codes from the Ottoman and French periods, academic theses, NGO reports and previous hydrological assessments. This provided the foundation for understanding the legal pluralism and socio-political context within which *birket* practices emerged and operated.



^ Fig. 3 Three case studies of Rmaich, Bint Jbeil and Marwaheen (Source: left, Conder and Kitchener, 1881; middle, Lebanese Army maps, 1962; right, Esri, NASA, NGA, USGS © OpenStreetMap, Microsoft, Esri, TomTom, Garmin, METI/NASA, USGS | Vantor).

To document the spatial distribution of *birket*, a comparative analysis was conducted using a combination of historical and contemporary cartographic sources. These included:

- The 1881 *Survey of Western Palestine maps*, produced by the Palestine Exploration Fund;
- The 1962 topographic series of the Lebanese Army (1:20,000 scale);
- Recent satellite imagery (2018–2023).

These sources were georeferenced using geographic information systems software, allowing for a spatial overlay of historical *birket* sites with current land-use patterns. This visual data was supplemented by ground-truthing (direct verification of remote data through field observation) during field visits across 86 towns and villages in southern Lebanon, covering the nine *caza* (districts) located within the South and Nabatiyeh governorates.

2. Fieldwork and Oral Histories

Field visits were conducted during the summers of 2018 and 2019, with follow-up site checks in 2022. In each village, local municipal authorities, elders and farmers were interviewed to validate the existence and use of traditional *birket*, identify names, assess current conditions and understand community perceptions. These interviews followed a semi-structured format, guided by questions around historical use, seasonal maintenance practices, water allocation systems, communal rituals and perceptions of decline or restoration.

Oral history was prioritized, particularly given the erosion or absence of formal records in many rural settings. In several cases, villagers could recall the year or circumstances under which a *birket* was constructed, expanded, damaged during war or converted into another use (e.g., parking lot, public park). This qualitative data not only enriched the mapping effort but also provided insight into the symbolic meanings and evolving social functions of the *birket* over time.

A total of 101 *birket* were identified, distributed across 86 villages. Each pool was classified according to its current status: functioning, abandoned, destroyed, repurposed or restored. Their physical characteristics – size, construction material, water volume and elevation – were documented where accessible. These were cross-referenced with historical maps to assess continuity and change.

Conclusion

Ancestral communal pools (*birket*) in southern Lebanon are not vestiges of a bygone water economy; they are living, small-footprint infrastructures embedded in social norms, seasonal rituals and place-based knowledge. Our survey across 86 villages shows that where communities still steward them, *birket* persist, and modest, well-targeted works deliver quick, low-cost gains in water security and local livelihoods. Read through the lens of legal pluralism, they also illuminate how customary practices have long complemented – and at times outperformed – centralized systems in marginal and borderland settings. The path forward is pragmatic rather than nostalgic: Prioritize light-touch rehabilitation in high-potential villages through municipal–NGO collaboration; fold *birket* into the next National Water Sector Strategy as decentralized, complementary storage; and formalize village maintenance committees that keep decision-making close to users, paired with practical financing mechanisms. Education matters too: Showcasing *birket* in school toolkits can sustain practice transfer and climate literacy, while recognizing key sites within a national hydro-cultural registry may help to prevent ad-hoc conversion. Taken together, these steps align heritage with adaptation – advancing SDG 6 (decentralized storage and equitable access), SDG 13 (low-carbon resilience to rainfall variability) and SDG 15 (support to cultural landscapes and micro-habitats) – and, crucially, strengthen rural agency.

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Matteo D'Agostino, Michele Tenzon and Pelin Yalçın.

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JAVA AND MADURA 1:500.000

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SUIKERFABRIEKEN SUGAR FACTORIES

REG. (Regency of) MADJALENGKA
1 Kadipaten
2 Ciateweg
3 Parongpiaja

REG. (Regency of) CHERIBON
4 Andjawimangoen
5 Gamlod
6 Soerowimangoen
7 Sindanglaoet
8 Karangsoewong
9 Nieuw Tersana
10 Loewoenggadjah

REG. (Regency of) BREBES
11 Kedawoeng-an – West
12 Bandjaranjar
13 Djatibarang

REG. (Regency of) TEGAL
14 Pagongan
15 Kemantren
16 Adiwerna
17 Pangkah
18 Kemangkon
19 Doesoen-harjangan
20 (Vervallen) (Cancelled)

REG. (Regency of) PEMALANG
21 Soemberrendjo
22 Bandjardawa
23 Petarookan
24 Tjomal

REG. (Regency of) PEKALONGAN
25 Bragi
26 Wonopringgo
27 Toeloe
28 Kalimati

REG. (Regency of) KENDAL
29 Tjandiroto
30 Gemoeh
31 Kaliwoengoe

REG. (Regency of) KEBOEMEN
32 Rembben

REG. (Regency of) BANJOEMAS
33 Kalibagor
34 Poerwodadi

GOUV. (Government of) JOGJAKARTA
35 Randoedongkal
36 Medari
37 Beran
38 Tjebongan
39 Rewoeloe
40 Wonotjatoer
41 Tandjoengtirto
42 Padokan
43 Kedaloeplerat
44 Barongan
45 Bannoel
46 Gesikan
47 Gondangtjipoero
48 Poendoeng

REG. (Regency of) JAPARA
49 Majong

REG. (Regency of) KOEDOES
50 Rendeng
51 Tandjong Medjo

REG. (Regency of) PATI
52 Trangkil
53 Pakis

GOUV. (Government of) SOERAKARTA
54 Kedoengbenteng
55 Modjo
56 Tasikmadoe
57 Tjolomadoe
58 Delanggoe
59 Tjoramalang
60 Gerbaren
61 Karangwoni
62 Tjepoer
63 Manishardjo
64 Gondangmanggoeng
65 Poandoeran

REG. (Regency of) NGAWI
66 Soedhono

REG. (Regency of) MAGETAN
67 Poerwodadi
68 Redjosari

REG. (Regency of) MADIOEN
69 Redjosarie
70 Kanigoro
71 Pagotan

J A V A - Z E E

I N D I S C H E - O C E

108° 109° 110°

Geographical Section, General Staff, Nº 4556.
Published by War Office, 1945.
Kind 648 2nd Edition. Published by H.Q. Survey Production Centre, South East Asia, Oct. 1945.
Extra road information supplied by I.S.T.D. (S.E.A.C.) Oct. 1945

SCALE 1 / 500000

AFKORTINGEN ABBREVIATIONS

Malay	Dutch	English	Malay	Dutch	English
G. Goewo	Grot	Cave	D. Darat		
G. Goenoeng			Rn. Ranau		
L. Igir	Berg	Mountain	S. Sinai		
Pe. Pasir			T. Telaga	M. Meer	Lake
W. Wagir			R. Ranjo		
Pgs. Gebergte	Range		W. Wadoek		
P. Poeloe	E. Eiland	Island	Kh. Kawah	Krater	Crater
Gl. Gin			Rw. Rawa	Moeras	Swamp
	Eil. Eilanden	Islands		b. Boei	Buy
O. Oenjoeng	Kaap	Cape	K. Kali		River
Tg. Tandjoeng				Wf. Waterval	Waterfall
H. Hoek		Hook, point, cape			

REFER TO THIS MAP AS:—HIND 648 SHEET 2 SECOND EDITION

LEGENDA LEGEND

Dutch	English	Dutch	English	Dutch	English
Standplaats Gouverneur	Seat of Governor	Hoofdwegen	Main Road	Mooi uitzicht	Beautiful view
Standplaats Resident en/of Assistent Resident en/of Regent	Seat of Resident and/or Assistant Resident and/or Regent	Andere autowegen	Other Motor Roads	Rivier, overzoomt, geschikt voor voertuigen	River, ferry, suitable for vehicles
Standplaats Wedana	Seat of Native Head	Wegen alleen in den droogen tijd berijdbaar	Dry season roads	Rivier, geen overgangsmiddelen voor voertuigen	River, ferry not available for vehicles
Standplaats Assistent Wedana en/of Mantri Politie	Seat of Assistant Native Head and/or Sheriff	Karrewegen en paden	Cart roads and paths	Spoor of tramwegen, met tunnel	Railway or tramlines with tunnel
Andere plaatsen	Other places	Bochtige weggedeelten	winding stretch of road	Provincie en Gouvernementsgrenzen	Province and Government boundaries
Hotel	Hotel	Hellende weggedeelten. De punt van de pijl geeft de richting van de stijging aan	Graded portion of road. Point of arrow indicates direction of ascent	Residentiegrenzen	Residency boundaries
Passanggrahan	Government Resthouse			Regentschapsgrenzen	Regency borders
Badplaats	Bathing Place				

Blue Papers 2026 (Vol. 5 No. 1), pp. 42–49
10.58981/bluepapers.2026.1.03
Received 04.12.2024; Received in revised form 21.07.2025; Accepted 29.09.2025

Repower the Harbormaster Towers: Managing Maritime Artifacts in Java's Port Cities

Rizki Dwika Aprilian, Ricky Purbaya & Miktha Farid Alkadri

Abstract
For centuries, Java played a pivotal role in the global shipping trade, connecting the spice islands with the Western world. Its northern coastline was home to three major port cities: Batavia (now Jakarta), Surabaya and Semarang, where trade was overseen by the *syahbandar* or harbormaster– a position dating from pre-colonial times. This role existed throughout the colonial era, when masonry towers with timber floors were constructed for harbormasters to manage port activities. Although revitalization efforts have emerged since the first decade of the twenty-first century, these towers have now been largely forgotten due to port relocations, land subsidence, sea-level rise and changes in ownership. Drawing on archival research and observation, this article examines how historic harbormaster towers in Java's three major port cities are being preserved amid climate change challenges.

KEYWORDS
heritage management
harbormaster
Syahbandar
Spice Route
Java

WATER VALUES

Policy Recommendations

- Encourage the Indonesian government and its subordinate municipalities to adopt a bold maritime paradigm in the development of heritage cities, by ensuring canals and water bodies become integral to the planning and revitalization of historical areas.
- Raise public awareness of maritime artifacts in urban spaces by promoting their significance through innovative educational initiatives and dynamic tourism programs.
- Promote the adaptive reuse approach to harbormaster towers, transforming them into functional spaces with modern roles while preserving their historical character for future generations as living heritage.

< Fig. 1 Java and Madura road map (Source: War Office, 1945. Public domain, via Wikimedia Commons).

Introduction

Java has long played a key role in global maritime trade and has been connected to transoceanic routes through exchanges with merchants from China, India and the Middle East, as early as recorded in Indian epic Ramayana and Ptolemy's Geographia of the second century. This role grew during the spice trade period marked by Western exploration and colonialism. After European traders arrived in the sixteenth century, northern ports like Jakarta, Semarang and Surabaya became major gateways to the Western world. Over time, these cities came under colonial control, with settlements and infrastructure built to accommodate trade in valuable commodities.

The *syahbandar*, or harbormaster, played a central role in port operations, managing shipping traffic, collecting taxes, supervising cargo and regulating trade. During the colonial period, these responsibilities were supported by brick towers with timber interiors, designed for wide visibility and surveillance. After Indonesia's independence in 1945, these towers were left unused as port activities shifted to newer locations and this situation has been exacerbated in the twenty-first century by environmental challenges, e.g., land subsidence and rising sea levels.

Although these structures were once vital to the maritime economy, the port infrastructure in the heritage city, such as harbormaster towers, has been abandoned and fallen into disrepair. Since the early 2000s, the preservation of these towers has varied. Jakarta restored its tower using historical materials and integrated it with tourism functions, along with a nearby water gate to manage floods. In 2022, Semarang rebuilt its tower's silhouette in glass, creating a public gallery and office space. In contrast, Surabaya's tower remains physically intact but functionally neglected, overshadowed by warehouses and detached from its context. These different adaptation approaches raise broader questions about how postcolonial cities deal with colonial infrastructure amid rapid urbanization and environmental challenges.

By examining the history and the reutilization of the harbormaster towers, we can gain a more holistic understanding of how the maritime symbol and identity from these heritage port cities have evolved and how they can be preserved for the next generation. These case studies are also essential in supporting conservation strategies within broader revitalization plans of the three port cities, ensuring the relevance and resilience in both the present and the future. This article uses archives, literature, and fieldwork to examine how Java's major port cities are working to conserve their maritime artifacts, showing how trade shapes cultural memory and urban development while suggesting new futures for these spaces.

The *Syahbandar* and its Significance in Trading and Port Management

Syahbandar is one of the most important roles in global navigation and trade history, crucial to maritime civilizations for centuries. The term comes from the Persian *shahbandar*, meaning “king of the haven" or “harbormaster" (Moreland 1920; Kooria 2019). The title spread across Asian maritime routes, adapting to local contexts, appearing as *shahbandar* in Malaysia, Singapore and Brunei, *shabunder* in India and *syahbandar* or *sabendar* in Indonesia. Despite regional differences, the core duties remained focused on managing port activities, taxation and trade.

Historically, the *syahbandar* led customs at ports, overseeing domestic and foreign vessel movements, assessing taxes on goods, and managing tributes to local rulers. Their role was deeply tied to the political and economic life of port cities. In some Indian Ocean regions, the *syahbandars* served as government agents or ministers, as seen in the Sultanates of Aceh and Banten (Moreland 1920; Andaya 1978), indicating their influence beyond port tasks.

In Java, the role predates European colonization, with records from the Sunda and Majapahit Kingdoms, and later Islamic Sultanates like Demak and Banten (Masyhudi 2018; Sundari 2018; Basundoro and Nugroho 2022). They were typically stationed near harbors, in buildings for customs duties known as *pabean*. This role persisted until European trading companies, particularly the Dutch East India Company (VOC) arrived and reshaped the region's political and economic structures.

The Power Shift: From *Syahbandar* (Local), to VOC (NL) to Raffles (UK)

After gaining control over the spice trade centers in the archipelago, the VOC moved its headquarters from Amboina to Batavia (now Jakarta), a new city built on the ruins of the town of Jayakarta. This strategic move allowed the VOC to consolidate its power over the northern coast of Java, turning it into a critical trade route in the archipelago (Nas and Grijns 2007; Van Der Brug 2007; Zuhdi 2014). By the mid-eighteenth century, the VOC had gained control over the entire northern coast of Java. This dominance lasted until the VOC's bankruptcy at the end of 1799, after which the Netherlands continued colonizing its territories.

During its peak, the VOC established three main ports: Batavia in the west, Semarang in the center and Surabaya in the east, each serving as a defense base for the VOC (Ricklefs 2008).

^ Fig. 2 Archival images of harbormaster towers in Batavia, Semarang, and Surabaya (from left to right), nineteenth century (Source: KITLV Digital Collection, Leiden University Library).

When the British took control of Java in the early nineteenth century, the island's major cities were well-established centers of trade and governance. In his book *The History of Java*, Raffles noted five principal cities: Batavia, Semarang, Surabaya, Surakarta and Yogyakarta (Boomgaard 1989). The port cities (Batavia, Semarang and Surabaya) flourished as significant maritime trade hubs from the eastern archipelago and became the largest ports in Java during the colonial era (Zuhdi 2014).

Batavia (Jakarta), Surabaya, Semarang, and Their Towers: Then and Now

Batavia, a harbor city at the mouth of the Ciliwung River, was the central hub for shipping in the Dutch East Indies and was rich in historical events. Before Jan Pieterzoon Coen founded Batavia, the area was known as Kalapa, the main port of the Sunda Kingdom. Portuguese explorer Tomé Pires noted that Sunda Kelapa was a busy port, with ships from Palembang, Lawe, Tanjungpura, Malacca, Makassar, Java and Madura (Pires 2016). This role continued until the VOC conquered this city in the seventeenth century.

The Syahbandar Tower of Batavia was built by the Dutch around 1640 and renovated in 1839, serving as the customs office of the harbormaster (Directorate of History and Cultural Values 2013). To the east, Semarang is a key transit point for ships from Surabaya and the eastern archipelago bound for Batavia, also a hub for its hinterlands. In 1825, the Dutch built the harbormaster tower in Semarang known

^ Fig. 3 Conditions of the three harbormaster towers: Batavia/Jakarta (after restoration, left), Semarang (before and after restoration, center), and Surabaya (current condition, right) (Source: Ricky Purbaya, 2024).

as *Uitkijk* (watchtower) and renovated it in an *Indische* style in the 1850s. Surabaya was Java's second-largest port that was established in the Majapahit era in the thirteenth century, and continued through the Dutch East Indies period, with trading centered on the Kalimas River (Dick 2022). Surabaya also had a harbormaster tower on the bank of Kalimas River built by the Dutch in the nineteenth century. Based on a nineteenth-century photo archive in fig. 2, the original tower was initially made of an iron structure and rebuilt using brick and stone in the twentieth century.

By the end of the colonial era in 1945, Indonesian cities underwent a rapid transformation, profoundly reshaping urban landscapes, including the harbormaster towers across Java's three largest port cities.

In Jakarta, the harbormaster tower gradually tilted due to unstable ground and heavy truck traffic. Restored in the early 2000s, it became part of the Jakarta Maritime Museum and Old Town Jakarta, shifting its role to education and tourism (Soedarsono 2011). In 2022, the local government redesigned surrounding water bodies as a water catchment area and public space to protect the tower from tidal floods and land subsidence.

The harbormaster tower in Semarang underwent a similar transformation. Abandoned after the harbor moved in the late nineteenth century and partially collapsed by 2017, it was restored in 2022 by the national gas enterprise PGN using new materials alongside the original structure. The tower was repurposed as a tourist attraction, while the riverside area was redesigned, reconnecting it to the river previously blocked by kiosks for decades. In contrast, the harbormaster tower in Surabaya remains in a state of neglect. Although structurally sound, the building exhibits significant façade deterioration, and its original entrance doors have been replaced with an iron gate providing access to adjacent settlements. Despite its riverfront location, the tower's historical function and significance appear to have been largely disregarded.

Conclusion

Indonesia's maritime heritage is deeply embedded in its coastal cities, yet numerous historical sites face deterioration, neglect, and environmental threats such as flooding, sedimentation, and climate change. The harbormaster towers in Jakarta, Surabaya, and Semarang exemplify diverse strategies for integrating maritime heritage into contemporary urban contexts. After independence, these towers were abandoned for decades and became increasingly disconnected from their surrounding waterways. However, two have since been carefully revitalized to respond to contemporary needs.

Preserving maritime artifacts requires more than restoring buildings. It demands ecological and spatial reintegration. Through comprehensive preservation efforts, cities can engage historical narratives while addressing contemporary challenges, transforming these sites into dynamic spaces for the future.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein, Kayi Zhu and Matteo D'Agostino.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 50–59
10.58981/bluepapers.2026.1.04
Received 03.07.2024; Received in revised form 15.07.2025; Accepted 01.10.2025

The Politics of Iraq's Waterscape: 1920–2024

Meg John

Abstract
Iraq and the Kurdistan Region of Iraq (KRI), historically a landscape with abundant water resources, has undergone significant geopolitical changes over the last century. Today, the country must find solutions for extreme water shortages. Dukan Dam serves as an example of how hegemonic and hierarchical effects from recent history have influenced water governance. While population growth and climate change along with unilateral water resource activities undertaken by neighboring states are exacerbating water shortages for Iraq and the KRI, it is important to analyze the internal waterscape and how it is managed. In this article, I focus on the period from 1920 to 2024 in Iraq to shed light on problems of governance strains pertaining to water. To achieve Sustainable Development Goal 6: Clean Water and Sanitation, Iraq must reckon with its past to ensure a sustainable future for generations to come.

Policy Recommendations

- Ensure justice for communities in national water policy by addressing the historical inequities in water distribution, recognizing that while the dam provided flood protection and economic benefits for agriculture and oil, many people within Iraq's borders have experienced inadequate water services. Policies should correct these disparities by guaranteeing equitable access to water resources and acknowledging all stakeholders, including ecological thresholds.
- Implement inclusive and transparent water governance practices that create meaningful mechanisms for community participation. These measures are essential to realizing water justice for civilians and ensuring that the gains of water infrastructure are shared rather than concentrated.

KEYWORDS

inclusive society
water
governance
Dukan Dam
sustainable development

WATER VALUES

< Fig. 1 A small inlet of Dukan Lake in summertime (Source: Meg John, 2022).

Introduction

The Tigris and Euphrates Rivers have given life to a multitude of civilizations with a long history of water management. The Land Between Two Rivers – Mesopotamia – and, today, in part, present-day Iraq, is home to ancient cities such as Mosul, Baghdad and Basra; cities shaped in part by the Tigris-Euphrates basin. The Kurdistan region, in the north, is threaded by five large rivers, two of which, the Upper and Lower Zab (also referred to as Lesser Zab), flow into the Tigris River of which the Lower Zab was dramatically transformed when Dukan Dam was built. Iraq, a place with fertile, arable land, cultural diversity, abundant water sources and the globally favored resource, oil, is now facing the hard truth that the Tigris and Euphrates are drying up, making urgent the need to address water scarcity in Iraq (Rodgers 2023).

The significant pressures of population, climate change and regional politics intensify the complexities of Iraq's internal water governance. Water scarcity occurs at a time when the country's population is at an all-time high. In 1920, the population hovered around 3 million. By 1970, it had reached 10 million and, by 2017, 40 million (Statista 2019).

Iraq is also among the countries most heavily impacted by climate change. From 2000 to 2023, the International Energy Agency reported that Iraq experienced a 0.48°C temperature increase per decade, well above the global average of 0.37 °C (IEA 2025).

A third significant pressure involves regional geopolitics. To secure its own national resources, Türkiye has been developing mega-dams along the Tigris and Euphrates, whose headwaters originate within its borders (Domalain 2022). The dams have reduced the amount of water reaching Iraq, which represents a significant problem since the two rivers provide most of Iraq's water. While negotiation has occasionally resulted in seasonal releases of water, Iraq's dependence on Türkiye results in a precarious situation (Marcellin et al. 2024).

These three pressures – population growth, climate change and unilateral upstream water developments – are not the only challenges facing water management in Iraq. As of the writing of this article, the Iraqi government has yet to publish and implement a comprehensive and transparent water strategy that incorporates efforts to mitigate these pressures. An effective strategy would facilitate mobilization and action in water governance and could also open the door for more explorative discussion on how Iraq's water heritage might offer integral pathways for sectoral development. Reconciling how power, positions of authority and financial resources have affected water governance over the last 100 years is essential to understand why such a strategy remains elusive. This brief article begins this exploration.

A Brief History of Water Governance in Iraq

Over the last 100 years, Iraqi leadership contributed to the universal development of centralized hydropower by creating Dukan Dam (and later Mosul Dam). It is not to say that centralizing water engineering was unprecedented in Iraq. On the contrary, engineered water solutions have existed since antiquity, such as advanced canal systems built between the Euphrates and Tigris to irrigate otherwise arid land. These systems were vital to ancient civilizations and made previously inhospitable land fertile (Adamo and Al-Ansari 2020). Yet developments over the past 100 years have reinforced power dynamics that hinder com-

^ Fig. 2 Hazy overview of Dukan Lake from afar, formed by the creation of Dukan Dam (Source: Meg John, 2022).

prehensive water governance. One challenge of centralized water engineering is that discussions about waterscapes often become limited to technical narratives, obscuring the socio-political landscapes, cultural heritage, and power relations at stake.

After World War I and with the fall of the Ottoman Empire which had loosely administered the region since the early sixteenth century, the British played a major role in developing Iraq's civilian administration, formally established in 1920 but sustained by British martial law. Iraqi elites, including Iraq's first king, were propped up with British support. These internationally and locally supported figures did not necessarily consolidate power through unified or structured processes; instead, a set of independent power networks gradually formed a "fractured elite" with diverse actors operating under an ambiguous Iraqi national label. This produced an elite capable of facilitating international cooperation but challenged in its ability to secure local cooperation for nation-building.

The historical pattern of shifting power, authority and resource control that has characterized the history of the region has greatly impeded the development of effective water management. What distinguishes power shifts in Iraq is that the idea of a unified Iraq has become synonymous with an exclusive Iraq – producing extreme winners and extreme losers in the struggle for power. Regulation and policy have rarely been neutral tools for national development; instead, political acts often served individuals seeking to maintain their position and access to resources. Trust, cooperation and long-term planning often clashed with short-term ambitions.

^ Fig. 3 King Faisal II visits Dukan Dam site in 1957 (Source: Unknown; reproduced by Meg John, courtesy of Dukan Dam Office and Director Kochar Jamal).

The Case of Dukan Dam

Dukan Dam was the first large hydropower dam in Iraq. Initiated in 1952 and becoming operational by 1979, the project was instigated by both British and Iraqi leadership. As interviewee 9 explained:

> The kingdom, […] had a UK consultancy. [The British] asked Iraq to build dams across the big rivers in Kurdistan. […] Iraq signed the agreement and with their teams went to take a look at the rivers. After that, Iraq asked them to find the best companies to hire for the design and construction of the dam. Only the money was provided by Iraq, everything else was done by the UK representatives in Iraq.

Iraqi leadership of the time hired the British engineering company Binnie & Partners, led by renowned engineer Geoffrey Binney, to design it. The British encouraged King Faisal to build a dam to irrigate Kirkuk, which Interviewee 9 noted had 1,000,500 dunams[1] of arable land at the time, with the dual ambition of also alleviating flood impacts.

Being able to finance such a project also signaled a new form of centralized governance and control over resources (Klaas 2022). However, Iraq's monarchy soon fell as a result of several coups, further indicating persistent power struggles. Nevertheless, the dam project was completed in 1979. Coincidentally, Saddam Hussein became president that same year, when the Dukan Dam began producing hydroelectricity. The top-down approach to water governance soon became systematically entrenched.

This centralized approach to water resources notably makes absent from this history the ways in which local communities were consulted or affected. As Iraq grapples with current water challenges, it is paramount to examine the changes that have occurred in Iraq's waterscape in order to imagine future pathways. Interviewee 9 described the pre-dam waterscape:

> Every village […] had their own resources of water. Water was everywhere. Every village of Kurdistan, even Sulaymaniyah, didn't require water from Dukan. The water quality in the villages was much better than the water in the rivers because the water was obtained from underground, and it was very clean. Women would carry water in cans to their homes and use the water in a very efficient way because they knew that if the water was gone, they had to go back to the well to bring more water. But when we are talk-

1. A dunam (or *dönüm*, *dunum*) is a unit of land equivalent to 1,000 m². See "Dunam," https://www.convertunits.com/info/dunam.

> ing about the rivers – they [villagers] weren't close to the rivers because they were afraid that the rivers would flood. When they built dams in Iraq, the problem was not storing water, it was the floods. Dukan Dam was for Kirkuk.

Interviewee 9's account suggests that water management before the dam was intimate, small scale and based on groundwater use, with women playing a central role. Large scale infrastructure altered these relationships, yet such social transformations are often understudied. Understanding these histories can guide more socially nuanced and inclusive water strategies today.

Dukan was built in a specific and suitable geologic location. The location best suited for Dukan Dam happened to be in an area predominantly inhabited by Kurdish communities. As Kurdish communities and the broader concept of nation state Iraq had not solidified a sense of unity or shared identity, a dam that was

^ Fig. 4 Stages of dam construction and its joint blocks (top left); gated spillway construction (top right); irrigation tunnels and valves (bottom left); dam area before preparation (bottom right) (Source: Unknown; reproduced by Meg John, courtesy of Dukan Dam Office and Director Kochar Jamal).

^ Fig. 5 A 1958 photograph in the Dukan Dam office, showing builders of the dam, which looms in the background. British, Arab Iraqi and Kurdish men are all present. (Source: Unknown, reproduced by Meg John; courtesy of Dukan Dam Office and Director Kochar Jamal).

built amidst Kurdish communities servicing the greater Iraq, put into question what water resource collaboration means in the region. Thirteen years after Dukan Dam became operational, the Kurdistan region of Iraq formed and legitimized the Kurdistan Regional Government which meant the government was semi-autonomous.

Today, Dukan Dam is governed by Baghdad but managed daily by the Kurdistan Regional Government. While not a source of overt political conflict, decisions on water allocation and strategy are often driven by short-term needs rather than long-term planning and vision. This will become increasingly critical as droughts intensify in both Kurdistan and Iraq. As water resources grow scarcer, pressure on decision-makers regarding how water is released from the reservoir will likely increase.

Maintaining minimum flows, which are essential for ecological health and for the dam's functionality, is not clearly mandated or enforced. Furthermore, when communities are excluded from the decision-making process, the implications of water-release decisions become far less clear. At the same time, those who are not dam experts may not fully understand the consequences of releasing too much water, even when political pressure demands it. These dynamics create difficult circumstances for effective planning and management.

Conclusion

Centralizing and scaling water resources has been a common pathway for nation building. The hierarchical and hegemonic structures that made Dukan Dam possible illuminate one way in which power was consolidated through water resources, in parallel with the consolidation of financial resources needed to build a large hydropower dam. We saw this first with the colonial forces (the British), who sought to use the rivers and their power for enhanced economic trade, followed by Iraq's monarchs who oversaw Dukan Dam's development.

Reviewing water governance and management beyond a centralized approach requires examining political and hydrological evolutions over time and confronting the power structures that shaped them. Moving forward, Iraq's waterscape has already been transformed by large dams and must realistically be worked with rather than removed in the near future. However, lessons from the history of water governance in the region remain essential, especially for understanding how to engage communities, heritage practices, and local contexts more fully in order to do justice to people's lived experiences.

Acknowledgment
I would like to acknowledge the support from my community of friends and family, who motivate me to research and write.

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein, Michele Tenzon and Carlien Donkor.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 60–69
10.58981/bluepapers.2026.1.05
Received 04.09.2024; Received in revised form 25.03.2025; Accepted 25.08.2025

Historical Water Governance in Turkmenistan and the Challenges of Soviet Interventions

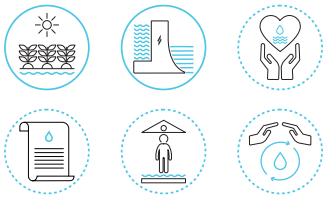
Estere Cvilikovska

Abstract
This article investigates historical water management practices in Turkmenistan and the development of canal construction technology, comparing the operation of traditional irrigation canals with Soviet water management policies. It explores how Soviet officials regarded water and used water management to consolidate state power and advance the region economically, arguing that centralized Soviet water management policies, which largely disregarded local expertise and participation, ultimately proved unsustainable and environmentally destructive. The article underscores the need to include diverse stakeholders in decision-making processes to avoid perpetuating outdated practices, further exacerbating the deterioration of the environment and societal customs.

KEYWORDS

USSR
irrigation system
environmental degradation
water management
local stakeholders

WATER VALUES



Policy Recommendations

- Large-scale irrigation systems must be developed following extensive interdisciplinary studies of the area's geology and soil hydrology to prevent problems such as water loss, swamp formation and salinization.
- An open dialogue must be initiated with affected communities, along with a bottom-up approach to governance, efforts to raise awareness, and consideration of existing vernacular irrigation practices. The involvement of a diverse set of actors and local participants can enable sustainable future development.

< Fig. 1 Hanhowuz (Khauzkhan) Reservoir, Turkmenistan (Source: NASA Landsat 8, 2014. Public Domain, via Wikimedia Commons).

Introduction

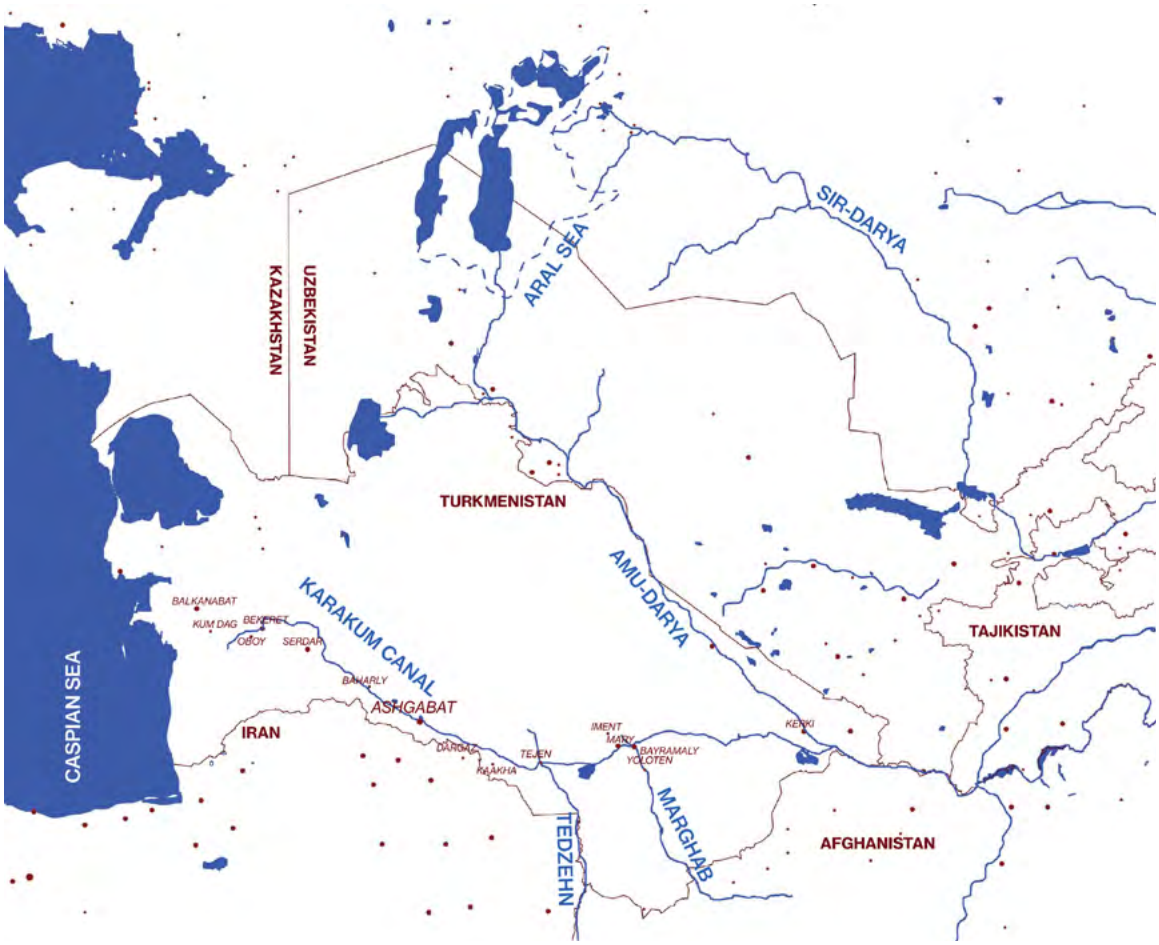
Until the twentieth century, cities in the Turkmen region of Central Asia flourished in natural oases despite limited access to water and daytime temperatures that could exceed 40 degrees Celsius. During the Soviet rule of Turkmenistan (1921–1991), water management became crucial to establishing sovereignty in this water-scarce region (fig. 2). Hydraulic infrastructure both symbolized and materialized state power by enabling naval transport and administrative control of irrigation and agriculture. Irrigation, in particular, became a core strategy for transforming the region toward a more "advanced" form of socialism. The Soviet rulers seeking to build the country's economy and industries presented their regime and its technology as superior to "backward" local practices (Brite 2018).

