BLUE PAPERS

Water & Heritage for Sustainable Development

ANCIENT HYDRO-TECHNOLOGIES

Carola Hein, Zuzanna Sliwinska & Matteo D'Agostino

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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 adapt to 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 are 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
- Integrated discourses and practices

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

- 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.

Blue Papers journal also publishes special issues focused on select themes or locations. This issue on ancient hydro-technologies is the first in a series of such themed editions. It brings together contributions on ancient hydro-technologies that were originally published in various issues of the *Blue Papers* journal. Each article must be cited individually, referencing the specific journal issue in which it was originally published.

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COVER IMAGE: Twin Hearts Stone Weir. Qimei, Penghu, Taiwan（雙心石滬, 七美, 澎湖）天鵝現身(Source: okman450, 2014. Wikiemedia Commons, CC BY-SA 2.0).

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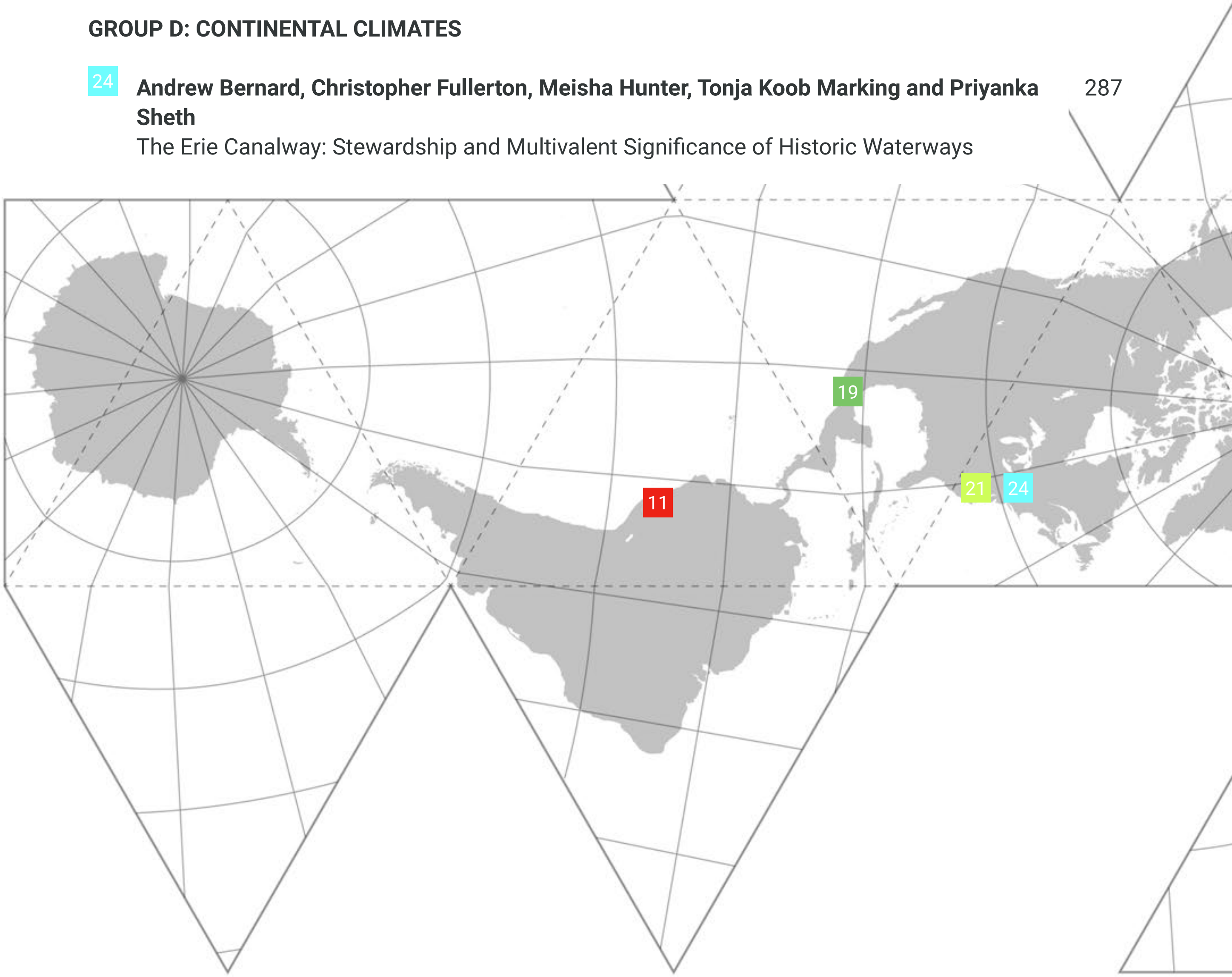
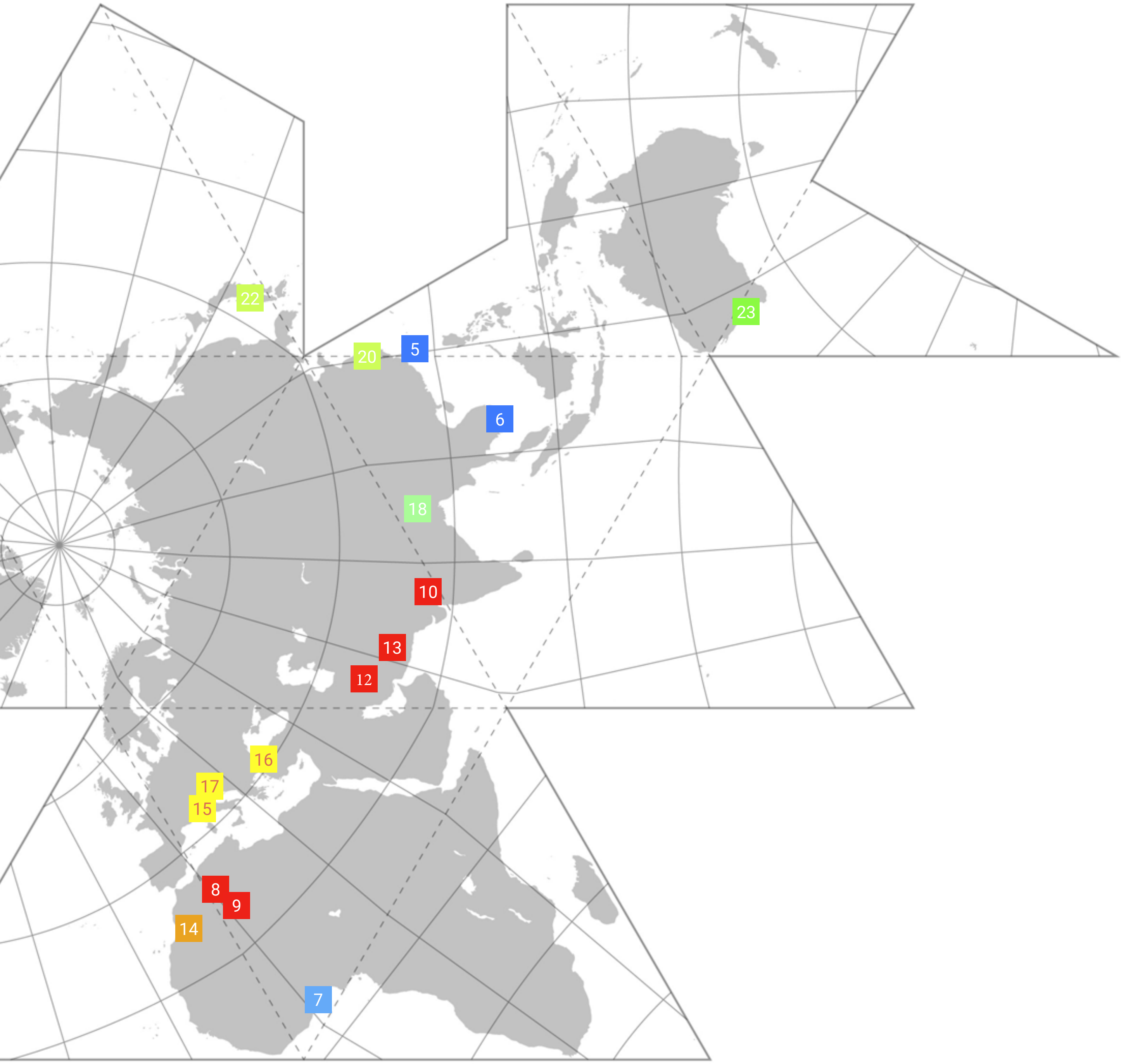
Content



** The contributions featured in this compilation issue were organized according to the standard Köppen climate classification system.*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Preface
Bridging Knowledge Gaps Through Ancient Hydro-Technologies

Rogerio Rosso
Director of the Regulatory Agency for Water, Energy and Basic Sanitation of the Federal District - ADASA (Brazil) and Coordinator of the International Water Memorial Project - MINA

As humanity becomes aware of the impacts of climate change and mobilizes to address the inescapable challenges of increasing resource scarcity and of protecting the planet from the damage caused by human activities, innovation becomes a key tool for rethinking our lifestyles and consumption models – that is, the organization of our societies. If it is true at the global level that water crises will inevitably escalate in coming decades, the kind of innovation that we adopt must consider future generations. Our goal should be to leave them an environment that respects biological diversity and ecosystems – where all forms of life coexist in natural balance – thereby ensuring a healthy environment for human communities as well.

If, then, the innovative approach is absolutely fundamental to overcoming a water and climate crisis that is unprecedented in human history, why not also consider what sustainability lessons we can learn from the development models that have preceded us, with a view also to learning from mistakes that have been made? Why not take a look, then, at those traditional knowledge and water management systems that we have often been so quick to relegate to the past - but which are actually the result of extraordinary social, cultural and technological innovations?

On closer inspection, in fact, these are solutions that have been "tested" over centuries and whose sustainability has been witnessed by countless generations residing in the most diverse ecosystem on earth. The uncritical application of new technologies risks the extinction of contemporary ways of life and social organizations that, by their very nature, are ecological and deeply respectful of nature. These are practices inherited from the past that we should take as models for rethinking our future systems of production and resource use.

Here, then, is where this thematic issue of *Blue Papers* dedicated to AHTs proves to be of fundamental help in rethinking current development models. The various contributions included here show concrete historical cases that can inspire new solutions based certainly on innovative technologies but anchored, at the same time, in that wise hydro-vision of centuries-old social practices of water management. These are practices that demonstrate a forward-looking coexistence with the ecosystems on which life depends – an important basis of a healthy and clean environment.

Blue Papers: Ancient Hydro-Technologies
pp. 1–2; 10.58981/bluepapers.AHTs.pref

Preface

ADASA is convinced that this is the right approach and it is with this in mind that we are working to realize our MINA Water Memorial project in Brasilia – a water museum that adheres to the UNESCO-IHP principles implemented by the Global Network of Water Museums. In this water museum, we intend to create a state-of-the-art exhibition space to give voice to management models based on ancient hydro-technologies. Indeed, museums represent a powerful medium of science communication, capable of translating complex scientific concepts into compelling narratives that resonate with audiences.

Such an exhibition on ancient hydro-technologies will showcase concrete examples as a platform for dialogue, discussion and sharing among government agencies, civil society, environmental associations and business to build a more just and equitable future.

In this spirit, ADASA intends to continue its efforts, also through MINA, for fostering holistic and multidisciplinary reflections for action that rely on forward-looking sources of knowledge for integrated governance of water and heritage.

Editorial
Ancient Hydro-Technologies

Carola Hein, Zuzanna Sliwinska and Matteo D'Agostino

This special themed issue of *Blue Papers* brings together twenty-four articles on ancient hydro-technologies (AHTs) originally published in the first seven issues of the journal (https://bluepapers.nl/). Together with our partners from the Global Network of Water Museums, a flagship initiative of UNESCO-IHP, we selected key articles that explore the functionality of ancient hydro-technologies in their historical context and their relevance in addressing contemporary water challenges. This special issue is the first in a series of thematic compilations from *Blue Papers*. It reflects the journal's commitment to establishing a platform for contributions that tackle urgent issues and present innovative solutions, ultimately leading to policy recommendations.

Climate and energy are key factors in shaping water management. From tropical climates to deserts, temperate zones to continental areas, mountains to oceans, a diverse range of hydro-technologies speaks to humankind's ingenuity. Over centuries, people developed a multitude of solutions to facilitate living in diverse climate zones. These systems were locally integrated and tailored to specific natural conditions and people's lifestyles. They were part of ecosystemic approaches that linked water to human survival for both individuals and societies, aligning with societal values and natural cycles (Hein 2022). Good water management has been key to human longevity and societal well-being.

Today, we face a new set of challenges as we attempt to manage water amid climate change: retention lakes are drying up, dams require constant dredging due to debris buildup and increasingly erratic rainfall patterns render agriculture more unpredictable. In response, we engineer energy-intensive solutions that work against nature—such as higher dikes, sprawling desalination plants and megaprojects like the MOSE flood barrier system in Venice. The latter epitomizes the double-edged nature of technological interventions. While MOSE has prevented 31 major floods since 2020, its ecological impacts reveal systemic trade-offs, including sediment starvation, water stagnation and climate lock-in (Moraca 2024).

Energy-intensive technologies, detached from ecological processes, often result in the depletion of vital resources such as aquifers, the loss of fertile soil from irregular flooding, and the accumulation of waste. Natural aquifers are no longer replenished and floods are no longer valued for the nourishment they bring to the soils. Despite technological advances, children and women in some parts of the world still spend hours fetching clean water –sacrificing education, work and leisure opportunities. The universal need for clean water remains a significant challenge, with two billion people lacking safe drinking water globally (UNESCO 2023). These unintended consequences stem from a fundamental disconnect between human systems and natural processes.

Editorial

This themed issue of Blue Papers opens with an introduction by Eriberto Eulisse, executive director of the Global Network of Water Museums, who highlights the urgent need to revitalize AHTs to address contemporary water challenges and reconnect communities with their cultural and environmental heritage. The introduction is followed by the contribution "Exhibition Highlights: The Voices of Water," which features excerpts from the display presented at the 10th World Water Forum in Bali, Indonesia, on AHTs.

The articles included in this themed issue are grouped following the Köppen Climate Classification, which divides Earth's climates into five main climate groups: A (tropical), B (arid), C (temperate), D (continental) and E (polar). This classification provides insights into how people have responded to diverse climates and allows initial insights into how humans have addressed challenges like drought and seasonal flooding in diverse climate regions by developing new technologies and water functions. Societies worldwide have developed water management systems tailored to their specific environments and climatic conditions, addressing needs like drinking water and irrigation while mitigating challenges such as floods (Jordi Morato, Vol. 4 No 1 [2025]). Traditional practices and intangible cultural heritage connected with AHTs provide valuable knowledge on climate-robust landscapes and on the capacity of communities to maintain – or revive – these techniques (Jet Bakels and Chantal Bisschop, Vol. 2 No. 2 [2023]).

Fresh water delivery to settlements is necessary for survival in all environments. This special issue includes the example of the oasis of Figuig, with a millennia-old traditional hydraulic sourcing and distribution network and communal governance of the scarce resource for multiple water functions, including drinking, bathing and irrigation (Ouafa Messous, Vol. 3 No. 2 [2024]). Lessons from this case study include the need for careful management of transitions of historical water governance and modern technologies in line with societal objectives and sustainable water management. Underground water provision structures, such as the *qanat* that emerged on the Persian plateau and spread globally (Vladimiro Boselli, Vol. 7 No 1 [2025] are linked to diverse natural and technical interventions from water reservoirs and mills to gardens and floodways (Massoud Ghaderian, Vol. 1 No. 1 [2022]). Water management systems like the *khettarat* that have served Marrakesh until the 1990s (Cristiana Strava, Vol. 3 No. 1 [2024]) demonstrate the importance of connecting sociocultural values and technical aspects for sustainable development.

Aquaculture practices have traditionally been connected to ecosystem preservation rather than exploitation. Fish and eel trapping systems used in Australia developed with specific governance structures and cultural practices to maintain them. These sophisticated technologies are inspirational for the future and Indigenous people's knowledge can help these practices thrive and sustain their communities (Katherine A. Daniell and Bradley Moggridge, Vol. 3 No. 1 [2024]). Traditional knowledge holders and communal knowledge can help advance the wise use of wetlands in line with the Ramsar Convention, as the example from the Keta Lagoon shows (Jonathan B. Doe, Vol. 1 No. 2 [2022]). Stone weirs used in coastal and intertidal zones were traditionally used for fishing and as spawning grounds and are models of traditional resource management (Akifumi Iwabuchi, Vol. 1 No. 1 [2022]).

Climate change, even a few centimeters of sea level rise, and stronger storms damage the traditional heritage, destroying its physical structures and the intangible practices associated with them. However, along the northeast Italian coastline, Venetians combined aquaculture with lagoon and seawater management beginning in the fourteenth century; today, questions of ownership, governance of the space between sea and land, ecological decline and sea level rise call for new strategies of living with water and fish farming under changing landscape conditions (Lucia Cipriani and Alessandro Destro, Vol. 2 No. 2 [2023]).

Irrigation for agriculture has been key to the development of many traditional societies. Floating gardens, so-called Chinampas, have been used for agriculture and sustainable water management in Mexico City since 200 BC and can inspire much-needed circular practices (Catalina Rey-Hernández and Inge Bobbink, Vol. 1 No. 2 [2022]). Revisiting historical practices such as traditional Khmer cultivation practices, which included diverse types of water provision through terraces and wells in line with the seasonal availability of water and the Mekong flood region, provides insights into living with changing water systems through various seasonal and daily practices (Vu Thi Phuong Linh, Bruno De Meulder and Kelly Shannon, Vol. 3 No. 2 [2024]). Underground weirs have also been used as a sustainable irrigation method, for example, in the Erfeng system in Taiwan. However, increased urbanization, pollution and the construction of canals have impeded the quality of this unique system (Szu-Ling Lin and Cheh-Shyh Ting, Vol. 2 No. 2 [2023]). The ancient irrigation canals of Lima, a model of watershed management and human ingenuity, have been heavily impacted by uncontrolled urbanization, causing unequal water access and loss of traditional knowledge; they have since become the focus of preservation activities and storytelling (Javier Lizarzaburu, Vol. 1 No. 2 [2022]).

Floods have always posed challenges to human life; they have also played a vital role in enriching the soil, and their waters have been harnessed and stored for use during dry periods. Instead of viewing floods as a nuisance or addressing them by constructing ever-higher dykes or diverting rivers to manage them, many traditional societies have developed constructive methods for utilizing and controlling them, as seen in examples from the M'Zab Valley in Algeria (Saïd Madani, Vol. 1 No. 2 [2022]) and Pakistan (Karim Nawaz, Vol. 1 No. 2 [2022]). The *khadeen* of Rajasthan in India represents another example of technology used to capture seasonal runoff for agriculture in a water-scarce environment (Pierantonio La Vena and Bhatta Ram, Vol. 3 No. 2 [2024]).

Historically, people have lived with changing water systems, establishing settlements and cities at the intersection of land and water while adapting to particular conditions, often integrating multiple water functions. Several examples in this special issue speak to humans' ability to adapt. *Chars*, or shifting riverine islands, provide yet another example of intangible practices vital to ecological systems and local livelihoods that make it possible for people to live in porous systems between water and land (Swagata Das, Kelly Shannon and Bruno De Meulder, Vol. 3 No. 2 [2024]). Similarly, the weitian (polder) system in the Yangtze River Delta, with its water towns, represents a particular form of water urbanism, integrating agriculture and human settlements (Wei Lei, Kelly Shannon and Bruno De Meulder, Vol. 3 No. 2 [2024]). While no longer in use, the water-harvesting system of cave village Sassi di Matera in Italy provides another example of capturing, channeling and storing water in an arid climate and of ancient structures that are being repurposed in line with contemporary needs and values (Inge Bobbink, Wenting Gao and Isabella Banfi, Vol. 2 No. 2 [2023]).

Transportation has also generated numerous innovative water management practices. The Erie Canal in the USA, once the gateway to New York, is an inspiring model of repurposing from transportation infrastructure to a historic, cultural and recreational corridor (Andrew Bernard, Christopher Fullerton, Meisha Hunter, Tonja Koob Marking and Priyanka Sheth, Vol. 2 No. 1 [2023]).

Historic water systems, even ones that are no longer in use, can inspire people to engage in more sustainable water practices while finding new uses that help preserve the heritage. The Valens Aqueduct, which has crossed Istanbul since Roman times to deliver fresh water, is no longer in use as a water delivery system. Yet, the structure remains a source of identity for citizens and can continue to inspire. The authors of the article included here, therefore, developed a project that proposes art installations, heritage walks and local community activities to reactivate the structure (Mariëtte Verhoeven, Fokke Gerritsen, Özgün Özçakır and Aysel Arslan, Vol. 2 No. 1 [2023]). Preservation and reactivation of former water infrastructure is also at the heart of the preservation of the Fairmount Water Works, a neo-classical ensemble housing a steam-powered engine (1815) built to pump water from the Schuylkill River to an elevated location from which the water could be fed by gravity to the city of Philadelphia. The site now serves as an education site for the Philadelphia Water Department (Joanne Dahme, Claire Donato, Victoria Prizzia, Ellen F. Schultz, Theresa R. Stuhlman and Karen Young, Vol. 1 No. 1 [2022]). It is not only water heritage structures that are under threat from changing water systems; in fact, all heritage sites are challenged by changing water systems, emphasizing the need to include water management plans for heritage sites in general and World Heritage properties in particular (Tino Mager, Vol. 3 No. 2 [2024]).

The examples of AHTs—systems once deeply embedded in ecosystems and aligned with natural cycles and societal values—included in this issue highlight the importance of reviving locally rooted practices that prioritize cultural heritage and environmental regeneration. The articles presented here provide but a glimpse of the opportunities and inspiration offered by traditional systems, some of which are included in issues of *Blue Papers*. Ultimately, this special issue calls for a renewed commitment to holistic, nature-aligned water management to ensure a sustainable future for communities worldwide.

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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. 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: *Port City Atlas* (2023), *Oil Spaces* (2021), *Urbanisation of the Sea* (2020), *Adaptive Strategies for Water Heritage* (2020), *The Routledge Planning History Handbook* (2018), *Port Cities: Dynamic Landscapes and Global Networks* (2011). Carola is also the leader of the PortCityFutures research group.

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Zuzanna Sliwinska is an independent researcher with a degree in architecture and urban planning from Delft University of Technology (MSc, cum laude) and Westminster University, London (BA). As an editor of *Blue Papers*, featured at the 2023 UN Water Conference, she investigates the interplay between water, culture, and heritage to inform sustainable water systems. She is also managing editor of a special issue on *Water Management in World Heritage Sites at a Time of Climate Change*. Her research explores the interdependencies between human cultural systems and natural ecosystems, focusing on resilience-building through historical adaptations with examples in Hong Kong and French wetlands. She examines how to protect the physical elements of heritage while supporting communities under dynamic change, including climate change.

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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 strategic reinterpretation of heritage by institutional and activist organisations.

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Editorial Team

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pp. 10–12; 10.58981/bluepapers.AHTs.wcht

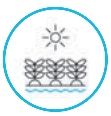
Capturing Water, Culture and Heritage through Icons: A First Attempt

Carola Hein, Matteo D'Agostino, Carlien Donkor, Queenie Lin and Hilde Sennema

Humans have engaged with water in multiple ways, creating physical structures – such as buildings, cities, infrastructures and landscapes – and sociocultural manifestations – for example, institutions, laws, artistic practices and rituals. They have transformed natural settings in keeping with climate and energy conditions. To understand the diverse conditions of water spaces and heritage, we have created a set of icons to categorize tangible and intangible objects and practices related to water. The icons help us identify different scales, functions and forms of water management-related heritage objects, as well as generic water-related structures. The categories identified are suggestions and not conclusive or mutually exclusive.

Tangible

Drinking
A key function of water management is the provision of freshwater and access to potable water; infrastructures and techniques to store, pump, redistribute and use drinking water.



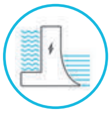
Agriculture and Irrigation
Numerous strategies and technologies exist to channel and exploit water resources for food production, including the irrigation of agricultural land and livestock watering.

Drainage and Sewage
The removal of excess water and sewage water – e.g., rainwater and excess surface runoff, and wastewater (black and gray water) – requires extensive infrastructure and cleaning systems.

Food from Water Bodies
Natural and artificial water bodies - including seas, rivers, lakes and ponds - are home to plants and animals and are a source of food, obtained through traditional and industrial fishing techniques as well as aquaculture.

Shelter and Defense
Humans have built shelters to protect themselves from harsh climatic elements (rain, snow, etc.), through architectural and urban forms. They have also made structures to defend themselves from and through water, such as dikes, dams, moats and fortification walls.

Health
Clean water is key to human well-being. Water quality is important for individual and public health. The pollution of water bodies through biological and chemical agents has notably influenced the development of spatial planning.



Energy/Industry
Water is used in industrial processes, e.g., for cooling down machinery, in mining activities and breweries; it is exploited for energy production, such as hydroelectric power. Energy is also key to controlling water and is used to generate energy.

Transport
Water bodies – seas, rivers and canals – are key to transporting people and goods for everyday mobility, tourism and commercial purposes. Specific infrastructures exist to transport people and goods from sea to land and vice versa (e.g., quays, cranes), and for storage (e.g., warehouses).

Places of Leisure
Water bodies, natural or manmade, in cities and landscapes serve leisure practices in multiple ways (e.g., waterfronts, water parks, rivers, swimming pools).

Places of Worship
Humans have created religious spaces for revering water and they may use water to express reverence for or connection with a spirit or deity. Structures such as churches and temples contain elements related to water, or can be part of the management of water resources.

Intangible

Daily Water Practices
Water is part of everyday practices, including drinking, bathing, washing and cooking.

Recreation
Recreational practices use water bodies, natural and artificial. These practices include water sports as well as spending time by the sea.

Rites and Rituals
Water is part of religious and spiritual practices all over the world, including those of major world religions. It is often associated with purification, and in some belief systems, it is revered as a source of all life.

Language/Idioms
Idioms, proverbs and sayings that concern water and water-related societal wisdom and ancestral knowledge.