To facilitate fertile conditions for the development of new agricultural lands in the Soviet Republic of Turkmenistan, Soviet bureaucrats planned the Karakum Canal, beginning its construction in 1954 and continuing to work on it until 1988. It became a poster project of the Soviet Union and its largest hydrological undertaking. The canal resulted in a fourfold expansion of Turkmenistan's fertile land, and when it reached the Turkmen capital Ashgabat, in 1962, its water helped shape the city's urban development. As of today, the Karakum canal remains one of the largest irrigation canals in the world, supplying water to approximately one million hectares of land (Brite 2018; O'Hara 1999).

This historical analysis of water heritage in Soviet Turkmenistan highlights the main drivers behind the evolution of water management, offering insights into its legacy and the challenges that exist today (D'Agostino and Hein 2024). Such understanding is especially crucial in water-scarce regions, where every decision related to water management can have a profound and enduring impact.

Water in the Turkmen Region

The region of Southern Turkmenistan has long been shaped by humans: irrigation in the Marghab Oasis dates back 10,000 years. After the region came under Arab control in the seventh century, an extensive and sophisticated irrigation network emerged, enabling land to be used for agriculture (O'Hara 1999; Obertreis 2017). By carefully allocating plots and water resources, inhabitants of Marghab Oasis could produce food for themselves and export it to neighboring regions. Sustainable water management was achieved, as the knowledge regarding the maintenance of the irrigation canals was passed down and improved through generations, with a large part of society contributing to their sustenance through tax payment and labor (Obertreis 2017). The amount of cultivated area was regulated based on the spring flow of the Marghab River. During years of reduced discharge, only the most crucial lands were farmed (O'Hara 1999). The preservation of the irrigation infrastructure was overseen by a governing body formed by Mirab, an administrative authority responsible for water resources, and other local officials (O'Hara 1999; Peterson 2019). 12,000 individuals were dedicated to managing and maintaining the irrigation structure, while Mirab was informed of water levels in the main canal on an hourly basis, which reflects the great care with which irrigation was managed in the Marghab Oasis during the 12th century (O'Hara 1999; Peterson 2019). For many local cultures around the Karakum Desert, water held religious and symbolic significance and was viewed as sa-



^ Fig. 2 Water and cities in the Aral Sea basin: the Aral Sea, the Syr Darya and Amy Darya Rivers and Karakum Canal (Source: Estere Cvilikovska, 2024).

cred and magical (Edgar 2004; Obertreis 2017). In the Khanate of Khiva, the irrigation season was ceremonially initiated by the ruler, or Khan, who participated in cleaning the main canal and plowing the first furrow, reflecting the role of irrigation systems as a cornerstone of social and political life (Obertreis 2017).

Starting in the sixteenth century, the Russian Empire gradually expanded control over territories in Central Asia ruled by khanates. The nineteenth century saw the conquest of present-day Turkmenistan. At the time, this area was controlled by three Muslim khanates with unstable borders, comprising many Turkmen tribes (Edgar 2004; Obertreis 2017). The perception of water among Central Asians contrasted sharply with that of Russian expansionists. Indigenous irrigation systems were deemed primitive by the Russians, which reflected the general attitude of Europeans towards non-European cultures that began in the eighteenth century (Obertreis 2017). Nevertheless, following the Russian Empire's conquest, only a few new canal networks were constructed, mostly to expand already existing ones (O'Hara 1999).

^ Fig. 3 USSR propaganda poster "We'll conquer drought, too" (Source: Viktor Ivanovich Govorkov, 1949).

During the rule of the Russian Empire and the first decades of the Soviet Union, large-scale irrigation schemes were planned but not realized, due to little enthusiasm and interest on the part of potential financial contributors (O'Hara 1999).

Water in the Turkmen Soviet Socialist Republic

In the 1920s, with the advent of Soviet rule, talks ensued about how to move the Turkmen-inhabited regions toward a more "advanced" form of socialism (Edgar 2004; Obertreis 2017). In Central Asia the Soviets saw national delimitation as imperative: by establishing a common language, culture and territory they sought to create a stable and modern society (Edgar 2004). Through their promotion of "national cultures," the Soviet state contributed to developing a sense of national identity in Turkmenistan and other Central Asian countries, even though the drive for unity often involved the erasure of distinctive customs and identities (Edgar 2004). Building national consciousness was fundamental in managing water, as rights to land and water were nationalized and redistributed.

The Soviet regions of Central Asia developed economically; until the 1950s, the Aral Sea region supported major fisheries and regional transport. However, under Stalin, combating the desert by transforming it into agricultural land

through infrastructure became key to strengthening state power. Khrushchev's rise saw increased emphasis on agriculture and large-scale industrial farming seen as critical to both nation-building and Soviet control. Higher crop yields bolstered Khrushchev's position, an indication that the ability to control water was linked to maintaining power in the Soviet Union (Peterson 2019).

The propaganda posters of the time portrayed nature and water as controllable by "Soviet man" (Obertreis 2017) (fig. 3). Although this poster features Stalin drafting new irrigation canals in Russia and Kazakhstan, the sensibility it depicts was applied throughout the USSR. The text presents the desert as something to overcome, translating to "We'll conquer drought, too". Water governance was dominated by the Ministry of Water Management and the Ministry of Agriculture, where officials often lacked proper expertise or local knowledge.

The Development and Impact of the Karakum Canal

Following Stalin's death in 1953, plans for the Karakum Canal developed rapidly, favoring a route close to the Trans-Caspian railway and Turkmen cities like Ashgabat (Zohn 2014). Soviet views on water involved naturalizing the canal infrastructure, as in the newspapers, it was often named the "Karakum River" or the "River of Life", normalizing the scale of interventions (Atajevs 1974; Rogočovs 1972). Despite propaganda claims, the canal's construction was relatively simple, with bulldozers carving out a preliminary route and the water flow widening it (Obertreis 2017). Barely any concrete lining was used in construction, resulting in water seepage issues in later years. Although the Soviets claimed that only 30 per cent of the water was lost, modern studies reveal that up to 70 per cent of the water is wasted in the irrigation processes (Obertreis 2017; Zohn and Kostianoy 2013; Верный 2023).

To a certain extent, the canal construction facilitated agriculture: By 1961, it had more than doubled the amount of irrigated land in Turkmenistan (Obertreis 2017). However, due to the region's geological conditions and poorly constructed outflow systems, the Marghab oasis soon began experiencing issues with inadequate drainage, resulting in salinization and waterlogging. By 1962, the expanding cotton farms were already confronted with yields declining because of salinization, and the accumulation of water led to a resurgence of malaria caused by increased mosquito populations (Obertreis 2017). The canal's construction and operation contributed to environmental degradation, with land being cultivated in an unsustainable, extractive manner, and in the 1970s, agricultural land that had been created with the Soviet introduced farming methods, using the water from the Karakum canal, was abandoned at the rate of 46,000 hectares per year (O'Hara 1999). Nevertheless, the canal was consistently framed as a triumph over nature. Soviet newspapers frequently highlighted the agricultural and infrastructural benefits of the Karakum Canal, emphasizing the quantities of cotton, vegetables, and grain that could be cultivated with its water, as well as the neighborhoods and public buildings constructed thanks to its supply (Korzuna 1982; Obertreis 2017). The head of Karakum Canal Construction trust, B. Annaniizov, in a newspaper, expressed that "the Soviet man has made the Karakum Desert blossom all year long" (Obertreis 2017).

While the primary purpose of constructing the canal was to increase Soviet cotton production, a significant objective was ensuring water

delivery to Turkmenistan's capital – a feat later celebrated as a monumental victory. The state propaganda asserted that the canal will be able to provide the previously limited water supply to Ashgabat's citizens and industry (Korzuna 1982; Obertreis 2017). To mitigate the harsh desert climate, the city was developed with a large amount of fountains, water cascades, open pools, and canals, using the canal's water (Kachelson 1987).

The Karakum Canal is a powerful example of the Soviet Union's approach to water management, rooted in standardization, monumental engineering, and centralized decision-making. Little consideration was given to the region's unique geological characteristics, as most decisions were made by authorities in Moscow or Ashgabat (Obertreis 2017; Peterson 2019). Through their depictions of infrastructure projects and urban landscaping enabled by canal water, Soviet officials sought to impose a uniform value system on the local inhabitants, who had previously maintained a site-specific understanding of water heritage and its management. Despite the canal's harmful environmental impact—such as salinization and widespread swamping caused by poor drainage — the Soviets hailed the canal as an immense success due to its quantifiable gains.

Conclusion

The Soviet perception of water as a financial and political asset led to ambitious plans for river rerouting. Water was viewed as uniform and part of a schematic hydrological cycle, justifying its manipulation without regard for local impact. Narratives carefully crafted by Soviet officials often prioritized the economic value of water while downplaying the complex, multifaceted value systems traditionally maintained by people in present-day Turkmenistan. Through institutionalization and strategic representation, these interventions became normalized and deeply embedded in local cultures and landscapes. Propaganda in state newspapers made exaggerated claims about water management projects and underscored the Soviet state's deliberate efforts to reshape perceptions of water and its cultural heritage – primarily to legitimize its exploitation. This reframing, however, contributed to significant environmental degradation. In contrast, historical studies of water governance in the region highlight the potential for sustainable irrigation practices, emphasizing the role of local communities in responsible water management.

The abstraction of water into a seemingly placeless, tasteless and odorless substance is a relatively recent development, originating in eighteenth-century efforts to rationalize the world (Neimanis 2014). This perception reduced water to its chemical formula and a resource to be exploited, stripping it of spiritual, cultural and ecological significance (Linton 2010). Such a reductionist view facilitated unsustainable practices throughout the twentieth century, leading to groundwater depletion, ecosystem destruction, pollution and salinization. Neimanis (2017) challenges prevalent perceptions of water, describing humans as "bodies of water," inherently connected to the planetary hydrocommons. This interconnectedness suggests that water governance should consider water's relational and cultural dimensions, not just its commodification.

The abstraction of water extended to its governance, resulting in administrative entities being disconnected from the realities of local environments and communities. The twentieth century saw similar approaches to water management implemented across the globe. In

projects focused on the Rhône River in France, the Tennessee River in the US and the Ebro River basin in Spain, centralized administrations lacked site-specific knowledge and an understanding of environmental processes (Swyngedouw 2015; Pritchard 2011). Large-scale hydrological projects were also undertaken as part of nation-building efforts in the post-colonial context, exemplified by the construction of the Aswan High Dam in Egypt and the development of dams and irrigation systems during the implementation of India's first Five-Year Plan. Control over water resources reflects societal values and priorities, with water management choices revealing underlying power dynamics and social structures (Mukerji 2022).

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 70–81
10.58981/bluepapers.2026.1.06
Received 18.07.2025; Received in revised form 20.08.2025; Accepted 08.11.2025

River Port Cities Facing Climate Change: Global Examples for Heritage-Based Sustainable Development

Noémi Mené, Avicenna Tanubrata & José Manuel Pagés Sánchez

Abstract
River port cities are on the frontline of climate change – as both part of the solution and as early victims of its impact, which demands new strategies for all river port communities. With several study cases, we explore how actions being taken relate to sustainability agendas such as Agenda 2030 of the Association Internationale Villes et Ports. We illuminate the role of heritage in maintaining and fostering identity, integration and sustainable development in port cities. In Strasbourg (France), we show how a port authority can act to improve the connection between port and urban activities, but also how port heritage can be used to educate citizens about port activities. We consider a more institutional approach to fluvial heritage preservation in the case of Lyon (France) and cases in Australia and Cameroon that show how local and port authorities can make efforts to respect local communities along the river and how those efforts can help them plan their development more sustainably.

Policy Recommendations

- Decision-makers in river port-cities should leverage their river heritage – whether historical, cultural, industrial or spiritual – to promote sustainable development of their territories.

KEYWORDS

river port cities
good practices
sustainable development
cultural heritage
climate change

WATER ICONS

< Fig. 1 Confluence of Rhône & Saône rivers, Jardin du Musée des Confluences, La Confluence, Lyon (Source: Guilhem Vellut, 2017. CC BY 2.0, via Wikimedia Commons).

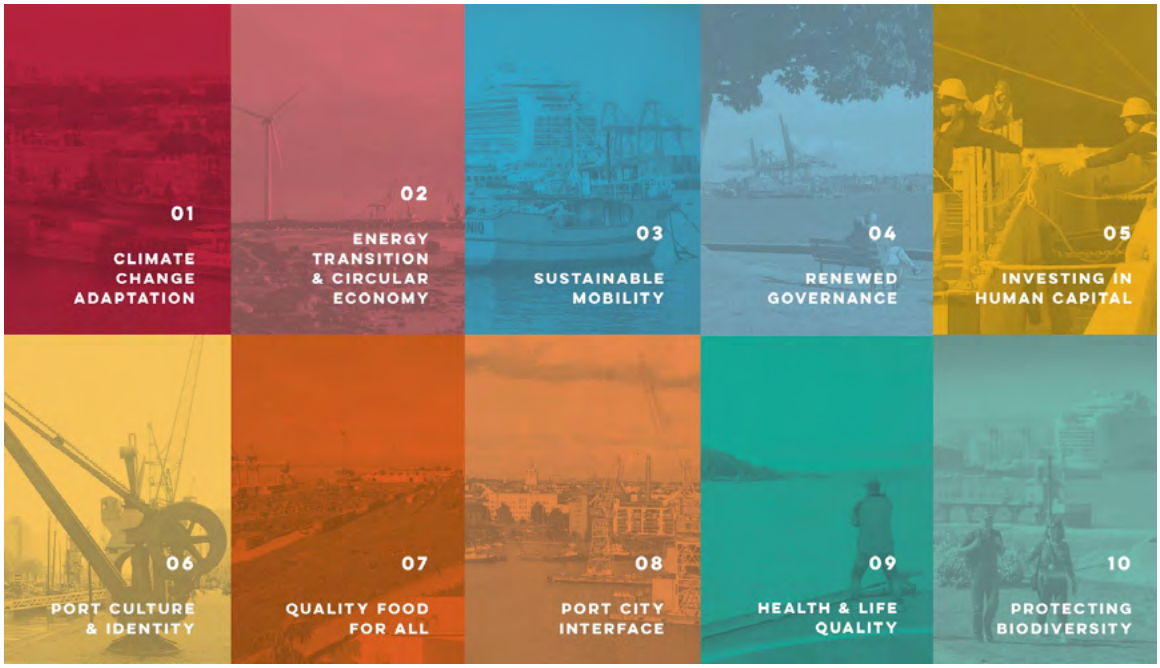
Introduction

Historically, many major cities have developed by taking advantage of a strategic location along a river (e.g., Paris, London, Hamburg, Rotterdam, New York). Watercourses have played a key role in urban development, fulfilling many functions necessary for their evolution from simple human settlements to the global cities of today. They have provided water for drinking, cleaning, farming, worship and spiritual and religious rites, but also have provided water as an infrastructure for transport and trade – effectively including a wide range of the water values identified in a previous edition of the *Blue Papers* (Hein et al. 2025). Each river port city has its own size, geographical, political, economic and social context. Members of the Association Internationale Villes et Ports (the AIVP), represent the global variety of river port cities, ranging from local ports to global epicenters of trade. Despite their diversity, we can observe similar processes everywhere, linked to the relationship between port and city, as well as the impact of climate change on both.

^ Fig. 2 AIVP Agenda 2030 Cover Image (Source: AIVP, 2020).

Improving the multifaceted relationship between local authorities, port authorities and local stakeholders was one of the original goals of the AIVP, which became an international NGO in 1988. Since then, the AIVP has developed a process of cooperation and economic development that aims to make ports and cities more sustainable, innovative and inclusive, while placing citizens at the heart of the dialogue. Notably, in 2018, the AIVP translated the framework of the sustainable development goals (SDGs), developed by the United Nations (UN), into its own Agenda 2030 (fig.1; the AIVP 2018b). While the 17 UN SDGs promote international cooperation and aim to provide a "shared blueprint for peace and prosperity for the people and the planet" (United Nations 2025), the AIVP's Agenda 2030 comprises 10 goals aimed at achieving its vision for sustainable port cities and offering a holistic framework for port-city relationships (see fig. 2). Addressing a wide range of issues, from biodiversity to governance, the Agenda 2030 recognizes the specific role of port cities as innovative and key players in sustainable development that is adapted to present and future effects of climate change. The adoption of the Agenda 2030 goals by port city territories represents a step forward in aligning with global and national efforts to implement the SDGs.

Challenges faced by river port cities can be captured in one key question: How can local stakeholders use their spatial, geographical,



^ Fig. 3 AIVP Agenda 2030: The Ten Goals for Sustainable Port Cities (Source: AIVP, 2020).

cultural and economic advantages, as well as their heritage, to be at the forefront of the fight against climate change? We offer some examples that showcase the resilience and resourcefulness of river port cities in adapting to threats, and how those examples can leverage sustainability agendas such as the AIVP's Agenda 2030.

Of the 10 goals identified in the AIVP Agenda 2030 we showcase/highlight four more relevant for the present paper:

- Climate change adaptation (Goal 01): River basins will be impacted heavily by climate change. More specifically, river port cities will suffer most from the two extremes of severe droughts and heavy flooding. In responding to climate change, quality of life in river cities should be considered important for example, their ability to offer cooling spaces. However, these advantages are severely impeded by climate change itself, with increased periods where the waterways are not navigable or usable due to extreme weather events.
- Sustainable mobility (Goal 03): inland waterways can be the facilitator of the transition to more sustainable modes of transport of goods and people (Notteboom and Rodrigue 2022), notable by being way more fuel efficient than other modes of transport (Niu, Shao and Zhu 2024). Inland waterways' restrictive geographical nature also tends to be a source of tension, with the shared usage of inland waterways an important challenge. Logistics companies need to ensure their operation while considering environmental impacts along the waterways and respecting a variety of recreational uses.
- Port–city interface (Goal 08): This goal aims to balance port and urban fonction by improving measures to reduce port

^ Fig. 4 View of the Capitainerie, to be transformed into a Port Center in the Port of Strasbourg (Source: Niko67000, 2014. CC BY-SA 4.0, via Wikimedia Commons).

nuisances and promote the architectural and landscape integration of port facilities. Recently in many cities, citizens have returned to rivers, notably for leisure activities. Whether for swimming, rowing, or stand-up paddleboarding, citizens request more access to the water and its leisure activities.

- Port culture and identity (Goal 06): (Re)creating a sense of identity linked to the river and activities carried out on it can be a way for port city actors to bring citizens closer to the port. According to UNESCO experts, heritage-based sustainable development plays a key role in promoting social cohesion and the livability of cities (Hosagrahar et al. 2016). This perspective is further supported by ICOMOS (the International Council on Monuments and Sites), which emphasizes a need to consider culture and cultural heritage in urban and infrastructure planning, while also working to conserve both tangible and intangible heritage (Hosagrahar et al. 2016).

The role of heritage for achieving the SDGs can be seen in several case studies, presented in the next section.

Using Heritage to Pursue Sustainable Development in River Port Communities: Strasbourg and Lyon

The river port city of Strasbourg (France) faces the challenge that both its urban and port areas are expanding. As they have expanded, the buffer zone between them has begun to disappear. To affirm its role as part of the solution and not as a source of the problem in terms of climate change, the Port of Strasbourg has formulated a strategy to enhance

^ Fig. 5 Quai Fulchiron in Lyon, France (Source: Krzysztof Golik, 2024. CC BY 4.0, via Wikimedia Commons).

its visibility and help the public understand its operations and significance. It implemented information boards outside port areas to allow residents to observe port operations and explain the work, without allowing residents to enter the operational area. The port authority is also converting the old harbormaster building, la Capitainerie, (fig. 3) into a Port Center[1] (a concept developed by the AIVP 2018a). The Port Center will offer a mediation space where port authorities can present their activities and foster dialogues with the local authorities and citizens. This building is in the Coop subdistrict, where the dichotomy of urban space usage and port activity is readily apparent. The Port Center is a good example of how a port heritage building can be used to improve the relationship between a port and its citizens to create a more sustainable future. The port authority also wishes to promote river transport and transition from traditional industrial activities to more sustainable ones, including a shift in the type of energy that is produced in the port. One of the energy transition projects is to transform the historic oil depot into a hub for decarbonized energy (Port Autonome de Strasbourg 2024a). The port has been working very closely with local authorities to align as much as possible with their policies and signed a "development contract" with the municipality, the Metropolitan Authority and the Region Grand Est, an administrative entity responsible for some policies over the whole administrative region (Port Autonome de Strasbourg 2024b). This strategy is heavily influenced by the New Green Deal of the European Union (European Commission 2025), and it is aligned with the AIVP Agenda 2030, more concretely with Goal 2, the energy transition, as the port authority has been a long-time member of the AIVP network. This is an example of a port authority using its heritage to promote sustainable development. It is also an example of the necessity of engaging in constructive dialogue with local and regional authorities.

To leverage heritage preservation amid sustainable development, stakeholders often need institutional assistance. Recognition as a UNESCO World Heritage Property can be a very

1. https://www.aivp.org/en/home/our-initiatives/port-center-by-aivp/concept/.

powerful tool to achieve sustainable goals and the Historic Urban Landscape (HUL) approach offers a means to achieve that (Hosagrahar et al. 2016). This can be seen in the case of the Saône and Rhône rivers in Lyon (France), which formed the city's historic boundaries. Approximately 10 per cent of Lyon's territory is designated as a World Heritage Site (UNESCO 2025), and both rivers are encompassed in the site, with the Saône riverbank particularly dotted with significant historical landmarks (fig. 4). The city's 2024–2030 strategic plan for the UNESCO site emphasizes the importance of leveraging the rivers and their heritage to future-proof the city (Métropole de Lyon 2025). Heritage quays are being used for testing innovative solutions in river transportation and urban logistics. Voies Navigables de France (VNF), the French waterway manager, oversees the two rivers upstream of Lyon and in the city center, providing technical and financial support for experiments concerning the urban logistics linked to waterways and cycle transport (Voies navigables de France 2025). The Compagnie Nationale du Rhone (CNR), the agency that oversees the Rhône River and its ports, is experimenting with projects such as a river-based waste disposal system to reduce congestion and CO_2 emissions (CNR 2023; VNF 2023). In 2024, the VNF, the CNR and the Metropolitan Authority of Lyon released a Riverbank Use Plan, a partnership agreement for the harmonious development of riverbank uses. It has three main axes: strengthening the link between citizens and rivers, preserving natural heritage and re-naturing spaces. These initiatives, supported by the continuous engagement of the stakeholders in the AIVP's activities and aligned with national river transport strategies, are key to Lyon's sustainable development, although viable business models for these experiments are still being established (Voies navigables de France n.d.).

Broadening the scope of the AIVP Agenda's goal on "Culture and Identity": International Examples of Religious and Community River Values

When analyzing the French cases above, we considered four goals of Agenda 2030. The discussion of the following two cases will emphasize on "culture and identity." Outside Europe, we can observe very different river port cities, with challenges and advantages of their own. In the cases of Congo and Australia, it is possible to consider the role of cultural and religious rites and how they can be used to promote sustainable development. As Fuldauer and colleagues (2022) emphasize, heritage-based sustainable development must involve the participation of Indigenous communities when they are part of the broader community. The port authority of Fremantle (Australia) developed in 2023 a Reconciliation Action Plan (Fremantle Port 2023) to support and engage with Aboriginal people following the environmental and ecological changes produced in the 1890s by the construction of Fremantle Inner Harbor. The Noongar people in the Walyalup/Fremantle region anchor their territory where the Swan River is located (Western Australia Government 2024). The Fremantle port is now located at the river's mouth, and the port authority acknowledges the Noongar people as the Traditional Custodians of the port land and waters. This involvement of the Aboriginal society is now crucial for balancing heavy industrial development of port areas and has the potential to protect the natural environment. This intangible heritage holds important value within the community and can serve as a driving force for sustainable development (Lerario 2022). While these aspects are not key levers in most Western countries, they can be powerful ways of syncing port development with the aspirations of

^ Fig. 6 Ngondo Festival scene (Source: BACHELOR45, 2024. CC BY-SA 4.0, via Wikimedia Commons).

local communities and should be highlighted as a way to translate and empower sustainability agendas in some parts of the world.

Another example of leveraging the cultural and religious heritage of a river for sustainable development is the Wouri River in Cameroon. The river is of great importance to the various populations living around it, such as the Sawa people, who highlight the importance of the river during their Ngondo festival (Mazo 2016). The autonomous port of Douala is situated at the mouth of the Wouri and is also responsible for several improvement projects along the river. The port authority's revitalization of infrastructure along the Wouri is much needed due to the popularity of the Ngondo festival, which has boosted tourism and contributed significantly to the local economy (Meikengang 2023; Mazo 2016). Many informal settlements are located close to the river, but with no access to it; most of the space is occupied by the port. The city is trying to improve the connection with the water, but a better balance of use has yet to be found. The port authority, citizens and the municipal government still lack a common vision for the city's sustainable development, which would need to consider both natural and cultural preservation. Port and local authorities could be inspired by measures such as the ones in Australia to promote sustainable development, including responsible tourism and port activities, while respecting the Wouri people's right to engage in spiritual activities.

In the AIVP's Agenda 2030, the culture-and-identity goal is more specifically related to port activities and history. However we believe

its interpretation should be extended to the relationship to the river itself. Activities and rites happening in the river's vicinity can help make a stronger case for sustainable development.

Conclusion

The initiatives mentioned above can serve as inspiration for river port cities around the world. The various cases are works in progress: Some solutions will need to be adjusted, as in the case of Lyon, where the different parts of the local governance are aligned, but the business case still needs to be made, and the strategy needs to be translated into practice. In the case of Douala, there is work to be done to develop dialogue between the port and local authorities.

The Agendas 2030, from the UN and AIVP's, both foster local dialogue and provide guidance towards sustainable development in the local contexts. While the United Nations framework serves as the primary global reference, the AIVP's Agenda 2030 constitutes a limited but valuable sector-specific initiative that complements and operationalizes these objectives within its scope. We also acknowledge that the SDGs and Agenda 2030 both have limitations that we cannot fully detail here. However, we support the idea that these frameworks can be opportunities for local stakeholders to grasp the very complex and global challenge that is climate change.

We call on river port city actors to use local levers they can make use of – whether heritage buildings, natural heritage, aligned governance or the national and international sustainability frameworks – to build a common vision and a commitment to action for port territories that are fit for the future.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein.

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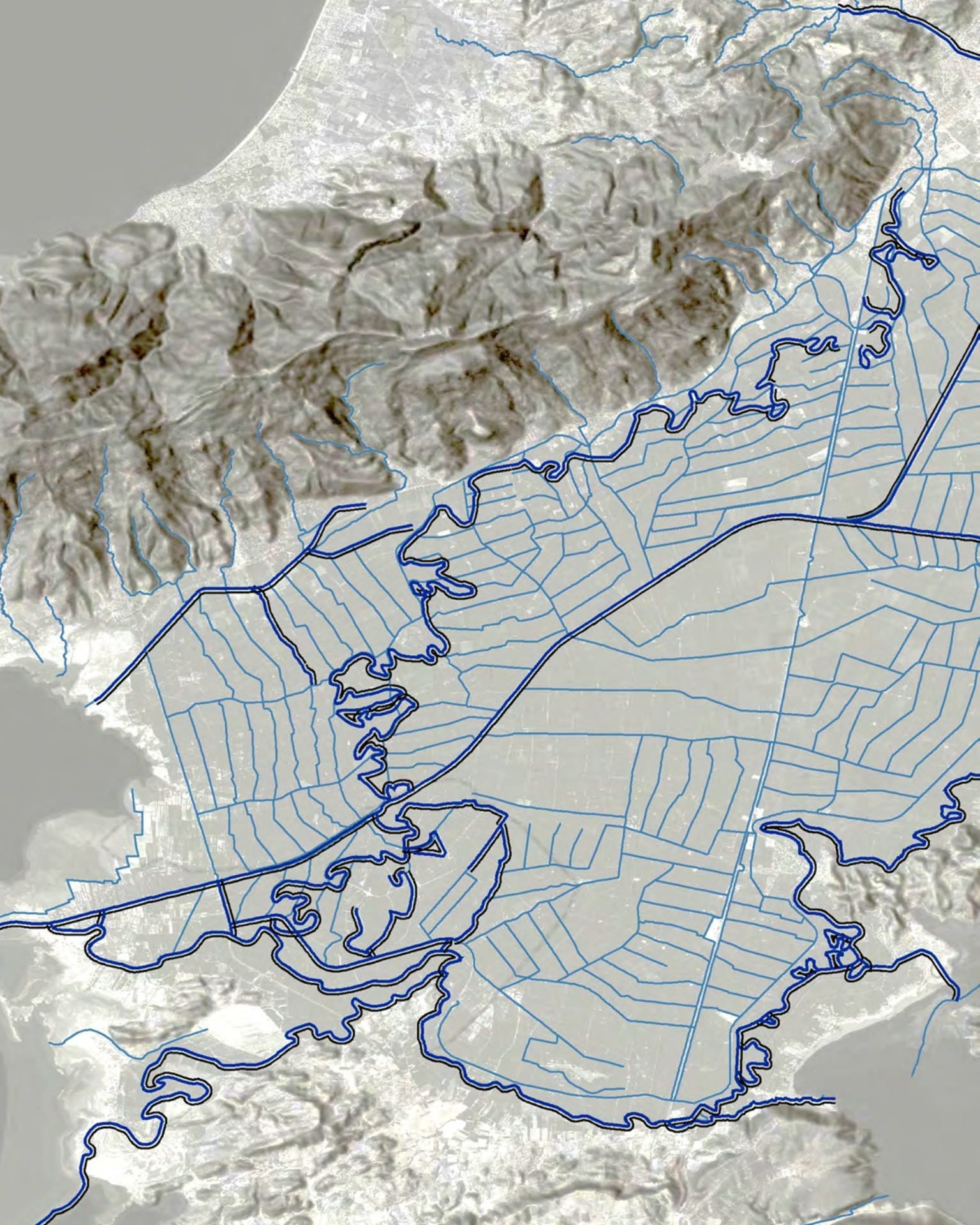
PART II Methodologies and Case Studies



Blue Papers 2026 (Vol. 5 No. 1), pp. 84–96
10.58981/bluepapers.2026.1.07
Received 17.11.2024; Received in revised form 01.07.2025; Accepted 26.08.2025

Reconsidering "Water" as an Initiator and Transformer of River Landscape Heritage: The Case of the Menderes (Maeander) Delta, Türkiye

Gökhan Okumuş, A. Güliz Bilgin Altınöz & Gerdy A.Verschuure-Stuip

Abstract
Historically, the Menderes (Maeander) River has played a crucial role in the development of settlements and cultures, shaping the natural, social, cultural, economic, and governmental dynamics of western Anatolia. Known as the "Valley of Civilizations," its delta contains water-related heritage, knowledge, and traditions, encompassing agricultural and urban development as well as industrial and technological innovation. Today, the river's layered landscape reflects a centuries-long history of water management and infrastructure. While the river remains critical to the continuity of life in the region, communities along its course have lost many sociocultural connections and meaningful relationships with water and the river. This article reports on research that aims to restore those connections by using water as a unifying element and catalyst, applying a "landscape biography" approach to promote the holistic and sustainable heritage conservation and management of the Menderes River landscape and its communities.

Policy Recommendations

- Water-related and riverine landscape heritage should be identified, and the complex legal and administrative framework for conservation and management should be strengthened.
- Conservation and management approaches should emphasize nature-culture unity and collaboration among actors, stakeholders, and local landscape communities.
- Adopt a holistic approach to challenges: socio cultural and economic issues (e.g., narratives and stories pertaining to river, agriculture, irrigation, and fisheries) should be considered together with ecological and heritage dimensions, and plans for adaptation to climate change should be integrated with heritage management.