Laws and Policies
Water management, access, and use have long been regulated through governmental policies and customary laws. Water politics affect and are affected by social, cultural and economic dynamics; they can determine rights and obligations for citizens and community members.

Institutions
Water management laws and policies are often designed and enforced by institutions. These can be political (e.g., a nation-state or a chiefdom), religious or social.

Education
Socialization is key to healthy and sustainable living with water. This can occur through community members, capacity-building programs, schooling, and initiatives to exchange or transmit knowledge and to raise water awareness.

Preservation, Adaptation, Reuse
Diverse traditional and contemporary practices and actions aim at preserving or strategically changing water bodies, related ecosystems and even the social customs connected to them.

Music, Arts and Dance
Ecological knowledge is contained in local songs and other oral traditions, poems, illustrations, paintings and artistic performances that connect life stories to water.

Festivals and Ceremonies
Many special events celebrate, commemorate or inaugurate water-related structures, practices and models. This includes fishing and seasonal festivals, events organized to honor or mourn historic water-related events and ceremonies to establish/launch new water-related objects or structures.

Introduction
Special Issue on AHTs

Eriberto Eulisse
Executive Director of the Global Network of Water Museums (WAMU-NET)

Keywords: *ancient hydro-technologies, climate change, museums, water sustainability education, sustainable lifestyles and patterns*

KEY THEMES

This issue of *Blue Papers* highlights the importance of promoting and revitalizing the functionality of ancient hydro-technologies (AHTs). Rejuvenating water-related heritage is crucial to building a “new culture of water” – in contrast to the shortsighted expectations of limitless development that have characterized recent decades on a global level.

Presenting the conclusions of 1,360 specialists from 95 countries, in 2005 the United Nations Ecosystem Report stressed that human activity and global economic production have greatly abused the regenerative capacity of the planet’s aquatic ecosystems (Millennium Ecosystem Assessment Report, 2005). Humans’ impact on nature has never been as evident – or devastating – as in recent years. This is why it is important today to recover the ancient hydro-vision and wisdom of water management, which is more respectful of aquatic biodiversity and ecosystems – that is, of the limits of natural resources available. AHTs, the traditional water management practices developed by local communities, mostly in rural areas, have regulated water use for centuries based on actual natural availability.

Losing our historical memory of water’s intrinsic value always makes us more vulnerable. That is why in today’s water management it is necessary to reconsider the long-term visions that past generations have passed on to us in every corner of the planet. Unfortunately, the current paradigm of development permeating so-called developed societies has distanced people from the places – and the "sense of place" – where they live. This development paradigm has supplanted local values, which are the fruit of centuries-old practices of knowledge, "respect" for the available water quantity, and, not least, coexistence with non-human life forms. In recent decades, traditional knowledge and farsighted values supporting complex biodiversity systems have been forgotten, distorted and sometimes deliberately destroyed.

In the past, as several papers collected here demonstrate, communities played a fundamental role in managing their natural resources. This contrasts starkly with today's consumption patterns and bureaucratic patterns of water management. The right to use water no longer coincides with belonging to a place and respecting its natural balances – thus continuing to shape centuries-old landscapes that communities have maintained in harmony with nature. Despite a plethora of "green" slogans, aquatic heritages, waterscapes and biodiversity are increasingly threatened by indifference and cynicism in an era dominated by consumerism.

Water sustainability education promoted by UNESCO-IHP (Intergovernmental Hydrological Programme) through Phase 9 fully responds to the need to change perceptions of and behaviors related to ecosystems and aquatic heritages (Priority 2 of the Strategic Programme Plan, 2022–2029). Moreover, Phase 9 of the strategic plan emphasizes that "solutions to the problems of water on our planet are not just technical issues involving engineering or natural sciences, but are linked to a strong human and socio-cultural component, in which the social sciences play an increasingly important role." For the first time in the various phases of IHP, sociocultural dynamics and water-related intangible heritages are being recognized for their crucial importance in maintaining water patterns that are forward-looking and sustainable (UNESCO-IHP 2022).

In recent decades, the gradual abandonment of many AHTs at the rural level – along with massive migration to cities — is not only a matter of the functional degradation of ingenious hydraulic management systems. It also implies the loss of local community values. Economic and sociocultural changes have also strongly determined their abandonment. For this reason, traditional knowledge and intangible heritage must be promoted hand in hand with the preservation of tangible heritage. Taking care of the land and water with the active participation of its inhabitants is today a key factor in the ecological transition. It is no longer sufficient to protect, preserve and restore ancient tangible heritages that document the richness of humanity's water history and ingenious hydraulic solutions devised in different cultures. Planning their rejuvenation with the involvement of local communities and younger generations is crucial. This involvement is key to the adoption of a holistic vision in water management that can aid the recovery of the multi-functional dimension of AHTs to restore our degraded ecosystems.

Today, museums play an especially important role in protecting and regenerating the water civilization heritage managed by small-scale communities worldwide. Indeed, museums today no longer limit themselves to preserving objects within four walls – but are increasingly oriented toward building a dialogue with local communities, with the goal of pursuing land and water regeneration. This is demonstrated by the methodical approaches developed in recent years by museums, eco-museums and "extended museums" – as highlighted at the

Triennial General Conference of ICOM (International Council of Museums) held in 2016 in Milan (Garlandini 2017).

In this regard, it is worth mentioning that a Resolution adopted in 2018 by the UNESCO-IHP Intergovernmental Council gave museums a key role in stimulating education that encourages more sustainable uses of water (UNESCO-IHP 2018). This recognition gives museums and interpretation centers not only the function of protecting the historical heritage of water civilizations including AHTs but also, in the current ecological transition, of promoting their educational value to inspire new management models and, when possible, revitalizing ingenious traditional techniques of water control in cooperation with local communities. This means promoting the crucial relationship between individuals, communities and water as the essential cornerstone of any educational water program: that is, the harmonious development of societies, which has always gone hand in hand with respect for aquatic ecosystems and preservation of biodiversity. With their exhibitions, museums, eco-museums and water-related interpretation centers have an enormous potential to promote new perceptions and attitudes toward water, making use of paradigmatic examples of AHTs.

To emphasize this pedagogical potential, the Global Network of Water Museums (WAMU-NET) created the multi-channel video installation "The Voices of Water" as part of the 10th World Water Forum in Bali (2024). The team of curators who created the video installation deliberately emphasized the emotional dimension of ancient community values, know-how and techniques – as well as data and information relating to their functionality. In fact, only a skilful combination of different languages related to emotional and informational aspects can significantly change people's perceptions and behavior. As such, the video installation promoted AHTs as new possible development models for an ecological transition in rural areas worldwide.

The attached exhibition highlights, "The Voices of Water," illustrates the eight case studies that made up WAMU-NET's video installation hosted at the 10th World Water Forum by the Italian Agency for Development Cooperation. The "immersive" installation, made up of five synchronized screens, aimed at sensitizing visitors and high-level decision-makers regarding the need to promote, through AHTs, greater respect for the functionality of aquatic ecosystems and to reconsider obsolete development policies. Among the distinguished guests who visited were water ministers from various countries who, in various capacities, confirmed interest in developing new activities on this topic in cooperation with WAMU-NET. These include the establishment of an international monitoring platform on AHTs, the creation of a network of desert oasis eco-museums, the WAMU-NET contribution to the forthcoming Virtual Science Museum of UNESCO, and the launch of a Water Film Prize on AHTs and arid lands, "Back to Our Future."

By addressing a wide audience, museums can help people understand how the more forward-looking water management practices of the past are better suited to encourage long-term perspectives. They can effectively address today's challenges and solutions to adapt to climate change. In an era of ever-increasing complexities in water management, with ever more extreme levels of scarcity and overabundance, museums can help change not only inadequate perceptions, but also obsolete policies and management models. Museums are in a privileged position to promote key messages and offer both formal and informal educational activities. This perspective is in line with key aspects of IHP Phase 9, which include improving critical issues related to river and groundwater management to prevent further pollution and stimulating new interdisciplinary approaches for more sustainable governance.

Over the past few years, with Professor Carola Hein and her team from the UNESCO Chair at the Leiden-Delft-Erasmus University consortium, we have committed to sharing diverse methodological approaches and research perspectives on this issue. A key effort has been the creation of a taxonomy for the inventory of water museums and heritage sites in line with UNESCO-IHP Resolution no.7-XXIV. We designed the taxonomy with a view to identifying and promoting hydraulic heritages that extend across a large territory and risk, as such, being invisible or even deleted from mappings – thus, disappearing from both cartography and people's perceptions. This is what has happened with AHTs in recent decades. It has happened despite the benefits of adopting and supporting AHTs becoming increasingly evident, especially since they help lower our consumption of material and energy resources. For this reason, a specific category was dedicated to AHTs when we developed the taxonomy of WAMU-NET's World Inventory.

Today mapping AHTs and making them visible again on maps is a key challenge. In fact, how can one appreciate that which is unknown, invisible or non-existent in maps? This is the starting point for mapping AHTs on a global scale and attempting to rescue them from oblivion. It is also a challenge that the WAMU-NET network proposes to tackle in cooperation with the UNESCO Chairs of Delft, Barcelona, Strasbourg, Trento and Montevideo, since all of them are committed to supporting new strategic approaches to investigating and promoting AHTs.

The knowledge, solidarity mechanisms and collective values that emerge in this thematic issue of *Blue Papers* persuade us that we can emerge victoriously from the harsh trials of climate change – but only with a vision to our future that is marked by long-term sustainability, even at the expense of certain biased economic interests. There is therefore a need to adopt a vision that can no longer disregard AHTs and instead can identify new holistic approaches, on a case-by-case basis, for water management in rural areas. In this perspective, we need to combine innovative technologies with the farsighted visions and practices of those who have gone before us – communities that implemented efficient and practical solutions while developing unique water-related landscapes and a powerful sense of place, or liquid “genius loci.”

This thematic issue turns our attention to ancient knowledge and values that have generated sustainable water management models that have strongly nurtured biodiversity. We can use these as a reference to devise a new educational paradigm that emphasizes a holistic approach to water management and can help us build a future that is more fair, equitable and suitable for all living beings. The hope is that this anthology is not so much a point of arrival, but a starting point for further beneficial interactions across fields of research, politics and governance without further excluding local communities and young people from the future they are seeking.

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The Voices of Water: Featured Video Installation to Promote Ancient Hydro-Technologies at the 10th World Water Forum (Indonesia)

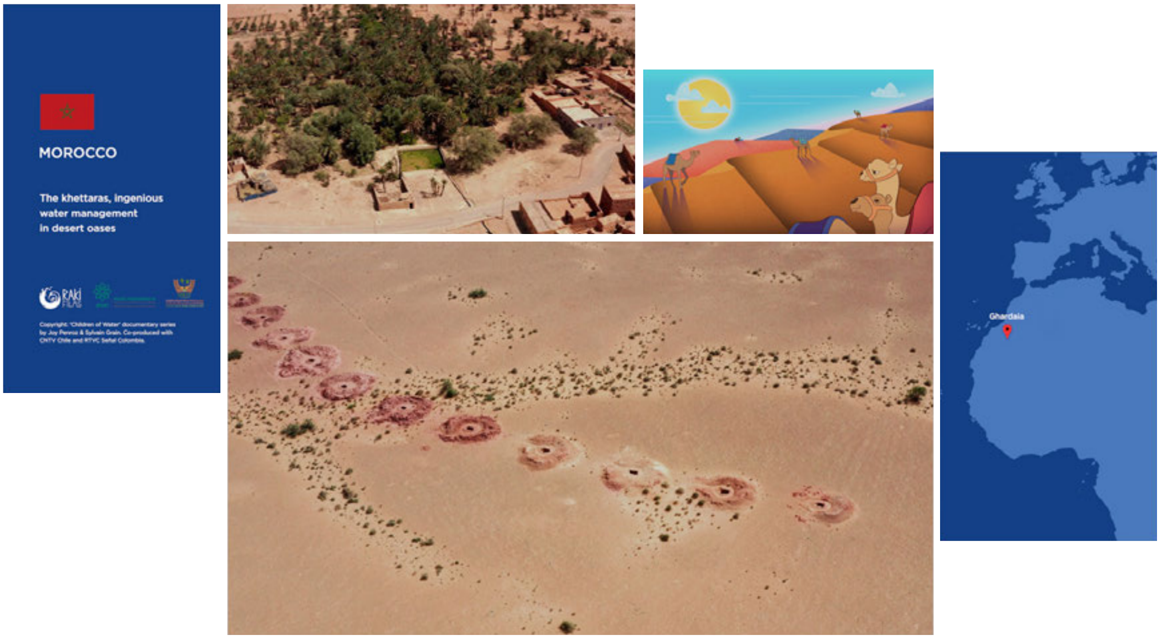
Eriberto Eulisse
Executive Director of the Global Network of Water Museums (WAMU-NET)

KEY THEMES

How can we improve water management by drawing inspiration from ancient knowledge and practices still in use in rural communities around the world? How can new solutions for integrated water management based on ancient knowledge provide an alternative to the most advanced technologies, which are often too expensive and environmentally detrimental? To answer these questions, the Global Network of Water Museums (WAMU-NET) contributed to the 10th World Water Forum (WWF) with "The Voices of Water," a multi-channel video installation on ancient hydro-technologies (AHTs) inaugurated in Bali in 2024. Selected case studies featured an "immersive" exhibition equipped with several synchronized screens to show how AHT practices and knowledge can inspire sustainable water management.

The installation's eight case studies offered examples from various parts of the world and stimulated a strong emotional reaction in visitors. A combination of emotional and informative language was used to convey the value and the multidimensionality of ancient water cultures. "The Voices of Water" sensitized policy and decision makers, stakeholders and the general public on the need to take a long-term perspective and reincorporate an invaluable

Exhibition Highlights



^ Fig. 1 The multi-channel video installation created for the 10th WWF consisted of five synchronized screens for a length of approx. 2’ for each of the eight case studies (total length: 18’). The ‘immersive’ experience shaped in an original way by Giuseppe La Spada, WAMU-NET’s art director, included (from top to bottom, from left to right) the following five screens: a screen with fixed indication of the title of each case study and its credits; a screen with a series of significant photographs in sequence; a screen with the sequence of the various drawings specially commissioned from professional drawers; a main screen, with audio, that combined video interviews with a series of short video sequences provided by local project partners; and, finally, a screen with geographical indication of each case study on a world map (Source: Eriberto Eulisse).

wealth of knowledge and practices in managing increasingly limited resources. It is only possible to restore aquatic ecosystems and nurture biodiversity if efforts are compatible with the productive activities of local communities that have inherited a sense of the limits imposed by local cycles of nature.

Inspiring case studies included examples of AHTs from Morocco, Algeria, Iraq, Ghana, Indonesia, Australia, Peru and Brazil. Videos devoted to each case lasted approximately two minutes and all were cleverly combined in the multi-channel installation, which consisted of five synchronized screens showing sequences of drawings and photos, for a total duration of twenty-one minutes.

Curated by WAMU-NET director Eriberto Eulisse and the video artist Giuseppe La Spada, the exhibition was developed to contribute to Phase 9 of IHP (Intergovernmental Hydrological Programme), with a specific emphasis on water sustainability education. Visitors who were able to see this meaningful combination of videos, interviews, drawings and images could appreciate the wisdom of ancient water management practices. Benefits of adopting and supporting these AHTs include significantly lowering the consumption of material and energy resources. Indeed, AHTs can help achieve the SDGs more effectively than approaches based solely on energy-intensive hydraulic technologies and large infrastructures, which alter ecosystems and often have negative environmental impacts.

Museums' Role in Promoting AHTs for Water Sustainability Education

Promoting knowledge of AHT through museums and exhibitions can help shape water policies and raise awareness in a way that is accessible to a wide audience, including young people. "The Voices of Water" was conceived as a tool available to institutions interested in strengthening water sustainability education activities promoted by UNESCO-IHP in Phase 9. Such advocacy for AHTs, is linked to the intergenerational flow of knowledge in many cultures around the world, which today, unfortunately, has often been disrupted.

Museums can facilitate a better understanding of the intrinsic values of ancient water cultures and related management models. These models and practices are locally inspired by perceptions and awareness of the value of water – understood as a limited, fragile and vulnerable resource according to beliefs and practices imbued with a special "genius loci" which is inextricably linked to the liquid element. Through educational activities, exhibitions and displays, museums can help change wrong perceptions of water and its management. Museums can also help stimulate the development of a more sustainable governance of the resource in the long term.

Museums exert a special attraction and are widely considered a reliable source of scientific information. Indeed, many people prefer to learn about scientific topics not in classrooms or from the media, but through personal interactions in informal settings, such as those offered by museums (Sforzi et al. 2018). Exhibitions and installations provide interactive spaces and can offer "experiential" learning opportunities that convey important concepts related to global challenges.

Museums offer creative spaces where adults and children can experience awe and wonder and can learn while enjoying themselves. In fact, museums are accustomed to dealing with complex scientific information and communicating it effectively through formal, informal and non-formal education. In this way, water museums can help pave the way for paradigm shifts and future resilience planning. They can promote better understanding of the extreme fragility of the biosphere and the limits of our present development models.

Algeria: Methods of Capturing and Using Flash Flood Waters in the M'Zab Valley

A case from Algeria, included in the installation *The Voices of Water*, is an example of a circular and sustainable economy that is crucial today for the ecological transition of rural communities globally. This is a model that contrasts sharply with the predatory water use that is typical of advanced capitalism: a development paradigm that has caused the destruction of biodiversity and ecosystems carefully built by local communities over the centuries. This is what has happened in some of the world's most extreme environments, such as the Sahara Desert, where water is a key resource.

The M'Zab Valley became a UNESCO World Heritage Site in 1982. Beginning in the year AD 1000, pioneers of the Ibadite faith (a sect of Islam) settled in the desert regions along a wadi, the bed of a seasonal watercourse, and built five fortified cities (*ksour*). To exploit scarce water resources, they learned to capture surface water from the oasis hydrological cycle (three flash floods per year in a semi-desert environment), diverting it into local circuits for human use. Globally, this was once a common practice that uses ingenious hydraulic structures for transport, such as the *seguia* (a system of underground tunnels for transporting water by irrigation canals). Surface water is stored in the aquifer by means of small dams and catchment wells. The stored resource is then shared among members of the community, following a strict protocol of rights and duties regarding the use of water. Wells with stored groundwater are shared by users whose rights depend on their involvement in the maintenance of the oasis hydraulic cycle (Saidani et al. 2022).

The irrigation system, the care of the oasis and the resolution of conflicts over water and land use were overseen by ancient institutions acting under the responsibility of the *Umana El Sayel* (water governing body) and subject to the authority of the mosque, which ensured the widest distribution without discrimination. The management of the oasis's "closed cycle" includes not only water, but also the recycling of animal dung used as fertilizer or compost, the recovery of composted human excrement and crop residues, such as firewood or palm trees used in building, and agricultural by-products, such as cattle feed (Saidani et al. 2022).

Beginning in the 1980s, industrial farming developed in the Algerian Sahara, involving the exploitation of groundwater and the heavy use of chemicals by non-local farmers. The Indigenous farmers, aware that the new agriculture would be incompatible with their systems, decided to develop an alternative agricultural model, combining ancestral practices with modern technology. They applied permaculture and a form of agroecology (as an alternative to the intensive use of chemicals), combined with low-water-consumption irrigation techniques, such as saffron and olive trees, and groundwater replenishment techniques. The oasis farmers, like their ancestors, respect the fragile balance between human needs and nature (Saidani et al. 2022).

Eventually, conflicts developed over the sharing of water between the new farmers, upstream, and those of the traditional oases, downstream. These represent two oasis management models that foreshadow, at first glance, an unsustainable battle. In fact, the new farmers today have priority access to water, while the old palm groves downstream, although weakened by depopulation, urbanization and land fragmentation, still manage to demonstrate farsighted sustainability in managing what remains of the ancient oasis. Their model is more sustainable than more recent agricultural practices (Saidani et al. 2022). In contrast to these, which rely on state subsidies, the traditional management practices of the ancient oasis involve a circular irrigation system – a use of water that considers the inherent limits of local ecosystems. Ancestral water management practices like these prove particularly useful in countering desertification, the impacts of climate change and the disappearance of Algeria's last historical oases.

AHTs at the Center of Local Development

Other cases in the exhibition include agricultural and irrigation techniques from Morocco, Indonesia and Peru, as well as the construction of traditional wooden boats from Iraq and Brazil, pile dwellings from Ghana and water conservation systems from Australia. These confirm the crucial importance of putting AHTs at the center of local development (UNCCD 2005; Lictevout et al. 2020; Tickner et al. 2020; Saidani et al. 2022; Jódar et al. 2022). Although none of these techniques are universally applicable, neither can they be repeatedly ignored or underestimated by the discourse on the ambitious goals of the 2030 Agenda.

"The Voices of Water" provides inspiring models that water museums and interpretation centers can use to promote a new "culture of water." This is a revolutionary educational perspective on how the current development paradigm, hinged on an exaltation of unlimited consumption of the planet's resources and unlimited growth, can be redeemed. In fact, in just a few decades, this paradigm of "development" has erased and destroyed the rich semiotic structures of water cultures permeated by an awareness of necessary coexistence with water (Bachelard 1942; Illich 1992; Teti 2003; Franzin 2005; Eulisse et al. 2023; Strang 2023).

By promoting ancient practices imbued with a holistic vision related to water and its management, it is possible to nurture the recovery of a "sense of place" and beauty that cannot be homologated to the consumerist paradigm's trivialization of water ecosystems (Illich 1992; Teti 2003; Franzin 2005; Eulisse 2010; Latouche 2012; Serres 2018; Vallerani 2019). As Ivan Illich emphasized, H_2O is the most common way we define water today. Nonetheless, this definition also reveals an emblematic expression of the widespread ignorance of the history of water: "the chemical formula H_2O is not 'water.' H_2O is a liquid deprived of its cosmic sense and its "genius loci." H_2O is a formula opaque to dreams" (Illich 1992).

Although little known or much deteriorated, some of the ancient irrigation methods showcased in "The Voices of Water" are still practiced by many rural communities. These techniques teach us that water can and should be managed in the long run according to its natural cycle and the intrinsic limits of an ecosystem. The combination of these technologies paired with social practices and commonly used know-how that are based on long-term visions should be further analyzed, readapted and revitalized, on a case-by-case basis, to meet new needs and challenges.

Conclusion

Humanity has always coped with water scarcity and abundance. Over the centuries, communities have developed specialized knowledge, technologies and local practices to manage water for various purposes. In this way they have shaped unique waterscapes where local communities have been able to live in harmony with nature and nurture rich biodiversity.

Today, museums have the potential to change paradigmatic approaches toward water. These institutions care for some of the most outstanding water heritage worldwide: they promote both formal, informal and non-formal education that can reconnect people to values historically associated with water. At a time when modern technological innovation has shown countless advantages but also limitations, museums can help us learn from the lessons of our predecessors and harness their long term hydro-visions to foster new ways of living with nature and shape sustainable futures for humans and all living beings.

Presentation of the Case Studies Exhibited at the 10th World Water Forum

The case studies presented in the following pages were included in the video installation curated by WAMU-NET, a network which calls for abandoning the outdated paradigm of domination over nature in favor of a new paradigm of ecosystem sustainability. Indeed, ancient water cultures provide a solid ground to strengthen nature-based solutions and test innovative ideas.

In a wide variety of contexts these "natural" solutions, which are nurtured and reinforced by ancient social practices, are more effective and sustainable in the long term than the stereotyped application of the most "advanced" technologies.

Through "The Voices of Water," WAMU-NET emphasized the need to regain a holistic vision that can stimulate appropriate integrated cultural, social, economic, environmental and, not least, recreational and touristic approaches to water-related landscapes worldwide. "The Voices of Water" is constantly evolving in terms of exhibition methods and techniques. As we have experienced and tested in Bali, it will certainly stimulate greater interest, especially among young people, in water-related places, and further promote their "liquid" heritage and stories across generations.

The Global Network of Water Museums

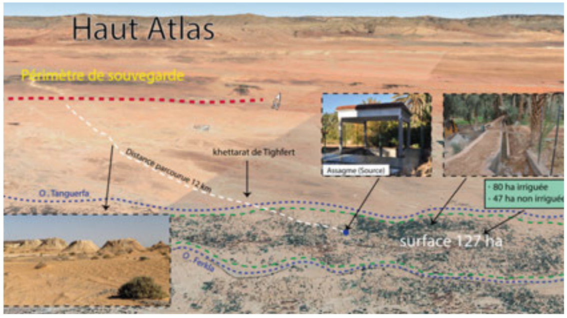
WAMU-NET is a non-profit organization aimed at changing people's attitudes and behaviors toward water. A flagship initiative of UNESCO's Intergovernmental Hydrological Programme (UNESCO-IHP), WAMU-NET aims to reconnect individuals to both natural and cultural water heritage. Through education and cooperation, WAMU-NET is committed to actively fostering a new culture of water among institutions and communities.

MORROCO | The *Khettaras*, Ingenious Water Management in Desert Oases

For centuries, oases have played a vital role within the complex network of trade routes that crossed some of the planet's driest regions. *Khettaras* (also known as *foggaras* in Algeria or qanats in Iran) are several kilometers long underground tunnels that gently draw water from geographical areas located at higher altitudes to the oases.

Water channeled through *khettaras* is suitable for all human uses but is mainly used to irrigate land through intensive agriculture, which, according to agroecological principles, combines perennial tree crops and seasonal crops in the same plot.

Desert oases stand out as highly productive anthropic ecosystems. Thanks to the farsighted use of groundwater, they not only sustain local communities but also generate a surplus of high value. If properly managed, oases are self-sufficient systems that are sustainable by definition.



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ALGERIA | Methods of Capture and Use of Flash Floods in the M’zab Valley

Desert oases represent highly productive anthropic ecosystems built by communities. Thanks to participatory methods of natural resource management, they manage to thrive through intensive agriculture with high added value. In such arid environments, water conservation from irregular rainfall and flash floods is crucial to establishing human settlements.

The M’Zab valley lies in the heart of the Sahara and is home to five *ksours* (fortified villages), founded between 1012 and 1350 AD. Over centuries, local communities have ingeniously preserved groundwater through a combination of small dams and infiltrating trenches that collect the water from flash floods.