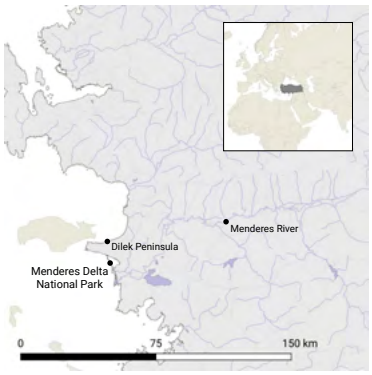
KEYWORDS

water-related heritage
heritage conservation
water & landscape ensemble
Menderes (Maeander) Delta
landscape biography

WATER VALUES

CLIMATE

Cfb: Hot-summer Mediterranean climate



< Fig. 1 Map showing the Menderes Alluvial Plain and surrounding settlements, river systems, irrigation canals, and protected areas (Source: Gökhan Okumuş, 2025. © Esri and © OpenStreetMap contributors, licensed under the Open Database License [ODbL]).

Introduction

Water is a fundamental element of human civilization, enabling diverse social, cultural, economic, and political developments across the globe. Throughout history, the need for water and its management have driven societies, shaping their development and prosperity (Hein et al. 2018).

The Büyük Menderes River (historically the Maeander or Meander, from ancient Greek: Μαίανδρος, Maíandros) is located in southwestern Anatolia (fig. 2). In ancient times, it became renowned for its winding course and is the source of the English word *meander*, used to describe a bend in a river or the action of moving in a winding fashion. The river played an important role in the birth of civilizations and the continuous settlement history of the region (Başgelen 2010). Many ancient harbor settlements named after the "Maeander" (Miletos, Priene Ad Maeandrum, Tripolis Ad Maeandrum, Nysa Ad Maeandrum, Magnesia Ad Maeandrum, Myous, Heracleia/ Latmus) have been established in the river basin.

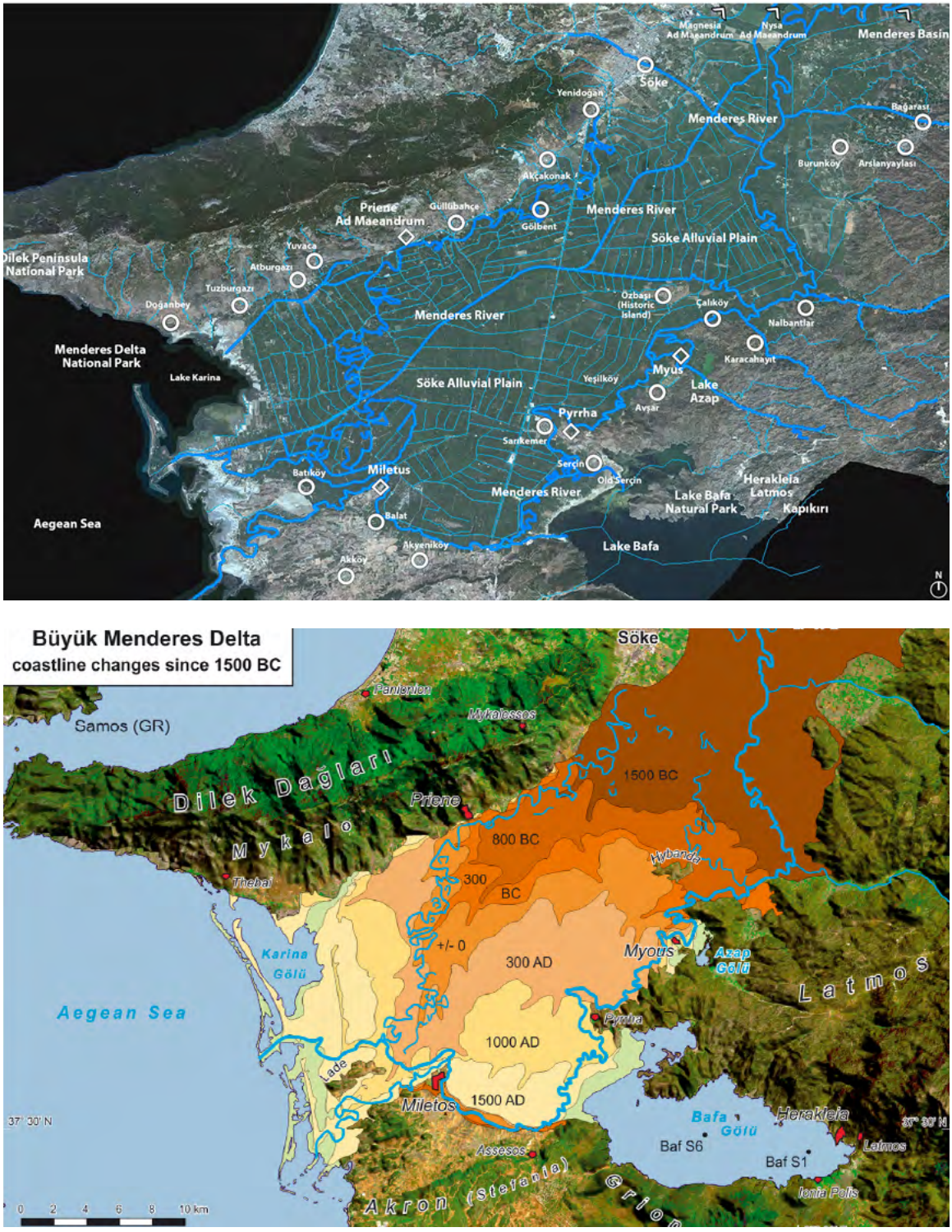
The Menderes River, with the alluvium it has carried over the ages, has created fertile lands that proved a source of great agricultural wealth for the societies in Anatolia (Göney 1975, Brückner et al. 2017). Alluvium shaped the Söke alluvial plain, and consequently, the sea passage gradually closed to form Lake Bafa and the Menderes Delta (fig. 2). This process of progradation resulted in ancient harbor cities losing their importance, but created a river landscape and fertile soils for today's settlements. The Menderes' ongoing progradation has continually altered the relationship between human societies and water, prompting evolving strategies and interventions that have left lasting marks on the landscape.

Current Situation and Approaches to Preserving and Managing the Menderes Delta as a River Landscape and Heritage

Today, the Menderes Delta landscape is home to many water-linked urban and rural settlements, some of which are listed as "natural," "urban," and "urban archaeological" conservation sites. The ancient harbor cities around the Menderes Delta-Alluvial Plain are also protected today as "archaeological" sites, although they have become disconnected from one another and the landscape due to the river's progradation over time. In that sense, the traces of water-related heritage include:

1) natural and cultural landscapes, wetlands, agricultural lands, alluvial plains and historic lakes, islands, irrigation canals and networks;
2) water-linked urban and rural settlements, delta and historic farm settlements and relevant buildings such as ports and warehouses, waterways, aqueducts, water mills, historic bridges, baths, fountains, dams, cisterns and wells;
3) archaeological remnants of ancient cities such as ancient ports and port streets, monuments and gates, port colonnades, city walls, temples, places of worship and sacred roads.

The river basin's natural, ecological, historical, and sociocultural richness has enabled it to become part of the global economy in Türkiye's modern period, with important roles played by its agricultural lands, industrial areas, cultural heritage sites, and tourist destinations. The Menderes Delta and Basin, which was connected to the nearby trading ports with Türkiye's first transportation investments, was one of the places where the first steps of industrialization based on agricultural production were taken in the 1930s (Yaşayan Nehirler Yaşayan Ege Projesi 2012). In the 1970s, the irrigation

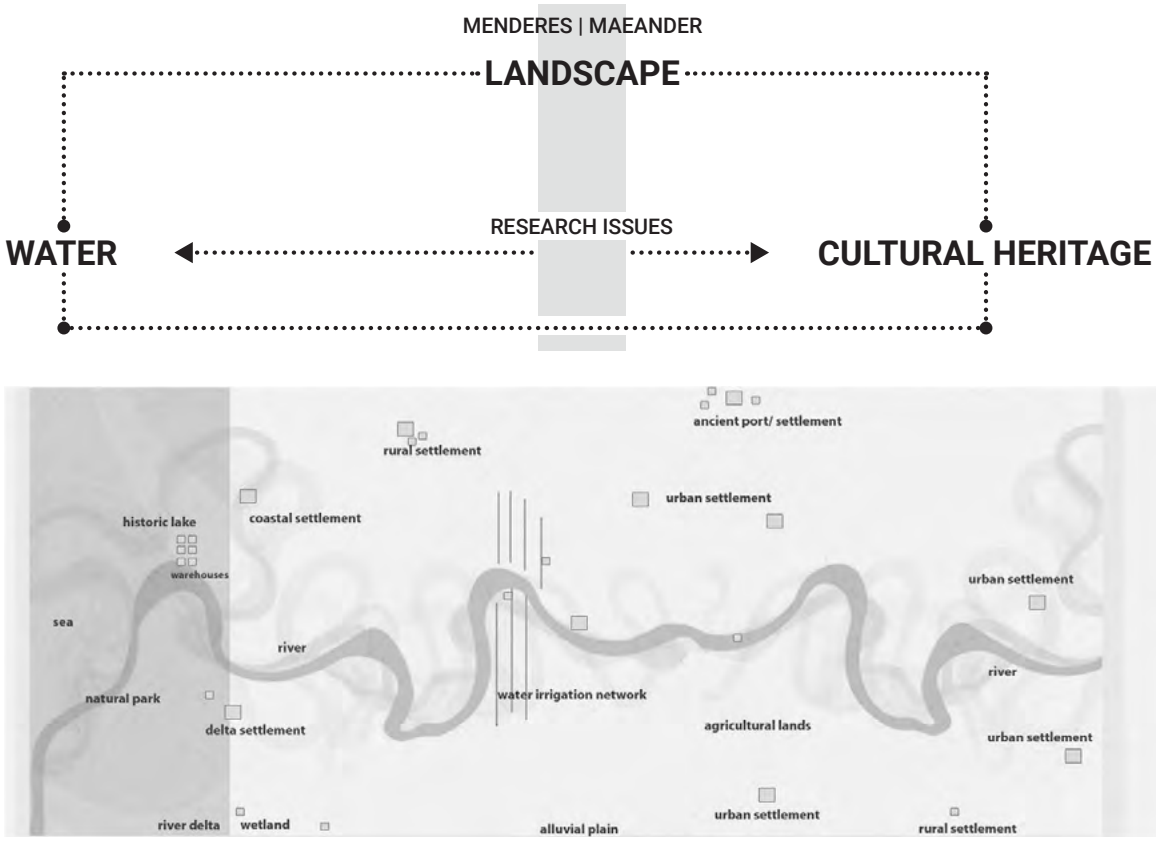


^ Fig. 2 Top: Menderes (Maeander) Delta and Basin in southwestern Anatolia (Source: Gökhan Okumuş, based on GIS Maps, 2024); bottom: The progradation process from 1500 BC to the present day of the Menderes Delta and alluvial plain shifts in the shoreline (Source: Brückner et al. 2017, p. 878, fig. 1).

^ Fig. 3 Top: The irrigation system built in the 1970s (Source: Map from Söke Irrigation Association Archive, 2023); bottom: The transformed and reconstructed landscape (Source: Photos by Gökhan Okumuş, 2024).

system was constructed in the entire delta and plain in cooperation with the General Directorate of State Hydraulic Works and relevant institutions from Germany (fig. 3). The system is also protected by the Irrigation Association Law Nº 6172.

While the river remains ecologically critical and is the main determinant of the landscape of settlements directly related to water, these settlements' relationships with water have changed due to a combination of natural-ecological dynamics, changes in the shoreline due to the progradation process, changes related to water management and collection of drinking water, human-made alterations to the natural and physical environment, economic developments and institutional and governmental changes. This transformation has led to the disappearance of water-related toponyms, the abandonment of once-meaningful places within the landscape, and the gradual decline of river-related themes in collective memory. The river, which historically was regarded as a life-giving entity that shaped ancient settlements and functioned as a sacred and regulatory force in spatial planning, settlement patterns, and ritual life, is now perceived primarily as an economic resource and through a technical and utilitarian perspective, framed by concepts such as irrigation management, flood control, and environmental challenges.



^ Fig. 4 A heritage approach to water as a physical and cultural connector and tool for the river landscape heritage (Source: Gökhan Okumuş, 2024).

When water is perceived solely as an agricultural and economic asset and the connections between water and the landscape are lost, communities and heritage sites become disconnected from one another, as well as from their main creator – in this case, the Menderes – which is crucial to the landscape and the network of settlements. Although the river continues to sustain some of the physical layers and functions of the landscape, it is largely perceived today merely as an irrigation channel, a boundary, and a functional corridor. The symbolic and cultural meanings once attached to water have been replaced by industrial and economically driven narratives. In that sense, this research aims to reframe the river as a cultural and biographical connector with narrative and mnemonic value, and to recontextualize it within the patterns of water-related heritage (fig. 4).

It is helpful to address such a complex landscape with a holistic heritage approach that integrates nature-based solutions, nature-culture interlinkages, and coexistence. A spatio-temporal perspective and a landscape biography approach can provide a basis for the development of relevant policies and future scenarios. In this approach, the Menderes River landscape is perceived through dynamic, multi-layered narratives shaped by interactions between natural processes and human interventions across time and space (Kolen and Renes 2015).

^ Fig. 5. Social surveys and field studies addressing socio-spatial, socio-cultural, and socio-economic issues in the Menderes Delta, using a landscape biography approach (Source: Photos [a-b-c-d-g-h] by Gökhan Okumuş, 2024; Photos [e-f] by Söke Municipality Archive, 2018).

By recognizing the central role of water in cultural heritage and landscape management, this framework aims to combine values, methodologies, and tools in a cohesive and adaptable approach.

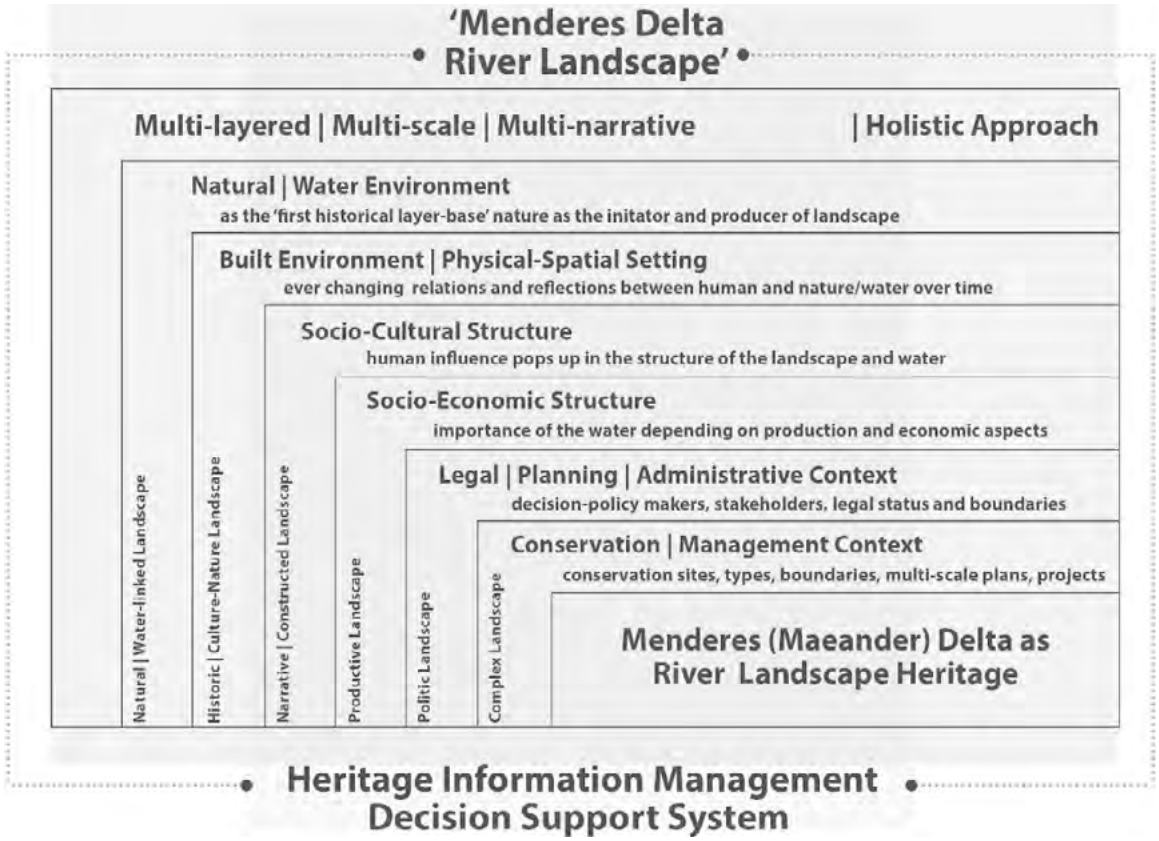
The approach was implemented through a three-stage methodological process: archival-historical analysis, field survey, oral history research, and spatial-temporal mapping using GIS. To trace the spatial transformations and reconstruct the diachronic evolution of the Menderes Delta, historical sources and maps were georeferenced and structured. Additionally, fieldwork – including social survey, observation, in-depth interviews and focus group discussions – were conducted with inhabitants of the settlements and relevant economic groups (farmers, fishers and people from related agricultural, industrial and tourism sectors), local authorities, decision-makers, policy-makers and NGOs (fig. 5). Accordingly, field notes were thematically categorized – as pertaining to, e.g., water-related local toponyms, changes in daily life with the river, transformations in land-use and irrigation practices, lost water rituals, floods and their impacts – and geospatially referenced as memory-based data.

Using place-based multi-layered data, a GIS-based heritage information management and decision-support system was developed to provide a comprehensive understanding of ongoing transformations of the multi-layered river landscape, emphasizing the interaction between natural and cultural components, as well as the key human and more-than-human agents that influence and shape its evolution (fig. 6). The system helps to store, structure, query, present, share, and monitor data regarding the landscape's different layers and components and the interconnections between them. By reconnecting these elements, the system enables the development of a more integrated, sustainable management approach that honors both the cultural and natural heritage of the region. By integrating multidimensional data, it fosters a holistic perception of the landscape including water-related relationships among communities and stakeholders.

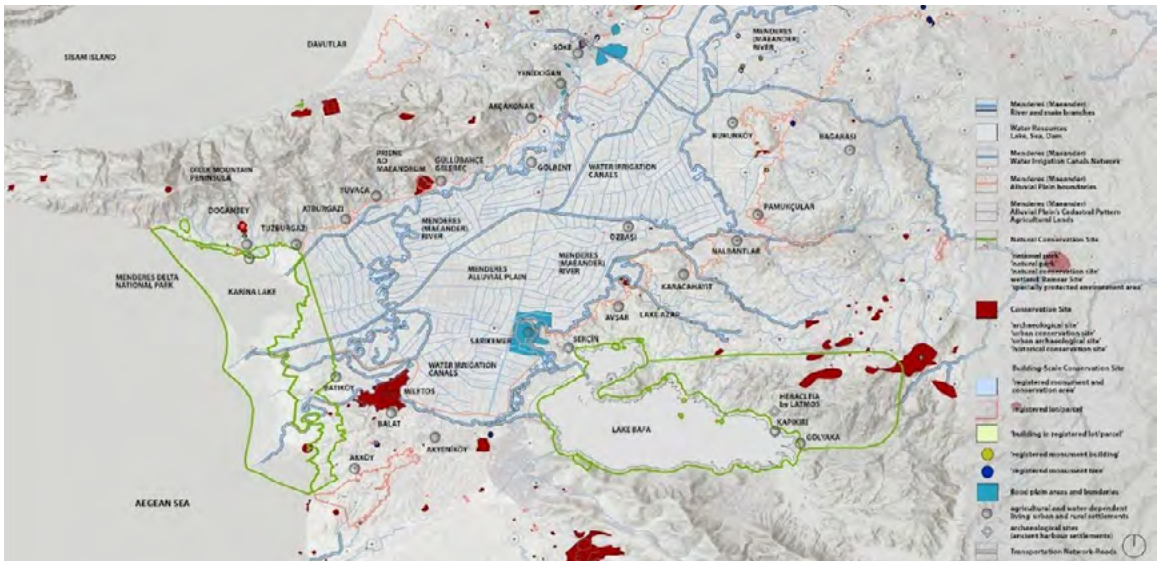
The Menderes River landscape heritage pattern encompasses multi-scale and multi-layered physical transformations, narratives, perceptions and dynamic human and natural forces. To (re)connect water-related links and heritage sites, the components of the natural, historical, cultural and constructed landscape and the network of relationships among them are systematically analyzed with a spatio-temporal, multi-layered, multi-scale and multi-narrative approach referred to as “landscape biography" (fig. 5). This holistic approach offers a comprehensive perspective on how these relationships overlap, correspond and form interconnected networks; it highlights the significance of water not only as a physical resource but also as a cultural and mnemonic agent.

Future Preservation and Management Issues and Challenges to the Menderes Delta

The conservation and management of the Menderes River and its delta involve numerous challenges. One of the most important challenges is the integration of natural and cultural heritage, since both nature and culture are in a state of flux. Furthermore, the delta and its surrounding landscape are increasingly vulnerable to the impacts of climate change, including risks posed by drought, floods, water scarcity and wildfires. Water-linked heritage and holistic management are crucial to the survival of local communities and for a sustainable and climate-compatible landscape.



^ Fig. 6 A holistic approach to the Menderes Delta as river landscape heritage: spatio-temporal, multi-layered, multi-scale and multi-narrative landscape biography (Source: Gökhan Okumuş, 2025).



^ Fig. 7 Menderes River landscape heritage information management and decision-support system (Source: Gökhan Okumuş,2025. Basemap from Esri © OpenStreetMap, licensed under the Open Database License [ODbL]).

These environmental changes threaten the sustainability of the region's agricultural practices and the ecological integrity of the landscape, making it even more crucial to develop a holistic, climate-compatible approach to its conservation. Therefore, while remembering water as a creator, connector and integrator of various tangible and intangible components of the landscape, water-dependent relationships need to be renewed and enhanced. Reconnecting local communities to the Menderes Delta is only possible by understanding culture-nature coexistence and the values it has created over time.

The ongoing nature-culture divide in heritage conservation adds complexity, as it necessitates addressing differing legal, administrative and practical issues related to the conservation and management of the landscape. In that sense, the Menderes River landscape is a network of relationships connected to water: its presence, absence, scarcity and abundance; its changes in form and type and its overlapping and conflicting values and dilemmas have created new types of heritage. Natural environments, urban and rural settlements and archaeological sites that have been formed and reshaped by water and the Menderes Delta are conserved with different statuses today. These include a wide range, from natural and cultural heritage sites at the upper scale ("national natural park," "natural conservation site," "specially protected environment area," "protected area network" [PAN Parks], "Ramsar (wetland) site," "urban conservation site," "historical conservation site," "archaeological site") to conservation statuses at the building scale ("registered monument," "registered building," "natural monuments and assets," "monumental tree"), depending on different stakeholders and decision-makers at both the national and international level. Considering contemporary approaches, decisions and plans, cultural heritage and special conservation areas at the site are defined as heritage without establishing a connection to water and the Menderes. Today, it is not possible to understand the water-linked relationships between these conservation sites, heritage places and ancient settlements, which maintain "Maeander" only in their names.

In that sense, the Menderes River landscape, which physically connects geographies, settlements and heritage places of different conservation statuses and characters, makes it possible to connect methodologies and scales of different disciplines with conservation efforts within the scope of this research approach, while also critically questioning the definition and boundaries of cultural heritage. Accordingly, the sustainable conservation and management of this landscape heritage as a water-related system, with the Menderes Delta at the core, is facilitated by remembering and reconnecting water-related heritage places. This research approaches the Menderes River landscape heritage for future preservation and management as a dynamic process shaped by the landscape's multi-layered nature – including natural-ecological dynamics, sociocultural aspects, stories, socioeconomic, institutional and governmental developments – with the 'water' acting as an inter-temporal and inter-scale connector (fig. 7).

Conclusion

The Menderes Delta is a multidimensional, and complex landscape involving many different relationships between humans and the environment. These relationships have been maintained across space and time and have natural, physical, spatial, sociocultural

dimensions. The Menderes River, which was considered sacred, has lost its cultural significance and meaning. However, it remains vitally important to the region, and a fundamental part of the ecosystem and agriculture-based economy. Since the connection to the river has been lost, urban and rural settlements, as well as archaeological sites, have disconnected from one another and from the main creator of the landscape, the Menderes. The landscape biography approach described here provides an understanding of such complex landscapes by revealing how the landscape transforms and changes over time, the components of different layers and the role of various actors in reshaping them. The approach can be helpful in developing a variety of sustainable management approaches. It makes it possible to reconstruct fragmented water-related relationships and use water as a connector to develop principles and strategies to achieve more holistic and effective management of the landscape. In this regard, water-related and river landscape heritage should be identified and the complex legal and administrative framework for conservation should be strengthened. Conservation and management approaches should emphasize nature-culture unity and collaboration among actors and stakeholders. Adopt a holistic approach to challenges: economic issues (e.g., pertaining to agriculture, tourism and fisheries) should be considered together with ecological and heritage dimensions and plans for adaptation to climate change should be integrated with heritage management.

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein, Carlien Donkor and Matteo D'Agostino.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 98–111
10.58981/bluepapers.2026.1.12
Received 23.01.2025; Received in revised form 18.11.2024; Accepted 17.12.2025

The Second Terrace: Reconnecting with Water and the Vernacular in the Ifugao Rice Terraces

Leonardo Zuccaro Marchi, Shubham Majumder & Sara Sabry

Abstract
The traditional ecological knowledge (TEK) that is deeply embedded in the Ifugao Rice Terraces offers crucial insights for socio-ecological adaptation and resilience in times of climate change. It helps sustain local biodiversity and supports ecosystem processes while inspiring new design ideas that encourage an epistemological shift that involves integrating traditional knowledge with incremental innovations from the past into future solutions. The Second Terrace Lodge research-by-design project highlights the importance of the Ifugao community's local landscape and cultural heritage, illustrating how traditional water and land management can be integrated into contemporary architecture and landscape design.

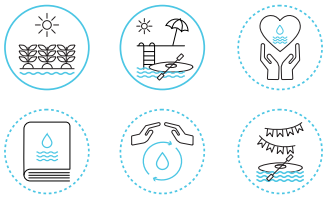
Policy Recommendations

- Use competitions as tools: Architectural competitions are key tools for supporting research and developing future transformation scenarios, especially in threatened landscapes like the Ifugao Rice Terraces (IRT) in the Philippines.
- Learn from TEK: Architects and stakeholders should learn from the traditional ecological knowledge (TEK) embodied in the IRT and other vernacular landscapes and reinterpret it in contemporary architecture.
- Balance technology and the vernacular: A wise balance between technological innovations and vernacular traditions is crucial, particularly for vulnerable areas.
- Learn from ancestral landscape farming landscapes like the IRT, shaped over thousands of years, which provide lessons in water, land, and heritage management that are useful for climate change adaptation in urban and landscape design.

KEYWORDS

Banaue
rice terrace
water systems
vernacular
landscape

WATER ICONS



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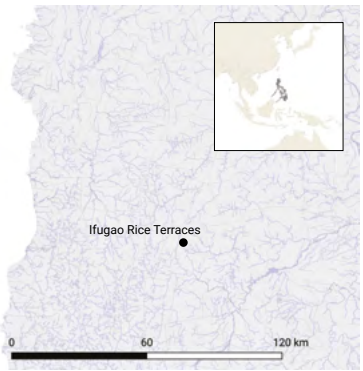


< Fig. 1 The Ifugao Rice Terraces (Source: Ericmontalban, 2012. CC BY-SA 3.0, via Wikimedia Commons).

Introduction

Mountain rice terracing is common throughout the Asia-Pacific region and is deeply connected to Indigenous cultures, traditional practices and the ecology of mountainous regions (Kawasaki 2012). However, climate change increasingly endangers these landscapes by worsening extreme weather events, such as heavy rainfall and disrupted water cycles. The iconic Ifugao Rice Terraces (IRT) in the Philippines, ancestral lands of the Indigenous Ifugao people – including groups like the Banaue, Bunhran and Mayayao – are particularly vulnerable.

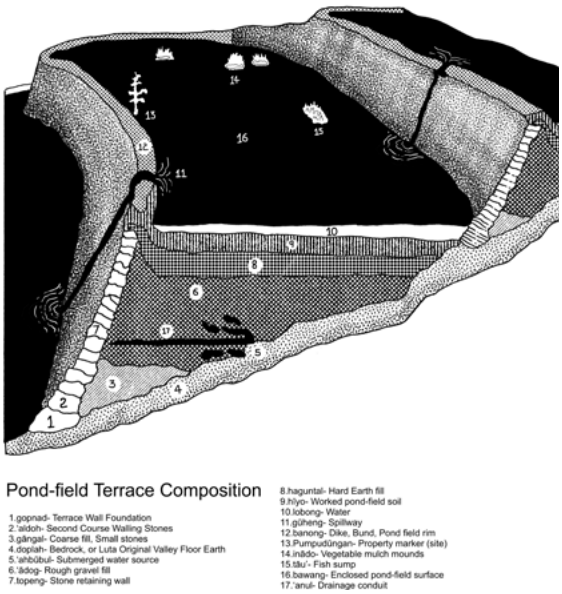
Learning from water and vernacular traditions offers hope and a strategy for rethinking our socio-spatial sustainable future. This article is based on a research-by-design project that won the 2024 Banaue Lodge competition (Zuccaro Marchi et al. 2024). Organized by TerraViva Competitions, the Banaue Lodge competition aimed to promote a new model of slow and sustainable tourism within the water landscape of the Rice Terraces of the Philippine Cordilleras in Banaue – a site designated as a UNESCO World Heritage property in 1995.

Competitions act as vessels of knowledge and opportunities for research and experimentation. This winning proposal relied on the dynamic nature of the IRT cultural landscape and its associated living heritage values to foster a more sustainable and respectful design approach. The project translated the local landscape's key elements and water heritage, developed over two millennia, into contemporary architecture. The typical section of the traditional Ifugao terrace, with its layering of different types of water and soil, became the main reference for designing tourism activities while also drawing lessons from its tectonics about sustainability, resilience and adaptation.

The project's main objectives were to translate the traditional Ifugao water systems into new spatial and architectural settlements that confront climate change threats, explore the role of architectural-landscape design in enhancing both cultural and ecological resilience, and promote sustainable tourism as a way to protect water-related Indigenous knowledge.

Water Systems and Their Role in Ifugao

The IRT are socio-ecological systems integrated into their natural environment and deeply connected to the local cultural heritage of rituals and agricultural knowledge. In 1995, the IRT property was designated as a UNESCO World Heritage site in recognition of its Outstanding Universal Value (OUV), serving as a dramatic testament to sustainable rice production, a memorial of the multigenerational history of labor and an example of harmonious cooperation between the environment and local inhabitants (UNESCO n.d.; SITMo 2008): "The Ifugao Rice Terraces epitomize the absolute blending of the physical, socio-cultural, economic, religious, and political environment." According to UNESCO, "the IRT is a living cultural landscape of unparalleled beauty" (UNESCO n.d.). The IRT property is also currently protected by the Indigenous Peoples' Rights Act of 1997 (IPRA), Republic Act No. 8371, a Philippine law that recognizes, defends and promotes the rights of local Indigenous cultural communities and their ancestral domains (SITMo 2008). Moreover, in 1973, the IRT had been declared one of the country's national cultural treasures by Presidential Decree No. 260, issued by then-president Ferdinand Marcos (UNESCO n.d.; SITMo 2008). The decree's primary purpose was to develop and preserve the site, promoting cultural and national identity and propelling new forms of tourism. In addition to local and in-



^ Fig. 2 Pond field terrace composition adapted and redrawn by the authors from Harold Conklin's (1980) Ethnographic Atlas of the Ifugao (Source: Leonardo Zuccaro Marchi, Shubham Majumder and Sara Sabry, 2024).

ternational laws and decrees, the terraces are protected through traditional practices within a cooperative approach involving the entire Indigenous Ifugao community and related ancestral rights and tribal laws (UNESCO n.d.).

Renowned for their expertise in sustainable ecosystem management, the Ifugao communities live at elevations between 800–1,500 m, carefully preserving forests and cultivating terraces in harmony with nature (fig.1). According to UNESCO, their living cultural landscape began to take shape in what is now the Philippines over 2,000 years ago (UNESCO n.d.), although more recent studies date their development to 1500–1600 AD (Acabado 2009). The terraces rely on the Muyong forest system, a community-managed hydrological system located at the top of the mountains that conserves water and protects the terraces (Jang and Salcedo 2013). The Muyong hosts a wide variety of fauna and flora, serving as the primary recharge zone and providing a stable nutrient-rich water supply to other parts of the production system (Camacho et al. 2012; 2016; Negro 2019). Some upstream runoff is directed into the terraces, while the rest is diverted to villages for daily water use (Herath et al. 2015). Water is sourced from streams and rivers, channeled through bamboo and log flumes into an intricate irrigation system. This setup supports rice farming as well as aquaculture, where species such as fish and edible mollusks thrive, thereby enriching the region's biodiversity. Communities historically developed the IRT by using natural water flows and interconnected irrigation channels to optimize water efficiency while preventing runoff and soil erosion. In Ifugao, the concept of "water districts" organizes agricultural leaders and workgroups to construct and maintain irrigation channels, which gradually release water into terraced paddies, ensuring consistent moisture levels for rice cultivation (Herath et al. 2015).