These ingenious geoengineering techniques not only allow water capture but also preserve fertile soil - unlike recently introduced intensive agriculture, which makes unsustainable use of aquifers.

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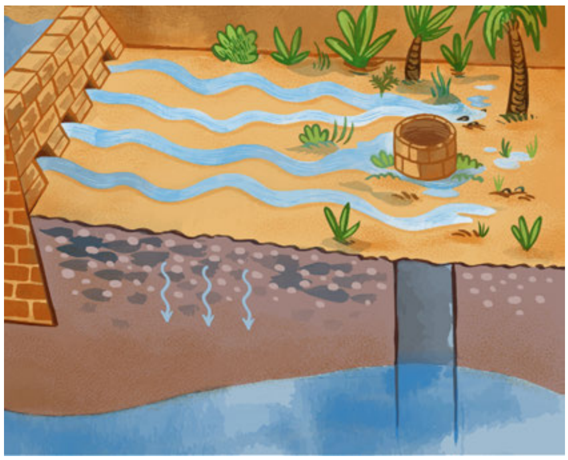

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IRAQ | Floating Architecture and Wooden Boats on the Tigris and Euphrates

Iraqi river heritage encompasses rich craftsmanship, thriving ecosystems, and unique ways of living in harmony with nature. Traditional wooden boats are not only the key to a harmonious relationship with water but also a sustainable means of transport.

Near the confluence of the Tigris and Euphrates rivers, local communities are spearheading a revival of ancient craft knowledge and techniques on the verge of extinction. A remarkable set of ancient boat types has been recovered, including, among others, Meshouf and Tarada (marshlands' wooden canoes), Shasha and Zaima (cane or plant fibre boats), Kaiya or Isbiya (barges of Anbar), and Guffa (coil basket of central Iraq).

According to tradition, riverside and marshes vegetation is used to build vernacular architectures and boats. Both artefacts materialize highly-specialized craftsmanship and showcase elegant designs.

OPEN MUSEUM INITIATIVE FOR WATER CULTURE


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GHANA | Hydro-Technologies of the Pile-Dwelling Lake Village of Nzulezo

The pile-dwelling village of Nzulezo, which means "surface of water," is located on Lake Tadane. This outstanding settlement exemplifies the harmony between humans and nature achieved in this region. According to tradition, Nzulezo was founded by a clan from the ancient Ghana Empire, who arrived here guided by a snail.

The settlement is the result of sophisticated and resilient building technology on water. All daily activities - including schooling, rites, baptisms, and burials - are ultimately connected to the lake and watery conditions, as symbolized even by the pounding of fufu, a traditional meal. This unique combination of natural and cultural heritage underscores a sustainable relationship with water. However, a plan for the dynamic conservation of this village must consider a type of tourism that does not harm the community's livelihood and pace of life.

creative industries fund NL

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INDONESIA | The *Subak* System of Terraced Rice Fields and Landscape in Bali

Subak is a sophisticated system of water management tailored to the landscape and agricultural practices of Bali. Central to this system are intricate networks of canals, locks, and hydraulic structures aimed at distributing water across fields in an equitable manner. Rice production is the pillar of local cultural identity.

This traditional irrigation system promotes the fair distribution of water among farmers and fosters a sense of community and cooperation. Decisions are made through consensus-building processes that prioritize the collective welfare of the community over individual interests.

Water temple rituals emphasize the community's dependence on the life-sustaining forces of Nature. Indeed, the *Subak* is based on the Balinese principle of "Tri Hita Karana" which integrates the realms of the spirit, humans, and nature for harmonious coexistence.

BALI KUNA SANTI

Mandala Mathika
MUSEUM SUBAK

BPPI
BUMI PELESTARIAN PUSAKA INDONESIA

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AUSTRALIA | Between Nature and Culture: the Heritage of the Martuwarra River

The Martuwarra Fitzroy River has historically been managed by Indigenous Nations employing distinctive hydro-technologies. Today, it stands as Western Australia's largest Aboriginal cultural heritage site, holding national heritage status.

Aboriginal people maintain a deep connection with water, as shown by expressions such as "Yi-Martuwarra" (I belong to the River). The Council of Elders asserts the right that the river embodies sacred ancestral serpent beings that are at the center of the universe and have the right to flow. This worldview is in stark contrast to Western notions of property and paradigms of over-exploitation.

The Martuwarra Council actively promotes regenerative culture and tourism economies of well-being that preserve the River and counter the increasing threats of unsustainable extractions of resources that disregard the sacredness of Nature.

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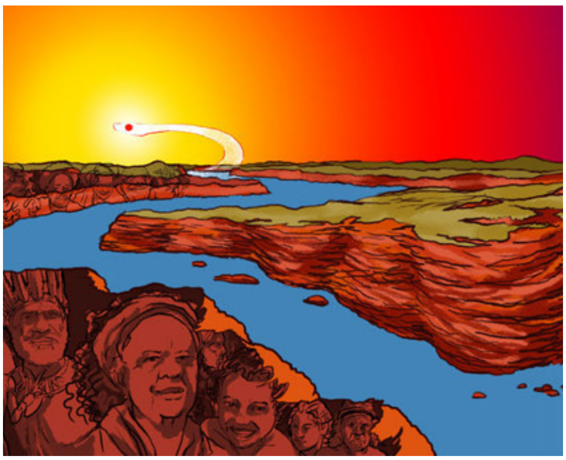

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PERU | Cultivated Terraces and Hydraulic Systems in the Willka Qhichwa

The terraced agroecosystems of Willka Qhichwa, nestled in the Andes, near the Urubamba sacred valley to the Incas, were built between 1000 and 1400 BC. These water distribution systems served as the agricultural backbone of the Inca empire.

The terraces and related hydraulic structures were built with unique expertise, employing extremely advanced and resilient construction techniques. These systems demonstrate remarkable resilience to extreme climatic events because they have stabilized large portions of the mountains at hydrogeological levels. Today, these areas continue to be cultivated and managed by local communities according to tradition.

Beyond their technical and architectural value, the significance of these agroecosystems lies in their preservation of an essential relationship between people and the ecosystem through an extremely rich and articulated cosmovision.

RAKI FILMS


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BRAZIL | Technologies and Lifestyles Respecting Freshwater Ecosystems

Since time immemorial, the Javaé indigenous people has maintained a profound bond with the Araguaia River which runs through the Cerrado biome. Over centuries, they have developed ingenious hydro-technologies for activities such as fishing, building wooden boats, and constructing canals and small dams for water conservation.

All technologies are rooted in the fair use of natural resources. At the core of Javaé's water management paradigm lies a system of beliefs aimed at preserving natural habitats and sustaining biodiversity. By safeguarding aquatic ecosystems, they foster a worldview which recognizes the inter-connectedness of all living beings.

Today, however, Javaé's lifestyles and technologies face a myriad of threats including impacts of large dams and unsustainable agricultural and mineral overexploitation, compounded by the effects of climate change.

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MOROCCO
1.1 The path of the *khettaras*, which bring infiltrated water from the Atlas Mountains to the driest lower areas for agricultural production (Copyright: Raki Films).
1.2 Maintenance of the *khettaras* network is carried out through communitarian work so as to guarantee each individual the right to water for oases irrigation (Copyright: Raki Films).
1.3 Panoramic view of ventilation shafts connected to *khettaras* (underground canals) that flow deep below the desert surface (Copyright: Raki Films).
1.4 Section of a *khettara* with ventilation shafts showing how water is managed by gravity and brought to the oasis (Copyright: Raki Films).

ALGERIA
2.1 Aerial view of the M'Zab valley, a large oasis in the heart of the Sahara where villages and fields were created thanks to ingenious ancestral water management techniques (Copyright: cirad, G-eau and Cread).
2.2 Through a combination of small dams and infiltration trenches, water from flash floods is piped into aquifers and kept here for irrigation in the dry season (Copyright: cirad, G-eau and Cread).
2.3 All traditional hydraulic artifacts in the M'Zab valley are functional for floodwater capture and regulation (Drawing by: Laura Micieli; Copyright: WAMU-NET).
2.4 Scheme with traditional geoengineering techniques aimed at collecting water after flash floods in the Algerian desert (Drawing by: Laura Micieli; Copyright: WAMU-NET).

GHANA
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3.2 People walking on wooden walkways: all daily activities such as schooling, rituals, baptisms, and burials are connected to lake waters (Copyright: AHFP films. Spacefourt, Iconic Ironic Architecture and C. Donkor).
3.3 Aereal view of Lake Tadane with the pile-dwelling village of Nzulezo: in its foundation myth, the village was created by a snail to favour harmonious relations of humans with water (Drawing by: Gabriele Melegari; Copyright: WAMU-NET).
3.4 Daily life scenes in Nzulezo, with details of traditional building techniques now at risk of abandonment (Drawing by: Gabriele Melegari; Copyright: WAMU-NET).

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4.3 Vernacular architecture and traditional boats are built with the skillful use of local materials along the Tigris and Euphrates rivers (Drawing by: Laura Micieli; Copyright: WAMU-NET).
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6.1 The artwork depicts totem animals along the Martuwarra River, where aboriginal communities have lived since time immemorial (Copyright: Martuwarra Fitzroy River Council).
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7.2 The unique water management system of Willka Qhichwa consists of a complex articulation of terraces and related hydraulic structures (Copyright: Raki Films).
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BRAZIL
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8.2 Over the centuries, the indigenous Javaé have developed ingenious hydro-technologies that cannot be separated from their deep connections with water and nature (Copyright: Universidade Federal do Tocantins).
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Intangible Heritage to Strengthen Local Water Management

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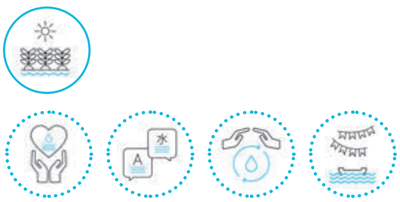
Can intangible cultural heritage (ICH) help to reduce biodiversity loss and and water shortages related to climate change? Can it contribute to managing water shortages and surpluses on a local level? This article argues that some useful forms of intangible, "living" heritage offer valuable knowledge and practices that can serve as adaptive strategies in a changing environment. Binding practitioners to a specific place and to each other and connecting past and future generations, ICH can bring local knowledge and experience into the work field. The examples introduced here include grassland irrigation, water milling and hedge-laying: all used in the past, replaced by new inventions (e.g. fertilizers, new techniques for grinding grains and barbed wire taking the place of hedges respectively), and reintroduced because of their potential role in water management and ability to help create a climate-robust landscape. The valuable insights and practices of "citizen scientists" using these traditional techniques are too often overlooked by policy makers and academics.

KEY THEMES



CLIMATE

A B C D E

Various climates*

** climate not specified in the original version*

< Fig. 1 Traditional irrigated grassland at Het Lankheet (Source: KIEN, 2021).

Introduction

The need for sustainable management of our natural environment, including water management, is one of the great challenges of our time. The Dutch Centre for Intangible Cultural Heritage (KIEN) and the Centre for Agrarian History (CAG) in Leuven (Belgium) believe that Intangible Cultural Heritage (ICH) can help us face this challenge. ICH can be a valuable source of knowledge when designing future climate adaptive strategies. This is why the two institutions have joined forces in a three-year project called "Water and Land. Intangible Cultural Heritage and Sustainable Development," which aims to inventory, research and promote ICH as a lever for ecological sustainability. The project aims to make both members of the public and policy makers more aware of ICH's strengths and opportunities.

The notion of intangible heritage has gained ground since the introduction of the UNESCO Convention for the Safeguarding of ICH in 2003. This convention is specifically concerned with traditions and living cultural expressions that are inherited from ancestors and passed on to future generations. It refers to oral traditions, performing arts, social practices, rituals, festive events, knowledge and skills used to produce traditional crafts and knowledge and practices concerning nature and the universe. These practices may offer especially valuable insights that can be applied to climate adaptive solutions.

ICH has several characteristics that make it a potentially powerful instrument in combating the negative effects of climate change. Communities that practice nature-related ICH express their knowledge, which is often embedded in and directly linked to their surroundings, through a wide range of cultural practices that have evolved over time as people have interacted with their environment. ICH, as living heritage, is flexible and adaptive – often it is precisely the ability to adjust to changing circumstances that has ensured its survival over time.

Practitioners of ICH are typically committed to their community and highly involved in their local environment, for their heritage practices not only bind them to one another, but also to their physical surroundings. The stakes can be high since the survival of natural surroundings and the survival of ICH practices are closely entwined. This at least partially explains why ICH often promotes a strong sense of responsibility and may even foster the feeling that one can indeed do something to ameliorate seemingly overwhelming global threats such as floods, (extreme) drought or the loss of biodiversity. In the words of Kathleen Ferrier, chair of the Dutch UNESCO Commission: "When climate adaptation is grounded in local traditions and customs, it empowers communities to take control and initiate change themselves" (Bontebal 2021). This showcases the importance of supporting communities in safeguarding their sustainable intangible heritage.

A Case in Point: Traditional Irrigation

An example of how ICH can make a vital contribution to local water management is the sustainable traditional technique of grassland irrigation. This is an ingenious and almost forgotten farming method that dates back to the Middle Ages and relies on the strategic use of gravitational force and manually created structures to distribute water from naturally occurring water catchment points closer to fields. More specifically, it cleverly utilizes minute differences in elevation, thereby distributing "stunted water" through channels and ditches or "beam weirs"

^ Fig. 2 Traditional irrigation in Lommel, Belgium (Source: Willem Tel, 2023)

(barriers made of stacked planks) and manually operated "inlet gates." This allows practitioners to maintain desired water levels over a wide area and respond to changes in weather and climate. It thus offers them a valuable tool to promote growth and increase (hay) yields. At the same time, traditional grassland irrigation allows lime and minerals to penetrate the soil, thereby creating a rich soil life and grasslands full of plants, insects and birds.

Today, practitioners of traditional grassland irrigation are dispersed around the world. As for the Netherlands, there are two areas where the practice is still in use. One of them is the estate Het Lankheet, below Haaksbergen. Eric Brinckmann, representative of the Water Park and Field Centre Foundation, Het Lankheet, explains: "What we are doing is moving with the landscape. You follow the water. Every week there is a different situation to which you have to respond. So, we take care of the landscape, and the landscape takes care of us. There are 30 volunteers working at the foundation, and together we are committed to restoring biodiversity and creating a climate-resilient landscape that suits nature-inclusive agriculture. People feel responsible and involved. This also strengthens social cohesion. And appreciation for nature. It encourages volunteers to become emotional co-owners of the landscape" (Bakels and Elpers 2021, 39). The Dutch irrigators are part of a European network of traditional irrigation practitioners from Belgium, Luxembourg, Germany, Austria and Switzerland. Learning from this technique is thus not only limited to the Netherlands.

^ Fig. 3 Water miller Ernst at work in Eindhoven (Source: Riet Meijer, 2023).

^ Fig. 4 Hedge-laying in the Netherlands (Source: KIEN, 2008).

Living Heritage: Traditions, Challenges and New Applications

The potential of ICH to contribute to climate-robust landscapes is by no means limited to grassland irrigation. There are many other practices that can play a renewed role in sustainable water and landscape management. Among them, for example, is the ICH practice of water milling. Both the Netherlands and Belgium have a long tradition of water milling. On the one hand, mills historically participated in the work of, for example, artisanal flour milling. But while doing so, their operation also actively influenced local water systems. Therefore, many water millers consider themselves not only millers but also water managers, and that dimension of their work may take on new significance considering changing weather conditions. In an online focus group conducted by the authors in 2022, Riet Meijer, herself a miller and member of the advisory board of Molenstichting Noord Brabant, explains: "I want to use the old techniques to sustainably manage the landscape around the mill. By managing the weirs in the river and streams, we can respond to drought and wetter times and maintain the water landscape well. This gives the mill a new importance. We must ensure that Waterschappen [the Dutch water management boards] and governments accept this new role of the millers." Supporting the renewed role of this old craftsmanship can thus strengthen local water management in a climate-robust landscape.

Hedge-laying is another example. Its practitioners make existing hedges, usually thorny hedges, impenetrable by braiding twines together.

^ Fig. 5 Water milling today means using old techniques to sustainably manage the landscape around the mill. Water milling landscape at Coll (Source: CAG, 2023).

The hedges were historically used to separate plots of land, but their benefits are wider. Braided hedges offer shelter to many different animal species, and function as small yet diverse biotopes. Recently, attention has also been drawn to their water-absorbing capacity – in the shade of hedges, temperatures may be up to five degrees cooler than in the surrounding landscape, resulting in less evaporation. And during heavy rainfall, the roots of hedges act as “flow paths” that transport water to deeper earth layers (Rijsdijk 2022). On the islands of Bonaire, St. Eustatius and Saba – the Dutch Caribbean – people braid cactus hedges. This ICH is receiving renewed attention since there is growing awareness that it may contribute to retaining water and preventing erosion. Curaçao and Bonaire also have natural systems of rooi (gullies) and man-made dams, which guide and catch rainwater. Lately, housebuilding has been allowed in the rooi area, resulting in local and downstream flooding (Loen 2022).

Opportunities for Change: Local Knowledge, Science and Governmental Decision-Making

KIEN has coordinated the implementation of the UNESCO 2003 Convention for the Safeguarding of ICH in the Netherlands since 2012. Its efforts to help practitioners safeguard (develop, promote and pass on) their ICH include the Inventory of Intangible Cultural Heritage of the Netherlands. From 2022 onwards, sustainability will be a spearhead for research (Bakels 2021).

CAG is a knowledge center in Flanders, Belgium, concerned with agrarian history and heritage. CAG studies, preserves, secures and makes accessible the history and heritage of agriculture, food and rural life in Flanders and Brussels as far back as 1750. CAG wants to contribute to the realization of the UN Sustainable Development Goals and a sustainable society.

KIEN and CAG believe that ICH offers valuable alternative knowledge systems for sustainable landscape development and water management. It can be used to inspire and inform environmental and climate change management and politics. Unfortunately, the opportunities offered by ICH are still relatively unknown in wider circles and are not clearly on the minds of policymakers (Fatorić and Egberts 2020; Altenburg and Elpers 2020). In our current society, so focused on official, managerial and scientific knowledge systems, the “intimate” or “local knowledge” of ICH is at best marginalized and most often is ignored altogether. This is unfortunate, as different knowledge systems can reinforce and complement each other – a reassessment of ICH in official policy and academic knowledge systems could lead to a more vital, accurate and widely shared approach to water management.

ICH can enrich landscape and water management. It binds the past, present and future; it can strengthen the appreciation of and emotional attachment to land and nature; and it can inspire responsible and sustainability-oriented attitudes (Ganzevoort 2021; Jagers et al. 2014). In particular, ICH contains concrete insights and knowledge tailored to local conditions. We will desperately need such attitudes in the future – for water management, but also for the well-considered and informed use of our natural resources in general.

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Qanats: Ancient Innovations Nurturing Sustainable Futures in Water Management

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The qanat, a timeless testament to human ingenuity, emerged on the arid Persian Plateau around three millennia ago as a sustainable solution to water scarcity. This technique channels water from aquifers using gravity through gently sloping sub-horizontal tunnels, avoiding over-extraction and ensuring a delicate balance between human needs and environmental preservation. By naturally regulating water flow according to aquifer levels, qanats prevent excessive depletion, serving as a model for sustainable water resource management. This study explores the fascinating journey of qanats, their geographical spread, historical evolution and enduring relevance. We highlight their adaptability to diverse environments, their role in fostering cultural continuity and their potential to address contemporary water challenges. By revisiting this ancient marvel, we uncover valuable lessons for contemporary water management systems worldwide.

Keywords: *qanats, oases, groundwater, ancient hydro-technologies (AHTs)*

KEY THEMES

CLIMATE

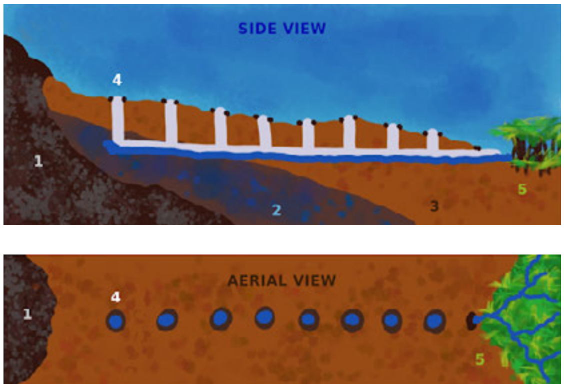
A B C D E

Various climate/not specified

< Fig.1 Qanats of Bam (Source: S.H. Rashedi, 2014. Nomination File, © S.H. Rashedi, whc.unesco.org/en/documents/141554).

Introduction

Qanats, a cornerstone of traditional irrigation systems, exemplify a profound understanding of the harmonious relationship among humans, technology and nature. Originating on the arid Persian Plateau approximately 3,000 years ago, qanats addressed the challenge of water scarcity in arid and semi-arid regions (Barontini et al.2018; English 1968; Lightfoot 2000, 2024; Remington 2018). These systems consist of gently sloping underground tunnels that transport groundwater from aquifers to surface areas using gravity alone. Qanats operate passively, delivering water sustainably. When aquifer levels are high, qanats yield more water, while during droughts, their output naturally decreases, preventing over-extraction and preserving long-term aquifer health. This self-regulating mechanism aligns qanats with natural groundwater cycles, supporting human activities such as drinking water supply, agriculture and horticulture. The ingenious design of qanats minimizes evaporation losses, allowing water to be transported over long distances in harsh climates. This sustainable approach has endured the test of time, inspiring numerous adaptations in diverse regions (Ashraf et al. 2016; Barontini et al. 2018; Barontini et al. 2017; Chunliang et al. 2014; Himat and Dogan 2019; Khan and Nawaz 1995; Martínez-Medina et al. 2018). This study examines the evolution and diffusion of qanats, tracing their development in ancient Persia and global spread, while emphasizing their contemporary significance in sustainable water management.

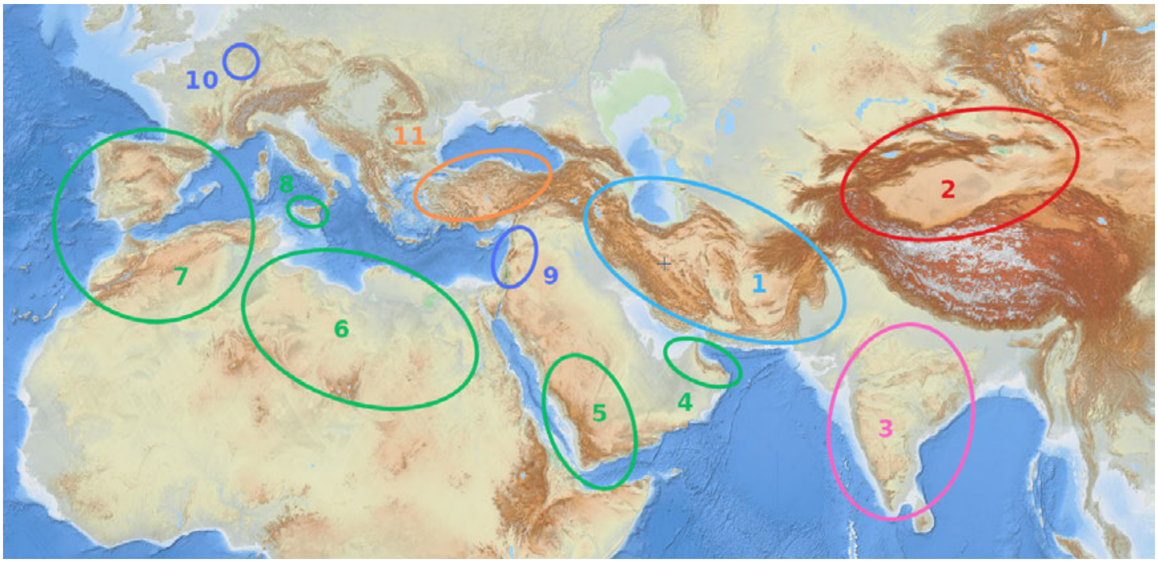


^ Fig. 2 Scheme of a qanat section: 1 Bedrock; 2 Water table, saturated zone; 3 Alluvium, unsaturated dry zone; 4 Mother well; 5 Outlet. The qanat drains water from the water table (Source: Massimiliano Borroni, 2024).

Historical and Geographical Diffusion of Qanats

The qanat system, originating in the heart of the Iranian Plateau along the internal fringes of the Zagros Mountains, likely emerged during the early first millennium BCE as an innovative response to arid conditions and the scarcity of stable, high-quality surface water. The period before the advent of qanats saw advancements in metalworking, which in turn drove progress in mining technologies. Early Persian farmers and miners, noticing water seepage in mining tunnels, adapted this knowledge to channel groundwater for irrigation. By connecting aquifers to farmland through gently sloping tunnels, they developed a reliable and sustainable irrigation system.

The rise of the Achaemenid Empire (550–330 BCE) coincided with the early diffusion of qanats. Ancient sources link the establishment of this imperial power to the extensive use of cavalry, which required substantial agricultural surpluses to sustain the animals. The dissemination of qanat technology made it possible to cultivate arid plains and expand agricultural areas, generating the surpluses needed to support the cavalry. Recognizing the strategic value of this innovation, the Achaemenids actively promoted the spread of qanats, creating a positive feedback loop that reinforced agricultural productivity and military strength (English 1968; Massoud 2022).



^ Fig. 3 Diffusion of qanats: 1 Iranian Plateau, place of origin; 2 Xinjiang region; 3 Deccan Plateau; 4 and 5 Oman, Yemen and Saudi Arabia; 6 Egypt and Libya; 7 Algeria, Morocco and Iberian Peninsula; 8 Sicily; 9 Syria, Jordan and Palestine; 10 Luxembourg; 11 Anatolian Plateau and Greece (Source: Vladimiro Andrea Boselli, 2024).

In summary, the agricultural surpluses generated by this ingenious irrigation system were instrumental in the empire's rise, supporting the development of a formidable cavalry that became a cornerstone of its military power. However, two centuries later, Alexander the Great's introduction of the Macedonian phalanx rendered cavalry tactics ineffective. This shift in military strategy contributed to the empire's downfall, culminating in Darius III's assassination by his own generals following their defeat in Bactria in July 330 BCE.

Persian rulers incentivized qanat construction by granting builders land and water rights for multiple generations, leading to the widespread adoption of this technology across their vast empire. Qanats initially spread westward to Mesopotamia, the Levant and Egypt, and eastward to Afghanistan, Central Asia and the Turpan Basin in western China (present-day Xinjiang) (Chunliang et al. 2014; English 1968; Lightfoot 2024; Massoud 2022). Administrative oversight during imperial expansions further facilitated the dissemination of this ancient system. The system was adapted to suit the specific environmental, hydrogeological and cultural contexts of various regions, reflecting the technique's intrinsic flexibility.

During the Roman-Byzantine period (64 BCE–660 CE), qanats were introduced to parts of Europe, including the Iberian Peninsula and the region of present-day Luxembourg. In the Levant, encompassing Syria, Palestine and Jordan, qanats were integrated into Roman aqueduct systems. However, during this period, Roman aqueducts remained the dominant form of water infrastructure. In Roman Gaul, qanats extended as far as present-day Luxembourg, where the Raschpëtzer qanat, dating to around 150 CE, operated for approximately 120 years (Govindan Kutty 2020; Kayser and Waringo 2000).

A second major wave of qanat diffusion occurred during the rise of the Islamic Caliphates in the seventh century and beyond. This expansion brought qanat technology to coastal areas of North Africa, the Iberian Peninsula and Sicily. During this period, the deepening of hydraulic knowledge over the first five centuries of the Islamic era led to significant advancements in qanat construction and maintenance techniques. With the establishment of Islamic Sultanates in northern India (eleventh–thirteenth centuries) and later in the central Indian subcontinent (fifteenth–eighteenth centuries), qanat technology spread across the Deccan Plateau (Barontini 2017; Govindan Kutty 2020). The diffusion of qanats during the Islamic period is well-documented, highlighting the existence of skilled labor teams, with each member specializing in a specific aspect of construction or maintenance. These teams, benefiting from the hydraulic knowledge accumulated during the early Islamic era and equipped with technical manuals in Arabic and Persian, further refined qanat technology (English 1968; Lightfoot 2000; Madani 2022; Malik et al. 2021; Martínez-Medina et al. 2018; Remington 2018). They likely facilitated the spread of qanats along trade routes connecting Central Asia and North Africa, particularly in regions with high demand for sustainable irrigation systems. These trade routes often strengthened oasis centers, enabling the expansion of irrigated agriculture and reliable water supplies in arid regions (Madani 2022; Massoud 2022; Messous 2024; Strava 2024). Later, Spanish colonists, familiar with qanat systems from their homeland, introduced variants of the technology to Latin America. They established qanats in regions such as Mexico, further extending the global legacy of this ancient innovation and enriching similar Indigenous pre-Columbian techniques, such as the *puquios* of Peru and northern Chile (Barontini et al. 2018; English 1968; Martínez-Medina et al.).

Localization, Adaptation and Regional Names

The diffusion of qanats followed ancient trade routes and the expansion of empires. This fact allows us to highlight the deep connection between centralized administration and qanat construction. The building and maintenance of qanats, like Roman aqueducts, could be managed by tightly organized local communities without extensive centralized authority, like oasis communities, or by labor groups directed and financed by central authorities or owners of large amounts of land. After the construction of a qanat, the relatively simple maintenance required was often left to the population occupying the area it served to irrigate. This was unlike the great architectural structures of Roman aqueducts, which required highly skilled and specialized workers for upkeep and resulted in the conservation of many functional qanats and the progressive abandonment of the big Roman aqueducts. This can also be observed in oasis regions of North Africa, the Persian Plateau, and the Deccan Plateau of India, where local communities maintain and modernize qanat networks (Ashraf et al. 2016; Govindan Kutty 2020; Himat and Dogan 2019; Khan and Nawaz 1995; Malik et al. 2021; Massoud 2022; Messous 2024; Taghavi-Jeloudar et al. 2013; Weingartner 2007).

Local conditions and cultural influences shaped unique adaptations and regional names, reflecting the integration of qanat techniques into local knowledge systems (the variety of languages involved leads us to abandon any claim to uniformity in romanization). While the word *qanat* is common in the Arabic speaking world (e.g., Iraq and Syria), in Sicily they are called *canate* arabe ("Arab qanats"). In Northern Iraq, Central Asia and parts of India, the Iranian word *karez* is commonly used (sometimes transcribed as *kareez* or *kariz*), and in India we find terms such as *kharejari*, *surang-bawdi, surangam, nahar* and *kundi bhandara*. In China's Xinjiang region, the system is known as *kanjing* or *kanerjing*, or again *karez*. The *dawudi falaj* (pl. *aflaj*) is another name for these underground tunnels, a term that we find in Oman and Saudi Arabia. In Southern Jordan, the name *dhwawi* may be used. In North Africa, specifically in Libya and Algeria, the system is known as *foggara*, and in Morocco, as *khettara*. In the Iberian Peninsula these systems are known as *galerías* ("tunnels"), a term carried to Meso and South America during the Spanish conquest (Barontini et al. 2018; English 1968; Martínez-Medina et al. 2018).

Contemporary Relevance and Future Sustainability

Qanats transcend mere technological innovation: they embody cultural and ecological heritage. Their construction and maintenance required communal effort, fostering collaboration and governance practices. Rituals and traditions surrounding water distribution underscore their central role in desert communities' social and spiritual lives, creating a shared sense of responsibility toward water as a precious resource.

In Spain, the *galerías con lumbreras* system in the southeastern region provides a striking example of qanat-inspired adaptation to address local challenges. One notable example is the Caño-Contracaño in Murcia, a qanat-like system designed to manage water efficiently. Beyond irrigation, it plays a vital role in mitigating eutrophication in saline lagoons, demonstrating how traditional techniques can be repurposed for modern environmental management strategies. The Caño-Contracaño's use of interconnected channels and ventilation shafts exemplifies the adaptability of qanat systems to local hydrological and ecological conditions. This harmonious blend of old and new highlights how heritage preservation can coexist with contemporary utility to create sustainable resource management frameworks (Martínez-Medina et al. 2018).

Oman offers another inspiring case of qanat revitalization. In the 1980s, government-led initiatives restored *aflaj* systems, ensuring the preservation of traditional practices while enhancing water accessibility. This effort underscores the potential of qanats to bridge the gap between heritage conservation and practical resource management, particularly in arid regions where water scarcity is a pressing issue (Remington 2018).

Similarly, the Naubad Karez in Bidar, India, has recently undergone conservation efforts, illustrating the ongoing relevance of qanats as decentralized water sources. These ancient systems offer viable solutions for sustainable urban and rural water supply, especially in areas grappling with dwindling aquifers and the adverse effects of over-extraction (Govindan Kutty 2020)

These contemporary applications highlight the enduring relevance of qanats, demonstrating how ancient wisdom can inspire innovative solutions for modern water challenges. Beyond their practical applications, qanats hold untapped potential as cultural and ecological tourism assets. Their unique design and historical significance captivate the imagination, transforming them into compelling attractions that celebrate human ingenuity in water management. From Spain to Oman, Iran, India and beyond, qanats can serve as focal points for heritage tourism, fostering economic opportunities while raising awareness about sustainable water practices. By seamlessly integrating traditional knowledge with modern needs, qanats stand as enduring symbols of resilience and innovation. Their lessons, deeply rooted in harmony with natural resources, offer

^ Fig. 4 Example of recent maintenance of a khettara near Ait Zeggane (Morocco) with modern techniques and materials. On the left you can see the systems for moving the material along the wells, in the center you can see two wells renovated with stone and bricks respectively, on the right you can see the maintenance work, during and after in a slightly kilned well (Source: Mhammad Houssni, 2024).

a timeless blueprint for the sustainable development of water systems worldwide (Barontini et al. 2018, 2017; Massoud 2022; Messous 2024; Taghavi-Jeloudar et al. 2013; Weingartner 2007).

Conclusion

The historical evolution and geographical diffusion of qanats underscore their enduring significance. By bridging diverse cultures and enabling sustainable resource management, qanats exemplify the potential of traditional knowledge to address modern challenges. Reviving this heritage not only honors its cultural legacy but also inspires innovative approaches to water resource management, blending ancient techniques with modern technology. This fusion can help mitigate issues such as groundwater depletion and inefficient irrigation practices. Moreover, it encourages global cooperation in water management, fostering knowledge exchange and intercultural collaboration to combat the growing threat of water scarcity worldwide.

Policy Recommendations

- Enhancing and safeguarding the heritage of qanats in their various territorial forms by preserving not only their historical legacy but also their functionality and efficiency as integral components of an integrated water management system.
- Prioritizing groundwater extraction through technologies like qanats, which operate without energy consumption and prevent aquifer depletion, thereby ensuring the sustainability and long-term functionality of water resources.
- Promoting both the tangible and intangible heritage associated with qanats as a catalyst for fostering dialogue and encouraging cultural and political exchange in addressing future challenges.
- Revitalizing and strengthening administrative and democratic bodies to supervise and monitor regions where qanats are present, ensuring a shared vision that transcends individual interests.

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Ancient Hydro-Technologies as a Response to Climate and Food Emergencies: Use of Cultural Heritage to Rescue the Future

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The Mediterranean region faces worsening climate challenges, including rising temperatures, water scarcity and ecosystem degradation. Climate projections indicate a temperature increase of up to 6.5°C by 2100, with reduced rainfall and increased evaporation exacerbating water shortages, particularly in agriculture, which consumes 70–80 per cent of the region's water. Competition for freshwater, declining agricultural productivity, and salinization of coastal aquifers further threaten sustainability. Ancient hydro-technologies—traditional water management systems developed by ancient civilizations—offer valuable insights for climate adaptation. Examples include Minoan rainwater harvesting, Roman aqueducts and the qanats originating in what is now Iran, which prioritized water conservation, efficient irrigation, and flood control. These systems, designed in harmony with nature, exemplify sustainability, resilience and multifunctionality, contributing to biodiversity conservation and climate adaptation. To scale up ancient hydro-technologies, integrated governance, legal recognition, capacity building and interdisciplinary research are essential. International cooperation and financial resources can help preserve and adapt these traditional solutions to modern challenges, integrating them into the Water-Energy-Food-Ecosystem Nexus (WEFE Nexus) framework for sustainable water, energy, food, and ecosystem management.

Keywords: *ancient hydro-technologies, nature-based solutions, climate emergency, SETs, WEFE Nexus*

KEY THEMES

CLIMATE

A B C D E

Various climate/not specified

< Fig. 1 Zenu Ancestral Hydrotechnology, Colombia (Source: Jordi Morató Farreras, 2020).

Introduction

The accelerating pace of climate change (CC) has exacerbated long-standing socio-environmental issues in the Mediterranean region. These challenges arise from a combination of factors, including shifts in land use, poor management of natural water resources, soil degradation due to erosion, increasing pollution levels and a decline in biodiversity. Today, over 180 million individuals in the Mediterranean region are affected by water scarcity.

Projections based on the latest findings from the IPCC (2023) and MedECC (2020) reports indicate a worsening scenario. Annual mean temperatures on land and sea across the Mediterranean Basin are 1.5°C higher than during pre-industrial times and they are projected to rise by 2100 by an additional 3.8 to 6.5°C for a high greenhouse gas concentration scenario (RCP8.5) and 0.5 to 2.0°C for a scenario compatible with the long-term goal of the UNFCCC Paris Agreement to keep the global temperature well below +2°C above the pre-industrial level (RCP2.6). Without additional mitigation, regional temperature increase will be 2.2ºC in 2040, and for each degree of global warming, mean rainfall will likely decrease by about 4 per cent and evaporation will increase nearly 7 per cent in much of the region, particularly in the south. On land and in the sea, heat waves will intensify in duration, with higher peak temperatures. Despite strong regional variations, summer rainfall will likely be reduced by 10 to 30 per cent in some regions, increasing existing water shortages, desertification and decreasing agricultural productivity, which could be reduced by 17 per cent in 2050 (MedECC 2020).

With agriculture using most of the Mediterranean's water (about 70–80 per cent) (Crovella et al. 2021), which is in competition with fresh water, touristic and industry sectors in a very volatile equilibrium, and climate change impacting water reserves, several challenges arise, including less runoff and groundwater, poorer water quality, more conflicts among stakeholders, ecosystem damage, coastal aquifer salinization and fewer nutrients for sea organisms, which affect fishing, one of the most important sources of protein in parts of the region.

Demand for irrigation is expected to increase by 4–18 per cent by 2100, although demographic change, including the growth of large urban centers, could enhance this demand by 22–74 per cent. Most significant climate risks are related to a shortage and excess of water, as shown in recent analyses of the Nationally Determined Contribution (NDCs) for the Paris Agreement, at the global level and for Africa specifically (Tollin et al. 2022). However, the NDCs are only defining actions to certain degree, and in only a few cases through an integrated, cross-sectoral and multi-risk approach. Despite challenges, the Mediterranean region has significant potential for adaptation by improving water use efficiency. Human societies have historically demonstrated resilience by developing socio-technical, cultural and environmental systems (SETs) that integrate traditional knowledge, cultural practices and technologies. These adaptive systems, recognized by scientists as SETs (Grimm et al., 2017; Reyers et al., 2018; Preiser et al., 2018; Nguyen et al., 2023), have enabled communities to endure and respond to environmental challenges while maintaining ecological balance. They reflect centuries of sustainable resource management and a deep connection between people and nature.

Ancient Hydro-Technologies: Lessons from Water Heritage

Ancient hydro-technologies are a key component of adaptive strategies developed by ancient civilizations to manage water sustainably. Designed in harmony with natural hydrological cycles, these systems ensured water conservation, efficient irrigation, and the regulation of floods and droughts, serving as nature-based solutions to climate variability.

These traditional water management systems and engineering practices were developed to harness, store, distribute and regulate water resources while maintaining ecological balance. By integrating traditional knowledge with ecosystem management, they supported long-term water availability for agriculture, domestic use and biodiversity preservation. Rooted in nature and adapted to local environmental conditions, ancient hydro-technologies exemplify NbS, demonstrating how human societies have historically leveraged natural processes for resilience and sustainable development.

Water management has played a crucial role in the development of civilizations across the Mediterranean, shaping their resilience, sustainability and prosperity. Over time, societies adapted and improved water infrastructure to address the challenges of arid climates, urban expansion and agricultural needs. Each period contributed to the evolving water heritage of the Mediterranean, demonstrating how civilizations adapted to environmental challenges through technological ingenuity and sustainable water management practices.

Egyptian water culture (c. 3150–31 BCE), was deeply connected to the Nile River, which served as the foundation for the development of sophisticated irrigation systems. The Egyptians implemented basin irrigation, canals and reservoirs to control seasonal flooding and sustain agriculture. They also constructed nilometers to measure water levels and predict harvests, demonstrating early hydrological expertise (Gad 2008; Driaux et al. 2016). In the Minoan civilization (c. 3000–1100 BCE), water management systems became highly advanced, with the construction of complex drainage and supply networks. The Minoans engineered underground clay pipes, terracotta aqueducts and multi-tiered cisterns to ensure a steady water supply. They also developed sophisticated rainwater harvesting techniques and built some of the earliest known flushing toilets, particularly in palatial centers like Knossos (Angelakis et al. 2013; Crovella et al. 2021). The Etruscans (c. 800–500 BCE) in central Italy contributed significantly to water infrastructure by constructing tunnel aqueducts, drainage canals and artificial reservoirs to manage water for both agricultural and urban use. The Romans (c. 100 BCE–476 CE) perfected aqueduct technology, enabling them to transport water over long distances with precision-engineered arches and tunnels. They constructed extensive public infrastructure, including baths, latrines, fountains and sewage systems, setting a foundation for modern urban water management. In the medieval period (fifth–fifteenth century CE), water management practices evolved differently across regions. While some areas experienced a decline in infrastructure following the fall of Rome, others flourished under Islamic and Byzantine influences. Islamic engineers in Spain and North Africa refined irrigation networks, introduced qanats and waterwheels (*norias*), and enhanced agricultural productivity through sophisticated water distribution techniques.

Without a doubt, the Minoans can be regarded as pioneering architects of many advanced water

^ Fig. 2 Water Heritage Cultures of the Mediterranean and convergent evolution in other world areas (Source: Jordi Morató Farreras, 2023; Background map: Nzeemin, 2012. Wikimedia Commons, CC BY 3.0).

management techniques that continue to influence modern systems today. Important aspects of this twater heritage include the following:

- They recognized the vital role of sanitation, water supply, and drainage systems in human survival and well-being, integrating these elements into urban planning to ensure the sustainable management of water resources.
- Water quality and safety were key considerations in the design and construction of their water supply systems, reflecting an advanced understanding of hydrology and public health.
- They employed a balanced approach, combining small-scale solutions like cisterns for rainwater collection with large-scale infrastructure such as reservoirs to store and regulate aqueduct flows.
- Their water technologies were characterized by their simplicity, efficiency and ease of operation, requiring minimal maintenance and complex controls while effectively meeting the needs of growing urban populations.

Parallel developments occurred among various civilizations, each geographically isolated from the Mediterranean, yet independently devising comparable water management strategies to sustain their communities. This phenomenon of convergent evolution, where different societies develop similar solutions in response to shared environmental challenges, was particularly significant in the Indus Valley (Pakistan) during the Bronze Age (c. 3200–1100 BCE), the Zenú society in Colombia (c. 600–400 BCE), and the Pre-Hispanic Amunas in Peru (twelfth–thirteenth century). These civilizations engineered sophisticated water systems tailored to their landscapes, demonstrating a deep understanding of sustainable resource management.

Key Properties of Ancient Hydro-Technologies

These water management systems and agricultural conservation practices, guided by traditional ecological knowledge and community-based governance, have shown centuries-long sustainability and resilience, enduring extreme events while efficiently utilizing resources. Good examples of such systems, including some still in use today, can be found all over the world: The acequias de careo in Spain, the zenu channels or camellones in Colombia, the Aflaj and Zajirah in Oman, the traditional stone weirs in ephemeral streams in Greece, the Persian qanat in Iran and the drystone walls in many parts of the Mediterranean region such as in Catalonia (Spain) and Cinque Terre (Italy) to name a few, but also the terraces built on sloping terrain in many Mediterranean areas, to help level the land, making it more suitable for agriculture, while also reducing soil erosion caused by rainfall.

If properly managed, these technologies could become an effective solution for CC adaptation and mitigation related to flood and drought control and disaster risk reduction, water regulation, ecosystem services and biodiversity conservation, among other challenges. They also provide multifunctional co-benefits for the management of pollution, food production, health security and economic development. From a cultural perspective, these technologies represent a wealth of ancient local and traditional knowledge that should be preserved and valued as cultural heritage. In summary, key properties of ancient hydro-technologies, which provide valuable insights for modern water management and climate adaptation strategies, include:

1. Sustainability and ecological integration – ancient hydro-technologies have a low footprint in terms of energy, resources and carbon. Designed in harmony with natural water cycles, these systems minimized environmental disruption and ensured long-term resource availability.
2. Adaptability to local conditions – Tailored to specific geographic and climatic contexts, ancient hydro-technologies optimized water use in arid, mountainous, and flood-prone regions.
3. Efficiency in water conservation – Many techniques, such as terraced irrigation, qanats, and amunas, prioritized water infiltration, storage, and controlled release to reduce losses and maximize usage.
4. Decentralized and community-based management – These systems operated through local knowledge and collective governance, ensuring equitable distribution and maintenance.
5. Resilience to climate variability – Designed to mitigate droughts, floods and seasonal changes, these technologies provided stable water access in extreme conditions.
6. Beneficial for biodiversity restoration. ancient hydro-technologies can be instrumental in preserving and restoring biodiversity and strengthening ecosystem services' provision.
7. Low-tech, high-impact design – Simple yet effective engineering principles made these systems durable, cost-efficient and easy to maintain over centuries.
8. Integration with WEFE Nexus - ancient hydro-technologies serve the further integration of WEFE Nexus at the local and regional scale as a result of their transfunctionality and their contribution to the Sustainable Development Goals (SDGs).
9. Multifunctionality – They often served multiple purposes, such as irrigation, drinking water supply, flood control and soil conservation, contributing to overall ecosystem stability.

Ancient Hydro-Technologies as a Solution to Climate and Food Crises

Ancient hydro-technologies should be recognized not only as historical infrastructure and cultural heritage but also as viable models for sustainable water management, adaptable to present and future challenges. Their effectiveness can be further enhanced by integrating innovations from social, ecological and engineering disciplines.

Many of these systems have significant potential for recovery and scaling, offering solutions for the transformative changes needed to address global challenges within the broader framework of sustainable development. Their value in tackling current crises – climate change, biodiversity loss, water scarcity, health and food security – has been well-documented with extensive evidence, case studies and the identification of best practices.

The implementation of ancient hydro-technologies today faces legal, economic, technological and governance challenges. Regulatory frameworks often fail to support traditional practices, while knowledge gaps, financial constraints and the erosion of traditional expertise hinder their revival. Additionally, urbanization, land use changes and competing water demands limit their applicability. Addressing these barriers requires policy reforms, institutional support, capacity building and interdisciplinary collaboration. Multi-level governance, financial investment and integrated planning are essential to effectively reintegrate these sustainable water management systems into modern contexts.
In summary, successfully scaling up ancient hydrohydro-technologies requires addressing the following critical challenges:

- Multi-level governance to align national policies with local practices and integrate sectoral policies on climate, water, energy, food, biodiversity, health and development.
- Legal recognition and protection of ancient hydro-technologies at risk of loss.
- Capacity building for policymakers, practitioners, researchers and communities to advance theoretical and operational knowledge.
- Multidisciplinary research integrating low- and high-tech solutions, scientific, socio-cultural and traditional knowledge, and the role of eco-museums.
- Awareness and advocacy to highlight the value of ancient hydro-technologies in resilience transitions.
- Financial support for large-scale demonstrations of these technologies that can inspire transformative change.
- Global networks for knowledge exchange, project development and implementation.

Despite these challenges, ancient hydro-technologies are gaining renewed interest. Cities and rural communities are integrating traditional systems like qanats, acequias and stepwells with modern innovations such as remote sensing and decentralized water governance. These hybrid approaches offer scalable, nature-based solutions for enhancing water resilience and sustainable management in a changing climate.

Conclusion

Ancient hydro-technologies represent nature-based solutions rooted in traditional knowledge and ecosystem practices, offering sustainable approaches to water management. These systems are characterized by low energy requirements, resource efficiency and minimal carbon footprints. By integrating ecological principles, they not only restore biodiversity but also enhance ecosystem services, such as hydrological regulation, artificial aquifer recharge and soil moisture retention. These benefits, in turn, improve carbon sequestration, soil fertility and local temperature regulation, making them invaluable for climate adaptation and resilience. These time-tested systems provide critical insights for addressing contemporary environmental challenges. Their ability to optimize water conservation, enhance irrigation efficiency and mitigate the impacts of floods and droughts has been proven over centuries. By reintegrating ancient hydro-technologies into modern water governance, new research opportunities emerge, highlighting their potential to strengthen sustainability and resilience in the face of climate change. However, realizing their full potential requires embedding them in modern policies through multi-level governance, robust legal frameworks, capacity building and interdisciplinary research.

As global water scarcity intensifies, combining these traditional practices with modern innovations can foster adaptive, nature-based water management strategies. Their multifunctionality supports biodiversity conservation, food security, and ecosystem services, aligning with the WEFE Nexus and the SDGs. Scaling up these technologies demands financial investment, cross-sector collaboration and awareness-raising initiatives to ensure their preservation and adaptation to future challenges.

By bridging traditional wisdom with modern innovation, ancient hydro-technologies can play a pivotal role in advancing climate resilience and sustainable water management, not only in the Mediterranean but globally. Recognizing their value and integrating them into broader strategies will be essential for building equitable and resilient water systems for the future.

Policy Recommendations

- Establish the political framework for a decentralized water governance model and its protection from external actors. Allocate structural funding for this type of local management.
- Develop educational programs to raise awareness about the importance of water conservation and the benefits of community-led water management. Encourage the adoption of a “water culture” that promotes visibility and respect for water as a shared resource.
- Recognize and integrate the principles of traditional water management systems and technologies.

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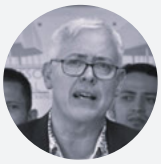

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Water Management for Sustainable Development of World Heritage properties

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As climate change and water-related threats like floods and droughts intensify, water management must become a key component of World Heritage management plans. Currently, these plans are not required to address water management even though an increasing number of sites are encountering water-related challenges. A lack of comprehensive data and knowledge sharing hampers efforts to collectively address these issues, posing a risk to the preservation of their Outstanding Universal Value. This article examines the significance of water management for World Heritage properties, including sites directly connected to water and those facing water-related threats. It presents three examples from Germany to illustrate these challenges and underscores the need for improved knowledge sharing and integration between World Heritage properties and their surrounding environments.

Keywords: *World Heritage, water management, climate change*

KEY THEMES

CLIMATE

A B C D E

Various climates*

** climate not specified in the original version*

< Fig.1 Shushtar historical hydraulic system panorama (Source: Iman Yari, 2014. Wikimedia Commons, CC BY-SA 4.0).

Introduction

Cultural World Heritage properties are inherently connected to water; their construction and preservation have always depended on effective water management. Especially in arid climates and floodplains, communities had to secure a reliable water supply while protecting themselves from water in excessive quantities (UNESCO 2011). Additionally, maintaining these sites for continued use requires a balanced water supply to ensure livable conditions and preserve the functionality and longevity of the properties. However, changing climatic conditions (ECMWF 2024) increasingly threaten cultural sites through water shortages, droughts, floods and damage to foundations.

Addressing these emerging threats demands sustainable adaptations in water management and comprehensive strategies to develop such adaptations. Water management plans have not been included in World Heritage nominations or in the management plans required for inscribed properties since 2005 (UNESCO 2005). However, incorporating these plans could enhance the conservation of World Heritage properties by ensuring adequate water supply and protection from water-related threats. As water problems escalate, appropriate water management can strengthen sites' resilience and long-term sustainability.