The Ifugao's soil and water conservation technology uses irrigation and bench terracing methods developed by their ancestors over many centuries. The steep terrain was smartly transformed into a series of horizontal platforms or "benches," with retaining walls and embankments that slowed water flow, allowing it to seep into the soil instead of rushing down. The paddies "act as mud and sand-traps" (SITMo 2008). Terrace ponds collect water, sealing cracks that might cause landslides. This preserves humus-rich soil and reduces siltation by trapping mud and sand. Moreover, the antique practice of planting camotes (sweet potatoes) on steep, unirrigated slopes limits erosion. Grass between crops stabilizes soil, preventing collapse (SITMo 2008). This method is an example of ancient mastery over natural forces and the environment, demonstrating a balanced harmony with nature and wise

management of local resources from which architects and stakeholders should learn.

The cross-section of a typical Ifugao pond field (fig. 2), redrawn from Harold Conklin's (1980) *Ethnographic Atlas of Ifugao*, exhibits the complex stratifications of retaining foundation walls, coarse gravel-earth fills and water systems from the submerged water source to water basins and spillway, to drainage conduits. The terraces and water systems are closely connected, with water carefully managed to support farming. Originally built as survival tools to cope with environmental challenges, these systems showcase Indigenous expertise in soil, water behavior and weather patterns. Over time, they have become cultural symbols of resilience, embodying the harmonious relationship between nature and community. According to researchers, the Ifugao water system is a model that can be replicated in other areas around the world with a shortage of water supply due to drastic climate and environmental changes (Jang and Salcedo 2013).

This ecological system and complex farm activities are inseparably linked with the local inhabitants' sacred collective rituals, chants, symbols and taboos in a way that nurtures bountiful yields (SITMo 2008; Negro 2019). The socio-ecological system of the IRT closely mirrors Indigenous knowledge of spiritually and productively connected practices developed over thousands of years of direct human interaction with the habitat (Camacho 2012).

Challenges

Recent pressures, such as climate change, tourism and changing agricultural practices, have disrupted traditional methods. The Sixth Assessment Report (AR6) of the United Nations (UN) Intergovernmental Panel on Climate Change (UN, IPCC 2022) highlights the increasing and serious impacts of climate change on the Philippines, including higher temperatures, altered rainfall patterns and more frequent extreme weather events, all of which threaten IRT and the communities relying on them.

Soil and cultural erosion: Climate change is introducing new risks, making terraces more susceptible to water shortages and droughts during dry seasons. As watersheds are disturbed, water flow to the rice terraces decreases, causing erosion in rice fields that struggle to be properly irrigated. This leads to further erosion and silt buildup, contaminating the rivers, a situation made worse by inadequate sewage systems in Banaue and neighboring areas (SITMo 2008).

Tellingly, the loss of the terraced landscape occurs in parallel with the "erosion of Ifugao cultural and spiritual heritage" (Herath et al. 2015). The threat is the loss and disappearance of traditional yearly farming practices, which were cyclically conducted by agricultural priests, and ancient rituals calling for abundant harvests. These ceremonies were woven into the landscape as a cultural layer over the stratifications of soil, vegetation and water that form the terraces. This cultural loss is linked to migration. Members of younger generations often migrate for better opportunities, contributing to a decline in traditional knowledge, including of Ifugao mythology (De Leon et al. 2021). This results in the abandonment of the terraces.

Tourism: Tourism provides economic alternatives that sometimes overshadow farming, raising challenging questions about preserving local identity, cultural heritage and environmental settings. Tourism in the area can be

traced back to the mid-1700s and it has continued ever since, gaining momentum in the mid-1970s after the Presidential Decree (SITMo 2008). Today, it exists in a delicate balance between commercialism and conservation (Dulnuan 2014). Once a pristine valley carved by rice terraces, in recent decades the IRT have faced threats from unchecked residential, commercial and tourism development, leading to noise, pollution and congestion that affects water resources and soil health. The Indigenous forestry and natural regeneration system of the Muyong community is at risk of being lost, causing territory erosion. Meanwhile, increasing demand for carved wooden souvenirs has accelerated deforestation. Since the forests provide essential watershed functions and a constant supply of nutrient-rich water for the rice terraces, deforestation has caused irrigation problems, leading many terraces to be abandoned (SITMo 2008; Negro 2019). In 2001, the IRT was placed on the World Heritage in Danger list "in recognition of the human-induced threats" and the urgency of short- and long-term protective actions (IUCN 2002; SITMo 2008).

Despite these threats, Ifugao communities continue adapting to new challenges from tourism and climate change by implementing policies that promote reforestation, sustainable forestry and community-led irrigation management, ensuring the lasting legacy of their agricultural heritage. To safeguard these systems, local authorities have worked to integrate contemporary strategies with traditional knowledge and new adaptive practices (Droogers 2004). Programs and plans, such as the CBLUZP—Community-Based Land Use and Zoning Plans – have been developed to document the site, uphold integrity conditions, reduce cultural degeneration and rehabilitate lost traditional practices (UNESCO n.d.).

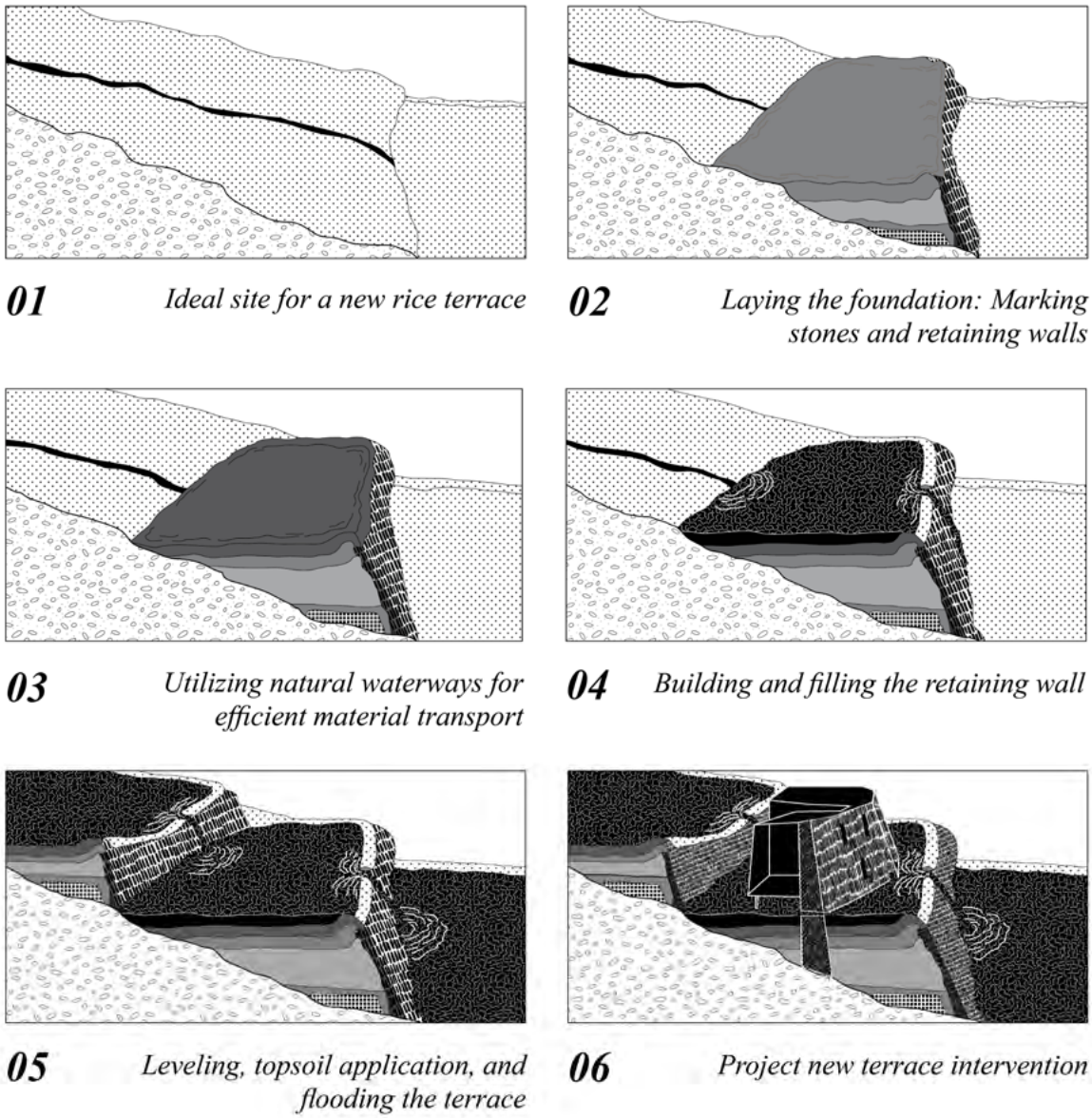
While tourists are attracted by local Indigenous culture, Indigenous communities, in turn, depend on sustainable tourism for protection and conservation (Dulnuan 2014). This interdependence helps reinforce and pass down vernacular traditions, rituals, and water and land management practices. This fragile connection between a new sustainable form of tourism and local traditions became the guiding reference for our project proposal.

Water and Vernacular: The Second Terrace Lodge Project

The Second Terrace Lodge project emphasizes the local land and water heritage of the Ifugao Community as a vital and functional inspiration for contemporary architecture and landscape design. The project holds that the traditional ecological knowledge (TEK) embodied in the IRT offers valuable insights for socio-ecological adaptation and resilience, contributing to the sustainability of biodiversity and ecosystem processes and inspiring future designs.

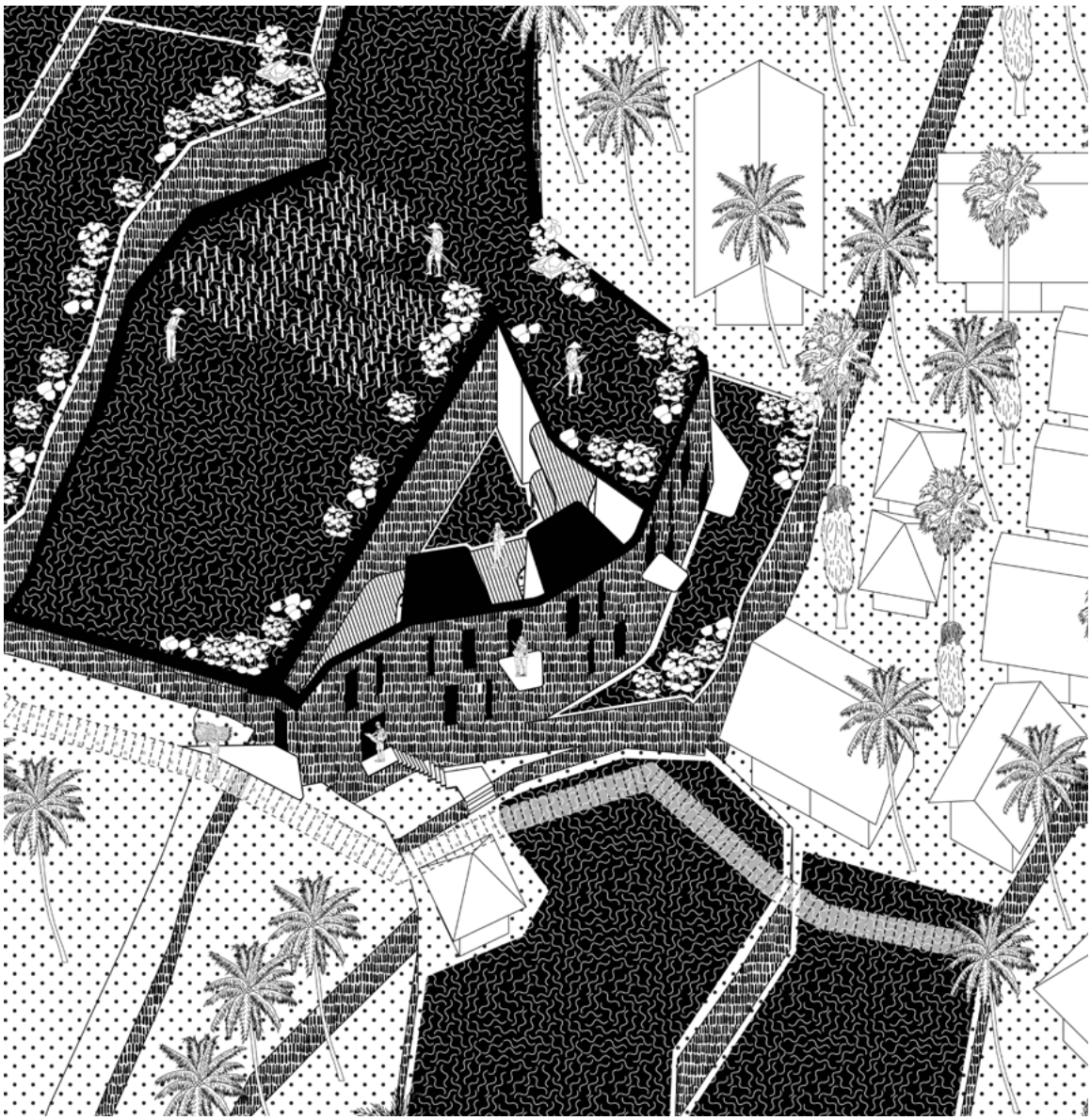
In the last two decades, several researchers have highlighted the necessity to reestablish equilibrium and synergy between the "mythology of technology" and vernacular "Indigenous innovation" (Gómez-Baggethun et al. 2013; Watson 2020; Piesik 2023). The IRT provided an opportunity to evaluate this equipoise. Indeed, the project reiterates the wise vernacular legacy embedded in the territory, becoming part of the historical terraced landscape while fostering a new, contemporary connection between people and nature.

The project grows out of the community's local landscape and vernacular activities without being disruptive or alienating. As shown in the phasing diagram (fig. 3), it is designed



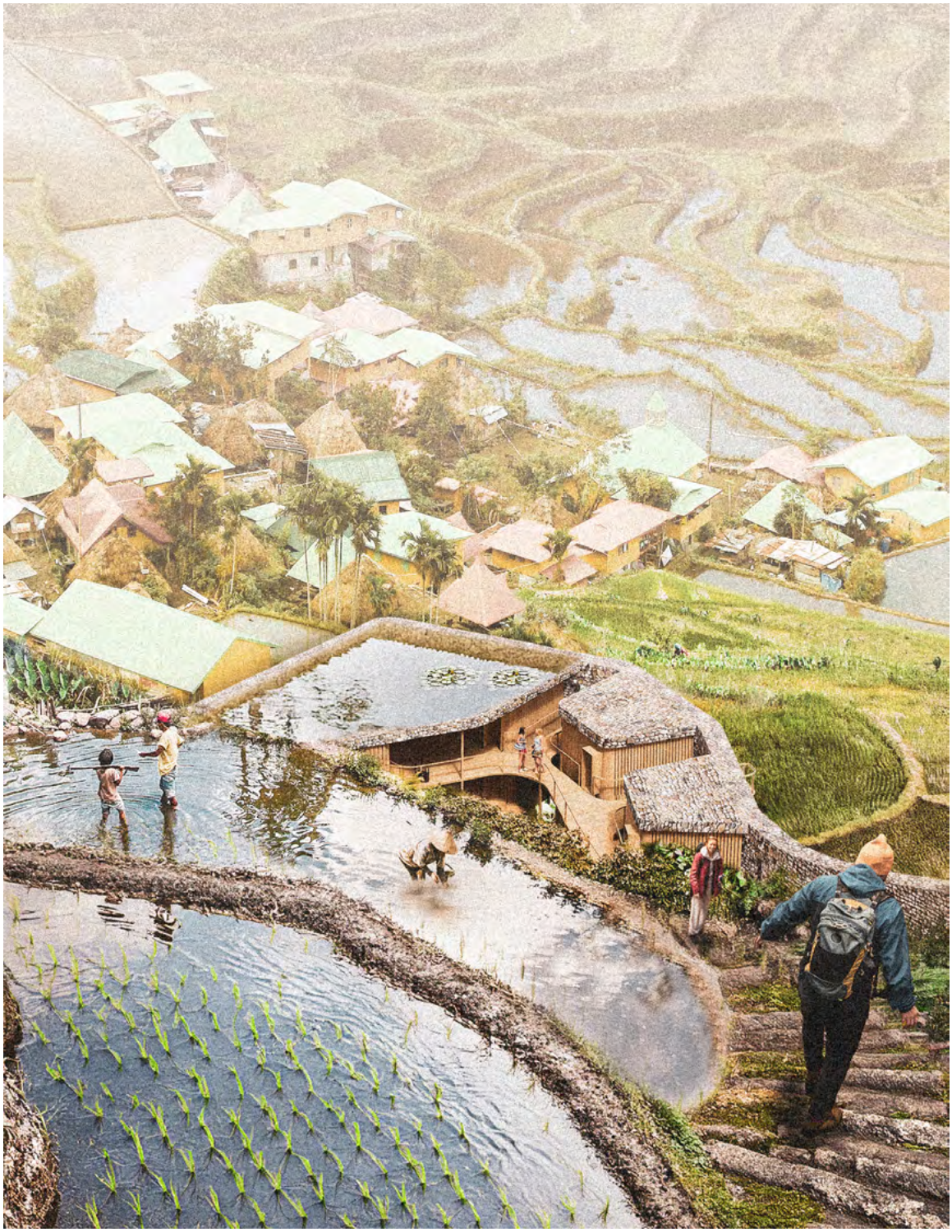
^ Fig. 3 From rice terraces to Second Terrace Lodge (Source: Leonardo Zuccaro Marchi, Shubham Majumder and Sara Sabry, 2024).

to be integrated into the terraces' construction process, following local traditions of stone retaining walls, topsoil application and natural flow of waterways. The project encourages new, sustainable forms of social interaction between visitors and local inhabitants, preserving rice-cultivation culture while incorporating it into a new model of tourism education (Dulnuan 2014). Hosts are actively engaged in local rites and cultivation, living alongside and learning from the community rather than observing it from a distance.



^ Fig. 4 Axonometric drawing of the Second Terrace Lodge (Source: Leonardo Zuccaro Marchi, Shubham Majumder, and Sara Sabry, 2024).

The "second terrace" proposes an additional cultural and economic opportunity to integrate the landscape's cultural heritage and local identity with a responsible, respectful form of tourism and hospitality. The area's existing hotels are modern structures built for mass tourism, rising prominently from the ground and seeking harmony with the topography and nature, like the Banaue Hotel & Youth Hostel. This modern building was constructed in 1970 with a capacity of about 500 people and is managed by the Department of Tourism (Baldo et al. 2017).

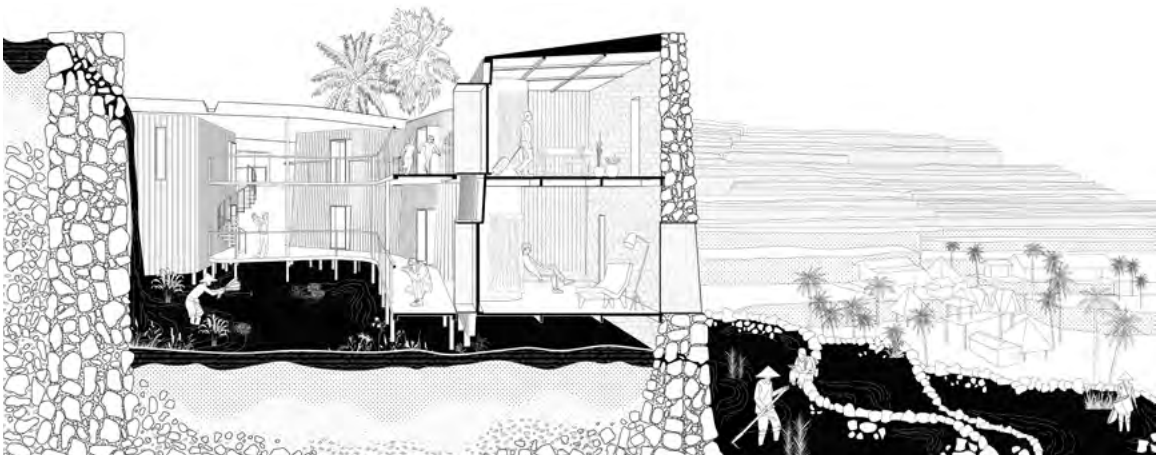


^ Fig. 5 View from above, approaching the Second Terrace Lodge (Source: Leonardo Zuccaro Marchi, Shubham Majumder and Sara Sabry, 2024).

Other tourist structures were built without adherence to building or construction codes, resulting in unfinished structures and temporary shanties that have marred the landscape (Dulnuan 2014). In contrast, the new lodge is intended for small-scale tourism and is camouflaged within the existing fabric, blending into the tectonics of the terraces, where agricultural-religious rituals and chants continue undisturbed (fig. 4).

Visitors are housed inside an emptied and inhabited new terrace, which is integrated into the intricate irrigation system of streams and basins that harvest water from the forests of the mountain above. If local people call themselves "*Ipugo*", meaning "from the earth" (SITMo 2008), the new visitors are also part of this cultural ground, in direct contact with the anthropological and natural essence of the place. The new hospitality architecture features a hollow space inside the ground, using the same stone wall that supports soil, water and gravel layers on the other full terraces. The rigid external wall contrasts with a more internal softscape of wood, water, and herb cultivation. Whereas the external wall adopts the same stone and mud materials as the other terraces' facades to obtain a mimetic effect, the internal volumes are wooden-made, inspired by the "*bahay kubo*", a type of stilted Indigenous house in the Philippines. The project includes three volumes with two floors, housing seven apartments – six single units and one for families – connected by a main retaining wall that extends from the terrace wall above. The existing path, which runs along the entire terraced hill, links the ground and first floors of the project, allowing the new structure to integrate smoothly with the existing paths and practices (fig. 5).

Water plays a primary role in reconnecting nature and community. The new terrace frames an internal courtyard, where water flows from the terrace above and continues to spill into the terrace below without disrupting the existing ecosystem. The new terrace's wall is porous, preserving and maintaining the existing water distribution channels that feed the terrace paddies (fig. 6). The water court, filled with local plants and crops, serves as a relaxing space for meditation and social interaction. It affirms the human-natural connection with the site, also becoming a place for meditation and relaxation for visitors (fig. 7). The inner courtyard is used for growing the local native rice variety, "*tinawon*" rice, meaning "once-a-year" rice (SITMo 2008), enhancing contextual sensitivity inside



^ Fig. 6 Perspective section of the Second Terrace Lodge (Source: Leonardo Zuccaro Marchi, Shubham Majumder and Sara Sabry, 2024).

^ Fig. 7 View inside the introverted water courtyard of the Second Terrace Lodge (Source: Leonardo Zuccaro Marchi, Shubham Majumder, Sara Sabry, 2024).

the lodge. The rest of the terrace is used for other local crops and an assortment of vegetables and decaying plant material during the rice cycle's fallow season ("*pingkol*" practice), such as rice stalks, floating fern ("*Azolla pinnata*"), rice field water weed ("*Najas graminea*"), water hyacinths, duckweed and other leafy succulent plants (SITMo 2008). The main building's roof also functions as a water reservoir, connected to the agricultural activities of the rice field above.

Finally, the visitors at the lodge will respect, learn about, and participate in the agricultural cycle rituals, the "*Hongan di Page*", which residents perform during the annual agricultural cycle to honor gods and other unseen beings in order to ensure healthy and robust rice crops (SITMo 2008). As highlighted by UNESCO, these ritual practices, chants, and symbols emphasize the ecological balance that the IRT has sustained over 2000 years, combining and addressing various and mutable ecological, agronomic, ethnographic, religious, social, economic, and political factors (UNESCO n.d.).

Coda: Hopes for Water Design

Blending contemporary architecture with vernacular landscape elements presents a new challenge for architectural practice, especially in adapting to severe climate change. The Second Terrace Lodge encourages a respectful, innovative approach to achieving proper synergy with natural elements and local communities, emphasizing an anthropological and ecological perspective of responsibility. It promotes harmonious intervention while maintaining and reinterpreting the place's socio-spatial authenticity, along with tourism that educates visitors about local rituals and practices. The Ifugao community's water–ground legacy is a "living cultural landscape" (UNESCO n.d.) that inspires future architectural and urban challenges, sparking new design ideas that explore an epistemological shift toward traditional knowledge in harmony with incremental innovations.

Acknowledgment
This research was possible thanks to NextGenerationEU, MUR - Ministero dell'Università e della Ricerca. Piano Nazionale di Ripresa e Resilienza (PNRR), Politecnico di Milano.

The "Second Terrace Lodge" (Zuccaro Marchi et al. 2024) is the winning project of the "Banaue Lodge" competition organized by "TerraViva Competitions": https://www.terravivacompetitions.com/banaue-lodge-competition-results-2024/.

We appreciate the initiative of the competition organizers, who focused on a relevant topic and an incredible site. Unfortunately, we were not able to visit the IRT before this competition and research. Although we acknowledge this as a limitation, we can still claim to have developed a successful competition project and written this article taking as honest an approach as possible for the site and its residents. We hope this article will open opportunities to visit the IRT and support further development of the project. Finally, many thanks to all the editors of *Blue Papers* for their helpful comments and reviews.

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Zuzanna Sliwinska, Matteo D'Agostino and Carola Hein.

Useful links
https://www.leonardozuccaromarchi.com/
https://www.leonardozuccaromarchi.com/banaue-lodge/

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Blue Papers 2026 (Vol. 5 No. 1), pp. 112–23
10.58981/bluepapers.2026.1.08
Received 11.08.2024; Received in revised form 11.11.2024; Accepted 16.12.2024

Rituals and Residues: Mapping Mining Landscapes and Spatial Practices Along South Africa's Klip River

Shreya Sen

Abstract
Gold mining along South Africa's Witwatersrand mining belt began in the late nineteenth century, significantly impacting water ecosystems, especially the Klip River, the largest tributary of the Vaal River. Despite challenges of acid mine drainage and compromised water quality, century-old religious practices like river baptisms persist, demonstrating cultural resilience as communities maintain their traditions amidst environmental adversity. This case study aims to illustrate how cultural resilience manifests through ritual practices and to propose a framework for addressing the socio-environmental complexities of post-mining landscapes.

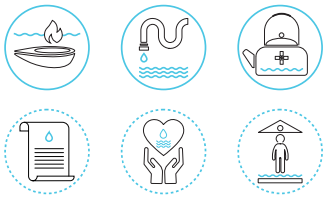
Policy Recommendations

- Promote Community-Led Environmental Education. Implement interactive programs to engage residents, especially youth and leaders, in understanding the Klip River's ecological significance and pollution issues, empowering them to advocate for sustainable practices.
- Ensure inclusive governance for river management. Prioritize the involvement of marginalized communities in decision-making processes, creating platforms for meaningful participation to ensure policies reflect their needs and values.

KEYWORDS

toxicity
Klip River
river baptisms
cultural resilience
environmental degradation

WATER VALUES



CLIMATE

Cwa: Humid subtropical climate

< Fig. 1 Grumeti River hippo pool - Migration Camp (Source: Self-photographed, 2019. CC BY-SA 4.0 via Wikimedia Commons).

Introduction

Flooding, drought and pollution can affect water sources that are often used for spiritual practices, such as river baptisms. Churches, especially African Initiated Churches (also known as African Independent, Indigenous or Instituted Churches), continue to baptize in polluted waters due to the scarcity of clean alternatives, reflecting the tension between spiritual necessity and environmental hazards. Flooding events during baptisms have sometimes resulted in tragic accidents, as seen in recent reports where rising waters during ceremonies have led to fatalities in South Africa (Christianity Today 2023). This raises critical questions: Are these practices a sign of faith overriding practical concerns, or a response to the lack of clean water? Recognizing both the cultural significance of water and the urgent need for environmental stewardship can help ensure spiritual needs and public health are balanced, something which is becoming increasingly important in the face of climate change.

The Klip River (or in Afrikaans: *Kliprivier*, lit. 'Stone River') in South Africa spans approximately 120 km, forming the largest tributary of the Vaal River (Freeman, et al. 1997). The river, functioning as a conduit for water and sediments, has played a pivotal role in shaping its surrounding landscape. Situated in the densely populated province of Gauteng, the Klip River serves as the primary drainage system for the Witwatersrand region, encompassing the southern part of Johannesburg, including the central business district (CBD) and the township of Soweto. Ultimately merging with the Vaal River at Vereeniging, the Klip River assumes a crucial role in Gauteng's broader hydrological network, supplying water downstream of the Vaal Dam (Pheiffer et al. 2014).

Since the late nineteenth century, gold mining along the Witwatersrand mining belt has left an indelible mark on the Gauteng region, with lasting consequences for its water ecosystems. Among gold mining's consequences are increased urbanization, acid mine drainage, heavy metal pollution, and compromised water quality. The Klip River and its extended network of wetlands face challenges stemming from mining effluents and industrial pollution, which flow downstream to the Vaal River and its extended dam system, contributing to an advanced degree of collapse (Bengu et al. 2017; McCarthy et al. 2007; Olasupo and Buah-Kwofie 2021) in the Klip River, creating a spatial manifestation of toxicity that resonates through time (Chetty et al. 2021; Freeman et al. 1997; Marara and Palamuleni 2019).

Embedded within this intricate narrative is the temporal nature of religious practices, notably river baptisms and immersion practices, which have parallelly endured over the course of a century (Kgatle and Modiba 2023; Kiernan and West 1977). These rituals draw from both Christian and pre-Christian traditions, blending spiritual cleansing with healing practices rooted in African cultural beliefs (Chamberlain 2012; PBS 2023). The symbolism of water as a source of renewal connects these practices to historical traditions across the African diaspora, underscoring their cultural resilience amidst environmental challenges.

The intersection of these practices with the urban environment unfolds as a rich socio-temporality, coinciding with the historical legacy of gold mining toxicity. Despite the looming threat of contamination from nearby mine sewage and waste, congregants in Klip River continue to partake in baptisms, immersing themselves in "holy water" believed to possess spiritual significance (Bega 2021; Mas-

weneng 2023). This century-old cultural practice not only reflects the resilience of religious traditions but also introduces a paradox – the coexistence of cleansing rituals with the potential hazards posed by the legacy of toxic gold mining.

Methodology

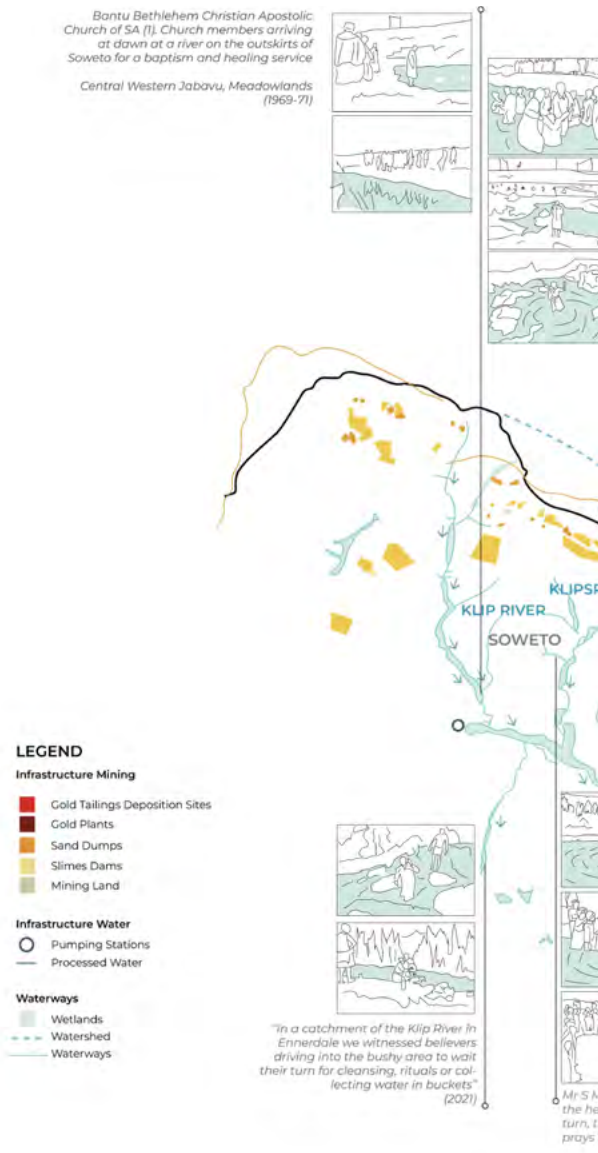
This study employs a novel methodology that integrates scientific mapping with socio-spatial practices to construct a nuanced understanding of how water systems, rituals, and historical legacies of resource extraction interact (fig. 2). Focusing on the Klip River, the research is organized into three methodological layers. What this methodology makes possible is an integrated analysis of environmental and cultural dynamics, enabling the identification of intersections between spiritual practices and ecological degradation.

The first methodological layer involves a comprehensive archival investigation using the Barlow Rand Mines Archive, covering the 1930s to 1950s. These records offer crucial insights into the origins of toxicity, documenting the shift from underground mining to surface contamination, including mine dumps and unlined tailings. This historical research is enriched by scientific mapping techniques, including contemporary satellite imagery like Google Earth, which identifies abandoned mining sites and persistent toxic residues, underscoring the lasting impact of contamination. Additionally, mapping of mining landscapes is supported by OpenStreetMap data and updated mining infrastructure from Tahira Toffah's study Mines of Gold, Mounds of Dust: Resurrecting the Witwatersrand (Toffah 2012). The second layer introduces a scientific dimension, incorporating existing literature and empirical data on the Klip River's ecological state. This involves analyzing water quality parameters, such as pH levels and concentrations of pollutants like heavy metals and polycyclic aromatic hydrocarbons (PAHs) throughout the river (Bengu et al. 2017; McCarthy et al. 2007; Olasupo and Buah-Kwofie 2021). Scientific mapping and data on aquatic systems, wetlands and peatlands provide a comprehensive view of ecological degradation and its spatial extent downstream (Pheiffer 2014). This layer elucidates the connections between mining effluents and water toxicity, emphasizing the cumulative impact on wetlands and downstream ecosystems.