The solution to these challenges can often be found within the heritage sites themselves. Many World Heritage properties explicitly relate to water, as they were created to provide or treat water, to utilize water for various purposes or protect against it. Examples include pumping stations, dams, polder areas and historic water management systems. These sites contain valuable information about historical water management practices and strategies that have stood the test of time. Studying these sites can lead to a better understanding of past strategies, as well as inspire contemporary approaches to today's water-related challenges (Dai 2023). Therefore, integrating water management in the conservation of World Heritage properties is crucial. This integration should focus on preserving sites in the face of climate change, while respecting or adapting them in line with historical water management practices. This integration of water and heritage can help develop solutions that inspire water management beyond the World Heritage properties (Chen 2016).

This article seeks to encourage further exploration of this topic by examining the relationship between World Heritage and water. It emphasizes the need for water management planning to be included in World Heritage management, arguing that water serves as a critical link between the local and global dimensions of these sites, as well as between their past, present and future. Using cases from Germany, the article considers a variety of relationships between World Heritage properties and water management, highlights the importance of such management, and outlines current and emerging challenges.

World Heritage and Water: Multi-faceted Relationships

While individual World Heritage properties have unique local relationships with water, climate change is increasingly connecting these relationships to global phenomena within an interconnected system. The water-related challenges for World Heritage properties need to be assessed individually but can be grouped into categories common to many sites. Although the World Heritage List traditionally maintains

^ Fig. 2 An eighteenth-century depiction of the oldest existing waterworks in Germany, the Augsburg waterworks at the Red Gate (Source: Neitram, 2014. Wikimedia Commons, public domain).

a strict division between cultural and natural sites, with separate responsibilities assigned to advisory bodies (the International Council on Monuments and Sites [ICOMOS] and the International Union for Conservation of Nature [IUCN]), recent efforts have aimed to bridge this divide to foster a more integrated approach.

Initiatives such as the Nature-Culture Journey at the 2016 IUCN World Conservation Congress and the establishment of an International Scientific Committee on Water and Heritage by ICOMOS are examples of efforts to close this artificial gap and promote a more comprehensive understanding of cultural heritage sites as part of a complex natural system. Also, there is growing interest from the field of hydraulic engineering in historic aspects of water management, as demonstrated by an increasing number of sessions on water heritage at international conferences.[1]

Water-Related World Heritage

Beyond the institutional level, there are important relationships between water and heritage at individual sites that make any conceptual separation between culture and nature inconsistent. This is particularly evident in World Heritage properties with an explicit connection to water, such as the Water Management System of Augsburg. Listed in 2019, the site comprises 22 elements, including a historic water-powered cooling system, weirs, wells, canals and water-

1. Examples of such sessions took place at Amsterdam International Water Week 2023 and at the UN Water Conference 2023.

^ Fig. 3 The Srah Srang, a tenth-century artificial reservoir close to Angkor Wat (Source: Diego Delso, delso.photo. Wikimedia Commons, CC BY-SA 4.0 DEED).

works (fig. 2). These components connect the city of Augsburg, its inhabitants and local industry with the surrounding natural environment, forming a larger, integrated system.

Augsburg's ingenious management of water resources has helped the city prosper for centuries, highlighting the interdependence of culture and nature. Inscribed on the World Heritage List specifically because of its water management system, Augsburg naturally plays a key role in emphasizing the importance of water management in World Heritage properties. The City of Augsburg has published numerous resources on their website (https://wassersystem-augsburg.de/de/mediathek), detailing individual elements of the system and their functions.

Other World Heritage properties represent different types of water-related heritage. These include sites associated with distribution and drainage (such as the Persian Qanat and the Mill Network at Kinderdijk-Elshout), the use of water for industrial purposes (Mines of Rammelsberg, Historic Town of Goslar and Upper Harz Water Management System), military purposes (Dutch Water Defence Lines), trade and exchange (Venice and its Lagoon, Canal du Midi), agriculture (Rice Terraces of the Philippine Cordilleras) and leisure and health (the Great Spa Towns of Europe). So far, their common challenges have not been addressed as a unifying and compelling issue for World Heritage properties and their managers. Research, exchange and education in the field of water management at World Heritage properties are urgently needed and will only become more important in the future.[2]

The sites mentioned above are prime examples of sustainable water management. They illustrate its specific forms and show what has worked well in particular places and contexts. Research on these sites can illuminate which solutions have worked over a long period of time and under certain circumstances and how past approaches may be relevant today. Even examples that tell of the failure of long-term water management can be instructive, such as Angkor Wat, an extensive twelfth-century temple complex in the historical Khmer kingdom (fig. 3). The empire perished when the water supply system failed in the fourteenth century, and the site now offers insights into the complexity of the relationship between culture and nature (Prasad 2020). Historical examples can aid the development of new water management strategies. Today's changing climatic conditions make it necessary to adapt historical systems so that they continue to function effectively and meet current and future needs.

Water Challenges at World Heritage properties

In addition to World Heritage properties related to water and water management designated as having Outstanding Universal Value, there are a number of sites that are facing water-related problems. These include the Palaces and Parks of Potsdam and Berlin. Located in Germany's most water-rich federal state and surrounded by lakes, the existence of the historical parks is increasingly threatened by dry periods and declining water tables. As a result, almost 80 per cent of the trees in the Sanssouci World Heritage Site have suffered damage and every year 160–300 trees must be cut down (UNESCO-Welterbestätten 2024). Changing precipitation patterns have made tree damage a widespread problem across Europe and call for effective solutions. If sufficient water cannot be provided through adapted management, significant changes, such as the introduction of more resistant tree species, may alter the character of historic parks.

While many World Heritage properties are affected by drought, an excess of water also poses a serious challenge, with over 20 per cent of World Heritage properties worldwide affected by river flooding (Arrighi 2021). These problems extend beyond the physical boundaries of heritage sites, as water cannot be managed in isolation. Issues like drought and flooding are influenced by climate but also by large-scale infrastructure planning and often require solutions at the regional or even international level – if they can be addressed at all. When increasing flooding can no longer be controlled by flood defenses, site managers must implement structural measures to protect the properties. Where drought is a problem, they must develop mitigation strategies.

Water-related hazards not only can damage or alter the sites but can jeopardize World Heritage status if adequate protection is not provided (Gerard-Sharp 2017). A look at the 56 properties on the World Heritage in Danger list reveals that, after armed conflict, water issues are a major factor threatening the survival of the sites. Threats include the loss of aquatic life, siltation, flooding and the construction of reservoirs. Two of the three delisted World Heritage properties – Dresden and Liverpool – were water-related and insensitive changes to

2. The upcoming conference "WORLD.HERITAGE.WATER - Water Management as a Potential and Challenge in World Heritage properties," on November 7, 2024, in Leipzig will explicitly address this topic for the German-speaking world.

their attributes led to the loss of their Outstanding Universal Value. In the case of Dresden, the construction of a bridge over the Elbe destroyed a cultural landscape that had been designated a special treasure of humanity.

Water Management for (the) Future (of) World Heritage properties

More than ever, site managers are required to incorporate water considerations into their preservation and operational strategies. This need aligns with a broader understanding of World Heritage as “a process influenced by social, environmental and economic dynamics” (Gioia 2022) and calls for a deeper understanding of the systemic integration of cultural heritage sites. UNESCO’s support for education in sustainable development, such as the e-learning curriculum series on water management at World Heritage properties, reflects increased awareness of water issues in heritage preservation (UNESCO 2024). Exchange and education on this topic are crucial for implementing effective water management measures.

A comprehensive consideration of water management is not only important for current sites but also enables better assessment of the values and vulnerabilities of potential World Heritage properties, guiding the designation of attributes that convey these values. A better understanding of water relationships and challenges at World Heritage properties can aid the integration of water management in required site management plans, which will become increasingly important as water-related climate variability grows. However, UNESCO’s *Policy Document on Climate Action for World Heritage* (2023) does not fully recognize this need; while it emphasizes researching and documenting water management techniques to support climate science, it omits any reference to water management plans for individual sites.

In many cases, water management was historically integral to these sites but was not recognized as essential to their heritage. For example, could better research into the now-defunct historic water supply system at Sanssouci and its recognition as a vital part of the estate help improve the park’s ecological situation? Sound water management can certainly support the preservation of World Heritage properties and inspire broader strategies to address increasing water challenges.

Conclusion

The risk assessment of World Heritage properties and changing weather patterns demonstrate that integrating water management is crucial for the sustainable conservation of many cultural heritage sites, including cultural landscapes. This article confirms the need for water management plans and encourages further research and communication on this topic. It serves as a call for ongoing international exchange to develop guidelines for integrating water management and preservation. Such efforts may play a key role in incorporating water management into the management plans of World Heritage properties, which currently do not adequately address climate and water-related threats. In order to ensure the sustainable preservation and development of heritage sites, it is essential to challenge the arbitrary and misleading separation of culture and nature. Instead, built heritage should be conceptualized as a synthesis of both cultural and natural elements. Monument preservation and climate protection are intertwined, and water management plans represent a valuable step toward an integrated sustainability strategy.

Policy Recommendations

- Water management must become an integral part of the management plans of World Heritage properties. This includes comprehensive research into each site's water management needs and the exchange of knowledge among site managers. A systemic understanding of heritage sites, viewing them not merely as cultural artifacts but as entities embedded in natural systems, will help promote innovative approaches to conservation.

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Collaborating on Sustainable Interflow Water Collection: The Erfeng Irrigation Canal System from the Period of Japanese Rule in Taiwan

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While the world struggles with limited water resources, interflow water is a hidden gem of a solution. Interflow is an important water source contributing to river flow. It is the movable water in the unsaturated zone, or vadose zone, which may return to the stream or go into the riverbed. The collection of interflow water was included in the design of the Erfeng Irrigation Canal System (EICS) during the Japanese period in Taiwan (1895–1945), and it is still used in the EICS in Pingtung in southern Taiwan. Today, urbanization and changes in land usage have reduced the EICS's irrigation function. At the same time, intensive habitation has introduced pollution to the canal area. Furthermore, new extensions and rebuilt facilities of the irrigation infrastructure have minimized historic values. We are involved in working to maintain the canal in a way that safeguards cultural heritage values and to expand other functions of EICS, such as by installing micro-hydro facilities over the canal to preserve its importance to local communities.

KEY THEMES

CLIMATE

A B C D E

Am : Tropical monsoon climate

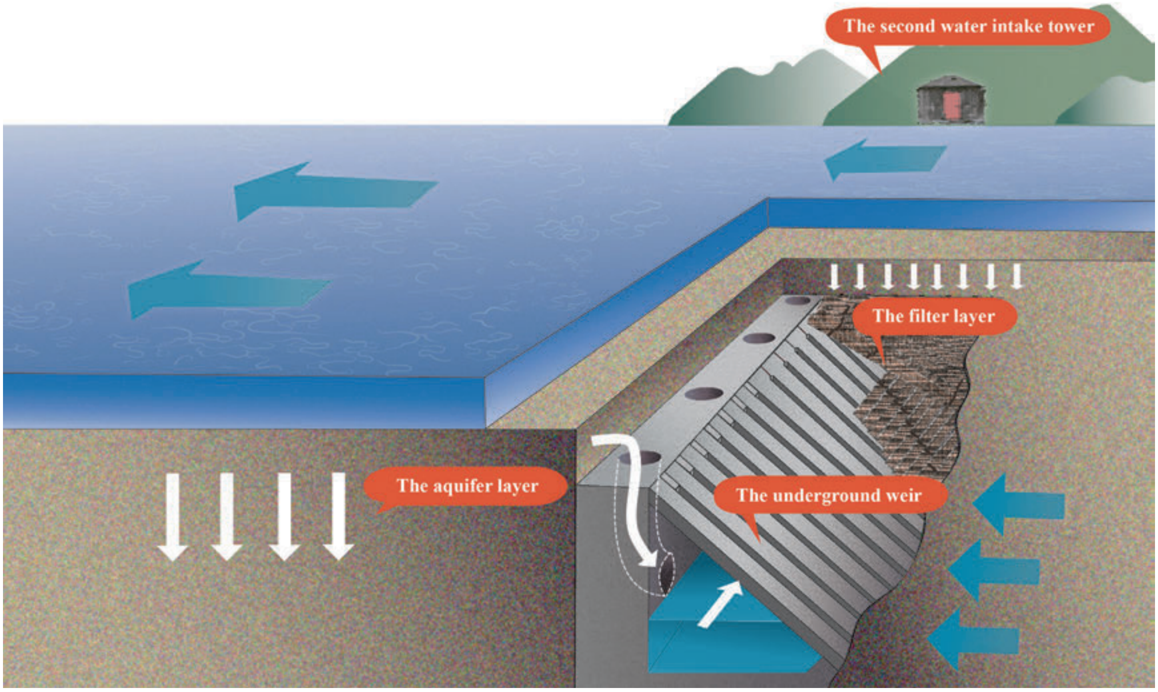
< Fig. 1 The EICS canal in the Pingtung farming area (Source: Szu-Ling Lin and Cheh-Shyh Ting).

Building the Erfeng Irrigation Canal System

The use of underground weirs to collect interflow water as a sustainable method of irrigation is not unique to Taiwan and Japan, but is an important hydraulic technology found worldwide. During the Japanese period in Taiwan, the Japanese wanted to plant sugarcane in a dry plain. Because of the slope of river and stone in the Pingtung area, dry plain conditions are common. The EICS used underground weirs to collect interflow water under the riverbed of the Linbian River to solve the problem of water shortage during the dry season. This kind of technology depends on precise water conservancy surveys to find a suitable water intake location. Then, an underground weir is installed to intake interflow water. With correct measurements of terrain height, it is possible to use gravity to send the captured interflow water to a farm 3436 meters away. In this way the EICS turned waste rubble into fertile fields of sugarcane.

During the Japanese colonial rule of Taiwan, the Japanese-owned Taiwan Sugar Company built two irrigation canals to irrigate sugarcane plantations and rice fields in the Pingtung Plain area in 1923 and 1925: the EICS and the Lili River Irrigation Canal System. EICS is larger and more famous than the Lili River Irrigation Canal System. EICS and its underground weir was designed by engineer Nobuhei Torii, who sought a way to collect interflow water from the riverbed of the Linbian River and solve the problem of water shortage during the long dry seasons in the Pingtung Plain (Torii 1936). After five years of investigation, Nobuhei Torri chose the proper site to bury the underground weir of EICS.

To build this irrigation canal system, the Japanese had to negotiate with local Indigenous people to obtain the territory and hire workers to build the irrigation canal system. Therefore, this irrigation canal system is a water conservancy project made possible by cooperation between the colonists and local Indigenous people. The underground weir of EICS consists of four parts: a trapezoidal weir, an arched tunnel, a catchment culvert and two water intake towers (a translation of the Japanese "*第一與第二取入水塔*") that function as manholes for maintenance access. The foundation of a water intake tower is laid underground, with the rest of its structure extending above ground. The trapezoidal weir, arched tunnel, and catchment culvert are laid to a depth of 2–7 meters beneath the alluvium gravel of the riverbed. The trapezoidal weir is 2.87 meters high, 0.91 meters wide at the top, increasing to 3.94 meters wide at the bottom. Its water intake surface consists of inclined concrete columns arranged to create a 25 per cent slotted seepage surface, forming a right-triangular water channel that is 1.82 meters wide at the bottom with a height of 1.82 meters. The trapezoidal weir, the main structure of the canal system, has a total length of ca. 328 meters, stretching from east to west at a gradient of 1/100 (figs. 2 and 3). The western end of the weir is connected to the eastern end of the arched tunnel, which admits interflow water from the weir into the water intake tower. The tower, which is the endpoint of the structure, is ca. 1.5 meters in width and 8.4 meters in height. The interflow water flows from the arched tunnel through the water intake tower and eventually enters the conveyance waterway. The conveyance waterway is ca. 3.6 kilometers long. A diversion structure (figs. 1 and 4) divides the irrigation water into three routes leading to farms. Using precise topographical measurements, Nobuhei Torii designed a suitable underground weir structure that can successfully collect interflow water without electricity and can use natural gravity to allow water for irrigation to flow to farms 3.6 kilometers away. The area of the irrigated farms were about 3,000 hectares



^ Fig. 2 In the EICS, the underground weir and the second water intake tower (Source: Szu-Ling Lin and Cheh-Shyh Ting).

during the Japanese period. Today, the area of irrigated farms is 2,193 hectares.

Preserving and Managing the Water Heritage of the Erfeng Irrigation Canal System

The canals and sugarcane plantations continue to be maintained by the Taiwan Sugar Company, which was inherited from the Japanese after World War II. The farms stopped growing sugarcane in 1998, and the company is leasing most of its farms, which are being used to grow other crops. Furthermore, some water from EICS contributes to the local Indigenous communities' daily water supply. In 2008 the system was registered as a cultural landscape under the Cultural Heritage Preservation Act because it qualified as industrial heritage with scientific value. This cultural landscape demonstrates one way that human beings can overcome constraints of the natural environment and use its characteristics to create irrigation canals that make it possible to grow crops. In 2017 the underground weir in EICS was part of a large-scale excavation and restoration project after damage occurred as a result of changes in the topography of the riverbed. The construction of the underground weir could then be documented by the EICS (fig. 5).

Today, maintaining and using water as a resource has become a major focus of human activity. Systems of land reclamation, water supply, irrigation, submergence, sewage and micro-hydropower generation help build, define and sustain societies. Water control has long been a strategic social and political consideration for communities.

After World War II, Indigenous people moved from their original village to an area along the line of the delivery waterway (conveyance wa-

^ Fig. 3 The interior of the underground weir in the EICS (Source: Szu-Ling Lin and Cheh-Shyh Ting).

terway) of EICS. In the early period of the initial relocation in the 1950s, the Indigenous people of this area did not pay close attention to domestic wastewater treatment and facilities. Nor did the government invest adequately in infrastructure. At present, the use of interflow water by the residents along the EICS has significantly increased and pipes are covering the conveyance waterway (fig. 6). Residents have been improperly withdrawing water from the EICS. In recent years, the number of residents has increased, and the Pingtung County Government is making progress improving wastewater treatment facilities. In the future, the EICS's excess interflow water could be diverted to the Taiwan Water Company and used for people's livelihoods, so that the EICS can continue to operate sustainably.

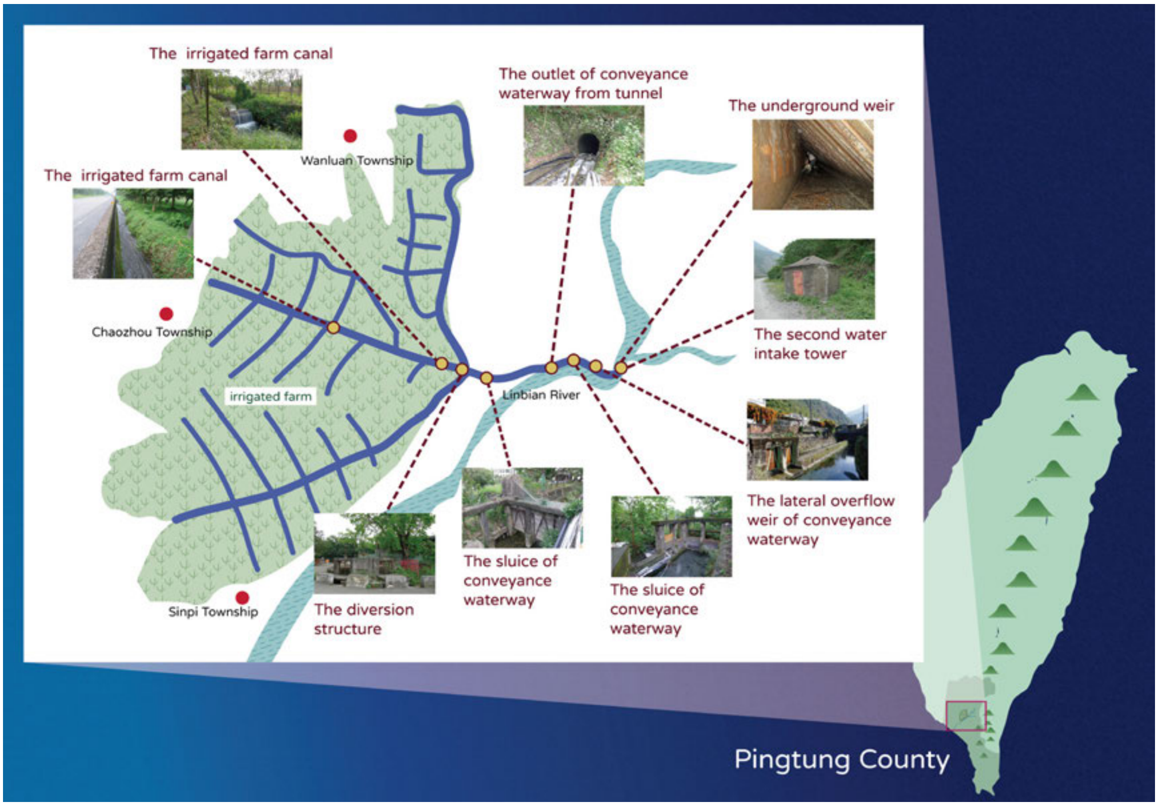
Water heritage conservation has a diplomatic function. The design and construction of the EICS is an example of sustainable and ecological thinking from a century ago. In 2008 when the EICS was listed as cultural heritage in Taiwan, the value of science and technology in the cultural landscape that was shaped by academic and cultural exchanges between Taiwan and Japan was recognized. This recognition is the basis for sustainable management as well. For the people of Taiwan and Japan, the need for management has led to a greater awareness of history. The preservation of the cultural heritage of the EICS has even led to cultural exchanges between Taiwan and Japan. Many Japanese tourists have been drawn by the EICS to visit the Pingtung Plain area. Because of such achievements, Prof. Cheh-Shyh Ting, one of the authors of this article, was honored with an award by the Japanese imperial family in 2023.

To expand the value of the EICS, engineers have been attempting to develop green micro-hydro power energy from the water collected by the EICS irrigation system. The power can be used by the local communities. Pingtung County is an area with abundant water resources, and the county government currently promotes special Green Micro-hydro Power Energy Development Projects in the EICS. In demonstrating and coordinating the micro-water green belts, the equipment has been installed, without interfering with the original water conveyance, to promote the monitoring and development of water conservation and green energy in the community.

Conclusion: Challenges to Developing a More Sustainable Water System

There are three main concerns motivating the current conservation approaches toward the EICS:

1. With intensified urbanization and rapid changes in land use, many irrigation canals

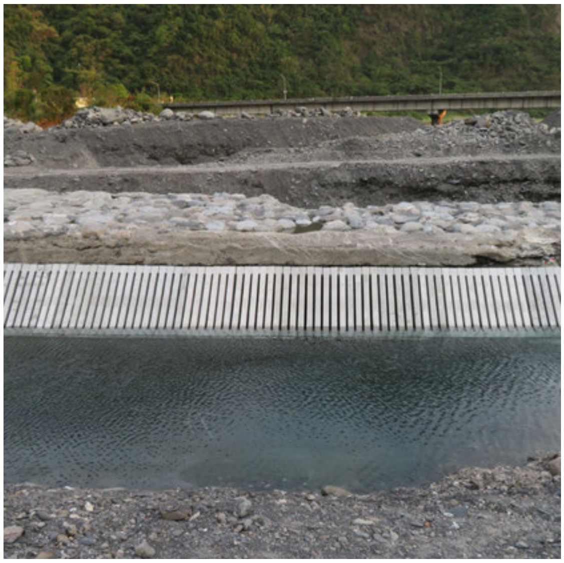


^ Fig. 4 The location and layout of the EICS (Source: Szu-Ling Lin and Cheh-Shyh Ting).

in the farming area have been destroyed.

2. The improper use of water by residents living along the delivery waterway pollutes and damages canals.
3. To improve the efficiency of water delivery or to expand the road, some canals in the farming area have been rebuilt, which has resulted in the loss of historical value.

Meanwhile, many EICS canals in the farming area have been partially destroyed. Moreover, some of the EICS canals in the farming area were converted to modern canal technology because of enhanced hydraulic efficiency. For the farming area of 3,000 hectares irrigated by the EICS, urbanization has brought many changes to the irrigation route. The function of the town has changed and reduced the scope, raising



^ Fig. 5 The construction of the underground weir in EICS (Source: Szu-Ling Lin and Cheh-Shyh Ting).

^ Fig. 6 The pipes covering the conveyance waterway of the EICS (Source: Szu-Ling Lin and Cheh-Shyh Ting).

questions about how to preserve the original irrigation function and the original facilities of the ECIS in the future. Preservation of the century-old irrigation project will also preserve important cultural heritage that includes knowledge of people, things, time and place. For this to happen, it will be necessary for the government and the public to strengthen communication.

In 2022 the Pingtung government launched a cultural heritage conservation plan to ensure a conservation area covered all the EICS canals in the farming area. This project is attempting to balance new kinds of land use with the preservation of the original EICS canals in the farming area. Interviews with stakeholders are clarifying the complex issues surrounding land use and preservation. Light detection and ranging (LIDAR) technology is being used along with field investigation and historical document research to reconstruct the original EICS channels in the farming area. The project follows proper preservation methods. According to the LIDAR results, we can observe changes in the canal structures in the farming area of EICS from the Japanese period to the present.

Here we recommend some important principles to follow in the conservation of EICS. When discussing the cultural heritage value of water resource engineering, it is necessary to pay attention to the integrity and authenticity of the operation of a single water resource engineering system, and to fully understand the systematic or serial relationship between different kinds of water resource engineering systems, to avoid a narrow vision that focuses on the value or preservation of a single or partial building or structure. It is important to clearly discuss the value of water as cultural heritage. Therefore, efforts to conserve the cultural heritage of water infrastructure should recognize the importance of

1. The integrity of a single water resource engineering system.
2. The authenticity of single water resource engineering equipment and structure. This will involve the application of engineering technology in different periods, which must be categorized according to the timing of the application of the engineering technology.
3. The systematic and serial correlation of different water resource engineering systems.

Implementing these steps will take time.

Furthermore, in terms of the national development of green energy policy, due to the stable flow of the waterway, it has been evaluated as suitable for hydropower generation. A set of demonstration micro-hydraulic power generation units was set up as a test, and the results were positive. The development of the power system makes the development of water conservancy resources on the waterway more sustainable. With cultural preservation, the interflow water conservancy wisdom of the past can be passed on to future generations and the new function of green energy can expand the system's value.

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Traditional Khmer Water Practices: A Case Study of Phnom K'to, Vietnam

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Phnom K'to (Cô Tô Mountain) is the easternmost peak of a small chain of granite outcrops of Vietnam's Mekong Delta. It reveals a long and rich tradition of water management that is often overlooked in present-day development. Although the region is under Vietnamese control, it had centuries of Khmer rule and inhabitation. Today, the marginalized Khmer settlements around Phnom K'to are spread across varied terrain, from rugged mountains to muddy floodplains, with monsoon-fed and flood-cycle cultivation. The Khmer's traditional water practices were carefully adapted to topography and water variations, forming interconnected habitats and productive mosaics specific to Khmer society. However, their vernacular landscape has been dramatically transformed and recast by modern canals (since the nineteenth century), dike building and granite mining (since 1975), and roads and reservoirs (since the 2010s). Whereas the entire region suffers from the consequences of global warming (particularly floods and droughts) and ecological destruction, there is an opportunity to revisit traditional Khmer water practices to provide insights for reconfiguring the water system. Fieldwork-based drawings, annotated with Khmer terminology, highlight morpho-topological readings of the relationship between water management practices and settlement. The research seeks to uncover opportunities to revisit and revalue such practices to renew stewardship of the territory.

Keywords: *traditional Khmer water practices, landscape mosaics, stewardship, adaptive (re)cultivation, traditional ecological knowledge*

KEY THEMES

CLIMATE

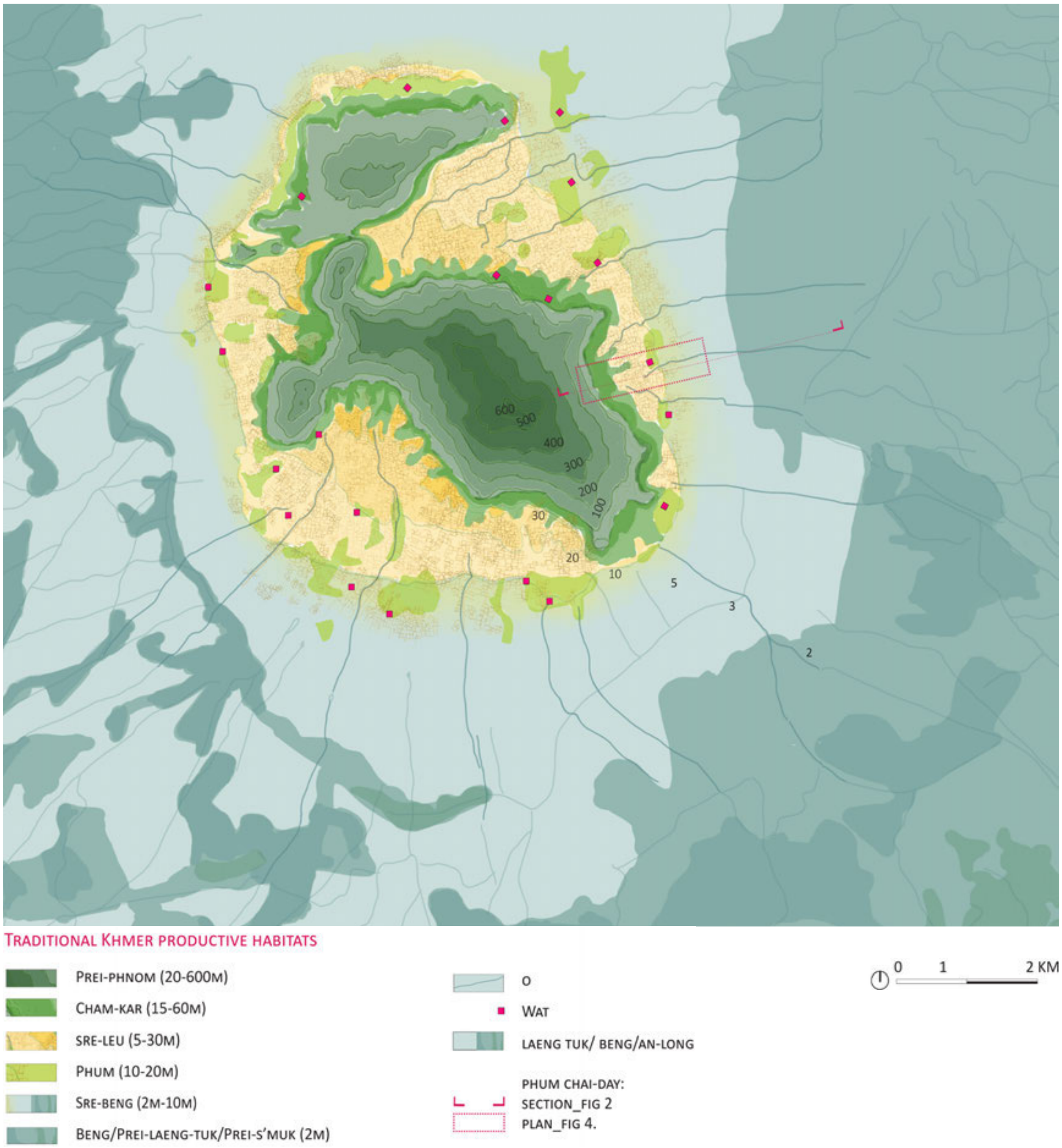
A B C D E

Am : Tropical monsoon climate

< Fig. 1 *Chamkar* (foothill garden/orchard forest) to *sre-leu* (terrace rice field) in Phnom K'to (Source: Linh Vu, 2022).

Traditional Khmer Water Systems and Habitats in the Mekong Delta

The Long Xuyên-Hà Tiên Quadrangle in Vietnam, along with the Plain of Reeds and Cambodia's Tonlé Sap Lake, form the primary seasonal freshwater reservoirs in the Mekong Delta. The Long Xuyên-Hà Tiên Quadrangle shares traditional Khmer water practices that also exist in present-day Cambodia. The transboundary flood regimes and interactions with mountainous topography have led to the development of



^ Fig. 2 Phnom K'to traditional water system (Source: Linh Vu, 2024).

a particular traditional Khmer water management system. Phnom K'to in Vietnam serves as a case study within this landscape. Phnom K'to (Cô Tô Mountain) is in the region known in Vietnam as the Seven Mountains (Thất Sơn). It is part of the Cardamom Mountains, mostly in Cambodia.

In folk tales, Phnom K'to is described as the most poetic and spiritual among the mountains in the Mekong Delta, where water is key. Its sacred mountain forest feeds several *o* (streams linking the foothills and the fields) that nurture productive habitats in the plain before merging with the flood regimes of the delta (Son 1959). Khmer cosmology is interwoven with the delta-mountain geography. Six major productive habitats are embedded in the water-topographical system, forming the Phnom K'to landscape. They are 1) *prei-phnom* (mountain forests); 2) *chamkar* (foothill gardens/orchard forests); 3) *sre-leu* (upper field/rainfed terraced rice field); 4) *phum* (inhabited garden/village) in the alluvial apron; 5) *sre-beng* (lower field/flooded rice field) and 6) *beng/prei-laeng-tuk/prei-s'muk* (marshland/swamp/flooded melaleuca forest) in the floodplain (fig. 2).

Traditional Khmer Water Management Practices and Cultural Landscapes

The Khmer Indigenous landscape has been maintained for centuries by a sequence of typo-morphologies across the topography and through habitats, from the mountain to the floodplain, reflecting the Khmer culture of respecting trees, water and soil (fig. 3). Beginning in the higher elevation, *prei-phnom* is the primary water source. It stores monsoon water, recharges aquifers and maintains biodiversity. In Khmer tradition, the *prei* (forest) is a sacred entity with limited access (Son 1959). The *mac-tuk* (mountain stream) is naturally retained at the *la-an* (ravine) foothills before being directed to fields. On the slopes, the *chamkar* is formed through selective clearing and planting, with a water management system centered on the *la-an*, *trapaeng* (natural pond/wetland) and *an-tuk* (constructed pond/water tank).

Different irrigation techniques are employed in the *sre-leu* and the *sre-beng*. Water from the foothills flows through the *o* to the *sre-leur* and cascades from one terrace to another through openings in the *pleu* (terrace wall). Various *an-don* (excavated ponds) and *o* (natural ponds) retain water, while the *andon-tuk-dei* (well) is used in the dry season. Meanwhile, in the *sre-beng*, traditional Khmer cultivation follows the Mekong flood regime, particularly through the practice of growing *srau-peang-tuk* (floating rice). Here, natural *beng* and *prei s'muk* host water and aquatic species. In the *phum*, water for production comes from common sources such as *o*, *andon-tuk-dei* or *sras* (pond of the wat). Each family typically has its own *andon*, *an-tuk* or a drilled well.

Role of the Wat: Water Management and the Social Construction of Space

Wats are Theravada Buddhist temple complexes that are the heart of Khmer society and important features in the landscape. Located in the foothills and in the alluvial apron near main streams, wats literally and figuratively sustain Khmer society and play an important role in the water management of the productive landscape (Taylor 2014, 162–90). Every *phum* has a wat; it provides a focal point for individual, religious and institutional milestones. Monks guide the community's cosmological and agricultural rituals (Le 1969). In Phnom K'to, a few extended families formed a *phum* with a wat, which ex-

Traditional Khmer productive habitats	**Water terms/typologies**
Prei-phnom (mountain forest)	*An-long* (all-year submerged area on floodplain)
Chamkar (foothill garden/orchard forest)	*Andon* (dug pond/shallow well)
Sre-leu (upper field/rainfed terraced rice field)	*Andon-tuk-dei* (well)
Phum (inhabited garden/village)	*An-tuk* (pond/water tank)
Sre-beng (lower field/flooded rice field)	*Beng* (marshland/swamp)
Beng/prei-laeng-tuk/prei-s'muk (marshland/swamp/melaleuca forest)	*Hoc* (small ditch)
	La-an (ravine/all-year mountain stream)
Features and plants	*Le-ron* (ridge and furrow)
Chai-day (stupa/ash-tower in wats/phum's name)	*Mac-tuk* (mountain stream)
Daem koki (Hopea odorata, growth as wat's forest)	*O* (stream from the foothill to the field)
Krang (garden/forest island on the field)	*O* (natural pond near the phum or stream)
Ktom neak ta (spirit house)	*O-tuk* (running water/ditch)
Neak ta (more-than-human-beings in Khmer animism)	*Pleu* (rice-terrace walls)
Prei (forest)	*Prek* (channel/canal/river)
S'muk (flooded melaleuca)	*Sras* (brick/stone pond in the wat)
Srau-laeng-tuk (floating rice)	*Trapaeng* (natural pond/wetland)
Sre (rice field)	*Tuk* (water)
Sre-co-beng (overlap system of sre-leu and sre-beng)	*Tuk-choh* (flood reversal)
Daem svay (mango tree)	*Tuk-haur* (water descends from the mountain)
Daem thnaot (palm tree)	*Tuk-kraom-dei* (ground water)
Wat (Buddhist temple complex)	*Tuk-laeng* (flood-rising/flooding season)
	Tuk-reak (water drying up/dry season)

* The terms were collected during fieldwork and in discussion with a local senior social worker. They are also mentioned in the published works of Taylor (2014), Nam (1959) and Vuong (1993). Khmer terminology reveals an intimate link of language, place names and everyday practices to landforms and ecological processes. The water-related terms also embody sacred meanings and social-ecological interconnectedness in landscape construction through generations of families and the larger community. It is critical to learn from the case since local Khmer practices and terms are being replaced by Vietnamese systems and names that do not necessarily carry the same embedded meanings. This in turn, results in both a disregard and loss of traditional water management practices and spaces and a loss in water management knowledge.

^ Table 1. Khmer words in the drawings and writing* (Source: Linh Vu, 2024).

panded and has been rebuilt over time. Wats institutionalize the inhabited landscape through labor and material offerings. However, despite the wat's domination, ancient animist traditions continue to be respected alongside Buddhism. This means that the wat does not dominate nature (mountain, forest, water regimes) but instead integrates with it (Phan 2014).

Water activities in the *phum* are spatially and symbolically linked to the wat, which helps maintain and protect water sources for the community. The *sras*, built by the community using stone, is important for storing water (Le and Nguyen 2021), especially in the dry season. Since water is central to Khmer cosmology, as a component of the wat, the *sras* is sacred and its water is used carefully. Lotus is often grown in the *sras*, which minimizes evaporation and purifies the water while serving as a religious symbol.

The wat is also the center of seasonal festivals and water ceremonies, which are essential to social and agricultural life. Events such as Choul-Chnam-Thmey (New Year Festival) and Ok-Om-Bok (Moon Festival) include rituals like welcoming and praying for rain, celebrating the recession of floodwaters and offering prayers to the moon for the monsoon season. Floating altars and lights are used in ceremonies to bless the community with good crops.

Historically, wats were closely connected to a natural water source and local animist practices and beliefs, particularly those involving *neak-ta* (more-than-human beings). For example, near the *la-an* in the *phum* Chai-day, local people planted a *daem svay* (mango tree) to mark the most critical communal and perennial water source. Traditionally, shrines or sacred rocks have been placed near *la-an* in gratitude to the mountain forest *neak-ta* for abundant water; these can still be found near historical wats and ruins close to the foot of the mountain. Throughout the Khmer's tumultuous history in the region, wats have been closely linked with the building and rebuilding of Khmer communities (Taylor 2014).

Mosaics and Flows as Integrated Systems: Kinship in Landscape Operation

The cascading productive mosaics and flows in Phnom K'to have been shaped and transformed over centuries through interrelated water management processes. These processes involve micro-topographical manipulation and the maintenance of shared ecological resources, often managed through kin networks. Traditional Khmer social structures – including household members and relatives, neighbors and friends within a hamlet or nearby hamlets – mobilize groups to engage in wet rice cultivation. This labor-intensive practice relies on simple techniques and rudimentary tools that minimize soil and water disruption (Son 1959). Despite modernization and the imposition of more generalized systems, these cooperative social structures, rooted in kinship and communal labor, persist to varying degrees (Biggs 2012; Linh 2016).

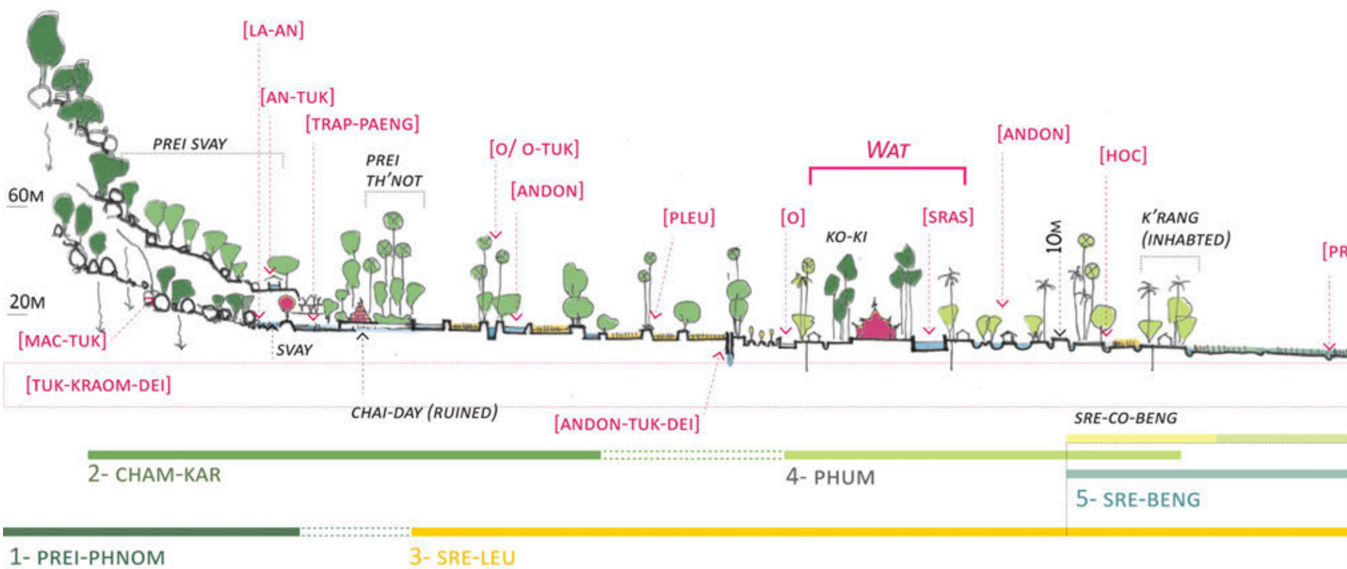
Slope reclamation in Phnom K'to has created productive landscapes with minimal earthworks. Effective water management for planting requires careful manipulation of micro-topography, while seasonal water, temperature and vegetation cycles make the earthworks dynamic. Precise quantities of water are essential for plant growth, which can be difficult to achieve in extreme wet or dry periods. A common technique, the *le-ron* (ridge and furrow), helps conserve water during droughts and drain excess during wet-season overflows. Flat areas are cleared to make the *sre-leu* (upper field/rainfed terraced rice field) and *pleu* (terrace walls) retain water. The topography defines an organic *sre-leu* morphology, with uneven *pleu* ranging from a few centimeters downhill to a meter uphill. These fields, typically small – often less than 0.3 ha – are crafted using simple, traditional methods that make them manageable for local farmers.

The cascading arrangement of productive mosaics and the careful maintenance of water flows create ecological connections across diverse terrains and habitats. The rough surfaces of foothills and wetter areas along streams are prioritized for *chamkar* and water retention, forming "wet-green flows" that are thick in the foothills and sparser in the floodplain. Natural streams and watersheds are reconfigured to integrate productive plots and water channels that divert the mountain water to various fields or discharge surplus water. This system incorporates a network of various ponds and wetlands, which act as micro-watersheds. Protected from evaporation by tree canopies and aquatic vegetation, these water bodies help minimize evaporation, ensuring sustained water availability for the ecosystem.

Finally, *bau-waq* (shared/aid-labor) is a Khmer tradition in which kin groups help one another in the fields, especially when planting rice, transplanting seedlings and harvesting crops. The rationale behind the collective practice is not only that it makes possible the required labor intensity but also offers a way of dealing with subtle differences in wetness and, consequently, in time-intensive work in the *sre-leu*. Many Khmer water terms, such as *la-an*, *trapaeng*, *pleu* and *o*, denote common use and care, as well as degrees of sacredness.

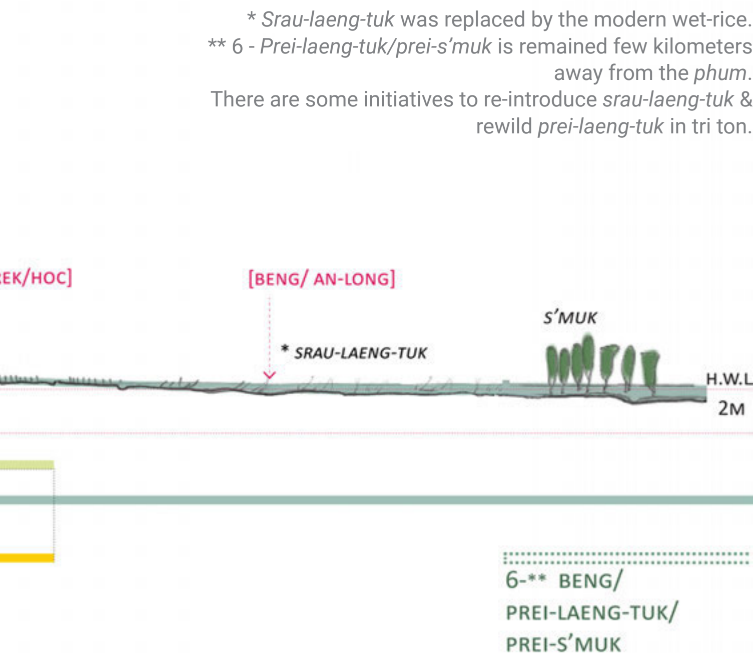
Seasonal Daily Stewardship: The Cultivation of Culture

For centuries, Khmer everyday practices were related to cosmology, where destruction precedes



^ Fig. 3 Khmer morpho-typologies (and terms) pertaining to water practices are related to habitats and topography across Phum Chai-Day, Phnom K'to (Source: Linh Vu, 2022).

^ Fig. 4 The reconstructed *sras* (pond) in 1995 in Wat Chi-mung, built in 1712 in Phnom K'to. These construction dates were written on the gravestone inscription near the entry of the wat (Source: Linh Vu, 2022).



rebirth (Taylor 2014, 252–71). Even today, everyday practices intertwine with water stewardship, forming natural–cultural interactions (Bourdeaux 2023). In Phnom K'to, farming takes place year-round, and everyday water practices are synchronized with the seasons. The Khmer seasons are named in relation to water regimes and their accompanying practices and rituals. In the upper fields, *tuk-haur* (run-down water) denotes the rainy season *w*hen monsoon water descends from the mountain, whereas *tuk-reak* (water dry-up) indicates the dry season. In the lower fields, the seasons are known as *tuk-laeng* (flood-rising) and *tuk-choh* (flood reversal). The beginning of the planting season is a time to pray to *neak-ta* for rain and favorable weather to start preparing the *sre* (rice field). Meanwhile, the cultivation season culminates with harvesting and the Ok-Om-Bok festival to thank the moon being for good crops. In traditional Khmer homesteads, cultivation of the annual rice crop is adjusted to natural water conditions and does not require large-scale hydraulic interventions. Farmers grow wet rice and gather fish in the rainy season; they grow drought-resistant plants and raise herd animals that graze on fields in the dry season. They make use of the *chamkar* throughout the year.

Conclusion: Learning from Traditional Khmer Water Management to Adapt to Global Warming

Traditional Khmer water management in Phnom K'to shows how local ecological knowledge frames the morphological identity and social meaning in collective processes of domesticating landscapes. All water elements and the cascading productive mosaics embody elements of Khmer cosmology and integrate daily water stewardship with cultural traditions. The cascading productive mosaics and water elements are not only functional but also symbolically tied to the Khmer worldview.

The Khmer vernacular landscape has been continually transformed by external influences, beginning with Vietnamese colonization during the Nguyễn Dynasty and continuing through the introduction of new technologies during the colonial period and centralized state interventions (Biggs 2012; Linh 2016). Key changes include deltaic canalization in the early nineteenth century, the construction of high dike systems since 1975, the expansion of rock mining in Phnom K'to since 1985, and, since 2020, extensive road widening and paving. Additionally, large-scale water reservoirs have been built since the 2010s to support intensive agricultural production. These interventions have resulted in severe environmental destruction, intensified water scarcity and the disruption of Khmer cultural identity. The language of the landscape has been altered, as traditional terminology has been replaced by engineering jargon, erasing

^ Fig. 5 Landscape mosaics and flows with micro-topographical manipulation and plantation are labor-intensive and involve traditional kinship patterns. Phum Chai-day (Source: Linh Vu, 2024).

the cultural significance embedded in the landscape.

Given these challenges, there is an urgent need for a radical shift in approach. Traditional water practices, which have been acknowledged as relevant in global warming discourse, can aid the development of innovative approaches, including those that involve integrating technology and social organization (Krupnik et al. 2018). Traditional knowledge that is deeply rooted in the Khmer landscape and everyday practices suggests the value of cooperative strategies and community stewardship that works in harmony with natural processes rather than by imposing conventional civil engineering solutions.

Policy Recommendations

- The design of water projects, programs and policies should be informed by a combination of current scientific knowledge – such as hydrological models that address the impact of global warming – and lessons from Khmer traditional water practices and knowledge. These traditional practices, which work with the forces of nature, offer an intelligent and culturally resonant alternative to conventional civil engineering approaches. In the case of the Khmer, the traditional water terminology and management are reflected in landscape morphologies and daily practices, promoting cooperation and sustainable water management through community stewardship.

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Keta Lagoon: Uncovering Suppressed Heritage Practices for Sustainable Wetland Management

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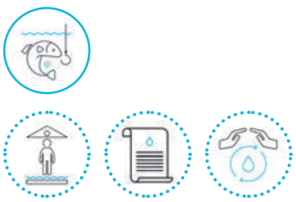
Current efforts to integrate heritage practices in the sustainable management of wetlands in postcolonial nation-states assume that these practices have always existed in the forms they are now. The colonial order, whether deliberately or otherwise, suppressed many local traditional practices. The postcolonial authority's adoption of Western science invariably continued the suppression, albeit in a more liberal form. In the Ramsar Convention, natural scientists were assigned the role of conserving wetlands "for the benefit of humankind in a way compatible with the maintenance of natural properties of the ecosystem." This became known as the wise use principle. This article highlights the history of the Keta wetlands and proposes an integration of key knowledge holders into management plans for a wise use of wetlands in postcolonial states. The colonial and postcolonial regimes made the knowledge holders invisible. Modern imaginaries – Western legal institutions, Western science and Christianity – were privileged over local heritage practices. It therefore requires historical and heritage expertise to uncover local sustainable knowledge for integration into the Ramsar management plan, hence a wise use of wetlands in postcolonial states.

KEY THEMES



CLIMATE

A B C D E

Aw : Tropical savanna climate

< Fig. 1 A fisher using sail on canoe (Source: Jonathan Doe, 2021).

Introduction

On August 14 1992, Keta Lagoon, located in Ghana, was designated the Keta Lagoon Complex Ramsar Site on The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) list. Although Ghana as a contracting party to the Ramsar Convention has five wetlands listed, the focus of this article is on Keta Lagoon, the largest and most complex wetland in Ghana, and the Aŋlo-Ewe people who live on the banks of the lagoon. Aŋlo-Ewe people migrated from the ancient town of Ŋotsie to the banks of the Keta Lagoon in the early sixteenth century (Amenumey 2008). Their institutions and belief systems made them well-adjusted to the vagaries of the Keta Lagoon and the Atlantic Ocean (Akyeampong 2001; Nukunya 1969). From the ethnographic record, they attribute female and male genders to the Keta Lagoon and the Atlantic ocean respectively. Many decades after that, the Aŋlo-Ewe people came under the control of Danish, German and British colonial regimes. Their chiefs, priests, diviners (*boko*) and belief systems became entangled with colonialism. Local belief systems were also suppressed in colonial and postcolonial regimes. Here, the local fishing practice, *atsidza*, will be highlighted as a *wise use* and as a sustainable fishing practice. In this article, "local belief systems" is used interchangeably with "heritage practices."