The third layer explores socio-cultural dimensions through photographic essays and archives, journalistic reports, and social media documentation. Departing from the traditional colonial narrative that often centralizes mining as a driver of economic progress and industrialization, the focus shifts to the Klip River as a site hosting small-scale spatial practices, in particular the baptism practices and immersion rituals that take place in its streams. Martin West's photo essay on the African Independent Churches of Soweto serves as a primary reference, offering insights into spiritual practices along the Klip River (Kiernan and West 1977). More recent sources, including news articles and social media, further illuminate how these practices persist despite environmental contamination. By geolocating photographic records of baptism rituals along the river, this layer reveals the complex relationships between religious tradition, environmental degradation and public health concerns.

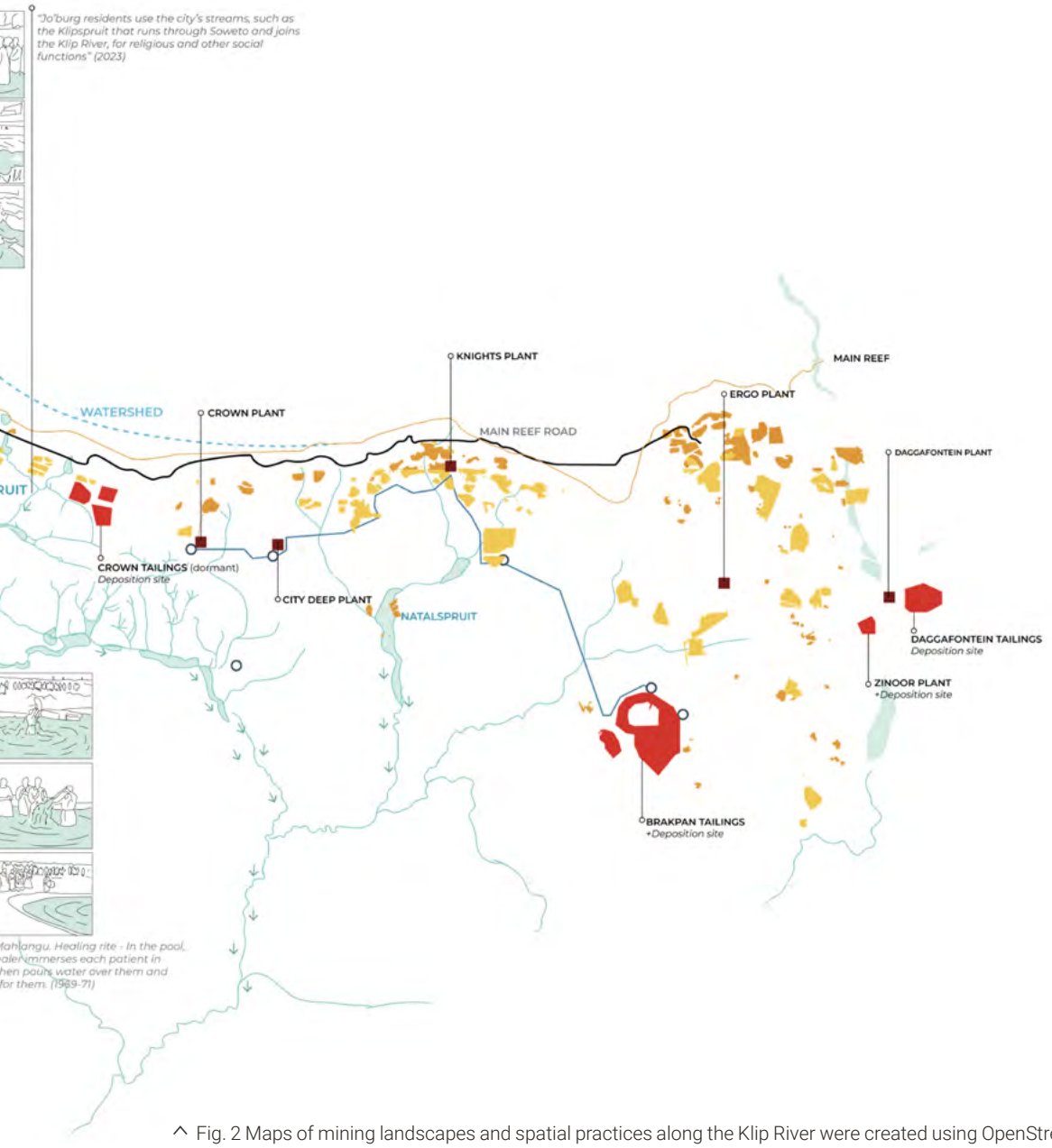
By situating the research within these frameworks, the study seeks to elucidate the historical and systemic dimensions of resource

extraction, particularly in post-mining landscapes like the Klip River in Soweto. This critical approach prompts reflections on power dynamics, environmental injustices, and the politics of resource governance, thereby enriching understanding beyond surface-level resource depletion to encompass broader socioecological transformations over time. By integrating scientific tools with cultural analysis, the study bridges gaps between environmental science and heritage management, fostering a deeper understanding of how ecological degradation intersects with cultural practices. The connection to heritage management lies in recognizing cultural practices, such as river baptisms, as living heritage that is inseparably tied to the natural environment. This perspective emphasizes the need to safeguard not only the physical integrity of natural ecosystems but also the cultural traditions and knowledge systems that depend on them. Understanding these interconnections allows heritage management to adopt a more inclusive approach, valuing both tangible environmental assets and intangible cultural practices.



From Mines to Rivers

The gold mining industry in South Africa's Witwatersrand region starkly illustrates the extensive environmental and social costs associated with mineral extraction. Deep-level gold mining, dating back to the early 1900s subjected workers to perilous conditions, exposure to extreme heat and hazardous substances like silica dust (Dube et al. 2021). The extraction process, involving explosives, crushing and cyanide solution, generated toxic waste stored in large dams, leading to groundwater contamination and atmospheric pollution (Durand 2012; McCarthy 2010).



^ Fig. 2 Maps of mining landscapes and spatial practices along the Klip River were created using OpenStreetMap data, which provides up-to-date cartographic information on transportation and land use, alongside modified mining infrastructure data sourced from Toffah's study on the Witwatersrand (Toffah 2012). This mining infrastructure data highlights the spatial footprint of historical gold mining operations and abandoned sites. Additionally, waterways and wetlands infrastructure from Pheiffer's study on aquatic ecosystems in Soweto and Lenasia (Pheiffer et al. 2014) was integrated to depict the hydrological connections and contamination pathways. The maps aim to visualize the intersections of environmental degradation and cultural practices, offering insights into the socio-spatial dynamics of the Klip River landscape (Source: Shreya Sen and Michele Tenzon, 2025).

Cartographic representations from archives often separated the above-ground world of city life from the below-ground world of mining – as can be seen in the "General Plan of the Goldfields" created by the Consulting Engineers Mining Drawing Office in 1964, despite the tangible impact of underground mining on miners.

While the map meticulously outlines the intricate network of mining infrastructure underground, it highlights only mining towns central to the gold industry, while excluding settlements that were impacted but not economically tied to mining. This reflects a colonial focus on industrial centers, ignoring broader social and environmental consequences.

Contamination plumes, underground aquifers rendered contaminated and unusable, rivers choked with mining effluents, and marginalized communities lacking access to clean water, are all eclipsed by the map's focus on industry and extraction.

It was not until acid drainage began seeping out of abandoned mines, alongside effluents mixing in surface and groundwater, that geological processes—once largely invisible to the public—became a tangible force shaping the city's political and environmental challenges. The leaching of toxic substances from mine tailings and the contamination of aquifers turned geology into a persistent and visible actor, influencing public health, access to water, and urban planning (McCarthy 2010). This interplay between geological forces and human systems marked a shift, drawing attention to the lasting impact of mining beyond its economic benefits. This situation exemplifies what Rob Nixon (2013) describes as 'slow violence'—a subtle but enduring form of harm that unfolds over extended periods, often concealed by layers of abstraction and historical narratives. The slow degradation of water quality, the long-term health consequences of exposure to pollutants, and the cumulative environmental collapse illustrate the insidious nature of this violence. It is crucial to acknowledge that colonial cartographic records not only serve as historical artifacts but also reinforce ideologies, shaping public perceptions of mining and perpetuating exploitative systems.

The Journey Downstream

The Klip River is a crucial component of Gauteng's hydrological network, vital for managing and distributing water across Johannesburg and its surrounding areas. Historically, the river has supported human movement, trade and settlement since ancient times (Tempelhoff 2006). However, its role has been compromised by mining activities, which have introduced pollutants that travel downstream, ultimately contaminating the Vaal River.

The river's transformation into a conduit for industrial waste has had severe ecological and health implications. Mining pollutants have significantly impacted the Klip River's wetlands, which once served as natural filters. Increased contamination and anthropogenic pressures have led to issues such as eutrophication and heavy metal release into the Vaal River, exacerbating water quality problems. Mining-related contamination has severe consequences, including the infiltration of radioactive pollutants into water, soil, livestock, and agriculture (Durand 2012). This contamination underscores the complex interplay between mining activities and environmental health.

Riverbank Rituals

In the late nineteenth century, African independent churches emerged in South Africa, particularly in Soweto, blending African and Western religious elements (West 1977). They maintain a reverence for ancestral spirits, emphasizing their potency and incorporating them into their belief systems. These churches also place significant emphasis on purification and healing rites, often conducted through immersion in rivers or streams. These purification ceremonies serve dual purposes: healing specific ailments and offering protection against spiritual malevolence. Prophets within these independent churches play a crucial role in prescribing healing methods, including immersion, and guiding congregants through spiritual practices, highlighting the importance of spiritual leadership in navigating urban life. Additionally, prophets are distinguished from other healers present in Soweto, such as faith-healers and diviners *sangomas*, by their centrality within the church hierarchy and their focus on supernatural healing methods (Kiernan & West, 1977).

Martin West's ethnographic analyses and photographic essays document how these churches adapted traditional African rituals to urban settings, with river immersion for baptism and healing becoming a central element of their practices (fig. 4). The Klip River is a sacred site for Zionist-type Independent Churches, where prophets prescribe immersion rituals for healing and spiritual protection. These rituals, integral to their religious practices, involve early morning gatherings with prayers, dancing, and individual immersions led by senior church members (West 1977).

The river's significance as a spiritual focal point remains central in the view of religious participants, who regard its waters as possessing sacred qualities essential for purification and healing rituals. However, it is not clear to what extent participants in the immersion rituals are aware of the risks to their health posed by the environmental contamination of the river. Reports suggest that some religious leaders acknowledge the river's pollution but maintain that its spiritual power supersedes physical contamination, while others downplay or deny the severity of health risks associated with environmental toxins, even in the face of outbreaks such as cholera (Masweneng 2023).

Mining activities and rapid urban development have led to the depletion of aquifers and the contamination of the river with toxic substances like arsenic, mercury, and lead (McCarthy et al. 2007). The river's contamination undermines the very rituals intended to offer purification and healing, creating a paradox where sacred practices coexist with environmental hazards. This stark contrast underscores the urgent need for action to restore the river's health. A comprehensive approach that integrates environmental cleanup with public health measures, while engaging religious leaders and communities to address misconceptions and build awareness, is essential to ensure the river can once again support both spiritual and ecological well-being.

Conclusion

The Klip River embodies the complex interactions between human activities, environmental dynamics and cultural significance, reflecting the legacy of gold mining in the Gauteng region since the nineteenth century. Decades of mining have left enduring problems such as acid mine drainage and heavy metal. The river's deteriorating water quality has a direct impact on SDG 6: Clean Water and Sanitation.

Despite these challenges, baptism rituals continue to be practiced along the riverbanks, underscoring the spiritual and cultural significance of water in the region. This paradox of cleansing rituals coexisting with mining hazards highlights the complex relationship between spirituality and environmental degradation. It also connects with SDG 11: Sustainable Cities and Communities, emphasizing the need to respect cultural practices while fostering safe and sustainable environments.

Exploring these interconnections offers an important perspective on resource dynamics and socio-spatial relationships, revealing the multifaceted interplay between human activities and environmental resources. This includes the degradation of aquatic ecosystems, which pertains to SDG 14: Life Below Water, and the damage to terrestrial landscapes, relevant to SDG 15: Life on Land. The juxtaposition of baptism rituals and environmental degradation calls attention to historical injustices within the mining landscape, highlighting broader issues of environmental justice. Recognizing the significance of socio-cultural practices in shaping resource use can inform more inclusive and equitable resource management approaches, prioritizing the well-being of both human communities and the natural environment in line with these SDGs.

To address the multifaceted challenges facing the Klip River, an integrated remediation strategy must be developed and implemented. This strategy should involve collaboration between government bodies, local communities and environmental experts to tackle pollution, restore habitats and adopt sustainable water treatment technologies. Importantly, it must align with local cultural practices to ensure that environmental actions also respect and support the river's spiritual significance to the community.

Acknowledgment

I extend my gratitude to the University of Cape Town Libraries for granting access to Martin West's invaluable photographic archives, which have been instrumental in illustrating the intersection of religious practices and environmental degradation along the Klip River. Their support in preserving and providing access to these historical records has greatly enhanced the depth of this analysis. I am deeply grateful for the guidance and mentorship provided by my thesis supervisor, Serah Calitz at TU Delft. Her expertise and encouragement have been invaluable in shaping the direction and scope of this study.

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein and Carlien Donkor.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 124–35
10.58981/bluepapers.2026.1.13
Received 01.04.2025; Received in revised form 26.07.2025; Accepted 28.08.2025

Playing with Water: A Value Case for Gamified Water Resilience in Alfândega da Fé, Portugal

Joao Camelo

Abstract
This contribution explores the case of Alfândega da Fé, Portugal, using a value case approach. It is based on a project completed in the course Water System Design: Learning from the Past for Resilient Water Futures, offered by the UNESCO Chair Water, Ports and Historic Cities team based at TU Delft. The article argues that by adopting an innovative water management strategy and engaging the community through gamification, Alfândega da Fé can become a sustainable city adapted to future environmental needs, with reduced and more responsible water consumption, aligned with current legislation and SDGs. Based on the value case approach, the article shows how we can learn from the past, make connections between water systems and connect to the local environment to achieve a more resilient, sustainable and inclusive water system. The plan is based on the creation of an interactive water services platform for local people designed to increase general knowledge about water and enable the local population to play an important role in water consumption and enhancing water reuse.

Policy Recommendations

- Integrate gamification, like digital games and interactive storytelling, in local and regional water policy to engage citizens, honor cultural water heritage and drive water-saving behaviors.
- Partner cultural institutions, water utilities, municipalities, and educational organizations to co-create heritage-based games that align policy objectives with community values.
- Water stress driven by climate change, overextraction and seasonal variability makes wastewater a vital resource; cutting potable water use and expanding reuse relieves pressure on freshwater sources.

KEYWORDS

droughts
water management
gamification
values
water consumption

WATER VALUES

CLIMATE

Csb: Warm-summer Mediterranean climate

< Fig. 1 Sambade dam, during a period of very low water levels and water scarcity (Source: Joao Camelo, 2022).

Introduction

Alfândega da Fé, a small municipality in northern Portugal, spans 320 km^2 and is home to around 4,300 residents. In an arid region, since the late twentieth century the town has built multiple water infrastructures to tackle recurring droughts. It has adopted practices to ensure reliable drinking water and support agricultural irrigation. Yet, future challenges demand a more resilient water system.

Climate change has introduced many new water challenges, and stand-alone technological interventions cannot sufficiently address complex social, cultural and economic aspects of the problem. Changing water patterns will affect everyone and every structure. How we manage water depends on local conditions, spatial and social developments and cultures as well as decisions made long ago (Hein et al. 2024). Engaging values, based on new tools and methodologies that account for local particularities and acknowledge historic path dependencies, are fundamental to designing sustainable and inclusive water systems (Hein 2022).

As explored in the 2024 TU Delft course Water System Design: Learning from the Past for Resilient Water Futures,[1] this article takes a value-based approach to Alfândega da Fé, demonstrating how gamification can be used to revitalize traditional water knowledge, engage rural populations and promote sustainable practices through interactive storytelling and by using digital tools. It connects cultural memory and environmental stewardship, aligned with regional development and climate adaptation.

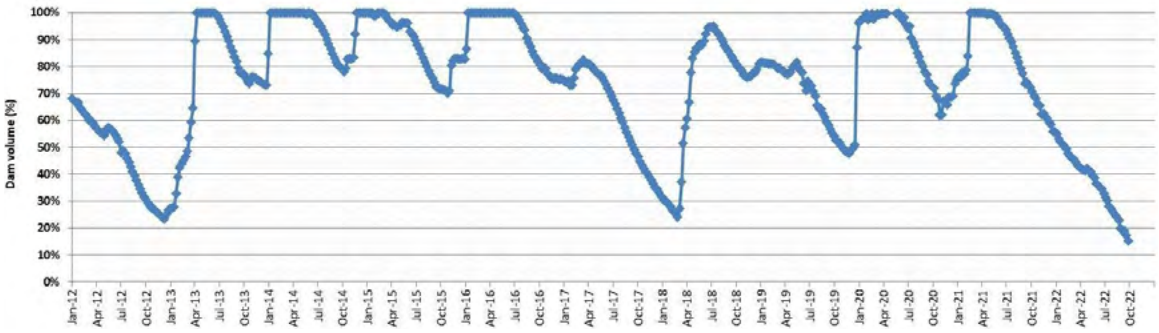
A gamification approach offers a novel and scalable solution to bridge the gap between awareness and action. By transforming water-saving behaviors and cultural heritage into interactive experiences, gamification can foster civic participation, reinforce local identity and promote sustainable consumption. The value case lies in its ability to translate complex water challenges into accessible, motivating formats - aligning with EU policy goals on public participation, heritage valorization and climate adaptation. The Alfândega da Fé case illustrates how playful digital tools can activate community knowledge, support behavioral shifts and contribute to integrated water governance in vulnerable rural territories.

Place and Context

Alfândega da Fé has complex and diverse water systems and many interconnections between them. The provision of drinking water has been the main focus of the water system, alongside the use of water for agriculture and irrigation. These two water uses have come into a constant conflict, especially in recent years, due to water scarcity. The demand for water, aggravated by recent climate change, has led to the establishment of multiple water sources, specifically dams and related pumping stations and networks.

For a long time, the municipality has created water infrastructures for community use, namely for drinking, irrigation and recreation. Examples are small wells and the Estevainha and Camba dams. In 2001, a new water management entity – Aguas do Norte – was established in line with the national drinking water

1. "Water System Design: Learning from the Past for Resilient Water Futures," https://online-learning.tudelft.nl/courses/water-systems-design-learning-from-the-past-for-resilient-water-futures/.



^ Fig. 2 Graphical representation of the water volume available in Sambade dam (Source: Joao Camelo, 2024. Based on the SNIRH - Sistema Nacional de Informação de Recursos Hídricos - database).

strategy, which consisted of centralizing all existing wells and creating a single drinking water system with Sambade dam as the main water source. The goal was to be more efficient in terms of quantity and quality of the water supplied. This new entity also promised more transparency and to possess a greater ability to achieve sustainability objectives.

Due to droughts in recent years, new infrastructure has been built and added to the system, through Aguas do Norte, and interconnections have been made between systems that previously were devoted exclusively to irrigation and other agricultural purposes. One example is a new water treatment plant in Estevainha and the connection of this system with the water network supply in the city of Alfândega da Fé.

Fig. 2 represents the Sambade dam volume available from 2012 to 2022. It shows the three water scarcity seasons in the last decade and a half: 2012, 2018 and 2022.

In 2016, the Ministry of Environment and Energy built a hydroelectric plant on the Sabor River. While it supplies power nationwide, the municipality also uses the river for tourism and recreation. In 2023, Aguas do Norte tapped it to provide drinking water to Torre de Moncorvo during a drought, highlighting its future potential to support regional water systems.

The massive use of water bodies for drinking water, followed by a good process-oriented approach, has completely solved the problems of water for this purpose. However, it created a negative impact on the use of water for irrigation and agriculture. In fact, conflicts with other stakeholders have worsened and persist nowadays.

For example, in the 2022 periods of water scarcity, Sambade and Esteveinha dams dropped to 27 per cent and 35 per cent capacity, respectively, threatening both urban water supply and agricultural irrigation. Alfândega da Fé was among 50 locations in Trás-os-Montes receiving truck-delivered water, affecting over 8,000 residents due to depleted supply systems (PortugalResident 2022). The following adaptive measures were also taken (24 Notícias 2022):

- Irrigation reserves were repurposed: Authorities redirected water from Esteveinha (intended for agriculture) to Sambade for human consumption, including installing mobile treatment units.
- Contingency planning: Local government is working with Águas do Norte and the Min-

istry of Environment to secure funding and implement drought resilience strategies, including public awareness campaigns.

Recent projects like I-ReWater (Interreg Sudoe 2021) and GreenValue (CITAB 2022) demonstrate that reclaimed water and biosolids (from Alfândega da Fé's wastewater treatment plant) can support both sustainability and agricultural resilience. By integrating these efforts with EU Directive 2020/2184 on the quality of water intended for human consumption and Portugal's "Water that Unites" strategy (Portal da Água 2025), this value case gains relevance and practicality.

Ecosystems, Flows and Networks

In the Water System Design course, we used a CANVAS tool to highlight the main flows and relationships between different components on a system-centered representation of this specific territory, inspired by the work of Vereecke and colleagues (2022). This mapping shows the importance of water for the purpose of irrigation/agriculture, displaying all the stakeholders and the connections among them. We can see the "conflict relationship" between the two main uses of the water bodies – for drinking water or for irrigation/agriculture. The analysis led to the finding that the relationship between the three direct stakeholders, which are Aguas do Norte, the municipal government and agricultural associations, should be maintained and strengthened, especially to safeguard the purposes of the water bodies in that region. Also, the design made it possible to identify the local water-dependent industries (olive oil and wine).

The potential water source of the Sabor River is also very important. Its focus is on producing capacity to produce electricity for all the country, but it can also boost tourism in the region. This water body fulfills multiple roles, it can substantially support other subsystems - for example, by supplying raw water to adjacent systems during droughts.

^ Fig. 3 Water systems and their connections in the Alfândega da Fé study case (Source: Joao Camelo, 2024. Basemap from © OpenStreetMap, licensed under the Open Database License [ODbL]).

^ Fig. 4 Reused water produced at Alfândega da Fé wastewater treatment plant is used to irrigate almond crops (Source: Joao Camelo, 2024).

Reclaimed water from the local treatment plant can bolster drinking water systems or serve agriculture and irrigation needs, presenting viable interventions in times of drought.

Strategy: Taking into Account Legislation and the SDGs

The initiative Right2Water (Parks 2014) emphasizes that marginalized communities still lack reliable access to drinking water. In line with SDG 6 (clean water and sanitation) of the UN's 2030 Agenda, Directive (EU) 2020/2184 – adopted into Portuguese law as Decreto-Lei nº 69/2023 – sets clearer water quality standards, boosts awareness of water losses due to neglected infrastructure and makes water quality information easily accessible online in customizable formats.

SDGs can also be used as a framework to rethink management of water systems. Developed as part of an exercise in the course, fig. 7 identifies the directly related SDGs, indirectly related ones and not related ones. This exercise is used to identify potential values that can improve the value proposition of a system. The current system prioritizes SDG 6 and integrates SDG 3 (health and well-being) and SDG

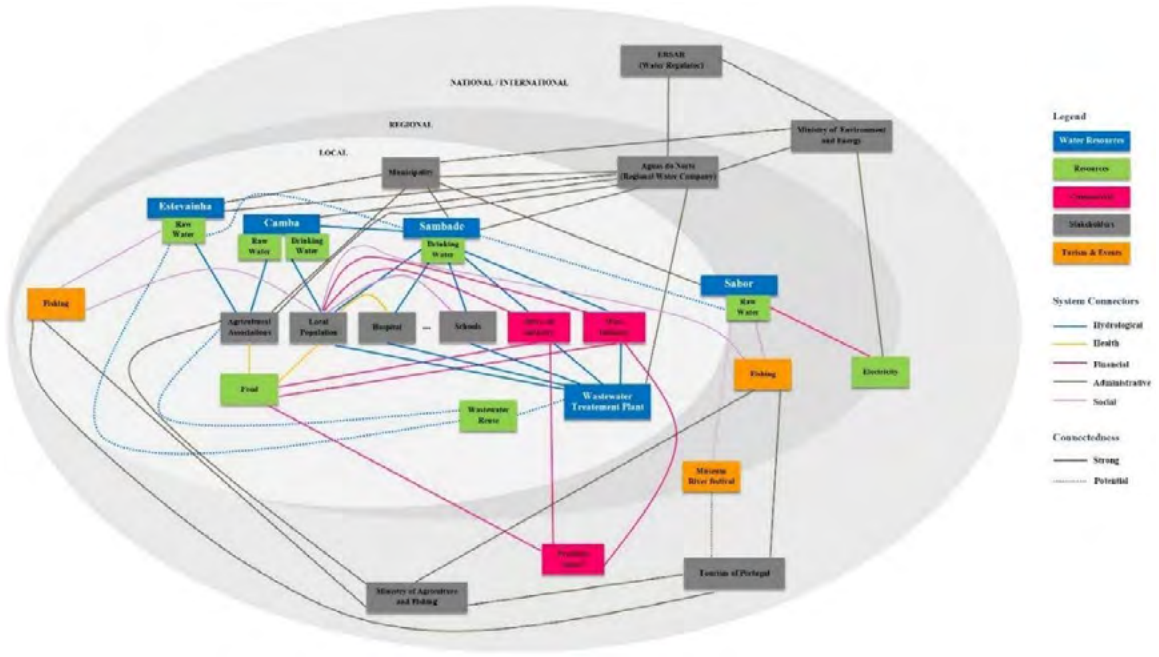
8 (economic growth) to harness water's industrial potential revealed by the CANVAS analysis. SGD 2 (zero hunger) is placed as directly related, not as the eradication of hunger itself, but in achieving food security and improved nutrition and promoting sustainable agriculture.

Resilient infrastructure, sustainable industry and innovation directly strengthen water systems and help mitigate climate impacts. These investments deliver fast results in drinking water and wastewater efficiency. They also drive SDG 8 (economic growth), SDG 10 (reduce inequality), and SDG 1 (tackle poverty) - both in Portugal and globally. In Portugal, they support the vital connection between countryside and coastline. While other SDGs may not influence SDG 4 (education), quality education powers progress across many goals. It fosters responsible water use, supports healthy ecosystems and enables sustainable cities and communities. Prioritizing water education now will deliver long-term resilience.

Rethinking the Water System

From a technical point of view, part of the resilience of the water drinking systems in this municipality comes from the diversity of water sources. The Sabor River can have a huge impact on other subsystems, such as reinforcing raw water for other systems in times of drought. Also, the wastewater reuse, considering its adaptability for different uses, represents a challenge but also a solution. Implementing these solutions balances water distribution between drinking supply and agricultural or irrigation demands.

Education is both a lesson from the past and a value that will shape the future. Building water awareness among local people is essential, fostering the ability to address many different concerns related to water, and strengthening the connection between people and this vital resource. Currently, domestic water consumption in Alfândega da Fé is around 400 liters per



^ Fig. 5 CANVAS design of Alfândega da Fé study case (Source: Joao Camelo, 2024).

^ Fig. 6 SDGs and their relevance to the Alfândega da Fé study case (Source: Joao Camelo, 2024).

person per day, well above the European average and higher than in other regions of Portugal (according to EUROSTAT 2007 [European Union 2007], Portugal's average is 161 liters per person per day, while Lithuania, for example, reports just 97 liters).

This situation in the region is due to irresponsible consumption by the population; examples include outdated high-flow toilets, showerheads and appliances; running taps and wasteful daily habits; excessive outdoor irrigation and watering of public and private green spaces, often amplified by seasonal tourism; and high distribution losses from ageing networks that inflate apparent per-capita use. This highlights the urgency of promoting "responsible consumption" as a key target, (SDG 12). Tourism can also play a role by using water bodies for recreational purposes, encouraging people to build stronger relationships with water in this area.

Looking ahead, meeting the challenges of water management will require cooperation among all stakeholders, water education and efforts to conserve both the quality and quantity of water resources - working together to secure a sustainable and equitable future for all.

Gamification for Water Utilities

Who doesn't appreciate a good game?

The initiative proposed in the course focuses on community education and involvement through gamification. Gamification uses strategies and game mechanics to foster deeper engagement between organizations or brands (and their products or services) and both internal and external audiences (Elsayed 2021). Games are among the oldest forms of social interaction and communication. While the typical function is entertainment, serious games have been developed to aid learning. Through gamification, stakeholders in the water supply chain can better understand each other's roles and responsibilities. This experience ultimately can support strategic decision-making, for example, related to asset maintenance and setting replacement priorities.

For water utilities, games offer many possibilities:

- Behavioral nudging – utilities use game-like elements such as points, badges and leaderboards to encourage users to adopt water-saving habits.
- Smart meter integration – real-time data

from smart meters allows users to track their consumption and compete with neighbors or household members.
- Rewards and incentives – users earn discounts, donations to community projects or loyalty points for meeting water-saving goals.
- Social engagement – sharing achievements on social media can boost motivation and spread awareness.

Action Plan

The demand for water, often associated with irresponsible use, has been increasing drastically. When water services no longer have the capacity to meet demand, there is often no capacity for expansion and investment. In addition to water management entities working to make production more efficient, encouraging responsible water consumption can play a fundamental role, adding sustainability benefits of water conservation.

Generally, city residents do not have easy access to water and are unaware of how water is distributed to residences. Public awareness regarding water conservation is expected to increase with television advertisements, freeway signs and pamphlets included with monthly utility water bills. These media still fall short of giving residents a clear picture of their water usage and the water cycle. There need to be better ways to bring information to the public and to encourage actions based on facts that are quickly and easily adopted. Technology can help. Increasingly, we live in a cellular wireless information age today. The impact on society is only beginning.

Led by the municipality and Águas do Norte, this project proposes an interactive digital platform that makes local water use a collaborative challenge. Designed for residents, it combines personalized consumption feedback with real-time data and social features to spark behavioral change.

The aim of the platform is to change behavior related to water in general and includes:

- Smart comparisons – users monitor their water footprint and benchmark it against friends, family or neighbors.
- Eco competition – rankings highlight "Most Responsible Consumers," encouraging neighborhood-level campaigns and inter-community contests.
- Points and rewards – every liter saved earns points, unlocking individual perks and collective benefits for the broader community.
- Real-time alerts – the system detects anomalies like leaks or excessive use, prompting timely action.

This platform doesn't just measure water – it inspires stewardship, pride and playful accountability.

In Alfândega da Fé, where home gardens, vegetable plots and personal water tanks are part of daily life. This initiative is designed to draw on community practices to advance a circular water approach. Residents earn points by repurposing treated wastewater for irrigation - turning everyday actions into sustainability wins. Indirectly, the engagement of the different institutions involved in this project (the municipality, Aguas do Norte and agricultural associations) will strengthen relationships among them and reduce conflicts regarding future decisions.

Awareness campaigns can address a wide variety of topics, including how to reduce water

Scene	Visual / Action	Purpose	Notes
Campaign Launch Poster	A banner in town square "Play for Water + Save Water, Celebrate Heritage!"	Introduce initiative and spark interest	Icons of water, badges, and Alfândega da Fé landmarks
App Home Screen	Gamified interface featuring goals, community goal tracker	User-friendly entry point	Includes local heritage motifs and water facts
Weekly Missions Panel	Example: "Shorten your shower by 2 mins"	Trigger behavior change	Tips drawn from traditional water-saving practices
Mission: Reuse & Repurpose	"Collect rainwater for garden" or "Reuse laundry water for cleaning"	Promote decentralized reuse	Tips based on traditional practices and modern tech
Community Progress Dashboard	"Maria saved 1,200L this week!"	Foster collective impact	Show progress toward tree-planting or civic rewards
Local Stories Feature	Short video or quote from a resident: "My grandma reused laundry water"	Build emotional connection	Authentic narratives to drive retention
Local Innovation Spotlight	Feature a local farmer using treated wastewater for irrigation	Inspire systemic change	Connects users to real circular economy champions
Share & Challenge Screen	"Share your badge!" + "Challenge 3 friends to play"	Viral loop and user acquisition	Social media integration with regional flair
Circular Trivia Pop-up	"Did you know Alfândega da Fé's cisterns were early circular systems?"	Link heritage to circular economy	Delivered between missions or as mini games

^ Table 1. Storyboard sketch for the Water information/challenge platform (Source: Joao Camelo, 2024).

consumption, basic aspects of the water cycle, application operation; they can be geared to the community in general or more specifically for use in schools. Games for children are also an option. Raising awareness about water among members of future generations is very important. Although the results are residual in the short term, it will bring benefits in the long term. The author proposes launching the challenge on social media, local news outlets, digital platforms and community associations to maximize reach and resonance. The next table shows a storyboard sketch with some examples of this water challenge platform.

Conclusion

Gamification offers a novel and influential tool for engaging communities at the intersection of the water-culture-heritage nexus. By transforming abstract concepts such as responsible water use and reclaimed wastewater use into interactive and locally grounded experiences, gamification fosters deeper public participation and awareness.

In fact, fostering responsible water use remains a steep behavioral challenge. Everyday habits – e.g., leaving taps running and overwa-

tering gardens - are deeply ingrained and hard to break. The invisible nature of water waste and the lack of immediate consequences dull individual motivation, while social norms rarely praise conservation efforts. Without compelling incentives, tailored outreach and visible feedback on savings, meaningful shifts in household and community practices continue to lag.