Suppression of Heritage Practices during Colonial and Postcolonial Contexts

In postcolonial Ghana, Western science, Western legal regimes and Christianity occupy a dominant position. All three have been perceived as vehicles of modernity and hence modern imaginaries that influence policy choices. Christianity was introduced during colonial encounters and embraced by a large section of the people. The local belief systems were thus perceived as non-Christian, non-scientific and antimodern (Akyeampong 2001). Colonial laws were established to regulate knowledge holders, local belief systems and practices in relation to the Keta Lagoon. For instance, the authority of the priests of Togbi Nyigbla and Mama Bate – a male and female god respectively among Aŋlo-Ewe – was undermined regarding how the lagoon could be used. In 1914 the priests in charge of gods banned the use of sails on the lagoon. The reason for the ban is not clear from the archival records. Suffice it to say, there were sails on European slave ships docked at the nearby Danish slave fort, Fort Prinzensten (Ghana Museums and Monuments Board). The people observed the ban from 1914 until 1920s when the colonial district commissioner teamed up with the paramount chief to remove the ban. Though sails are part of contemporary fishing practices in the area (fig. 1), the agency of knowledge holders had been chipped away. In the same period, some of the mangroves along the banks of the lagoon were seen as shrines, and thus were (p) reserved as such. In 1915, a sub-chief who had been converted to Christianity destroyed the mangrove-shrines in his jurisdiction as an attempt to "christianize" all his subjects. Then, in 1959 the colonial government introduced the concept of a forest reserve along a portion of the lagoon, but there was no relationship between the reserve and local belief systems nor was the agency of the priests of Togbi Nyigbla and Mama Bate engaged in management of the forest reserve (Asafu-Adjaye 1961).

The trend of suppression of local belief systems and knowledge holders took place under colonial direct rule and indirect rule regimes. The forest reserve laws and the laws that banned some of the local practices were implemented through the chiefs of the Aŋlo-Ewe. Thus, the priests, diviners and leaders of the shrines were sidelined. When Ghana attained independence in 1957, Christianity and its associated modernity continued to be on the rise, while the local belief systems, as well as holders of such knowledge forms, continued to be suppressed. The logic in modern philosophy that allowed for the suppression of local beliefs took on new forms when Ghana ratified the Ramsar Convention in 1988. The lagoon was seen as a scientific object, and it was scientists who determined who should play what role in its management. The involvement of local knowledge holders followed the same logic as the colonial indirect rule system. The Keta Lagoon management plan acknowledges that the traditional council of Aŋlo owns the Keta Lagoon. It is further acknowledged that the Aŋlo traditional council determines who is a community member; the council also resolves conflicts among traditional members.

Furthermore, the council makes "by-laws for wetland resource management based on local knowledge of the ecological dynamics and institutes measures to deter local people from using wetland resources" (Tufour 1999, 27). However, the composition of the traditional council did not directly include priests or diviners, nor was any role directly assigned to them during either the colonial or postcolonial period. Again, the notion of ownership does not include the families and clan heads, some of whom could disagree with the traditional council (Doe 2022).

Instead, traditional authorities, district assembly and civil society groups, which are mainly modern institutions, are recognized as having "decision-making" roles (Ministry of Lands and Forestry 1999, 17). These groups are not direct knowledge holders, as was the case in 1914. There is no clear-cut role for diviners (*boko*), Togbi Nyigbla or Mama Bate priests.

The *Atsidza* Fishing Technique

The *atsidza* fishing process begins with cutting stems and branches of trees from the bank of the lagoon or on the mainland. The number of trees depends on how big the fisherman wants the *atsidza* to be. The cut branches are allowed to dry for about three weeks. The fisher then piles the branches in a boat and ferries them to a desired part of the lagoon, which is usually in deeper areas (*Uego*). The branches are dropped at a specific spot to cover a radius of about three meters. The fisher uses stronger and taller stems for three purposes. The most obvious is to serve as a barrier to prevent the lagoon currents from dispersing the branches. The *atsidza* eventually becomes compact and firm, trapping sediment (mainly anaerobic mud, sand and shell) and creating soft ground for fish to burrow in. When it is left for about a year, the bigger fish (tilapia) go deeper by digging holes in the ground, and the *atsidza* becomes a covering. The other purpose is that the poles serve as a signpost and a warning to other fishers that there is a deposit of branches there. The final purpose of the taller poles is as a stamp of ownership. In some cases, the fisher hangs a bundle of red cloth and cowries, signifying that the *atsidza* is under the protection of his god, so everyone in the community knows the *atsidza* is owned by a particular member of the community.

With the poles showing, it is clear that the *atsidza* occupies space in the Keta Lagoon and has an owner (fig. 2). However, if the poles become weak, it is pushed down by the lagoon currents and it is assumed that no one owns it, so others can harvest the fish residing in the *atsidza* or they may find different uses for the branches. Therefore, *atsidza* ownership is subject to time: it is temporary, with no guaranteed ownership. After a period, the space

^ Fig. 2 A fisherman using the atsidza technique in the Keta Lagoon (Source: Jonathan Doe, 2021).

^ Fig. 3 Seine fishing net (Source: Jonathan Doe, 2021).

can revert to another person in the community. There is yet another factor that is important for the duration of ownership: labor. Sure enough, there is labor involved in the cutting of the trees and the making of the *atsidza*. Continued maintenance is needed to ensure the lagoon currents do not overpower the poles. The individual's time and labor become intervening factors in the duration of ownership. It can be said that the time-labor factor, the involvement of personal gods and the belief in the instructions of local priests regulate(d) communal resource ownership in the Keta Lagoon. Given the time-labor factor, most fishers prefer seine net fishing with wooden canoes and sails. However, the *atsidza* fishing technique is sustainable in that it does not pollute the lagoon and does not necessarily deplete the fish stock, but serves as a temporary haven for the fish from those who use the seine net method daily (fig. 3).

Conclusion

In conclusion, the search for sustainable heritage practices for wetland management in postcolonial states requires a deep look at heritage practices that have been suppressed in the colonial and postcolonial periods. There are some that remain visible, like the *atsidza* fishing technique, but they require a shift from dominant modern imaginaries to see how they innovatively complement sustainable measures of SDGs 14 and 17. The combination of archival research, participant observation and awareness of colonial direct and indirect rule would help uncover sustainable heritage practices and their knowledge holders. The current roles ascribed to some local leaders were convenient for the colonial enterprise and may not be helpful for fully integrating heritage practices in wetland management plans. Communal ownership is one viable concept that could be part of management plans. Finally, when heritage practices in Aŋlo are better known, they could promote Ramsar's *wise use* philosophy.

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An Ingenious Heritage System for Collecting and Distributing Flood Water in the M’zab Valley of Algeria

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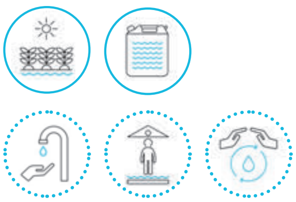
University Ferhat Abbas of Setif

Foggaras are traditional Algerian water systems, which historically have made it possible to collect and redistribute water in the Sahara Desert. Although threatened by climate change and unsustainable urbanization, foggaras are still in use today and for hundreds of years have been managed by the same customary laws and groups. They are an example of tangible water heritage and ingenious water works, adapted to the needs of an arduous environment along with local society and culture. Such structures can inspire future ways of engaging with nature.

> *“These are not human settlements that are valued only because of the effort made to maintain them and the relative degree of production and well-being, these are settlements valued for their absolute perfection. They represent the best we can imagine and achieve as an oasis culture.”*
> *(Quoted in Parvard 1974).*

KEY THEMES



CLIMATE

A B C D E

Bwh : Hot desert climate

< Fig.1 M’zab Valley (Source: D. Sloan, 2017; Creative Commons Attribution-Share Alike 2.0).

Historical Introduction

The M’zab Valley is a region in the northern Algerian Sahara that consists of a vast rocky plateau cut by four deep major valleys. Ghardaia, the main city, is located at a distance of 600 km south of the capital Algiers. It is the capital of the *wilaya* (administrative division, translated as “state” or “province”) of the same name. It runs along the M’zab River over an area of 25 kilometers. The inhabitants have largely preserved the same lifestyles and construction techniques since the eleventh century, adapting both spatially and socially to the demands of this unique environment. This traditional human habitat, created in the eleventh century by the Ibadites, ancestors of the current Mozabite population, has been preserved intact in the M’zab Valley. The M’zab River crosses the valley from northwest to southeast. This configuration is known as the “Chebka” (network) (Cataldi and Al 1996). Between the eleventh and fourteenth century, urbanization led to the creation of five *ksour*, or fortified oasis towns: El-Atteuf (1012), Bounoura (1046), Ghardaia (1048), Ben-Isguen (1347) and Mélika (1350). Each contains a system of irrigation, cemeteries and a palm grove. The distribution of private land, divided into garden plots assigned in the palm grove, was based on an agreement made among the co-founding families (Diafat and Madani 2019; Babanedjar 2008). The town structure reflected the social structure with a series of interconnected spaces with various functions: *ksar* (attached dwellings) for urban life, cemeteries for the dead and palm groves as agriculture (Cataldi et al. 1996).

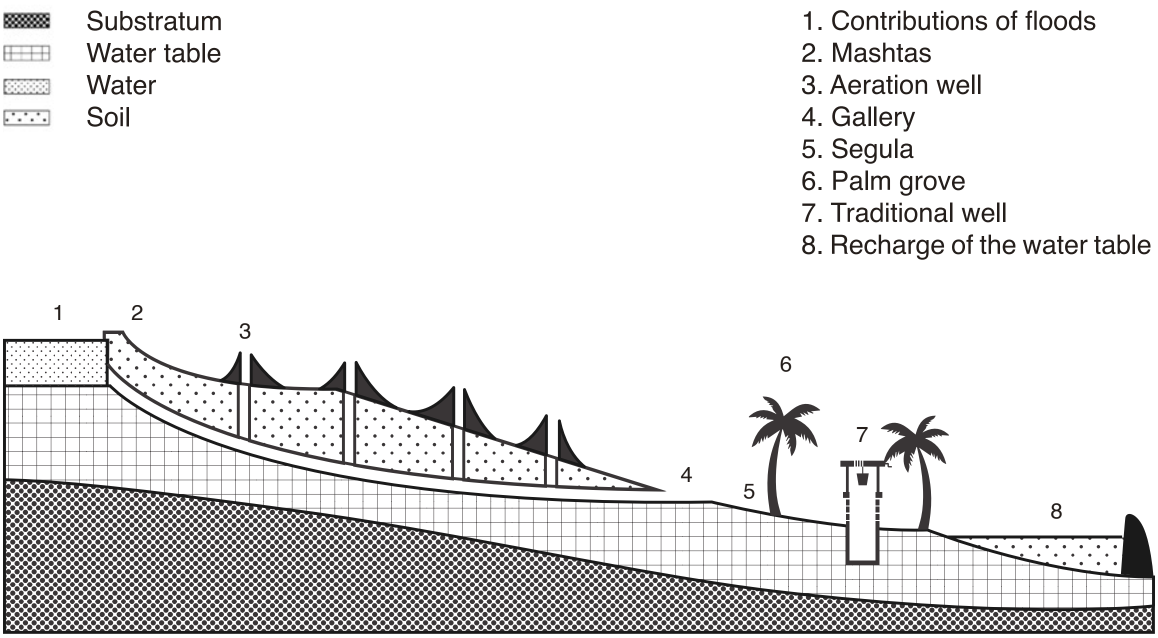
As unlikely as it may seem, the scarcity of water was the primary draw of the M’zab Valley. The Mozabites retreated to this difficult, uncultivated and inhospitable area of the Sahara Desert to hide from enemies. They established an urban civilization that includes fortified towns with a mosque, a minaret that also serves as watch tower, grain storage and arsenal. Living in this area is made possible by a very complex ancestral hydraulic system that exploits and regulates floods for irrigation purposes and recharges the aquifers.The Mozabites have implemented a technical and social organization to manage the danger of floods and take advantage of the floodwaters to supply the *ksar* and meet the demand for irrigation. The Mozabites have conserved practically the same way of life and the same building techniques since the eleventh century, ordered as much by a specific social and cultural context, as by the need for adaptation to a hostile environment, the choice of which responded to a historic need for withdrawal and a defensive imperative.

Water System Characteristics

The M’zab Valley, as a hyper-arid region, suffers from drought (Atlas of Ghardaia 2004). The scarce rainwater is exploited in an innovative and useful way. The Mozabites have invented a hydraulic system unique in the world, a network of underground tunnels for collecting and managing floodwater, called foggara.

As a collection system of galleries and wells, foggara have similarities across the region. They are found in many parts of Algeria, and in Iran there is the similar qanat, the *khettara* in Morocco and *falj* in Oman. In the Algerian Sahara there are seven types of foggara that differ in terms of the source of the water and the technique of water sharing. The Mozabite foggara serves the oasis of Ghardaia, in the M’zab Valley, and is a unique example of water management in Algeria. Once it is collected at the *bouchene (*reservoir), the water is channelled by four galleries, approximately 200 meters long, equipped with ventilation shafts.

^ Fig. 2 Sharing waters of the flood foggara at Mzab (Source: Remini 2007).



^ Fig. 3 Diagram of flood foggara (Source: Remini, Achour and Kechad, 2010).

This distribution system allows all existing gardens and orchards to receive the same amount of water. In addition, this network allows the city of Ghardaia to avoid flooding of the river. During floods, the water flows through the valley directly to the reservoir (*Tissembath*). Once the reservoir is full, it feeds the groundwater of the region. From the reservoir, the water flows through underground channels to reach the paths between the gardens. In times of high water, the paths act as canals. In times of drought, they act as a walkway. Each canal feeds a specific area of the gardens, which are equipped with various rectangular openings. The width of an opening is different from one garden to another depending on several parameters: the distance of the garden from the arrival of the underground canal, the surface of the garden and the number of palm trees. When the garden is flooded, excess water flows into the M'zab Valley (Khelifa and Remini 2019). This foggara system of floodwater sharing, mainly composed of dams, dykes, gullies and underground canals, is characterized by very high precision, allowing a rational use and an equal distribution of water. The ingenuity of the process lies in its design and its adaptation to the conditions of Saharan life and climate.

The water system represents an ancestral technique bequeathed for more than seven centuries which was structured – and is still structured – by the socio-cultural system of the region. The urban and spatial organization of the *ksour* (fortified oases) of the M'Zab includes integrated social and political structures and religious buildings with urban components. They are a balanced ecosystem, a projection in space of a particular way of living and thinking. A ksour is the organization in a delimited space of a homogeneous population in the form of clans and fractions. *'Achiras*, notables, *'arsh* and *'azzabas* are the institutions (religious and secular) that ensure the management of the *ksar* and various aspects of life (political, economic, social and moral), while guaranteeing total autonomy from the other *ksour* (Naidja 2022).

Water and Heritage Management

Water is managed according to written Ibadite legislation established in the twelfth century. The system is still managed by a group of controllers called Oumana Essayl, under the authority of the Djemaa, called Halqa Azzaba, the Committee of the Wise, which guides the Mozambites spiritually and advises. The Oumana Essayl monitor weather and climate change with their local expertise, which helps to prevent floods. They use a system of signs with mirrors or fire to allow communication between the different water diversion points to the gardens, while their watchtowers also function as warehouses. Their role is to enhance this ancestral heritage (the watershed system in the M'zab), to preserve the place as a site of history and civilization, as well as to aid related ecotourism activities. They are called upon to shed light on all the ancestral hydraulic works and to determine possible actions to preserve this heritage in close collaboration with the Office for the Protection and Promotion of the M'zab Valley (OPVM), in accordance with the regulations and the law concerning the preservation of cultural property (APS 2018).

The Algerian government recognized the region (particularly the M'zab Valley) as "national heritage" in 1971. In 1982, UNESCO designated the whole M'Zab Valley as a UNESCO World Heritage Site in recognition of its *ksourien* urbanism, a (pyramidal) shaped oasis in an arid area and its ancestral hydraulic system (https://whc.unesco.org/en/list/188). Following this classification, a permanent plan to safeguard and

^ Fig. 4 Devastating floods of 2008 in the M'Zab valley (Source: Smail Babaousmail).

develop the protected area (P.P.S.M.V.S.S) was launched. The OPVM committed to an ambitious program of restoring historic monuments such as religious and defensive buildings as well as a few water structures (https://whc.unesco.org/en/list/188).

The OPVM has created a number of technical guides, educational materials and brochures on traditional water management systems and wells. The technical guides include clear explanations of construction principles, materials and techniques, in an accessible format and language, with large illustrations. The publications aim to raise awareness about cultural heritage values and guide residents in the maintenance and restoration of their buildings. In 2001 UNESCO approved $25,000 USD to fund the rehabilitation of the traditional hydraulic system in M'Zab Valley and the organization of training workshops. In 2002 during the "Elaboration of a Preliminary Plan of Conservation and Development of the M'Zab Valley," UNESCO approved $35,000 USD and requested the World Heritage Centre to coordinate the implementation of the activity in close collaboration with the national authorities concerned (UNESCO 2001).

Contemporary Challenges

This oasis system has functioned well for centuries and the *djemâa* has supervised the free supply of drinking water to the *ksar* until today. The Mozabites have managed to face floods and maintain the balance of the ecosystem, on which sustainable life in this region of the Sahara absolutely depends. However, the balance of this system is currently disturbed by uncoordinated human actions, aimed at responding quickly and in an unsustainable way to a social and economic demand. Accelerated urbanization, significant population growth and the lack of urbanizable space inside the valley have led to vertical extensions, the occupation of part of the palm grove, and the degradation of the landscape, further altering the natural oasis ecosystem. The water quality is increasingly suffering from pollution produced simultaneously by the accumulation of infiltration by sewage from the Albian aquifer in the Algerian Sahara, the largest freshwater reserve in the world, and the retention of dams built upstream, which reduce floodwater and the periodic washing of the aquifer (Dahmen and Kassab 2020).

Furthermore, climate change considerably increases the risk of flooding, drought and desertification (fig. 5). There is a need for better-adapted amenities and suitable developments in this hyper-arid zone. These developments require consideration of prior impact studies, taking into account the increase in population, urban sprawl and climate change scenarios, to ensure sustainable development that recognizes the value of the foggara heritage.

Takeaway Points

The M'Zab Valley is not only a simple urban site that must be protected from flooding: the particularity of this remarkable space and the need to safeguard this World Heritage Site must also be taken into account. The heritage of the M'zab Valley is not only historical and architectural, it is also cultural and intangible. Tts classification as a World Heritage Site is an additional asset for the economic development of the region based on tourism (Zafane 2022). Today, several elements of the system have been destroyed, putting this heritage in danger. The actors concerned must save what remains of the ancestral hydraulic system, which reflects the genius of the ancestors of the Mozabites.

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Learning from the Hydraulic Heritage of Figuig, Morocco

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In the face of water scarcity and climate change, the Figuig Oasis exemplifies resilience through the integration of culture, heritage and sustainable development. This arid region has preserved ancient water management practices that have sustained life for millennia, offering a model for achieving the United Nations' Sustainable Development Goals (SDGs). Figuig's significance lies in the potential to harmonize traditional and modern water governance systems, optimizing its hydraulic organization as a living cultural heritage to ensure the sustainability of ecosystems in desert environments amid growing water scarcity.

Keywords: *resilient water management, oasis irrigation systems, water scarcity, water governance*

KEY THEMES

CLIMATE

A **B** C D E

BWh : Hot desert climate

< Fig. 1 Figuig Oasis: lifeblood of a fragile ecosystem in the arid desert (Source: Ouafa Messous).

Figuig: Resilient Oasis at the Edge of the Desert

Figuig (fig. 1), located in the eastern region of Morocco, 841 km from the capital Rabat and 373 km from Oujda, the regional capital, lies deep within the desert. The city is characterized by significant temperature fluctuations, ranging from 0°C in winter to 45°C in summer, with an average annual rainfall of only 150 mm. Historically, prior to the geopolitical and macroeconomic upheavals of the twentieth century (fig. 2), Figuig served as a strategic commercial hub along desert trade routes, connecting eastern Morocco with the sub-Saharan regions of West Africa (Vallat 2014). Today, Figuig's local economy is strongly dependent on its oasis and date palm groves. The ecological, economic and social balances in this context are exceedingly fragile and important, posing critical challenges to the sustainability of the region.

The example of the Figuig Oasis is particularly noteworthy due to the survival of its millennia-old traditional hydraulic system (El Fassi 2015), as well as the resilience of its traditional system of governance, which is based on communal management. The fundamental principle of this is that water use must be equitable and meet essential needs (basic domestic use) balanced with productive needs (agriculture).

The case of Figuig calls for careful consideration of governance models in extreme situations, whether they arise from water scarcity

^ Fig. 2 Section of the oasis destroyed in the early twentieth century due to a conflict between villages, triggered by a water management dispute. Ongoing urbanization in the distance (Source: Ouafa Messous, 2019).

or from social, economic or even geopolitical tensions. To prioritize the survival of the oasis and its ecosystem, both traditional and modern hydraulic systems should converge toward this goal, starting with the rationalization and optimization of water use by all possible means.

Traditional Water Management in Figuig: Subtleties of a Resilient Hydraulic System

Water management in Figuig is intricately linked to the social structure of the oasis. The inhabitants, distributed among the various *ksour* (traditional villages), collaborate to maintain the irrigation network and regulate water distribution. In the past, each *ksar* (village) had its own specific rules governing water distribution.

The *raïfi* or *aiguiadiers* (water guardians) responsible for allocating *kbarrouba* (units of time) and *tigbirte* (units of volume) (Lahlou 2017), historically have played a crucial role in balancing water rights, taking into account seasonal variations and the specific needs of each agricultural plot. Each *kbarrouba* corresponds to 45 minutes during which a specific amount of water is allocated to a plot. This time is then converted into a water volume within storage basins, allowing for flexibility and optimization in water usage. This system has not only proven effective for the survival of the palm grove but also strengthened social ties and community cohesion.

The hydraulic network in the Figuig Oasis is designed to optimize and maximize water usage. Water is sourced from various springs within the oasis, and at junction points, distributors channel the water into primary basins of various *douars* (small clusters of human settlements). From these basins, a network of *seggias* (surface channels) runs throughout the palm grove, delivering water by gravity to the plots needing irrigation. Water is also conveyed via aqueducts when the rugged terrain necessitates it. Besides the natural springs, water is brought into the oasis from external sources through *khattarates* (underground conduits) or *foggaras* (underground galleries capturing runoff) (Smith 2015). This system also includes *ahfires* (rainwater capture pits), where underground cisterns are constructed. The most remarkable feature of this hydraulic system is the use of geothermal energy to maintain water at an optimal temperature year-round, facilitated by the construction of *bahbouha* (subterranean crevices) used for both public and private baths.

^ Fig. 3 The landscape in (left) and outside (right) the Figuig Oasis (Source: Ouafa Messous, 2019).

The optimization of water usage is also evident in agricultural production methods, which maximize the use of space and water, ensuring productivity in an arid environment. The stratification of crops into three levels – date palms, fruit trees and low-growing plants – creates a microclimate that reduces evaporation and protects the lower crops from extreme weather conditions (Harrouchi 2010).

The scarcity of water resources has led to the development of a hydraulic system that makes use of all possible water resources, rationalizes consumption and intensifies usage. Thus, each water resource is used and reused at different stages based on its sacred purity and level of cleanliness: purified water isused for religious tasks like ablutions and is then repurposed for less sacred uses, such as cleaning or irrigation, depending on its condition.

The Geopolitical Challenges of Water Management in Figuig

In Figuig, water management, along with the preservation of its traditional network, has reached critical limits, unveiling a set of complex new challenges. One is a duality of local governance: The coexistence of the traditional system and modern approaches to water management reveals a stark contrast in governance, with no carefully considered or gradual transition between the two systems. On the one hand, the local population advocates for the preservation of their hydraulic heritage – despite its vulnerabilities, such as unequal distribution (Amrani 2020), inter-village tensions (Benchekroun 2018) and individual pumping practices. Water was allocated based on agricultural needs and household size to ensure food security. Conflicts arose when access, previously governed by communal rules, shifted to favor status and power, leading to the rise of individualistic practices at the community's expense. On the other hand, the administration promotes standardization to facilitate the control of water as a national resource. This dichotomy has led to escalating political and social tensions. The primary challenge, both locally and regionally, lies in modernizing traditional social structures, institutionalizing them and potentially transforming them into "Public Interest Social Structures." Preserving this heritage also requires upgrading its governance mechanisms, as well as exploring solutions to optimize water use as a vital resource.

Another challenge has been the exacerbation of border tensions. The border between Morocco and Algeria is not merely a political demarcation but also a hydrological divide. The aquifers and springs that supply Figuig are shared between the two countries, making water management even more delicate (Harrouchi 2010). Bilateral water agreements often fall short in preventing disputes, and the political tensions between the two nations further complicate cooperation (Benchekroun 2018). The coordination of water policies is frequently hindered by broader geopolitical considerations, which further complicates the implementation of sustainable solutions (El-Fassi 2015). In this context, water, initially a local concern, has become a national issue, exacerbating already strained relations, even among villages within the same oasis.

> Fig. 4 The hydraulic system in the Figuig Oasis includes many components:

1. Sources supplying the oasis with water; 2. *Seggias* (surface channels; also shown in image 5); 3–4. Storage basins; 5. Hydraulic distribution structures, such as aqueducts (see image 6) or underground canals called *fouggarates* (see image 9); 6. Aqueducts; 7. *Ahfire*, hollow areas with underground cisterns used to store rainwater for later use; 8. *Bahbouha*, subterranean crevices used for baths; 9. Underground canals (Source: Ouafa Messous, 2019).


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Managing the Transition: Challenges and Tensions in Water Governance in Figuig

The late 1990s witnessed the establishment of Agricultural Water Users Associations (AUEAs) as a state initiative and as part of structural adjustment plans. These associations were tasked with representing irrigators to public administrations and organizing water management, with the aim of improving the efficiency and sustainability of irrigation systems (FAO 2019).