In the same way, despite environmental and economic benefits, the adoption of reclaimed wastewater remains a profound behavioral challenge for communities. Deep-seated perceptions of cleanliness, cultural taboos and psychological discomfort often lead to resistance, regardless of scientific assurances of safety. The "yuck factor," amplified by limited public awareness and trust in treatment processes, continues to hinder widespread acceptance.

Playful digital strategies can reinforce cultural memory, build resilience in rural water systems and align with broader sustainability goals, particularly in regions facing environmental strain. The example of Alfândega da Fé suggests the scalable potential for integrating gamified models into participatory governance and heritage-based water planning.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein and Matteo D'Agostino.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 136–45
10.58981/bluepapers.2026.1.14
Received 14.05.2025; Received in revised form 02.09.2025; Accepted 26.11.2025

Mapping and Reviving Ancestral Communal Pools (*Birket*) in Southern Lebanon: Survey Methods, Findings and Policy Pathways

Georges Gharios

Abstract
This article presents a mixed-methods survey of 101 *birket* across 86 villages in southern Lebanon, combining historical cartography, satellite imagery and ground-truthing with oral histories. It details site typologies, spatial patterns, present condition (functioning/abandoned/destroyed) and contemporary uses, and it demonstrates how dispersed small reservoirs can complement centralized systems. A focused case study of the village of Marwaheen traces the pool's rehabilitation and associated gains in irrigated land and community engagement. Building on a resilience-based assessment (access/equity, adaptability, participation, ecological value, cultural relevance), the article identifies priority pools for restoration and translates results into practical policy pathways for municipal–NGO partnerships. The article offers openly reproducible mapping conventions and field templates to support future documentation without reliance on proprietary basemaps.

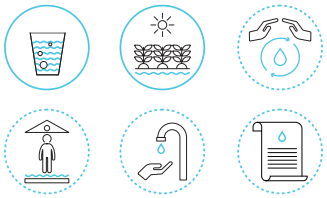
Policy Recommendations

- Rehabilitate approximately 30 priority *birket* (2025–2027) through municipal–NGO partnerships using light works (cleaning, repairs, relaunch).
- Establish village maintenance committees with simple seasonal calendars and basic safety rules.
- Keep monitoring light: one-page annual log (storage filled, irrigated area, maintenance day).
- Share open templates (bylaw, logbook, mapping sheet) so other villages can replicate quickly.

KEYWORDS

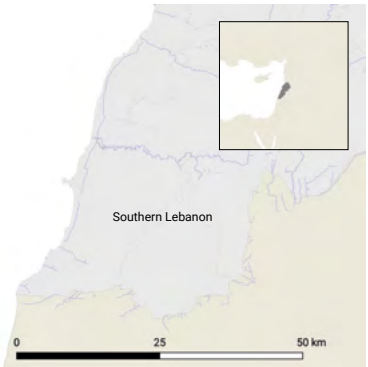
field survey
historical maps
oral history
decentralized storage
Southern Lebanon

WATER ICONS



CLIMATE

Csa: Hot-summer Mediterranean climate



< Fig. 1 Birket of Marwaheen (Source: Georges Gharios, 2022).

Introduction

Lebanon's water challenges are increasingly shaped by climate variability, uneven infrastructure and governance gaps. In southern Lebanon, many villages long relied on ancestral communal pools (*birket*)—small, distributed reservoirs that capture runoff and support seasonal irrigation, livestock and local ecologies. Yet despite their practical value, *birket* remain under-documented, inconsistently maintained and largely absent from contemporary planning tools. Reliable, reproducible evidence on where these pools are, what condition they are in and how communities still use them is scarce.

This article addresses that gap by presenting a mixed-methods survey of *birket* across 86 villages in Southern Lebanon, conducted in 2018–2019 with spot checks in 2022. The work combines historical cartography with ground-truthing and oral histories. To ensure open, reproducible mapping, this study has georeferenced nineteenth- and twentieth-century map sources and has applied a simple, repeatable field protocol to classify each site's status (functioning, abandoned, destroyed/filled, or repurposed), construction, approximate capacity, and use patterns.

The article does three things. First, it details the survey design – map sources, georeferencing workflow, field sheets and interview prompts – so other teams can replicate the method without proprietary tools. Second, it reports core findings: a typology of *birket*, spatial patterns, current status counts, contemporary uses and ecological signals. Third, it translates results into action through a case study of the village of Marwaheen, a concise resilience-based prioritization (equity, adaptability, participation, ecology, culture) and light-touch implementation steps suitable for municipal–NGO partnerships.

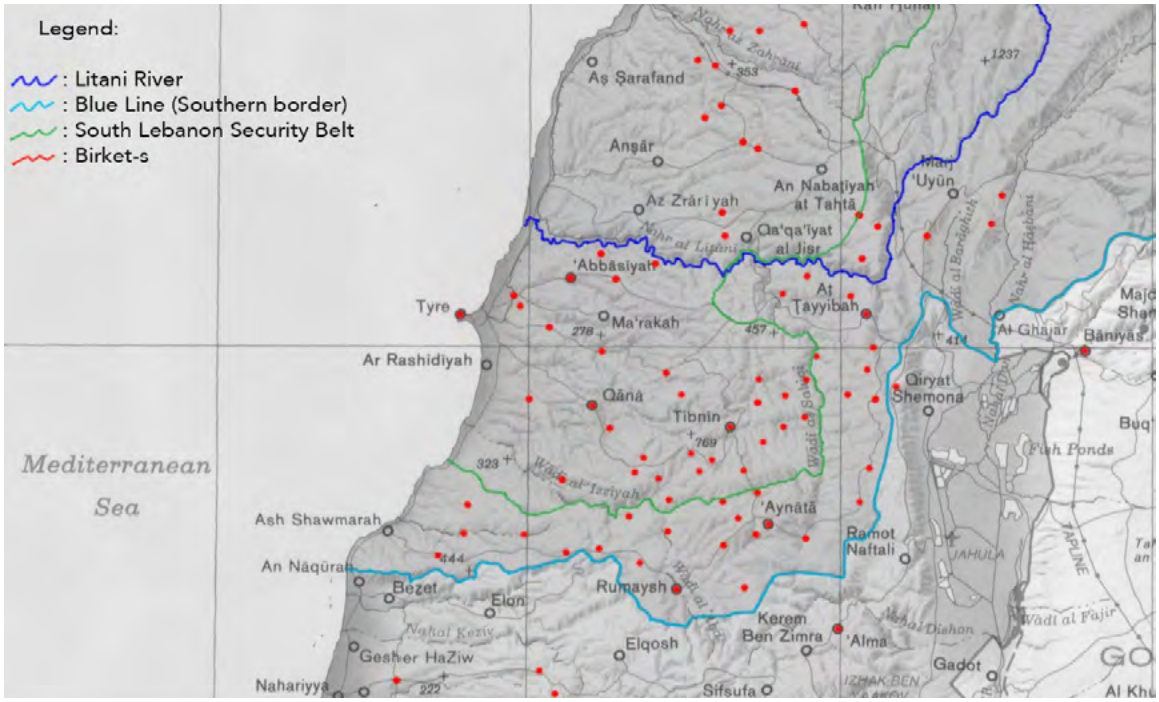
Methodology

This study focuses on a single, well-documented case. Marwaheen – a small border village heavily affected by occupation, displacement and agricultural decline – offers a clear arc from abandonment to community-led rehabilitation of its *birket*. The case assembles diverse evidence (project reports, student theses, interviews, field measurements, and satellite change analysis) and traces tangible outcomes for storage, cropping, and local governance. It thus bridges method and policy, illustrating how ancestral pools can be revived under real constraints and scaled to comparable villages.

1. Selection of Case Study: Marwaheen

The *birket* of Marwaheen was selected as a primary case study due to its unique trajectory from abandonment to restoration. Marwaheen is a small border village that suffered heavily during the Israeli occupation (1978–2000), particularly given its proximity to the former "Security Zone" (Shibli 2011). The village experienced extensive displacement, infrastructure damage and agricultural decline.

By 2009, the *birket* of Marwaheen, once the main water source for irrigation and livestock, had been abandoned for over three decades (CCECS 2011). Following the Israeli withdrawal in 2000 and a slow return of displaced populations, the municipality – supported by the American University of Beirut's Center for Civic Engagement and Community Service (CCECS) – initiated a pilot restoration project in 2009.



^ Fig. 2 Location of historical birket sites indicated by red dots (Source: Georges Gharios, 2017. Basemap from Central Intelligence Agency (CIA) 1976 map, public domain).

The project aimed to rehabilitate the *birket* as a means of securing supplementary water for vegetable farming and reviving community identity around ancestral practices. The methodology for analyzing this case included:

- Review of project reports from CCECS and final-year civil engineering student theses from the American University of Beirut (AUB);
- Interviews with municipal officials and farmers;
- On-site measurements of the rehabilitated pool and assessment of surrounding infrastructure (e.g., runoff channels, irrigation pipes);
- Comparison of pre- and post-restoration satellite imagery to quantify land-use change and crop expansion.

2. Analytical Framework

The research applied a resilience-based framework, using a set of criteria to assess the potential contribution of *birket* systems to climate adaptation and sustainable development. These criteria, adapted from global nature-based solutions and integrated water resources management indicators, included:

- Democratic access and equity (do all villagers have access to water?);
- Flexibility and adaptability (can the system cope with seasonal changes and drought?);
- Participatory governance (are users involved in decision-making and maintenance?);
- Ecological impact (does the system support biodiversity and groundwater recharge?);

- Cultural relevance and knowledge retention (is the practice consistent with local identity?).

In summary, the methodology adopted in this study bridges technical analysis with socio-cultural understanding. It underscores the importance of combining GIS-based documentation with community-led storytelling, thereby elevating the voices of rural actors and recognizing their role as knowledge holders and stewards of hydrosocial heritage. The case of Marwaheen exemplifies how such integrated approaches can yield practical, scalable and sustainable solutions rooted in the wisdom of place.

Findings

The comprehensive survey of 101 *birket* across 86 towns and villages in southern Lebanon yielded a layered understanding of their current condition, historical continuity and socio-ecological value (fig. 2). The findings, organized in three dimensions, point to both the fragility and resilience of these ancestral communal pools. While many have been abandoned or repurposed due to conflict, urban expansion or shifting livelihoods, others remain active and have been adapted to new uses.

1. Typology and Spatial Patterns

Analysis of the spatial data confirmed a historical continuity between pre-twentieth-century *birket* sites and present-day village layouts. Most *birket* were found in low-lying areas near the edge of built-up zones, often adjacent to farmland or on the downstream side of old village clusters. Their placement was strategic – maximizing runoff capture from rooftops, paths, and fields, while also ensuring ease of access for livestock and farming communities. Several *birket* were co-located with ancient springs (*ain*), forming a hybrid system that blended rainwater storage with spring capture. The survey identified two major types of *birket*:

- Intra-village pools: Typically smaller in volume (500–3,000 m³), these pools served daily domestic and livestock needs. They were constructed with stone masonry or clay and located near residential clusters or hawch (central courtyards). With urban sprawl, many now lie embedded within dense settlements.
- Peripheral or agricultural *birket*: Larger in scale (5,000–20,000 m³), often referred to local *birket* barriyeh or *birket* istina'iyeh, these were used to irrigate crops, cure tobacco and water herds. Constructed in fields or wadis (dry streambeds), they were either dug directly into soil or fortified with mud, clay or gypsum. Their locations often coincide with key agricultural corridors or pastures.

Of the 101 *birket* recorded:

- 32 were classified as functioning;
- 39 as abandoned or dysfunctional;
- 30 as destroyed, filled in or transformed for other uses.

The highest concentration of functioning *birket* was observed in villages that predominantly maintained an agricultural economy and had not undergone severe postwar urbanization, such as Kounine, Aita el-Chaab and Debel. By contrast, areas that experienced intensive bombardment or rapid population growth – like Bint Jbeil or Srifa – showed a marked decline in intact pools.

2. Use Patterns, Decline and Transformation

Traditionally, *birket* supported a diverse range of activities: irrigation, water for livestock, domestic use (washing clothes, dishes, wool and kitchen utensils), fishing and even limited recreational uses (children swimming or seasonal festivals). These uses were tightly linked to seasonal cycles and ritual maintenance activities, such as the collective de-silting conducted every autumn.

However, post-1990s developments – especially the extension of municipal water networks and the spread of household appliances – have reduced the domestic role of *birket* (Gharios 2022). The widespread use of washing machines and dishwashers has made the communal washing functions obsolete. Similarly, the sharp decline in herding practices, once a mainstay of village economies, has diminished the need for animal watering. In several cases, the surrounding community saw the *birket* as obsolete or even hazardous, prompting infill and conversion to public squares, playgrounds or parking lots. Yet not all *birket* have followed a trajectory of neglect. In 32 cases, the pools were still used primarily for:

- Irrigation, especially of water-intensive crops such as tomatoes, squash or leafy greens;
- Construction, with water tankers collecting from *birket* to supply nearby building sites;
- Tourism and recreation, where village councils or private actors have developed cafes, walkways or picnic zones around well-maintained pools.

The renewed interest in *birket* for tourism – though modest – has led to partial restorations in villages like Yaroun, Tibnine and Maroun el-Ras. These projects often start with minor clean-up campaigns, followed by masonry repair, installation of fencing for safety, and aesthetic improvements such as murals and fountains. However, such initiatives are often short-lived or symbolic unless paired with a long-term water management or agricultural plan.

^ Fig. 3 Workers laying a steel-rod mesh with ready-mix concrete at the birket of Marwaheen (Source: American University of Beirut's Center for Civic Engagement and Community Service Report, 2013).

3. Resilience and Restoration Potential

The restoration of the *birket* of Marwaheen serves as a compelling example of how ancestral water infrastructure can be successfully revived and reintegrated into modern development efforts (fig. 3). The rehabilitation project more than doubled the pool's volume (from 12,770 m³ to 26,000 m³), introduced impermeable linings to prevent infiltration losses and added runoff channels to capture additional rainwater (Bou Lahdo et al. 2011). As a result, farming area in the village expanded by more than 100 per cent, according to the municipal records. The restored *birket* not only secured supplementary water during dry months but also fostered a renewed sense of community ownership and pride in local heritage (Gharios 2022).

Similar potential exists across southern Lebanon. Many abandoned *birket* are structurally intact or require only modest interventions (de-silting, reinforcement, perimeter walls or spillways) to become functional again. Because they are dispersed and small-scale in nature, they are well-suited to decentralized water management strategies, especially in areas underserved by national infrastructure.

The resilience of *birket* systems lies not merely in their physical robustness but in their embeddedness in local knowledge systems. Practices such as seasonal cleaning, consensus-based water distribution, and communal financing of maintenance reflect strong social capital. In fact, interviews in functioning *birket* communities revealed high levels of local awareness about rainfall variability, evaporation rates and soil permeability – suggesting that ecological monitoring was being conducted informally but effectively.

Moreover, *birket* contribute positively to micro-ecologies. Several restored pools were found to support frogs, fish and aquatic plants, indicating potential for biodiversity enhancement and habitat restoration. In arid months, they offer critical water refuges for birds and insects. The cultural landscapes surrounding the *birket* – with olive groves, terraced fields and grazing areas – also benefit from proximity to these water bodies, reinforcing synergies between ecological and cultural resilience.

Together, these findings collectively paint a picture of *birket* as dynamic, multifunctional systems capable of adaptation and renewal. Their decline is notably not inevitable but contingent on social valuation, institutional support and modest technical investment. Revitalizing these pools could serve as a powerful entry point for integrated rural development strategies that center locally grounded agency, heritage preservation and sustainable resource use.

Conclusion

This study shows that ancestral communal pools (*birket*) are not relics of a pre-modern water economy but enduring, community-managed, climate-responsive infrastructure. Combining historical cartography, field verification and oral histories, this study documented 101 *birket* across 86 localities – revealing both the breadth of this hydro-cultural tradition and the depth of its neglect. While many sites have been filled in or degraded, a significant share remains intact, functional or clearly poised for revival. Empirically, two typologies recur (intra-village and peripheral/agricultural), with functioning sites clustering where agriculture persists and local stewardship is strong. Field observations also point to ecological co-benefits – amphibians, birds, vegetated shallows – that extend the value of *birket* beyond storage alone. The Marwaheen case demonstrates feasibility under real constraints: modest rehabilitation expanded effective storage, supported crop diversification and reactivated communal governance.

Method matters. A light, reproducible protocol – maps, simple status classes, qualitative resilience criteria (equity, adaptability, participation, ecology, culture) and minimal monitoring – turns dispersed evidence into actionable priorities. Translating that evidence into practice is straightforward: targeted rehabilitation in high-potential villages, village maintenance committees with seasonal calendars and concise annual logs; in parallel, policy alignment through recognition of *birket* as decentralized, complementary storage in the next National

Water Sector Strategy, supported by education toolkits and a hydro-cultural registry. Taken together, these steps bridge centralized agendas and grassroots water cultures, advancing SDGs 6 (clean water and sanitation), 13 (climate action) and 15 (life on land) while anchoring adaptation in place-based knowledge and collective action.

Moving forward, the challenge lies in bridging the gap between centralized infrastructure agendas and grassroots water cultures. Policymakers, development agencies and academic institutions must actively support the mapping, protection and reintegration of *birket* systems into national strategies. Doing so offers a powerful, culturally resonant path toward water justice, rural sustainability and heritage-based resilience.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Matteo D'Agostino, Michele Tenzon and Pelin Yalçın.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 146–55
10.58981/bluepapers.2026.1.10
Received 04.12.2024; Received in revised form 02.06.2025; Accepted 29.09.2025

Adaptive Reuse of Maritime Infrastructure: Case Study of Colonial Harbormaster Towers in Java's Port Cities

Ricky Purbaya, Rizki Dwika Aprilian & Miktha Farid Alkadri

Abstract
The north coast of Java has been well known to overseas traders as a hub for commodities, as well as spices brought from the Spice Islands (now Maluku Islands or the Moluccas). By the early nineteenth century, the Dutch government took control of the maritime trade in the region through the Dutch East India Company and developed the major port cities of Jakarta (formerly Batavia), Surabaya and Semarang, where the remnants of the colonial past continue to exist. After Indonesia's independence, several colonial port structures, such as the harbormaster tower and its riverside facilities, were neglected until recently, when cities began programs to restore them. This article examines the preservation and adaptive reuse of historic towers in Java's three major port cities and attempts to revive them amid the climate crisis challenges.

Policy Recommendations

- Encourage application of the adaptive reuse approach to maritime infrastructure, transforming them into functional spaces with modern roles while preserving their historical essence for future generations as living heritage.
- The adaptive reuse approach should go beyond the existing structures and should be developed as one narrative with the surrounding environment.
- Further planning should consider and take advantage of relevant water bodies as an integral part of maritime infrastructure.

KEYWORDS

heritage management
harbormaster
Syahbandar
Spice Route
Java

WATER VALUES

CLIMATE

A B C D E

Am: Tropical monsoon climate

< Fig. 1 The Harbour Canal with the Uitkijk in Batavia (Source: Leiden University Libraries. CC BY-SA 4.0, via Wikimedia Commons).

Introduction

Cities are dynamic entities and cannot be frozen in time (Damayanti 2021). However, most cities have a layer of history that includes a variety of older buildings. The presence of neglected historic buildings in the middle of a city is a double-edged sword: the buildings represent values and narratives but can reduce the visual quality of the city (Aprilian and Widiastuti 2021). In Java's case, some cities are taking the initiative to protect and rejuvenate the heritage buildings. Jakarta designated its heritage sites in Kota Tua Jakarta (Old Town Jakarta) in 1973, followed by conservation projects of several buildings in 1975 and the Masterplan for Kota Tua Jakarta in 2014. Surabaya regulates the preservation of cultural heritage buildings and environments in 2005. Semarang has also designated its old city compound as a cultural heritage with a Mayor's Decree in 2018.

In Java's major cities, the neglected port infrastructures are results of ports' relocation to accommodate larger ships. In 1883, the colonial government relocated the former port of Sunda Kelapa in Batavia (now Jakarta) to Tanjung Priok to accommodate rapidly growing shipping activities (Yusuf 2023). For Semarang, the old port suffered from sedimentation and the new port was built in 1872. The same situation developed in Surabaya, where the port was moved from the mouth of the Kalimas River to an area further north in Tanjung Perak during 1910. These conditions left the old port and the harbormaster tower unutilized for decades until revitalization efforts began in the 2000s.

The national government later updated the regulation to protect the cultural heritage through Act No. 11/2010 on Cultural Heritage, which identifies preservation as an effort to maintain the existence of cultural heritage and its value by protecting, developing, and utilizing the buildings. Protection focuses on preventing and addressing damage to buildings. Development focuses on increasing value potential, information and promotion through research, revitalization and sustainable adaptation. Utilization stresses service to the people of Java and attention to sustainability (Soedarsono 2011). One of the strategies to make it possible to utilize heritage buildings is through an adaptive reuse approach.

According to Wong (2017), adaptive reuse is not a new concept and has been practiced since prehistoric times when humans first began repurposing caves as dwellings. Today, adaptive reuse involves a dialogue between old and new, balancing harmony with contrast, and tradition with innovation. Beyond heritage preservation, adaptive reuse supports climate goals by reducing carbon emissions through the reuse of existing structures (Stone 2020). This article discusses the preservation strategy and alteration of historic towers in Java's three major port cities using cross-case analysis, site visits and archival studies.

Adaptive Reuse Methodology

Remodeling or adaptive reuse is a building alteration process to utilize buildings with cultural significance for different functions. Brooker and Stone (2004) liken this method to reading a palimpsest and present a framework for understanding old buildings that guides designers in adaptive reuse and helps them evaluate, reinterpret and revitalize projects. The most critical aspect of an adaptive reuse project is understanding how old and new elements will mesh, which requires knowledge

^ Fig. 2 Views of the harbormaster tower: (A) façade; (B) tower, Museum Bahari, and surrounding landscape; (C) view from the top; (D) view toward the pump station; (E) interior of the tower top; (F) historical information display (Source: Ricky Purbaya, 2025).

of the building, utilities, code requirements and financial implications (Plevoets and Cleempoel 2019; Brooker and Stone 2004).

Analysis is the first step in adaptive reuse, focusing on understanding the existing building. This includes form and structure, history and function, context and environment, as well as the intended new purpose for the building. *Strategy* is the next step, with an approach chosen after the analysis. Brooker and Stone introduce three types of adaptive reuse strategies based on the level of treatment. First is *intervention*, which means permanent modifications integrating new and old elements into a single entity. Once made, these changes cannot be reversed without damaging the original structure. Second is insertion, which makes additions that attach to the building but are not permanent, and can be removed without damaging the original structure. Third is *installation*, which makes temporary additions, such as art installations, which can be easily removed without causing physical harm to the original building (Brooker and Stone 2004).

Case Study: Adaptive Reuse of the Harbormaster Towers in Java's Port Cities

Harbormaster tower in Jakarta

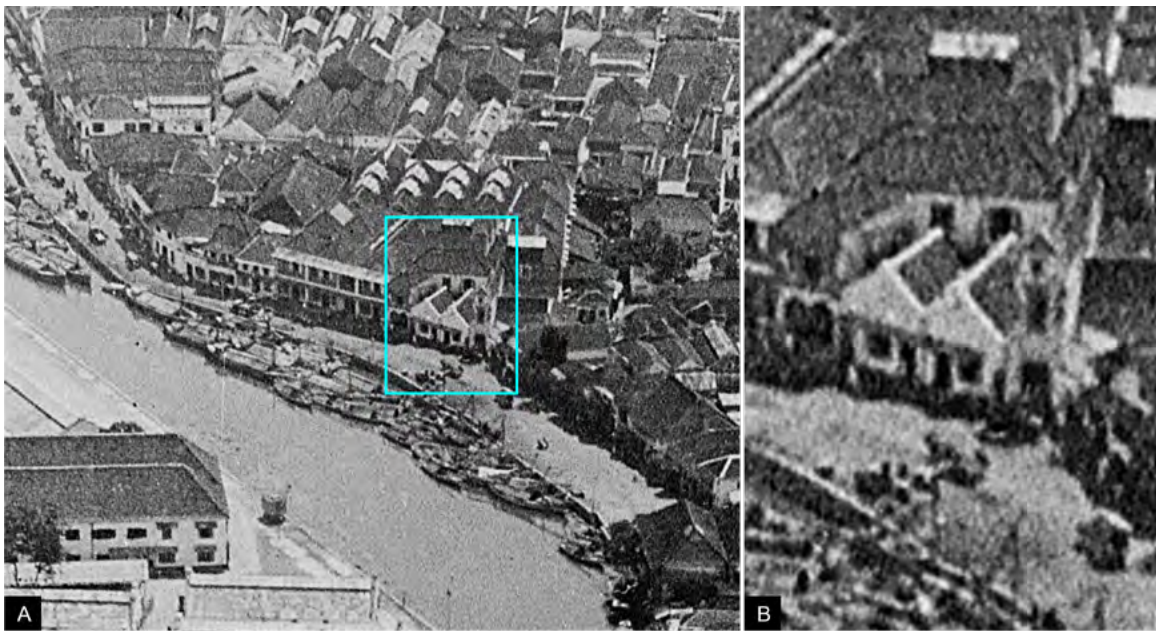
Before its restoration in 1977, the tower had significantly deteriorated due to changes in the soil's bearing capacity and the frequent passage of heavy vehicles along the road, which caused the structure to tilt. In April 2007, the tower underwent renovation, with efforts focused on preserving the existing structure through an installation strategy. The color of the top of the tower was changed from white to red (fig. 1, 2A), and the Maritime Museum logo was added to the right-hand side wall. While the overall exterior design saw no ma-

^ Fig. 3 The harbormaster tower Sleko in 1915 (Source: KITLV Digital Collection, item 117602, Leiden University Library).

^ Fig. 4 Views of the harbormaster towers in Semarang after adaptive reuse: (A) overall view; (B) main entrance; (C) renovated pedestrian walkway; (D) curtain-wall intervention restoring the tower's original configuration; (E) glass addition distinguishing old structure from new (Source: Ricky Purbaya, 2024).

jor alterations, the interior was repurposed to prioritize tourism, with the addition of galleries and graphic information panels (fig. 2E, 2F). However, these changes did not compromise the authenticity of the original materials, as the additions were minimal and reversible.

In addition, the surrounding area was revitalized using a permanent modification or intervention strategy. The connection between the water body near the tower (fig. 2B) and the syahbandar (harbormaster) structure is essential, serving as an integral part of the site's



^ Fig. 5 Views of the harbormaster tower: (A) aerial view of the tower, ca. 1900–1940; (B) close-up view of the structure (Source: KITLV Digital Collection, item 6402, Leiden University Library).

historical narrative, and thus are the results of careful preservation. In the past, the water functioned solely for transporting goods to the center of Batavia, but today it faces the threat of sea level rise that could lead to submersion. In 2022, the surrounding water was redesigned using a polder system and sluice gates to regulate the basin (fig. 2D). This basin now functions as a freshwater reservoir for the surrounding area (fig. 2B, 2C), playing both a protective and adaptive role in relation to climate-related challenges.

Harbormaster tower in Semarang

The harbormaster tower known as "Sleko" in Semarang offers a notable example of adaptive reuse. Originally part of the Nederlandsch Indische Gas Maatschappij, the tower fell into neglect after the harbor's relocation in the late nineteenth century and by the 1980s it had been abandoned (fig. 3). It deteriorated over time, collapsing in 2017 and causing casualties. In 2022, Perusahaan Gas Negara (Indonesia's National Gas Company) restored the Sleko tower through an intervention strategy that combined preserved brickwork with a contrasting glass structure and steel staircases (fig. 4).

The building was repurposed as a tourist site, blending historical authenticity with modern functionality. The revitalized riverside area as a promenade restores the visual connectivity between the tower and the river. This project goes beyond simple preservation; it revitalizes the structure by merging historical authenticity with contemporary expression. The result is a space that not only honors the building's historical significance but also embraces innovation and forward-looking use. This restoration demonstrates how heritage sites can evolve, maintaining their significance while adapting to contemporary needs. It illustrates

^ Fig. 6 Views of the harbormaster tower in Surabaya: (A) façade; (B) view toward the Kalimas River; (C) masonry detail; (D) emblems of Surabaya (left) and Batavia (right) (Source: Ricky Purbaya, 2024).

how heritage structures can be reimagined as dynamic spaces, alive with new meaning and public relevance while remaining rooted in their historical contexts.

Harbormaster tower in Surabaya

Located along the Kalimas River and dating to the nineteenth century, this tower originally served as a key navigation point, an aid in monitoring maritime traffic, managing trade and ensuring security in Surabaya during the Dutch colonial period (fig. 5A, 5B). Over time, as a new port was created and the old port lost significance and was overshadowed by urban development, the tower's function diminished. However, it remains an important historical landmark, symbolizing Surabaya's maritime past.

Compared to the towers in the other two cities, the tower in Surabaya has not undergone adaptive reuse; instead, it has only been subject to maintenance work. The tower is still abandoned, with its structure and facades showing signs of decay (fig. 6). At the entrance on the first floor, the original doors have been replaced with an iron gate, which now serves as an access point to the nearby local settlements. The riverside is still used to transport goods to the warehouses and fish market next to the tower. Still, the tower's current condition seems to be completely disconnected from any historical narrative.

Conclusion

Indonesia's maritime heritage is deeply embedded in its coastal cities, yet many historical sites face decay, disuse and escalating environmental threats such as flooding, sedimentation and climate change. The harbormaster towers in Jakarta, Semarang and Surabaya illustrate varied and often uneven strategies in adapting maritime heritage to contemporary needs.

Jakarta's tower has been carefully preserved with minimal alteration, emphasizing authenticity and the redesign of the adjacent canal aids adaptation to climate change challenges. Semarang offers a more architecturally impressive yet fragmented approach. The tower was innovatively restored with contemporary materials, and the redesigned riverscape adds to the tower's historical function and narrative. In contrast, Surabaya's tower has not undergone adaptive reuse, and the preservation initiative is limited to maintenance work only. It is informally repurposed as a passage to nearby settlements and suffers from a lack of a clear heritage strategy.

True preservation requires more than restoring buildings. It demands ecological and spatial reintegration. Without reconnecting heritage structures to their natural and urban contexts, Indonesia risks turning its maritime legacy into static monuments. A stronger, more integrated vision is needed, one that aligns cultural memory with environmental resilience and urban continuity.

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein, Kaiyi Zhu and Matteo D'Agostino.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 156–65
10.58981/bluepapers.2026.1.09
Received 04.09.2024; Received in revised form 25.03.2025; Accepted 25.08.2025

Constructing the Karakum Canal: The Urbanization of Soviet Turkmenistan and the Aral Sea Crisis

Estere Cvilikovska

Abstract
The collapse of the Aral Sea ecosystem is regarded as one of the most devastating environmental tragedies in history. Primarily driven by Soviet-era irrigation practices aimed at expanding agriculture in Central Asia's arid regions, the catastrophe has had lasting ecological and socioeconomic consequences. To address the repercussions of past actions, it is essential to move beyond perceiving water as a "national" resource: It cannot be fully comprehended or effectively managed within national borders. An ecosystem-based approach can help divert from a technologically and economically based mono-functional value system, promoting possibilities for sustainable development in the region.

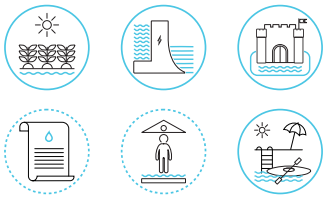
Policy Recommendations

- Stakeholders should be educated about how water management can damage the environment. Understanding its impact is essential for addressing and mitigating ecological problems.
- Ecosystem thinking is necessary to manage the current problems. Water should be understood as a transboundary asset, and neighboring countries of the Aral Sea basin should work toward shared management of cross-border water resources while also considering intangible water heritage and practices.
- To solve complex problems, governance based on mono-functional water use should be substituted by policies addressing multifaceted challenges.

KEYWORDS

irrigation system
ecosystem thinking
USSR
Turkmenistan
cross-border governance

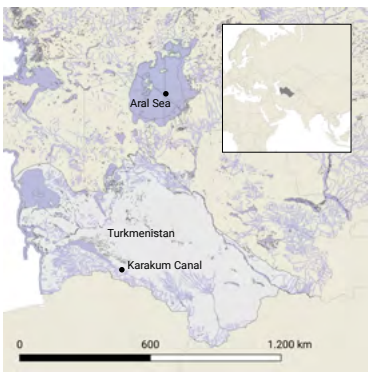
WATER VALUES



CLIMATE

A **B** C D E

BWh: Hot desert climate



< Fig. 1 Graveyard of Ships (Aral Sea) (Source: Mirfayzbek Abdullayev, 2025. CC0 1.0, via Wikimedia Commons).

Introduction

Today, the Aral Sea, located between Kazakhstan and Uzbekistan, contains 10 percent of its original volume of water (fig. 2). The region's economy has been destroyed, and its landscape is heavily polluted due to a tenfold increase in the water body's salt concentration. The water and soil are contaminated by fertilizers, pesticides and heavy metals, and the area is experiencing frequent dust storms (fig. 3). Many of its inhabitants suffer from devastating illnesses, such as respiratory, heart and kidney diseases (Wæhler and Dietrichs 2017). The demise of the Aral Sea, a lake that once covered a land area one-half as big as the Netherlands, has been closely linked to the irrigation practices of the Soviet Union and the construction of the Karakum Canal (Brite 2018; Obertreis 2017; Peterson 2019).

This article examines current challenges and emphasizes the importance of adopting an ecosystem thinking, which underscores the need for value-driven decisions on water governance, enabling multi-functional, holistic water use. Such a perspective aligns with the work of researchers who have proposed including social, cultural and environmental aspects in the long-term perspectives and development (D'Agostino and Hein 2024; Ghaderian 2022; Maria et al. 2022).

The top-down approach and dominant view of water as a strictly economic asset is one of the main causes of environmental degradation. Until the 1950s, a thriving fishing industry brought prosperity to the region of the Aral Sea; however, during the last years of Stalin's rule, the Soviet government emphasized irrigation and agricultural development. Soviet officials recognized Central Asia's hot desert lands as suitable for large-scale cotton growing, which had not been attempted previously due to limited water availability. The officials viewed this natural obstacle as something to overcome, leading to the development of one of the largest irrigation infrastructures in history – the Karakum Canal.

In the 1970s, the water level of the Aral Sea began to drop, and the construction of the canal was acknowledged as one of the main factors in the collapse of the Aral Sea ecosystem (Brite 2018; Obertreis 2017; Peterson 2019), as it draws 15–30 per cent of the flow of the Amu Darya River, one of the primary inflows for the Aral Sea. Due to the Aral Sea being an inland lake with a closed basin, the water withdrawals have been pinpointed as the cause of an extreme decrease in the lake's volume (Peterson 2019). Although more than 700 km away, the cities of Southern Turkmenistan are linked to the Aral Sea by the Karakum Canal, highlighting the interdependence of urban and ecological systems.

Turkmen Cities in Response to Water

Before the canal's construction, due to limited water resources, Turkmen cities were confined mainly to oasis areas (Cvilikovska 2025). Following the development of the Karakum Canal, many Turkmen cities, like Balkanabat, Mary, Gyzylarbat and Tejen, have been expanded and organized in a way that makes them greatly dependent on the canal's water supply. The country's capital, Ashgabat, was devastated by an earthquake in 1948. It then became the focus of an experiment in Soviet urban planning. Rebuilding was facilitated by the arrival of canal water in 1962, which increased per capita water availability fivefold and enabled the construction of entire neighborhoods where the canal became the primary water source (Korzuna 1982).

^ Fig. 2 The Location of the Aral Sea. The Historical Borders of the Aral Sea (hatched) and the Aral Sea in 2008 (solid color) (Source: Aplaice, 2021. CC-SA 4.0, via Wikimedia Commons).

Water from the canal made it possible for urban areas to expand into the irrigated lands that once surrounded them, extending new street networks into the desert. Soviet urban planners viewed large green spaces and bodies of water as essential for mitigating the harsh desert climate. This approach was reflected in Ashgabat's design, earning it nicknames like the "Green Pearl" and the "City of Gardens" (Liepa 1981). The cityscape featured expansive parks, interconnected boulevards and numerous fountains designed to be aesthetically appealing and to enhance living conditions (fig. 4). However, landscape design began to face problems with sustainability in the early 1970s, as many water-demanding foreign species were planted in hot and dry environments (Kachelson 1987).

Despite threats of water scarcity, Soviet planners continued to expand Ashgabat's green infrastructure throughout the twentieth century. An example of this ambition is the Central Esplanade, created as the city's focal point. Symbolizing state authority, the Esplanade served as a stage for military parades and offered locals and visitors alike a place to stroll. It housed significant buildings like the Karl Marx Library, designed by Abdula Akhmedov, surrounded by lush gardens and fountains, showcasing monumental architecture integrated with natural elements. Water features and greenery in public spaces reflected a commitment to enhancing the urban environment through landscaping and urban design. Decorative water infrastructures, such as fountains and cascades, were constructed in front of most public buildings, sculpturally and functionally creating united ensembles with their surroundings and often extending to shaded inner courtyards. However, the romanticized vision portrayed in Soviet propaganda often diverged from reality. Ashgabat's climate posed significant challenges to maintaining the vast

^ Fig. 3 USSR propaganda poster "We'll conquer drought, too" (Source: Viktor Ivanovich Govorkov, 1949).

areas of greenery, as the temperature frequently exceeded 45 degrees Celsius. Despite efforts to create shaded areas and increase humidity through evaporative water bodies, photos from 1980s often depict dried lawns next to fountains (Kachelson 1987), evidence of the struggle to sustain greenery in extreme heat (fig. 5). The construction of the Karakum Canal, while integral to urban development, also produced socioeconomic disparities within the capital and among cities. Soviet newspapers mentioned that the canal's proximity to Ashgabat facilitated leisure activities and recreation along its banks (Sein 1962). However, access to the canal was often restricted by fences, limiting direct interaction between city dwellers and the water. Meanwhile, peripheral neighborhoods faced challenges such as water supply interruptions and inadequate infrastructure maintenance (Kachelson 1987). The canal's impact on urban life varied across Turkmen cities. Cities like Mary featured private residential structures along the canal, with roads running parallel to it but with no public amenities or recreational spaces. In certain instances, access to the Karakum canal was privatized

^ Fig. 4 Boys playing in water, Ashgabat, Turkmenistan (Source: Hammond, 1964. CC-SA 4.0, via Wikimedia Commons).

and limited exclusively to the property owners along its banks. In the areas that did not contribute to Turkmenistan's national image, little to no attention was given to the appearance or amenities of the waterfront.

Future Water Insecurities

Soviet urban planning traditions persist in the twenty-first century, Turkmenistan planted half a million trees in 2023 despite many places in Ashgabat not being able to sustain greenery (fig. 6) and severe water stress that has been noted by the United Nations (Sheraz 2022). The unsustainable practices are even more evident in cities like Balkanabat, where green spaces were developed with water sourced through a 270 km underground piping network connected to the Karakum Canal. The extensive irrigation created 30 m^2 of greenery per inhabitant by 1970 (Ūdresole 1977). However, this reliance has intensified water insecurity, and in 2015 Balkanabat faced a three-day water shortage (Jardine 2015).

Soviet urban planners, while creating elaborate green spaces and water features in Turkmen cities like Ashgabat, appeared unconcerned with the environmental impact of unsustainable resource extraction. Although already in the 1980s legislators were emphasizing the need for carefully planned interventions and urbanization in desert environments (Kachelson 1987), many Turkmen cities face water shortages today. This contrasts sharply with the lavish use of water for decorative purposes in Soviet urban planning and highlights the

^ Fig. 5 Withering grass in front of Ashgabat Airport (Source: Hughes, 2024. CC-SA 4.0, via Wikimedia Commons).

^ Fig. 6 Thousands of newly planted trees in Ashgabat. The grass is only sustainable in certain places (Source: Kalpak Travel, 2018. CC-SA 4.0, via Wikimedia Commons).

disconnection between planning ideals and environmental realities exacerbated by global warming.

Compared to other states in the Aral Sea basin, Turkmenistan appears to be the most conservative in implementing inclusive and sustainable water reforms. While efforts have been made to promote transboundary cooperation in water management, many attempts have proved unsuccessful. Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have incorporated integrated water resource management in their policies, but these initiatives are frequently hindered by conflicting interests and implementation difficulties (Harriman 2015; Yakubov 2021).

Conclusion

The demise of the Aral Sea, starting in the 1970s, has been linked to the increase of irrigated lands in Central Asia, but has rarely been connected to the expansion and landscaping of Turkmen cities. However, its deterioration is closely tied to both urban and agricultural expansion, driven by water management policies that have failed to adapt to changing environmental conditions, intensifying water scarcity and worsening the ecological crisis.

The exorbitant use of water without considering future scenarios and its display as a part of nation-building may appear increasingly problematic as water scarcity becomes more frequent in Turkmenistan. The present regime continues the Soviet legacy by expanding green areas, even though, in recent decades, the vegetation has been dying at an increasing rate. The urban spaces developed during the Soviet era depict the shaping of space with no regard for sustainability, as many amenities are only possible with excessive water use. In recent decades, withering trees and empty fountains have appeared as precursors of a gloomy future. Due to the complexity of the problems and their causes, sustainable development can only be achieved by rethinking the governance of water heritage and collaborating with other countries in the Aral Sea basin.

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 166–77
10.58981/bluepapers.2026.1.15
Received 25.10.2024; Received in revised form 12.12.2024; Accepted 04.11.2025

Drowning Heritage: The Impact of Climate Change and Erosion on Azizakpe's Water Culture

Rhoda Osei-Nkwantabisa & Martin Larbi

Abstract
Islands have built their culture and heritage around bodies of water. However, due to climate change, the coastal islands are steadily disappearing because of severe flooding and erosion, as in the case of Azizakpe, a fishing community whose history and culture are strongly connected to water. Human activities, including the dredging of the estuary, along with sea level rise exacerbated by global climate change are the primary drivers for this loss. Although various coastal management and adaptation measures have been introduced, their outcomes remain uncertain. This study examines the Azizakpe community and the rapidly deteriorating state of the island. It highlights the effect on local livelihoods and how the community is attempting to cope with the situation and safeguard their water-based heritage, which will be at risk if islanders are displaced.

Policy Recommendations

- Implement eco-engineered shoreline protection in erosion hotspots and support locally tested flood-resilient housing.
- Restore mangroves through regulated replanting, establish community-enforced protection zones, and reduce pressure via alternative energy solutions.
- Strengthen freshwater access through rainwater harvesting systems and pilot solar desalination to address salinization risks.
- Preserve water-related knowledge through a community-led archive, intergenerational education, and partnerships.
- Integrate Azizakpe into national climate frameworks, mobilize climate and heritage funding, and support community-led adaptation.

KEYWORDS

erosion
flooding
habitable islands
heritage preservation
coastal management

WATER ICONS

CLIMATE

Aw: Tropical savanna climate

< Fig. 1 Fallen palm trees on Azizakpe Island in Ghana as a result of severe erosion (Source: Hannahkasak, 2023. CC BY-SA 4.0, via Wikimedia Commons).

Introduction

Small island communities across the globe are increasingly threatened by climate change, sea level rise and human-induced environmental transformations. In Ghana, these challenges are particularly acute for island settlements along the Volta River and the Gulf of Guinea, where erosion, flooding and ecological disruptions are undermining livelihoods and endangering cultural heritage. Azizakpe, a fishing community in the Ada East District, exemplifies this precarious reality. Historically sustained by its estuarine location and distinctive water-based practices – including fishing, crab trapping, boatbuilding and coconut oil production – the community faces the prospect of disappearance as its land area steadily diminishes.

The plight of Azizakpe is not unique, but it has been largely overlooked in scholarship and policy. Existing research on the Volta Basin has focused primarily on the economic and environmental implications of large-scale infrastructure such as the Akosombo Dam (Alhassan 2009; Chambers 1970; Miescher 2021), or on broader assessments of coastal vulnerability in West Africa. Far less attention has been paid to the localized, community-level impacts of erosion and flooding on small islands whose cultural heritage and water-dependent ways of life are deeply tied to place. This gap is critical, as the disappearance of such communities entails not only the loss of physical settlements, but also the erosion of intangible heritage, ecological knowledge and social identity.

This paper addresses that gap by examining Azizakpe as a case study of cultural resilience and ecological vulnerability. It explores the community's historical relationship with the Volta River, its livelihoods and traditions rooted in water and the challenges posed by climate change, erosion and infrastructural interventions. It demonstrates how environmental pressures threaten both tangible and intangible water heritage and argues for more inclusive and research-informed strategies to preserve and adapt vulnerable island communities. Although it focuses on Azizakpe, the article contributes to broader debates on climate adaptation, heritage preservation and sustainable development in small island contexts. The article asks what aspects of Azizakpe's water-based heritage can realistically be preserved in the face of accelerating erosion and sea level rise.

Community's Water Heritage and Relationship with the Volta River

The relationship between Azizakpe and the Volta River is multidimensional, encompassing material survival, settlement patterns, cultural practices and moral worldviews. Water in this context is not merely a physical resource but the foundation of the community's identity and continuity.

A key community strategy has always been material and spatial adaptation. For centuries, the Volta River has provided Azizakpe with fertile land, abundant fisheries (fig. 2) and a reliable transport route. Its estuarine setting allowed the community to thrive through farming, fishing and trade, shaping both its economy and spatial form. Families initially settled near the estuary to benefit from fertile soils and plentiful fish stocks, but as flooding and erosion intensified, settlement patterns shifted. Houses were increasingly built with protective features, such as higher plinths and adaptive layouts, to withstand the river's fluctuations. These adaptations demonstrate how survival has depended

^ Fig. 2 Fishing activities on Azizakpe (Source: Rhoda Osei-Nkwantabisa, 2022).

^ Fig. 3 Crab trapping practices on Azizakpe (Source: Rhoda Osei-Nkwantabisa, 2022).

on intimate knowledge of the river's rhythms, with the landscape itself becoming an archive of the community's responses to environmental change.

Another strategy lies in ritual and festival practices that sustain cultural resilience. Beyond its material functions, the Volta River is a central axis of cultural life. For the Adangme people, water symbolized both survival and protection in times of conflict. The river's natural barriers enabled them to withstand invasions and establish the Ada Kingdom (Sanza 2019). This historical memory continues to be celebrated in rituals tied to water. Returning warriors were once welcomed with purification rites which involved washing their feet in the river and firing muskets across its surface (Tsofanye 2016; Sanza 2019). These practices became institutionalized in the Asafotufiam Festival, one of the most important cultural events for the Ada people. During the festival, participants gather at Kpomkpo-Panya, the riverside point of departure and return for warriors, to perform foot-washing rituals and symbolic water-fetching ceremonies where priests carry water in a mysterious basket without spilling a drop. Such practices reaffirm the river as both a spiritual force and a guardian of the people, embodying their resilience across generations.

Water also permeates Azizakpe's moral and regulatory frameworks. Proverbs tied to the river articulate lessons about social conduct and the natural order. For example, the saying "The river that does not flow in the right direction will never find peace" links the integrity of a river's flow to the importance of ethical behavior, underscoring the belief that human society should mirror natural harmony. In addition, cultural laws and taboos regulate the community's use of water resources. Fishing is forbidden on Tuesdays, a practice that serves both spiritual and ecological functions, allowing fish populations to regenerate. Similarly, restrictions on women crossing the river during menstruation, while controversial today, highlight how cultural codes once governed interactions with water. Together, these practices show that the Volta is not only a natural feature but also a social institution that enforces order, sustainability and respect.

Finally, strategies of continuity and change shape how the community negotiates modernization. In contemporary times, modernization,

^ Fig. 4 The Asafotufiam Festival (Source: Gold Coast XP, 2023).

migration and exposure to globalized culture have reshaped aspects of life in Azizakpe. Younger generations, in particular, often view rituals, proverbs and taboos as symbolic rather than binding, raising concerns about the long-term preservation of intangible water heritage. Yet many traditions - such as the Asafotufiam Festival or proverbs about the river - remain vibrant, passed down through oral storytelling and community gatherings . What is changing, however, is the balance between cultural resilience and physical vulnerability. The same river that embodies identity and spirituality is also eroding the very land on which this culture is practiced. The erosion of cultural practices is thus inseparable from the erosion of physical space, with each amplifying the other.

This intertwined vulnerability suggests that Azizakpe's heritage cannot be reduced to "minor details." The rituals, settlement patterns, proverbs and taboos represent an entire worldview in which water is central to survival, morality and meaning. As the island continues to shrink, what is at stake is not just a fishing community, but a unique cultural system that has developed over centuries of living with and adapting to water.

Challenges Endangering Community's Water Heritage

Small island communities are particularly vulnerable to the impacts of climate change (Scheyvens and Momsen 2008). Their protection should be prioritized, with measures taken to strengthen resilience and mitigate risk. Yet because of their economic vulnerabilities many such communities have not received the attention or help. Water levels are steadily increasing and have been predicted to rise an estimated 5 m by the year 2150 (European Environmental Agency 2024). The changes in water levels will impact many different but related systems of island life including agriculture, fisheries and infrastructure.

Azizakpe's elevation is relatively low, with the highest point being only a few meters above sea level. The village is situated near the riverbank, which is prone to erosion and flooding during heavy rainfall and river surges. Azizakpe lies in a region where the Volta River flows into the Gulf of Guinea, placing it in a deltaic zone where both fresh water and salt-water interact. According to the Intergovernmental Panel on Climate Change (IPCC), global sea levels are expected to rise by 0.3–1.1 m m by 2100 (IPCC 2021). The Gulf of Guinea region is expected to experience higher rates of sea level rise due to local oceanographic factors, such as thermal expansion and glacial melt. Based on regional studies, the coastal areas of Ghana, including the Volta River region where Azizakpe is located, are expected to experience rising sea levels of around 0.5–1 m by the end of the century. In coastal areas like Azizakpe, small rises in sea level (even as little as 0.3 m) can result in significant flooding. Regional studies of Ghana's coast, including the Volta estuary, show that sea level rise and associated saltwater intrusion are already degrading fresh

^ Fig. 5 Erosion control with car tires (Source: Rhoda Osei-Nkwantabisa, 2022).

water resources and threatening agriculture and drinking water supplies (Nyekodzi et al. 2016; Avornyo et al. 2023).

The most immediate challenge is the loss of land and ecosystems. Approximately 20 acres (8.1 ha) of Azizakpe's land, nearly a quarter of the island's total area, have been lost to erosion. This reduction has displaced families, disrupted trading activities and diminished the viability of the settlement. By 2023, only four shops remained active, a stark indicator of the island's economic contraction. Ecologically, erosion has destroyed mangroves, farmland and animal habitats, while aquatic species such as crabs and fish have retreated from degraded waters. The disappearance of land is therefore not only a spatial loss but also an ecological and economic one.

Water and food security are equally threatened. Saltwater intrusion has compounded the crisis, contaminating boreholes and the Volta River, the community's primary drinking water source. What was once an abundant and free supply of fresh water has become unsafe, forcing residents to rely on imported water at high cost. This change has reshaped daily practices of drinking, bathing, and washing, while also threatening cultural rituals such as foot-washing ceremonies tied to the river. Similarly, the salinization of soils has halted farming, eliminating an important supplement to diets and incomes. The resulting food and water insecurity has raised the cost of living and has led to increased emigration from the island.

Livelihoods have been destabilized and disrupted. As a fishing community, Azizakpe has traditionally depended on a diverse set of water-related occupations, including crab hunting, fish mongering, boatbuilding and coconut oil production (fig. 2). Flooding and erosion have severely undermined these livelihoods. The decline of coconut trees has led to reduced oil production, cutting off a major source of household income. Fishing yields have dropped, both because of ecological disruptions and because the physical space for fishing-related activities is shrinking. These cascading effects illustrate how climate change threatens not just one economic sector but the entire interconnected system of livelihoods in Azizakpe.

The cultural consequences of these transformations are profound. The erosion of land and resources also erodes intangible heritage. Rituals, proverbs and taboos tied to the river lose their resonance when the material base, including fresh water, fertile soils and abundant fish, is degraded. For example, the practice of foot-washing in the Volta River is increasingly constrained as access points are lost to flooding and erosion. Thus, environmental changes undermine not only survival but also the cultural expressions that define Azizakpe's identity.

Taken together, these challenges reveal the depth of the community's vulnerability. The threats to land, ecosystems, livelihoods and

^ Fig. 6 Erosion control with sand tubes (Source: Rhoda Osei-Nkwantabisa, 2022).

^ Fig. 7 The Mangrove Restoration Project (Source: Rhoda Osei-Nkwantabisa, 2022).

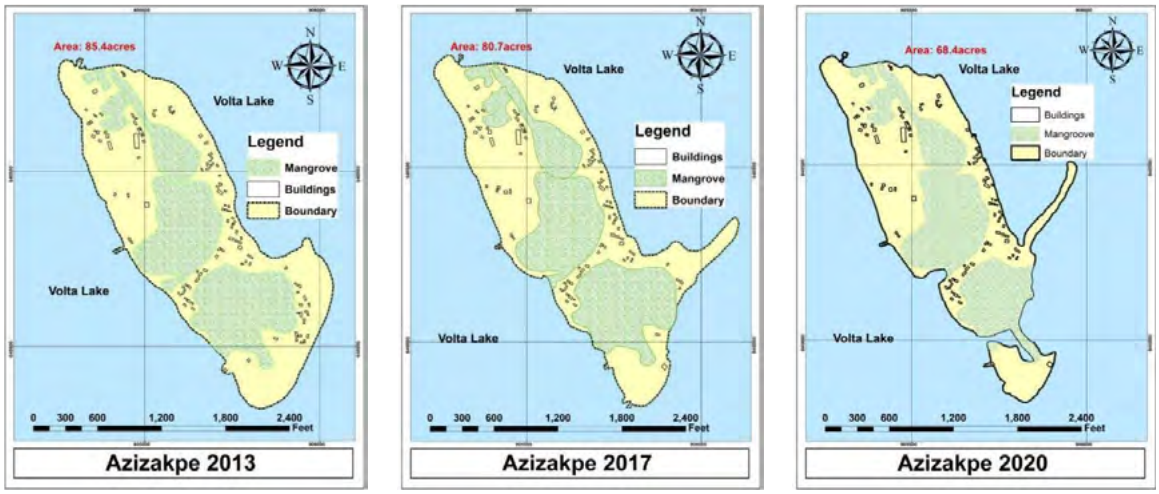
heritage are interlinked, reinforcing each other in ways that compound the risk of total disappearance. What is at stake is not only the survival of a small island settlement but also the preservation of a unique water-based culture.

Adaptation Strategies and Their Shortcomings

In response to the accelerating erosion and flooding, both external actors and the people of Azizakpe have attempted a range of adaptation strategies. These interventions vary in scale from government-led dredging and mangrove restoration to household modifications, but they share a common outcome: limited and temporary effectiveness. Understanding why these measures failed is essential for explaining the community's current vulnerability.

The most significant government intervention was undertaken by the Volta River Authority (VRA). They undertook dredging of the main estuary between 1990 and 2016, primarily to control weed infestation and improve water flow (Nyekodzi et al. 2016; VRA 2022). While this reduced bilharzia and improved navigation, it also altered sediment dynamics. Many residents attribute the acceleration of erosion after 2016 to the abrupt cessation of dredging activities, which left the shoreline destabilized. In the early 2000s, a mangrove restoration project (fig. 7) was jointly launched by the District Assembly, the Forestry Commission, and the Ada Tourism Stakeholders Association. The project aimed to reinforce the shoreline using natural vegetation. However, without enforcement or alternative energy sources, residents continued to harvest mangroves for firewood and construction, gradually undoing the intervention. The project illustrates how ecological restoration efforts fail when livelihood pressures are not addressed.

At the community-scale, Azizakpe residents have long experimented with small-scale protective structures. Since the 1990s, they have installed rock sills perpendicular to the river, constructed sea walls from concrete-filled car tires and deployed sandbags and sand tubes (figs. 5 and 6). These measures were funded collectively by residents and through contributions from local philanthropists. While ingenious, their effectiveness was highly localized: The tire sea wall protected a small section of



^ Fig. 8 The levels of erosion 2013–2020 (Source: Rhoda Osei-Nkwantabisa, 2022. Basemap from ARCGIS © Esri and DeLorme, HERE, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, Tomtom).

shoreline but left the rest exposed, and sandbags disintegrated quickly under wave action.

At the household level, families have sought to adapt their homes to recurrent flooding. Common strategies include raising plinths, elevating houses on stilts, reinforcing foundations with concrete-filled pipes and installing sand-filled planters as protective barriers. These measures provide temporary protection for individual households, especially during the rainy season when the Volta River overflows. Yet they cannot address the broader processes of shoreline retreat and saline intrusion.

The failure of these strategies can be traced to several interrelated factors. Localized and fragmented measures cannot match the scale of estuarine hydrodynamics. Institutional support has been weak, with interventions rarely embedded in broader coastal defense policies or backed by sustained funding. Livelihood pressures – such as the reliance on mangroves for energy and construction – directly conflicted with ecological restoration. Many community-led efforts lacked technical or engineering expertise, leaving them vulnerable to the river's force. Finally, chronic socioeconomic constraints limited the community's capacity to invest in durable solutions or maintain protective structures.

The limited success of these strategies should not be evidence that Azizakpe is unsalvageable. Instead, their failure highlights the structural neglect of small island communities and the inadequacy of fragmented, under-resourced interventions. The erosion of Azizakpe is not an inevitable "natural" outcome but the result of governance gaps and a lack of integrated, research-informed coastal management. Unless such measures are developed, abandonment will continue, but it will be the consequence of institutional failure rather than environmental determinism.

The Community Tomorrow

Over the past decade, Azizakpe has lost roughly a quarter of its landmass (fig. 8), and projections suggest that continued erosion and sea

level rise will make permanent habitation increasingly difficult. The acceleration of land loss since the cessation of dredging activities in 2016 highlights the severity of the threat: If current trends continue, the island may become uninhabitable within a generation. This physical decline has forced the community to confront an uncomfortable reality. Despite their persistent efforts to protect the shoreline through sea walls, mangrove planting and household-level adaptations, most of these measures have been short-lived or ineffective. As a result, many residents now live with a sense of uncertainty, with some preparing psychologically for eventual relocation.

This looming future raises a central question: What does preservation mean in a context where physical land is steadily disappearing? For Azizakpe, preservation cannot be understood solely as holding back the sea. While temporary interventions such as coastal defenses, elevated housing and fresh water management projects can reduce immediate risks and buy valuable time, they cannot reverse the underlying processes of climate change, sea level rise and sediment loss. It is unlikely that the island, in its present physical form, can be secured indefinitely.

At the same time, abandoning the island without a preservation strategy risks erasing an entire cultural world. Azizakpe's heritage is not only material, where it is embodied in boats, traps and houses, but also intangible, embedded in rituals, oral traditions, ecological knowledge and a symbolic relationship with the Volta River. These dimensions of life can, and must, be preserved even if the island itself is eventually lost. For example, the annual rituals of foot-washing in the river, proverbs that encode moral teachings through water imagery, and traditional fishing and boatbuilding skills, represent cultural resources that extend beyond geography. If carefully documented and transmitted, they can survive relocation and continue to inform community identity in new environments.

The future of Azizakpe therefore demands a dual approach. On the one hand, short- to medium-term physical interventions are necessary to sustain life and livelihoods in the immediate horizon. Strengthening flood defenses, experimenting with resilient housing and securing alternative fresh water sources such as rainwater harvesting or small-scale desalination could extend the viability of the island and reduce the trauma of sudden displacement. These measures would not “save" Azizakpe forever, but they would provide time for gradual adaptation rather than abrupt collapse.

On the other hand, the long-term preservation of Azizakpe lies not in defending its territory alone but in safeguarding its heritage. This requires deliberate documentation of oral traditions, ecological knowledge and ritual practices, as well as institutional support for transmitting these elements to younger generations. Here, NGOs, academic researchers and heritage organizations could partner with the community to record and preserve water-based culture in written, audiovisual and educational forms. Schools and cultural associations could serve as vehicles for teaching these traditions, ensuring continuity even in new locations.

Seen in this light, the community tomorrow is not only a story of loss, but also of transformation. While the island itself may eventually disappear beneath the sea, Azizakpe's cultural and historical identity does not have to vanish with it. Instead, it can be carried forward, re-

interpreted and re-rooted elsewhere. The critical challenge is therefore not merely to delay the physical erosion of the island but to create pathways through which its heritage, both material and intangible, can endure in the face of inevitable environmental change.

Conclusion

Azizakpe illustrates the dilemmas facing small island communities under climate change: The scale of erosion and sea level rise makes full physical preservation unlikely, while the erosion of land simultaneously threatens cultural heritage. The key question is not whether Azizakpe can be "saved" in a material sense, but how its heritage can be carried forward in ways that honor its history and sustain its identity.

This requires a dual strategy. First, short- to medium-term measures – such as strengthening coastal defenses, supporting resilient housing and securing fresh water supplies – can prolong habitation and reduce immediate risks. These interventions will not eliminate the threat of disappearance, but they can create space for communities to adapt rather than be forced into abrupt displacement.

Second, and more crucially, proactive documentation and transmission of Azizakpe's water-based culture must be prioritized. Recording rituals such as the foot-washing ceremonies, preserving oral traditions and proverbs tied to the Volta River and supporting the continuation of fishing and boatbuilding knowledge will ensure that Azizakpe's identity survives beyond the land itself. Here, NGOs, heritage organizations and academic institutions can play as central a role as the state.

The preservation of Azizakpe, then, is not about resisting inevitable physical change but about ensuring cultural continuity under displacement. By reframing preservation around heritage rather than territory, the community's survival can be reimagined in ways that are both realistic and meaningful. This approach avoids naive appeals for intervention and instead offers a pragmatic response to the question at the heart of this study: What is it that we aim to preserve, and how can it endure in the face of climate change?

Acknowledgment

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Matteo D'Agostino, Michele Tenzon and Carlien Donkor.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 178–87
10.58981/bluepapers.2026.1.16
Received 21.06.2024; Received in revised form 24.02.2025; Accepted 10.05.2025

Colonial Disaster, the "Capitalocene" and Contemporary Lessons: The Great Flood of 1924 in Southern India

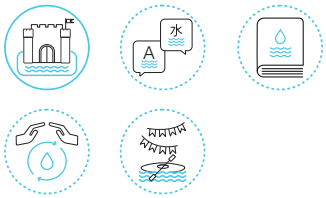
Mahendranath Sudhindranath & John Bosco Lourdusamy

Abstract
Floods impact many Sustainable Development Goals (SDGs) and aspects of sanitation and water supply. They are especially detrimental to those in lower socio-economic strata. The 2018 Kerala floods disrupted the lives of 5.4 million people, resulting in funds and attention being diverted from SDGs priorities and toward rebuilding and rehabilitation efforts. Such ravages of nature often result from the over-exploitation of local natural resources and the mismanagement of infrastructure. Colonialism was a watershed in such ecological destruction. The Great Flood of 1924, which devastated parts of present-day Kerala, is an example of a colonial-era-induced natural disaster. A century later, revisiting this disaster in the light of Kerala's 2018 floods offers instructive pointers for achieving disaster resilience today – in a region known for its rich biodiversity and population density. This study also highlights how historical forces like colonialism contributed to transforming this once peripheral region into a "risk society."

KEYWORDS

Great Flood of 1924
Kerala Flood 2018
colonialism
disaster history
resilience

WATER VALUES



CLIMATE

A B C D E

Am: Tropical monsoon climate

Policy Recommendations

- Introduction of disaster history in the school and college curriculum.
- Prominently marking disaster memories (e.g., with flood marks) to create awareness.
- Co-production of resilience through local (e.g., flood memories, traditional knowledge) and scientific knowledge (e.g., dam management, flood mapping).
- Advocating sustainable development and thoughtful conservation of the Western Ghats.
- Turning the proactive popular response into a human resource bank mobilized through social networking.

< Fig. 1 Kerala Floods 2018 - Angamaly (Source: Ranjithsiji, 2018. CC BY-SA 4.0 via Wikimedia Commons).

Introduction: Disaster as Part of the "Capitalocene"

Disasters offer a unique lens for examining entrenched fissures in society, including social inequality and the vulnerability of particular groups. Scholars have described "the past" as a "laboratory" in which events and relations can be scrutinized to comprehend "the present." The past allows us to identify and compare "distinct and divergent social and environmental patterns and trajectories" (Bavel et al. 2020, 1). It must be noted that even when the trajectory of a disaster is the same, the outcomes would often be different, primarily because of socio-cultural and political differences. The emergence of human beings as significant "geological agents" – prompting the idea of "Anthropocene" – demands the supplementing of global histories of capital with the species history of humans (Chakrabarty 2009). Jason Moore (2016) attributes climate change to an "audacious accumulation strategy" termed "Cheap Nature" (the dual understanding of nature as "cheap" in an economical and "ethico-political" sense). This approach becomes particularly stark in the context of colonial expansion. The proponents of the use of "capitalocene" rather than Anthropocene, like Moore, argue that the effects of capitalism were especially evident in the peripheries – following Wallerstein's World System Theory.

Modern colonialism, which incorporated most of the world into the capitalist order through various regimes of violence, also handed a particular legacy of impunity regarding the overexploitation of nature, which the colonized were not hesitant to carry forward. Hence, the value of this study is of great relevance – given the continuities, and therefore, the identical and comparable nature of crisis and resilience over time.

The "Capitalocene" in Travancore

The environmental histories of princely states in India, which covered two-fifths of the Indian subcontinent, have been largely neglected. Focusing on disasters, can help reveal the ecological impact of colonialism. Travancore was a princely state (constituting parts of the present-day Indian states of Kerala and Tamil Nadu in southwestern India) under a native monarchy and indirectly controlled by the British. It was a narrow strip of land sandwiched between the Western Ghats on the east and the Arabian Sea on the west (the Malabar Coast). Numerous rivers – mostly fed by the monsoon – flow across the region, making it fertile and green (for the geography of Travancore, see Pillai 1940a). From time immemorial foreign traders sought to benefit from its spices, ivory and teak. After prevailing over other foreign players, the English East India Company established political dominance over the area through unilateral and uneven treaties that subjugated the princely state beginning in the late eighteenth century. By the nineteenth century, colonial capital had cleared the rich tropical evergreen forests to make way for monocropping plantations of tea, coffee and rubber (Baak 1997; Ravi Raman 2010). The expansion of the railway network resulted in further clearing of dense forests for precious wood (which was also exported to England for use in shipbuilding).

The post-independent development regime continued to follow patterns inherited from the colonial plantation era, including the continued depletion of forest land, government regularization of encroachments and population influx (Moench 1991). The colossal capital influx also resulted in massive rice-land reclamations from the Vembanad Lake (the longest lake in India and the largest in Kerala), where four major rivers drain (the Pampa, Manimala,

^ Fig. 2 1924 Munnar Flood. Image reproduced from original on display at the Tea Museum, Kanan Devan Hills Plantation (KDHP), Munnar (Source: Unknown, reproduced by Mahendranath Sudhindranath, 2025).

Achenkovil, and Meenachil). These, along with the construction of various dams and embankments, have significantly contributed to deviations in the natural courses of rivers in the region.

The Great Flood of 1924: A Disaster of the "Capitalocene"

The 1924 flood, popularly referred to as Thonnoottompathile Velapokkam or Flood of 99, (referring to the year 1099 of the Malayalam calendar), inundated significant areas of Travancore, resulting in an estimated loss of at least one thousand lives (there is no official record of mortality) and the displacement of tens of thousands. The monsoon of 1924 (June - August) brought the highest recorded rainfall - 64 per cent higher than normal. The heavy downpour of 16 - 18 July became the immediate trigger of the deluge, with all rivers overflowing and, causing significant damage to regions that witnessed the most anthropogenic transformations. The plantation belt suffered considerable destruction as a result of recurring landslides. Along with Parur and Kuttanad, this belt suffered the heaviest damage in terms of habitat, communication facilities, crops, cattle, and public buildings (Pillai 1940b). The flood destroyed the ongoing Kanni crop (usually harvested in August - September) and damaged the seedlings meant for the Kumbham crop (whose harvest period is February - March). Despite Travancore's history of flooding, the scale of destruction in 1924 and the slow recession of water caught everyone by surprise. The flood became etched in popular memory as "Great." The disasters of 1882 - 1883 and 1906 - 1907 paled in comparison with the devastation of 1924, while some contemporary commentators compared it to the mega-flood of 1824 (Jacob 2022). In India as a whole, it could be compared to another catastrophic flood in the upper Ganga and Yamuna that also took place in (1924) with huge loss of life and the destruction of much colonial infrastructure (Ramaswamy 1985).

^ Fig. 3 Periyar Dam, c. 1899 (Source: Nicholas & Co., Madras. Published in The Queen's Empire, Volume 4. Public domain via Wikimedia Commons).

Mitigating the 'Great Flood'

The flood relief operations of 1924 were decentralized in character, with a Flood Relief Committee overseeing the efforts of local committees. The government, missionaries, affluent sections of society, community organizations, and even protesting political groups (like the Indian National Congress) immediately aided the affected by distributing food, clothing, and money. Newspapers reported the disaster locally and internationally. This resulted in coming in from outside the state to supplement the free grants from the government to rehabilitate the poorest among the victims. The Forest Department provided building materials such as bamboo, reed, and grass to farmers (Pillai 1940b).

Travancore had a very hierarchical society based on the caste system, which was more rigid than in the rest of India. Even in the face of a disaster, caste showed its ugly face with segregation manifested in the rehabilitation measures. The diary entries of S. C. H. Robinson (the land revenue and income tax commissioner, appointed as the state's special officer for flood relief) offer considerable insights regarding the relief operations. The caste Hindus were accommodated in the temple buildings, while the lower castes (who were considered polluting) had to stay in boats or public buildings. Mealtimes in the relief camps were also based on caste hierarchy (Robinson 1924). On the positive side, Robinson's diary alludes to widespread community participation in feeding the refugees and arranging motor boats to res-

^ Fig. 4 SNC initiates Operation 'Madad' in Kerala (Source: Indian Navy, 2018. CC BY-SA 4.0 via OpenStreetMap Wiki).

cue people and bring them to shelters – long before the state could lend its support (Robinson 1924). Afterward, many temples, public buildings, and houses that survived the deluge displayed plaques to mark the flood-water level and remind the coming generations of the tragedy. However, the tragic experience does not seem to have left a 'mark' in terms of lessons learned, as some of the contributing factors persisted.

Return of the "Flood of the Century" in 2018

After 94 years, another deluge, widely recognized as the "flood of the century," afflicted Kerala (the state linguistically formed in 1956 with most of the erstwhile Travancore territory). The downpour of 25 trillion liters of water in a state with the third-highest population density in India caused massive damage (Venkitesh and Kuttappan 2018), with 450 deaths, the displacement of a million people to relief camps, and property losses of 2.8 billion USD (Basak et al. 2018).

There are interesting similarities between the deluges of 1924 and 2018 in terms of cause, extent, and response (Mani 2021). The more-than-average precipitation and unprofessional dam management (releasing dam water into already flooded rivers) were the causes of both disasters. The core affected areas remained the same (of course, with a difference in the scale of damage given the denser population in 2018). There were similar immediate and long-term responses from civil society and respective governments.

^ Fig. 5 Volunteers at the Central Collection Centre for Relief Materials, Trivandrum (Source: Mahendranath Sudhindranath, 2019).

Addressing Historical Factors to Achieve Resilience

The historical data of a disaster offers valuable insights into the interconnected socio-political-environmental factors that contributed to it. As Mike Hulme (2008, 5) argues, understanding the "complex interweaving of our ideas of climate with their physical and cultural settings" is essential to prepare ourselves for "different configurations of this relationship in the future." The Western Ghats, an ecological hotspot, has suffered significant degradation due to unchecked capital-driven exploitation. In post-independent India, deforestation and granite quarrying have surged, with human activity and rapid urbanization severely degrading 35 percent of the forest cover over the past 90 years (Viju 2019). Moving forward, conservation efforts must be strategic and collaborative, with the government and local communities working together to protect the ecosystem.

Kerala of the twenty-first century is increasingly a "region of risk." There is an over-emphasis on the flood-of-the-century narrative concerning mega-floods worldwide (Skilton 2023) and such disasters may likely recur with increasing frequency in this region. Yet, people have not developed a "culture of disaster" by developing resilience through frequent exposure to risks (Bankoff 2003). Resilience becomes ambiguous when the "autonomy of technical expertise" and "role of politics in environmental discourse" collide (Gandy 2014, 214). This disconnection often aggravates the situation, especially in the "landscape of hydrological uncertainty" (Gandy 2014, 203).

Historical memory is pivotal in enabling a society to prepare for disasters of the future. One way to enable this is the inclusion of disaster history in the school/college curriculum. A pragmatic approach to disaster studies is to make it an interdisciplinary field "that active-

ly embed(s) conceptual insights derived from cultural and historical analyses into broader, collaborative research projects that are oriented toward achieving change in real-world practices" (Carrigan 2015, 123). Proper dam management (using past failures as lessons), effective public communication of reliable forecasts, updating researchers with high-resolution terrain data, sensitisation through local flood mapping, and reorientation toward sustainable construction could improve resilience.

Conclusion

The two floods that ravaged Kerala within the span of a century underline the importance of popular memory in achieving resilience. The critical factor that led to the floods was the degradation of the Western Ghats, a result of the "capitalocene." Environmental degradation and disaster mark a continuum in the ecological timeline of the region. The stark similarities of the causes and extent of the floods and people's proactive response in the two instances also characterize that continuum. Understanding past floods' physical and cultural settings and absorbing the appropriate lessons will prepare us better for future incidents.

Acknowledgment

Mahendranath Sudhindranath gratefully remembers his late grandfather, N. P. D. Nair (born in 1924 during the 'Great Flood'), for handing down his generation's memories. He also thanks RWTH Aachen University, Germany, which hosted him for the Future Environmental Leader Scholarship 2023 (awarded by the Global Water and Climate Adaptation Centre) and the academic mentor there, Axel Siegemund. Both authors thank Jacob Sebastian Vellukunnel, Rajeev Pallikonam, Sanjay Menon, Ajith Kumar, and Jobin Francis for sharing their personal experiences and valuable local support in Kerala and Mr Joshen Joji, who was instrumental in facilitating access to the Tea Museum.

This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Carola Hein.

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Blue Papers 2026 (Vol. 5 No. 1), pp. 186–97
10.58981/bluepapers.2026.1.11
Received 29.03.2025; Received in revised form 20.06.2025; Accepted 03.09.2025

Allowing Natural Sedimentation in the Nieuwe Waterweg to Reduce Salinity Intrusion and the Effects of Sea Level Rise

Maarten Kleinhans, Silke Baltussen, Eise Nota, Jana Cox, Han Meijer & Jasper Hugtenburg

Abstract

The Nieuwe Waterweg is the artificial mouth of the Rhine and Meuse Rivers in the Netherlands and an important shipping channel for the Port of Rotterdam. The channel, about a half-kilometer wide, is dredged to depths of more than 16 m to allow navigation. This substantial depth has adverse effects on flood safety, ecology and salinity intrusion in the lower river system. Mitigating these effects through engineering is costly and increasingly unviable with rising sea levels. A straightforward, nature-based alternative is to allow natural sedimentation, gradually making the channel shallower again while the port continues to expand seaward. We present 1:1000 scale physical experiments as a future vision for sedimentation in the ports and the Nieuwe Waterweg. The observed behavior aligns with that of similar estuaries and ports worldwide, demonstrating the broader applicability of this approach. Based on the current sediment budget, the sedimentation rate is estimated 0.5–1.0 m per decade. If transitional and structural changes in port logistics are coordinated with this sedimentation rate, the port economy can be expected to benefit.

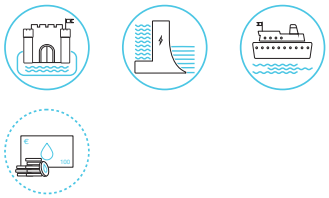
Policy Recommendations

- Conduct a large-scale pilot field study of sedimentation in the Nieuwe Maas, building on existing small-scale inventories and tests with local stakeholders and knowledge institutes.
- Redirect dredged sediment from seaward ports to the Nieuwe Maas and disused port areas, instead of the North Sea, to enable the development of tidal flats and new urban spaces.

KEYWORDS

sea level rise
dredging
port
salinity intrusion
analogue scale modeling

WATER VALUES



CLIMATE

A B **C** D E

Cfb: Temperate oceanic climate

< Fig. 1 Vessels moored in the New Waterway (Source: Jana Cox, 2022).

Introduction

The Netherlands is regarded as one of the best-protected lowlands against fluvial, pluvial and coastal flooding, demonstrating clear awareness of the accelerating climate crisis, as evidenced by a national program headed by an appointed "delta commissioner" (van Alphen et al. 2022). At present, the port and city of Rotterdam are protected against storm surges by a storm surge barrier, which closes at seawater levels above 3.05 m, while the upstream rivers have dikes designed to withstand extreme river floods. However, the barrier was constructed in the late 1990s as the final part of the Delta Works, built after the 1953 flood, to cope with a 1 m sea level rise that will likely be reached by 2070. Strategies to construct a new barrier and manage the mouth area are now being devised.

Long-term dynamic planning is urgently needed to address the compound challenge of increasing frequency and magnitude of river floods and precipitation, combined with the certainties of sea level rise of 1–2 m at the end of the century and soil subsidence of a few cm per year in the deepest polders, at 6 m below sea level. Such dynamic planning can involve many strategies ranging between the two extremes of continued reliance on hard engineering structures and accommodation by strategic coastal retreat. While public discourse in the Netherlands indicates support for technological solutions, replacing and strengthening hard infrastructure is unlikely to keep up with the external changes (e.g., Haasnoot et al. 2021). The necessary change from a strategy based on strengthening hard infrastructure toward a strategy based on the dynamics of the natural system is relevant for many ports in estuaries, like Antwerp (Meire et al. 2005), Hamburg (Van Eekelen et al. 2017), New Orleans (Lewis 2023), Nantes (Duval and Bahers 2023), and many others.

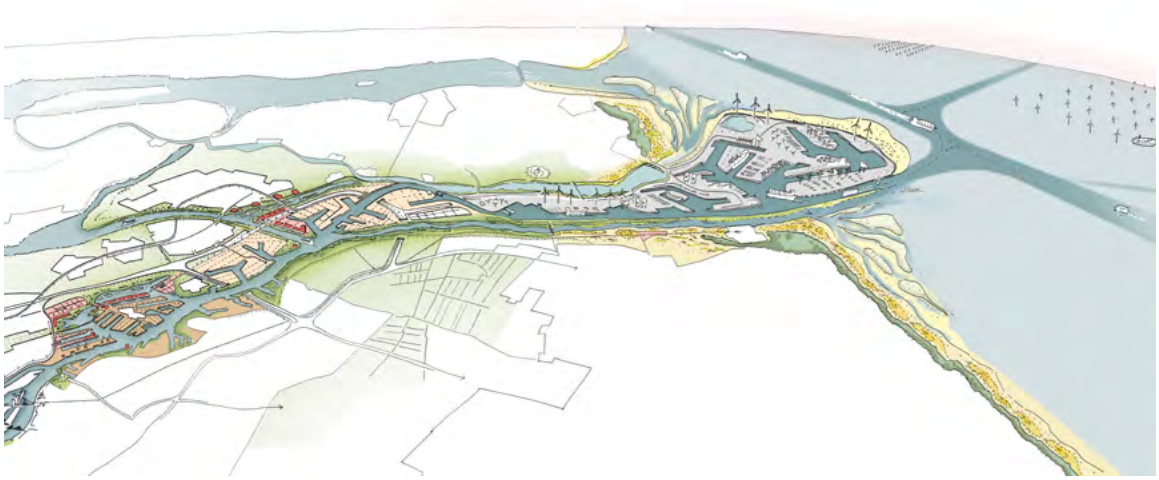
Rotterdam must confront these challenges and commit to a sustainable, adaptive pathway to climate adaptation. While over 60 per cent of the port's income depends on fossil energy – an important source of regional revenue – the port has set the ambitious goal of becoming the first fossil-free port.[1] Achieving this will require multiple transitions to be undertaken simultaneously lest the area remains in a lock-in situation.

Here we focus on a no-regret measure that can be part of any strategy: relying on natural sedimentation instead of continued dredging to reduce salinity intrusion and the height of upstream stormwater levels and to promote nature restoration. This paper has two parts. The first reviews a general plan for the area. The second part focuses on dedicated experiments in a unique laboratory facility, which provide tangible results and visualizations of what natural sedimentation in the Nieuwe Waterweg and harbors would look like.

A Multi-Purpose Plan for the River Mouth Region

In 2023, a competition was organized to deliver plans and ideas for the future of the mouth of the Rhine and Meuse.[2] The competition was won by an entry called Tweestromenland (Land of two rivers). The winning team included two design firms, two nature organizations and two universities.[3] The name *Tweestromenland* re-

1. Port of Rotterdam, "The Goal is Completely Fossil-Free Terminals," https://www.portofrotterdam.com/en/news-and-press-releases/the-goal-is-completely-fossil-free-terminals.



^ Fig. 2 Tweestromenland proposal for sediment management strategy (Source: Palmbout Urban Landscapes, 2023).

fers to the two main outlets through which the Rhine and Meuse discharge their water to the sea: the Nieuwe Waterweg/Nieuwe Maas and the Haringvliet.

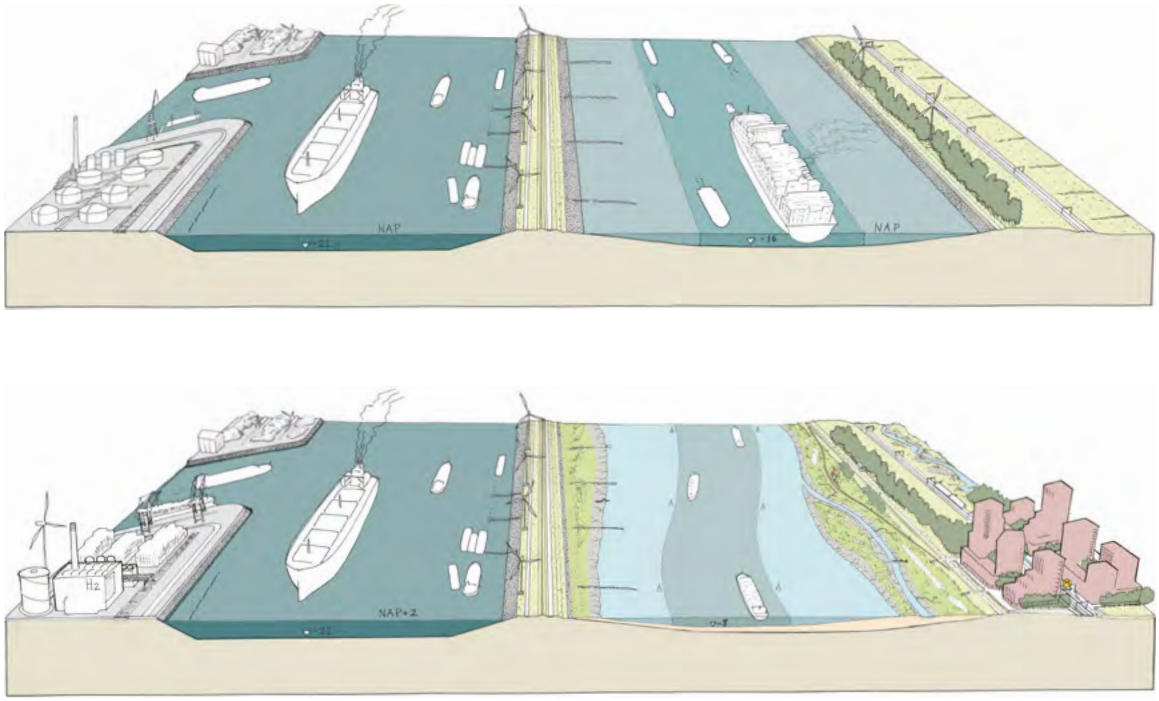
The role of the Haringvliet as the main discharge channel increased in the fifteenth century (De Haas et al. 2019). As a result, the Nieuwe Maas silted up, which created problems for the accessibility of the Port of Rotterdam (Cox et al. 2022b). In 1872, to enhance accessibility of the port for the increasing ship traffic and draft due to increasing ship size, a new navigation channel was dug between Rotterdam and the sea: the Nieuwe Waterweg. This was made possible by the introduction of steam-powered dredging technology, which marked the beginning of large-scale canal and channel excavation globally, driven by a fast-growing shipping economy.

In the twentieth century, the Nieuwe Waterweg was deepened repeatedly, from an original depth of 6 m to the current 16.2 m, to allow passage of increasingly larger ships. While the Port of Rotterdam experienced an explosive growth, 90 per cent of the intertidal flats in the estuary of the Nieuwe Maas-Nieuwe Waterweg disappeared, resulting in (1) a dramatic loss of biodiversity (Paalvast 2014), (2) an increase in high water levels upstream (Paalvast 2014; Cox 2021) and (3) greater salinity intrusion (Iglesias 2022).[4] Several engineered waterworks in the delta (especially the Haringvliet dam, part of

2. The competition was initiated by the Eo Wijers foundation, which organizes design competitions related to important issues on a regional scale every two to three years. The design competition on the Rhine-Meuse mouth was supported and coorganized by the City of Rotterdam, the Province of South-Holland, the National Delta Program and the Water Authority Hollandse Delta. See the Eo Wijersstichting web page at https://eowijers.nl/.

3. Members of the Tweestromenland team are H+N+S Landscape Architects, Palmbout Urban Landscapes, the World Wildlife Fund, ARK Rewilding the Netherlands, Technical University Delft and Erasmus University Rotterdam. Authors Meyer and Hugtenburg contributed to Tweestromenland and are proponents of executing the plan.

4. The salinity intrusion problem has long been recognized, e.g., in the draft Deltawet (1955): Kamerstuk II, 1955-1956, 4167, nr. 1-3, https://repository.overheid.nl/frbr/sgd/19551956/0000278501/1/pdf/SGD_19551956_0002279.pdf.



^ Fig. 3 Top: current situation with unnaturally deepened beds of both the Calandkanaal (left) and Nieuwe Waterweg (right). Bottom: future situation according to Tweestromenland: the Calandkanaal can be maintained as a deep shipping channel while the Nieuwe Waterweg will become shallower; regeneration of intertidal areas and combination with new urban development (Source: Palmbout Urban Landscapes, 2023).

the Delta Works, completed in 1971) contributed to directing the main discharge through the Nieuwe Waterweg. Continuous dredging activities remain necessary to maintain the depth of the bed, especially in port areas. The volume dredged from the Nieuwe Waterweg and adjacent harbor basins and returned to the North Sea has increased with deepening to over ten million m^3.

The basic idea of the Tweestromenland proposal is to discontinue maintenance dredging and allow the natural tendency of the Rhine and Meuse to discharge their water mainly via the Haringvliet (fig. 2). The hypothesis is that this "nature-based solution" will, over time, result in the gradual shallowing of the Nieuwe Waterweg, moving it toward its natural undredged equilibrium depth, also allowing it to restore tidal flats, leading to substantial recovery of biodiversity and new urban landscapes in former harbor basins (fig. 3).

The Tweestromenland proposal assumes a parallel transition of the channel-port area of Rotterdam. Currently, more than 60 per cent of the port area is used for the transshipment, storage and processing of fossil fuels. Especially the Botlek area, completely dedicated to fossil fuel-related activities and situated 20 km upstream, will need to be transformed in the coming decades (Van der Lugt et al. 2025). The other large parts of the Rotterdam port area, Maasvlakte and Europoort, will not be influenced by this proposal, because they are accessible by independent channels.

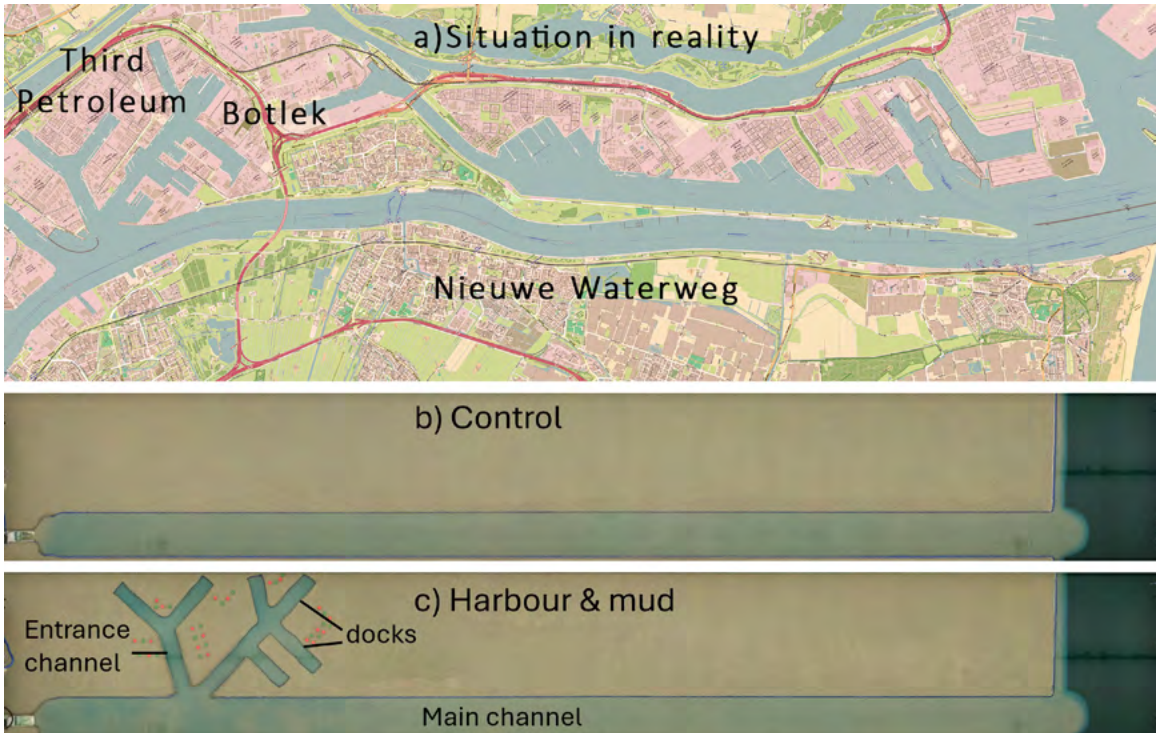
In this paper we show how the natural process of the transport and depositing of sediments can result in (a) the transformation of the Nieuwe Waterweg from an artificial shipping canal into a river mouth with tidal flats, and (b) the accretion of new land and a change of function in the harbor basins of the Botlek area.

Experiments Demonstrating Sedimentation Patterns

Given the sediment budget and a known potential sedimentation rate of 0.5–1 m per decade (Cox et al. 2021), an important question remains: what will sedimentation in the Nieuwe Waterweg look like? Laboratory experiments provide valuable visualizations of self-forming waterscapes, but reproducing tidal systems at scale is particularly challenging. Here we present experiments created in the Metronome at Utrecht University, a unique tilting tidal flume measuring 20 by 3 m. By periodically tilting the flume on its short axis with a 40-second cycle and an amplitude of less than 0.1 m, the facility generates tidal currents strong enough to transport sediment.

The Metronome has previously been used to model estuaries with sand, mud and vegetation, all with freely erodible banks, allowing estuaries to develop a natural, seaward-widening trend while being exposed to constant and rising sea levels as well as being subjected to dredging. Experiments with sand and crushed nutshell (a proxy for mud due to their similar behavior), showed that mud tends to deposit upstream and on higher intertidal elevations. The deposited mud takes up space which reduces the tidal prism (i.e., the volume of water that flows into and out of the system in a tidal cycle), which, in turn, reduces the tidal currents along the estuary (Braat et al. 2019). Additional experiments compared estuaries with and without dredging, applying the same deepening and maintenance protocols used in the Western Scheldt, both with and without sea level rise (Cox et al. 2022a). The results showed that dredged estuaries experience greater bank and bed erosion, as well as increased upstream tidal penetration with rising sea levels. These effects occur because the surplus water and additional momentum are concentrated in the artificially deepened channels.

Here we present novel experiments conducted with fixed banks, representing the Nieuwe Waterweg (fig. 4) (Baltussen 2025). As in previous experiments, the riverbed was composed of coarse sand, the sea level was kept constant with waves generated from the seaward boundary and a small river inflow was supplied at the upstream boundary. Tidal components were M2 and M4 as in the North Sea, causing larger velocities in the flood phase than in the ebb phase (flood dominance), which leads to a tendency to import sediment making the system initially flood dominant. The banks were fixed at an angle of 45º and covered with coarse sandpaper. The Nieuwe Waterweg barely widens in a seaward direction because nineteenth-century engineers aimed to create a self-deepening canal, so we kept the experimental channel straight with a width of 70 cm, an initial uniform water depth of 1 cm representing the pre-deepened situation, and a bed thickness of 5 cm (fig. 4). Three experiments are presented here: (1) a control experiment with a straight channel and sand only, (2) an experiment with two harbors added, namely the Botlek and the Third Petroleum harbor to assess sand sedimentation and the tidal prism added by the harbors, and (3) an experiment with the same layout but a mud supply at the upstream boundary. The morphological development without dredging, as proposed in the



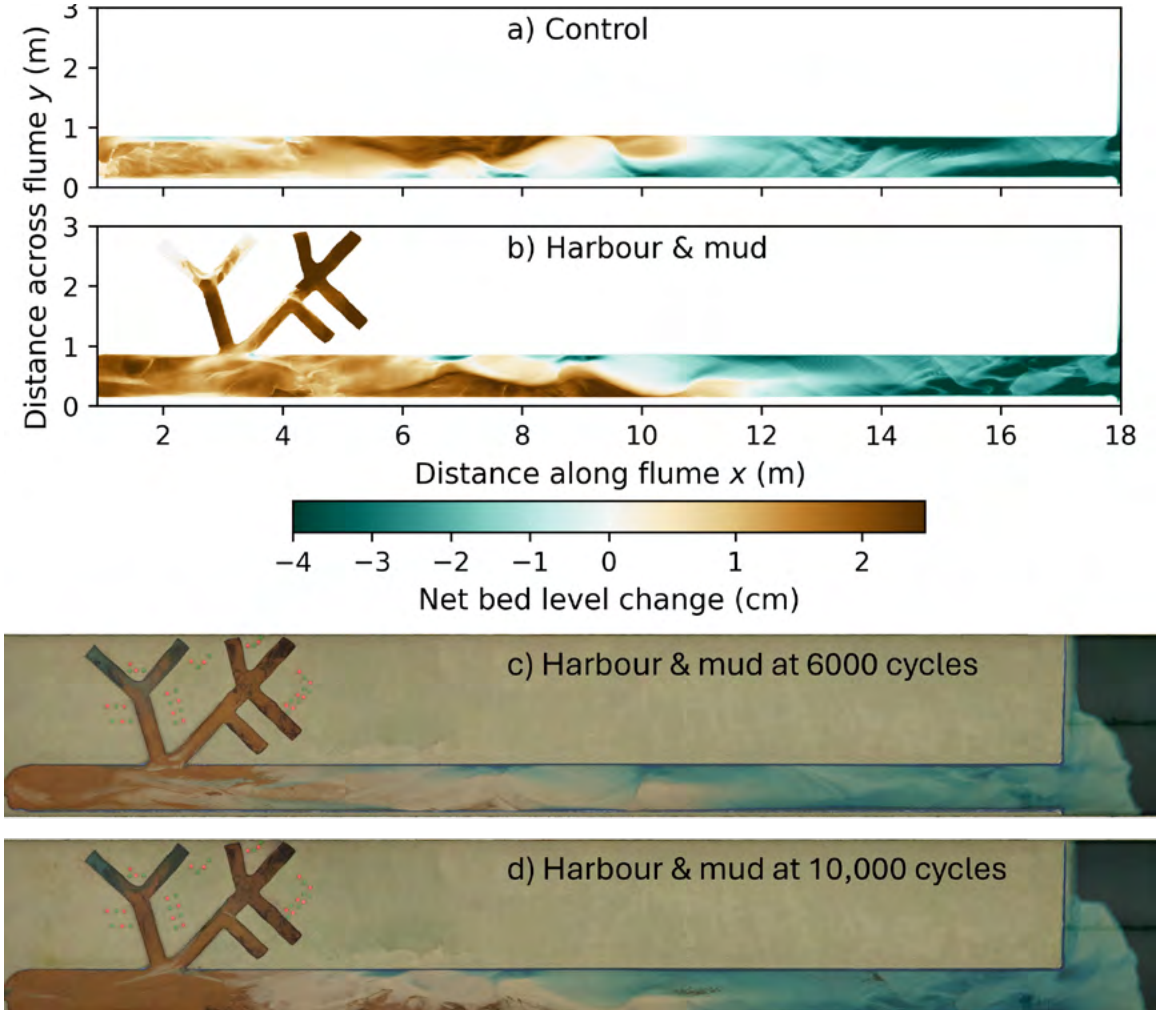
^ Fig. 4 a) Situation of the Nieuwe Waterweg and setup of the straight channel with harbors in the Metronome (sea is on the right side in the images; Metronome is 20 by 3 m) (Source: © OpenStreetMap contributors, 2024. Open Database License, ODbL v1.0); b) Control; c) Harbor and mud setup schematic representations (Source: Authors, 2025).

Tweestromenland plan, was documented in over 10,000 tidal cycles by frequently repeated overhead photography and less frequent dry-bed laser scanning.[5]

The experiments showed net sedimentation in the upstream reach of the channel and erosion in the seaward half (fig. 4). In the experiment, the erosion occurred because the channel was not over-deepened initially as in the Nieuwe Waterweg. The experiment with the harbors without mud showed more downstream erosion and upstream sedimentation than the control experiment because the harbors increased the tidal prism. The experiment with mud, on the other hand, showed more sedimentation upstream and less erosion downstream, but otherwise showed similar patterns and trends. In both experiments with the harbors, net sedimentation took place in the harbors, especially with mud (fig. 5). This demonstrates that the harbors function as efficient sediment traps.

Fig. 4A and B, laser scans with initial bed level subtracted, showing siltation in the upstream half in the control and in the experiment with harbors; C and D, overhead images of the experiment with harbors and mud showing continuous sedimentation in the upstream half of the system.

5. The overhead images, laser scans and movies are available here: https://doi.org/10.24416/UU01-T9W1M2. The methods of photogrammetry and projection mathematics are given here: https://doi.org/10.24416/UU01-SGM22N.



^ Fig. 5 A and B, laser scans with initial bed level subtracted, showing siltation in the upstream half in the control and in the experiment with harbors; C and D, overhead images of the experiment with harbors and mud showing continuous sedimentation in the upstream half of the system (Source: Authors, 2025).[6]

In the Nieuwe Waterweg, landward sedimentation is expected to commence when dredging ceases. The tidal amplitude in the upstream part of the system was reduced in the experiments. In reality, the depth reduction would reduce the landward salinity intrusion. As the natural pre-urbanization depth of the upstream river was about 5 m (width-averaged) (Cox et al. 2022b), ships for inland navigation, adapted to long periods of reduced discharge, will remain unhindered while seagoing vessels would navigate through the Caland canal to the seaward ports, the Europoort and the Tweede Maasvlakte. The harbors trapped a lot of mud and formed new supratidal land, which could be used for nature development, recreation

6. Movies and data are available on https://doi.org/10.24416/UU01-T9W1M2.

and housing. At present, such new land must be created by sediment disposal as in a pilot planned in the expired Rijnhaven.[7] The sediment budget for the lower Rhine and Meuse Rivers indicates that without dredging, the sedimentation rate would be 0.1–0.15 m per year (Cox et al. 2021). Although this estimate spans a wide range, it implies that shallowing from 16 to 5 m would take roughly a century. This timescale coincides with projections of significant sea-level rise of 1–2 m (van Alphen et al. 2022) as well as with the energy transition and port transitions required to address the causes and effects of the climate crisis (Notteboom et al. 2022; Van der Lugt et al. 2025).

Acknowledgment
This contribution was peer-reviewed. It was edited by members of the editorial team of the UNESCO Chair Water, Ports and Historic Cities: Michele Tenzon.

Useful Links
https://www.proeftuinsediment.nl/

7. https://www.rotterdam.nl/rijnhaven.

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