The transition to this new form of governance was not without tensions. AUEAs often found themselves in competition with traditional water management structures, particularly the informal arrangements between irrigators and *aiguiadiers*. In some instances, AUEAs were perceived as a way for the state to interfere in local affairs, challenging ancestral practices and institutions.

The construction of a dam near Figuig in 2010, though not yet fully operational, has accelerated the broader socioeconomic and socio-spatial transformations that have been unfolding since the early twentieth century, reshaping the oasis's traditional landscape and its relationship with water despite its conservative character.This project has strengthened the role of AUEAs, which will be responsible for distributing this "new water," but it has also raised concerns about equitable distribution and the impact on traditional practices (Smith 2015). Discussions surrounding the dam's water management have highlighted the challenges of updating water management information and integrating new users (Ministère de l'Agriculture et de la Pêche Maritime 2020).

Conclusion

In the context of water scarcity, the emergence of social, economic and political tensions underscores the urgency of finding new solutions and objectively reassessing the current situation. The example of the Figuig Oasis illustrates that the traditional water management system, which has continually adapted to challenges, deserves to continue evolving. Its integration with modern technologies, such as dew collection for localized irrigation (Hasila 2020; Yang 2024), could further strengthen this system.

The case of Figuig suggests a modern, sustainable framework: Water consumption should be based on actual needs rather than financial capacity, ensuring efficient use of resources and minimizing waste. From this perspective, viewing water as a resource for shared management projects, rather than through the lens of exclusive use, can replace inherent tensions with a societal approach that emphasizes shared benefits – a "win-win" strategy.

Finally, it is important to highlight the triptych – community goals, accepted governance and optimized solutions – demonstrated by the Figuig case. This model encourages intensified water use while clarifying both societal objectives and the principles of sustainable water management. Water use should be tiered within homes, with water being reused based on its cleanliness for tasks like cleaning and irrigation before it is sent to neighborhood and city treatment stations, maximizing efficiency and minimizing waste.

Policy Recommendations

- In adapting to climate change, water management authorities should ensure balanced sustainable development by integrating traditional and modern practices. By enhancing local communities and their governance, geopolitical risks can be reduced.

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Traditional Water Management in the Thar Desert: The *Khadeen* of Rajasthan, India

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IHE Delft Institute for Water Education

The khadeen system of the Thar Desert, in Rajasthan, is an ancient technology that takes advantage of peculiar geohydrologic formations to create temporary lakes. A careful water management practice, the khadeen are an example of age-old methods of capturing and using seasonal runoff for agriculture, ensuring water access in arid regions. Khadeen have played a crucial role in supporting agricultural activities since the sixteenth century, offering impressive yields in a water-scarce environment. However, the enduring efficacy of khadeen faces contemporary threats, including mining encroachment, labor outmigration and road development. The delicate balance between preserving traditional knowledge and succumbing to external pressures poses challenges to their cultural, ecological and agricultural significance. This paper comments on the historical, hydrogeological and socioeconomic dimensions of khadeen, emphasizing the importance of their preservation in sustaining communities and ecosystems in the Thar Desert area.

Keywords: *nature-based solutions, Indigenous technology, non-motorized irrigation, khadeen, water harvesting*

KEY THEMES

CLIMATE

A B C D E

BWh : Hot desert climate

< Fig. 1 The Masurdi Khadeen (Source: Bhatta Ram, February 2021).

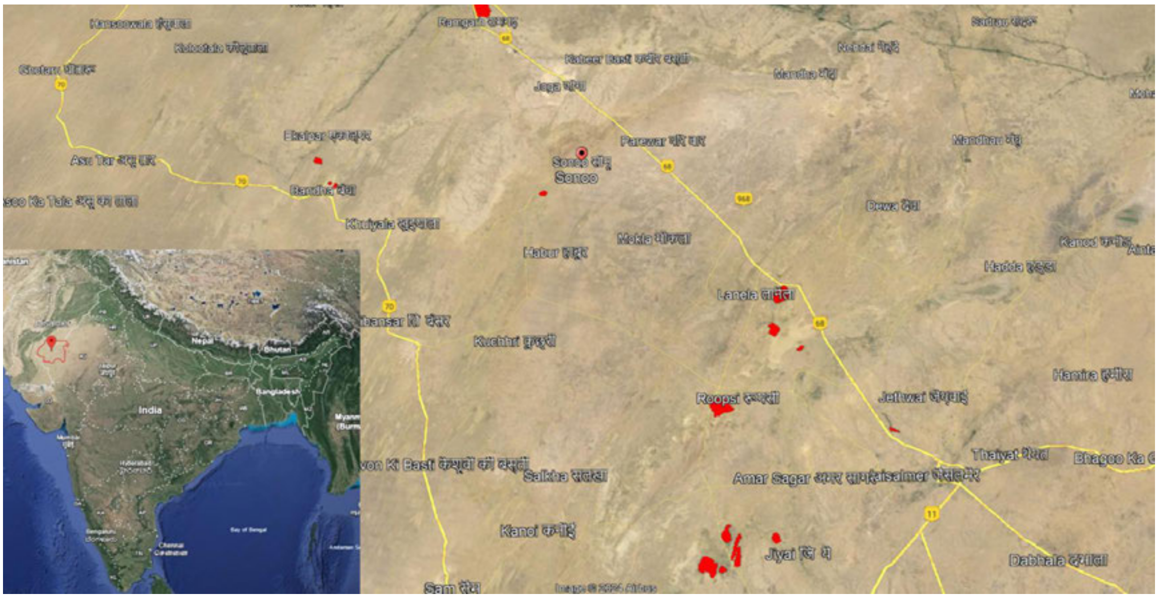
Introduction

In the Jaisalmer district (Rajasthan, India), located in the Thar Desert, water scarcity poses a considerable challenge. In approximately 60 per cent of the region, the annual rainfall is quite low, reaching a meager 200 mm on average. The monsoon season, from July to mid-September, sees 90 per cent of the area's precipitation, usually in the form of torrential rain. In addition to strong winds, high temperatures and elevated groundwater salinity, this contributes to a complex ecosystem where access to water is not a given.

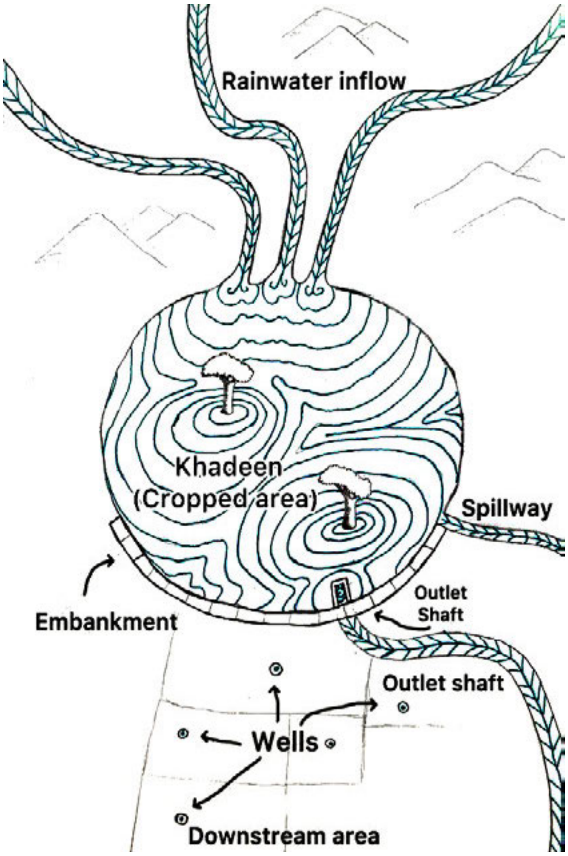
During dry periods, various non-motorized infrastructures used for harvesting, storing and managing water make it possible for area villages to have access to water. Traditional hydrogeological knowledge, with its correlated water practices, is deeply embedded in the cultural and religious ethos of Rajasthan and has played an important role in the economic prosperity of the Thar Desert's urban centers. For instance, elderly community members clean the catchment before the beginning of the rainy season to eliminate rubble and facilitate the centralized collection of rainwater runoff. Additionally, since well-diggers play a crucial role in society, they can count on donations from community members (Miśra 2001). This hydrogeological knowledge revolves around a detailed understanding of where freshwater is likely to be found within the desert landscape, and which tools and practices are needed to access it, resulting in a meticulous approach to water management embedded in people's everyday lives. In areas of the Thar Desert where motorized approaches remain less effective because of material constraints, these non-centralized and non-motorized water practices play an important role in accessing water.

Practices for Water Scarcity

For centuries local people have used a variety of infrastructures to access water in the Thar Desert, including ponds, *kua* (wells), *beri* (narrow, shallow wells) and *khadeen* (temporary lakes)



^ Fig. 2 Shown in red are 19 of the 800 *khadeen* of the Jaisalmer district. The location of the district is highlighted in the map on the bottom-left (Source: Google Earth, 2024, adapted by authors).



^ Fig. 3 Illustration of different elements of a *khadeen* (Source: Pierantonio La Vena, co-produced by Bhatta Ram, 2024).

(fig. 2). These are a lifeline for the local people, granting access to water for domestic uses and livestock (Agarwal and Narayan 1997). While ponds and *khadeen* are used for rainwater harvesting, *beris* allow access to shallow percolation water (locally referred to as *rejani pani*), and *kuas* access the deeper groundwater (known locally as *patal pani*).

The *khadeen* is a traditional water infrastructure used in Rajasthan, which accumulates seasonal runoff, enabling agricultural practices even for relatively water-intensive crops (fig. 3). The study of *khadeen* allows stakeholders to appreciate how practices of care for water resources have ensured the continuous inhabitation of this region, within strict hydrogeological and climatic constraints.

These temporary lakes were (and are) created to capture rainwater during the monsoon season, storing it in the shallow layers of the soil during drier months. They are built by interrupting the course of seasonal rivers with an embankment, creating a reservoir fed by the upstream catchment (fig. 4). The resulting structure ensures the practice of agriculture even in years of scarce rainfall.

Building a well-functioning *khadeen* requires locating specific characteristics in a landscape, such as the course of temporary rivers and shallow groundwater quality. In most parts of the Thar Desert, the deeper groundwater is too saline for human consumption or agricultural use. To preserve freshwater after precipitation, the *khadeen* is built as an artificial perched water table, constituted by an impervious geologic layer, below a previous layer (fig. 5). This protects the infiltrated water both from surface temperatures and subsoil contamination.

Construction and Functionality of a *Khadeen*

A *khadeen* creates an artificial lake from the seasonal precipitation falling in a valley (or water catchment). An embankment, or wall, is the main structural element of the *khadeen*, preventing lake water from flowing away. The embankment can be built out of stone, dirt and, in recent years, cement. In addition to the embankment, the construction of *khadeen* can involve raising dikes along the two sides. The length of the dikes is calculated based on the expected seasonal influx of water in the reservoir and can sometimes reach 5 to 7 km.

The lakes created in this manner infiltrate gradually downstream and dry up. The speed of this process depends on the underlying impervious layer, the amount of yearly rainfall and the integrity of the catchment. *Khadeen* are usually emptied of water in September so that wheat can be sown on the lakebed for the winter season (from October to March). The water is let out through an outlet shaft, and it is used to irrigate other fields downstream (fig. 6).

The sediments collected in the catchment and the biotic activity in the lake confer fertility and humidity to the soil at the bottom of the basin. These conditions allow the cultivation of wheat and other (relatively) water-demanding crops in a region where their growth would otherwise be impossible. In normal conditions, *khadeen* have a relatively high productivity, yielding 15 to 20 times the amount of wheat sown (Miśra 2001). Downstream from the embankment, agriculture is supported by shallow well irrigation, fed by the gradual percolation of the lake's reservoir.

Khadeen and Heritage

Khadeen have played an important role in defining local people's relations with water, inspiring a cautious use of scarce water resources. Their dependence on rainfall demands a meticulous approach to preserving rainwater. To this day, *khadeen* allow irrigation in the area more reliably than modern, motorized water technologies.

According to Mishra (2001), it is likely that *khadeen* were originally created as a replica of naturally occurring water pools (known locally as *deobandh*), which allowed access to water along the trade routes crossing the Thar Desert. However, *khadeen* construction was initially occasional, sparse and marginal. Since the thirteenth

^ Fig. 4 Stone embankment overrun by vegetation at the Bada Bagh Khadeen (Source: Pierantonio La Vena, 2023).

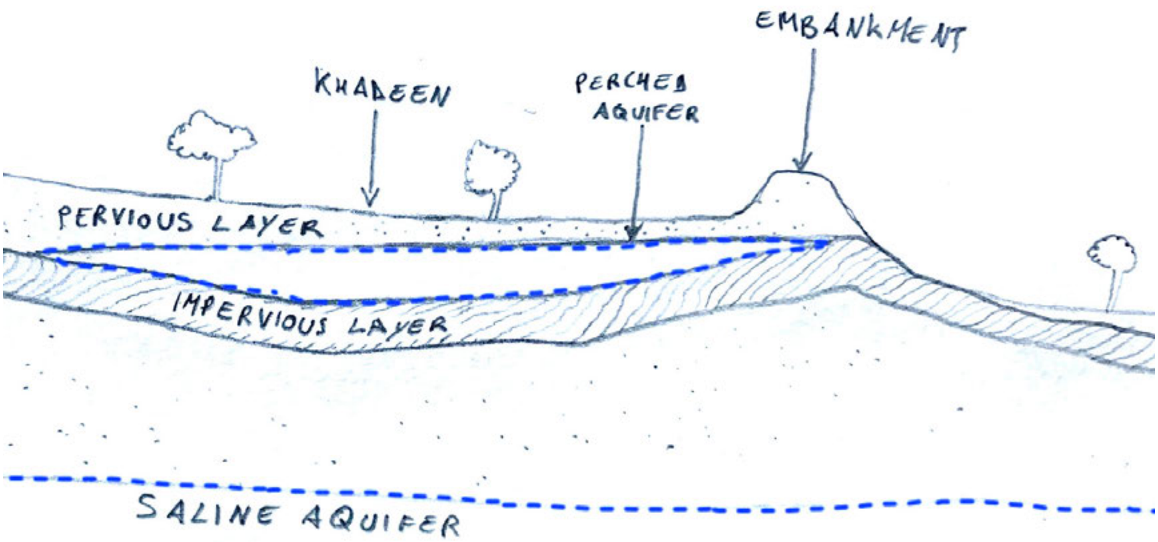
century, the district of Jaisalmer has witnessed creation of several *khadeen*, including interconnected khadeen systems, at the hand of the Paliwal Brahmins. Originally from Pali (central Rajasthan), the Paliwal Brahmins seem to have played a crucial role in transforming the landscape of the Jaisalmer district, particularly in the emergence of agriculture, until they abandoned the area in the early eighteenth century, allegedly due to conflicts with local rulers (Rezavi 1995). Although isolated *khadeen* were previously used in the area, this group is credited for the construction of interconnected systems of *khadeen*, which drain into one another (Miśra 2001).

Khadeen often take the name of the village in which they are located. For example, the Masurdi Khadeen takes its name from the nearby village of Masurdi. It is not easy to establish the total number of *khadeen* present in the region: Malik and Singh (2023) mention a total of 650 structures, while Singh and Singh (2018) report 800 of them, including those of more recent construction. The local government has promoted the construction of new *khadeen*, both to encourage settled livelihoods and to promote agriculture. However, according to Agarwal and Narain (2008), the older *khadeen* are structurally more solid in a way that is difficult to replicate in more modern ones.

These more recently built *khadeen* tend to be smaller and are meant for individual rather than communal use (Agarwal and Narain 2008). The *khadeen* in Dabbla Par and Ekla Par have been built with the specific purpose of supporting the settlement of nomadic groups such as the Bheel tribal community.

Among the *khadeen* of older manufacture, the Lanela Khadeen extends over 758 ha, and is used in a communal capacity by members of a dozen villages (Singh and Singh 2018). Masurdi Khadeen (fig. 1) spans over 300 ha and is used communally by ten villages. The Jajia Khadeen, extending over a few hundred hectares, will be decommissioned in the upcoming years as its catchment will be converted into a mining site (Malik and Singh 2023).

The Bada Bagh Khadeen extends over 29 ha and historically belongs to Jaisalmer's royal family.



^ Fig. 5 Hydrogeological cross section of a *khadeen* (Source: Pierantonio La Vena, co-produced by Bhatta Ram, 2024).

^ Fig. 6 Outlet shaft at the Bada Bagh Khadeen (Source: Pierantonio La Vena, 2023).

Its imposing stone embankment is adjacent to a complex of cenotaphs commemorating royal family members and is often visited by tourists. Although *khadeen* are (and have been) generally used communally, the use of Bada Bagh Khadeen has recently been privatized, with a yearly contract that yields up to ₹600,000.00 (roughly $642.00) to its owners. The local community of Mali, an occupational caste group traditionally working as orchard gardeners and farming the *khadeen* under a sharecropping system – which allowed the community to cultivate the land in exchange for 50 per cent of the agricultural yield – has lost access to the land.

Discussions over the heritage dimension of *khadeen* cannot ignore how local communities are entangled in wider socio-political tensions resulting from increasingly neoliberal policymaking in the region, which in some cases prevents vulnerable social groups from accessing the cultivable land central to their agrarian livelihood.

Concerns for the Future

Traditional water management practices related to *khadeen* face contemporary challenges threatening survival. The recent advent of mining industries constitutes one significant threat. The extraction of minerals and natural resources can disrupt the natural flow of water in a catchment, affecting the recharge of *khadeen*. Additionally, contamination stemming from mining activities has the potential to adversely affect the quality of water stored in *khadeen*, putting agricultural practices at risk.

Another pressing challenge is the outmigration of labor from rural areas to other regions in Rajasthan or beyond. As younger generations seek better economic opportunities in urban centers or near the Indira Gandhi Canal Irrigation Scheme – a canal stretching 650 km from the Harike Barrage in Punjab to the district of Barmer in Rajasthan built to expand the area of irrigated land in the Thar Desert and increase the local production of food crops – the communities that have historically maintained and nurtured *khadeen* find themselves dwindling. This outmigration results in a decline of traditional knowledge and a disconnection from age-old water conservation practices. Dwindling numbers of committed community members can jeopardize the maintenance and upkeep of khadeen, putting these vital water reservoirs at risk.

Urban development threatens *khadeen*, since it may lead to encroachment on *khadeen* areas. The development of roads disrupts the natural flow of water to the basin at the bottom of the catchment. These changes compromise the natural flow of water into the *khadeen*, reducing their ability to collect and store water for extended periods. Furthermore, in an era where water is increasingly commodified, communities practicing traditional water conservation face increasing pressures to participate in the water market, leading to the exploitation of local water resources for profit. As scarce water resources are diverted toward the tourism and mining industries, less water is allocated to agriculture and communal use. *Khadeen*, originally designed for community sustenance, are challenged with resisting such external commercial and market forces, which alter their original purpose and raise issues of distributional justice.

Conclusion

The study of *khadeen*, along with other water conservation structures, illustrates how practices of care for water resources ensure sustainable and resilient livelihoods in an environment characterized by water scarcity. In the

Jaisalmer district, these structures have been and continue to be instrumental to agriculture for centuries, yielding impressive production in the face of scarce precipitation. However, these time-tested structures face contemporary threats, which can compromise the community-based capacity in which they function.

The delicate balance between traditional practices and external pressures necessitates urgent attention to safeguarding the social, ecological and food-security significance of *khadeen* in the Thar Desert. As challenges loom, concerted legal and administrative efforts are needed to ensure the preservation and revitalization of these ancient water harvesting systems, securing a sustainable future for the communities they have long supported.

As these structures are being converted to serve private and commercial interests, historically marginalized communities are denied access to the source of their subsistence. This process, considered functional to the industrialization of rural spaces, leaves skilled farmer groups with no other option but to migrate to urban areas and seek work as "unskilled laborers."

This results in the gradual delegitimization of the water practices surrounding the *khadeen*, which can ultimately threaten the existence of an invaluable system of water knowledge. The loss of *khadeen*, which depend on communal efforts and practices, would represent the loss of an irreplaceable chapter on adapting to water scarcity. As more and more regions of the globe experience unprecedented levels of water scarcity, *khadeen* and their communities could instead play a central role in shaping successful adaptation to climate change.

Policy Recommendations

- There is an urgent need for the government of Rajasthan to adopt an integrated policy approach and support *khadeen* as a cultural and ecological resource. Policies should focus on providing legal recognition to *khadeen*, increasing community awareness, and promoting sustainable tourism in the Thar Desert area.
- The government should recognize the *khadeen* as protected heritage sites, as well as support local communities and encourage community-led restoration projects by expanding existing governmental schemes (e.g., the Mahatma Gandhi National Rural Employment Guarantee Act) to support the restoration and protection of *khadeen* and provide employment for local communities.
- The preservation of historical *khadeen* for the present and the future should include related water management knowledge in school curricula and efforts to raise public awareness about their importance.

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The Canals of Lima: Landscape and Memory

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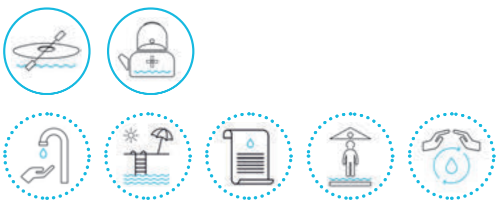
This article examines the ancient irrigation canals in Lima, the capital of Peru, and it reveals the role of indigenous groups who transformed the desert into agricultural valleys over millennia. The current role of the surviving canals is explained, as is their relevance to the city's environmental sustainability. It discusses aspects related to their management from precolonial times to the present and outlines the key elements of the campaign for their declaration as cultural heritage of Peru, sharing the main results, including the 2019 declaration. It also discusses the work done to decolonize traditional narratives that had obscured the indigenous role in the creation of the canal system.

KEY THEMES



CLIMATE

A B C D E

Bwh : Hot desert climate

< Fig.1 Beginning of the route of the Surco canal (Source: Gonzalo Cáceres, published in "Canales de Lima, 2000 años regando vida").

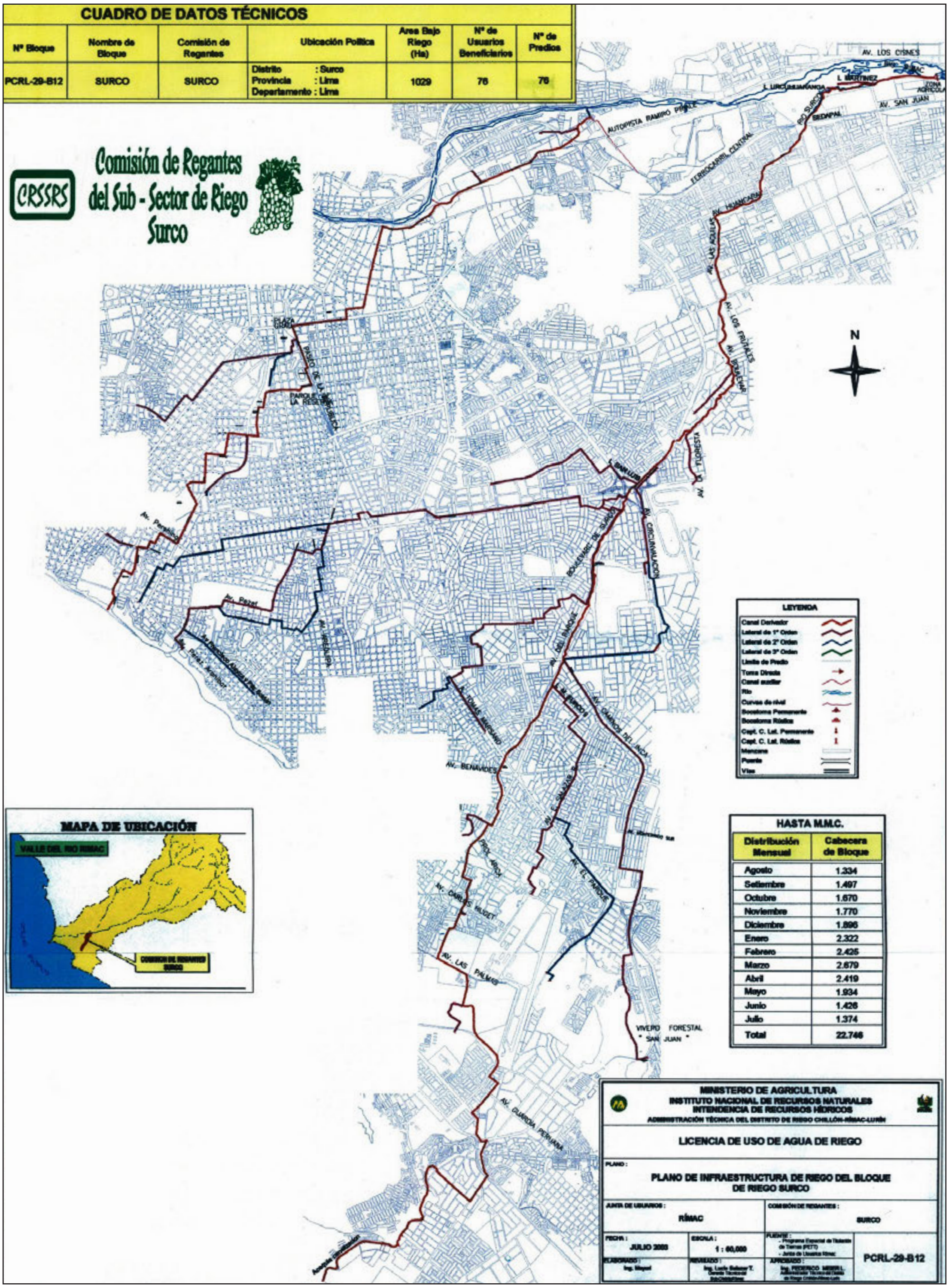
^ Fig. 2 Surco canal running through a park in Lima (Source: Roger Haro, 2018).

Introduction

The city of Lima sits on cliffs overlooking the Pacific Ocean and is part of the Rimac River basin, a vital source of water supply for human consumption, agriculture and energy, including five hydroelectric power plants. The Rimac River originates on the western slopes of the Andes at an altitude of 5,500 meters, some 130 km from Lima, and flows into the ocean. Even though water availability is limited, the Rimac River meets 90 per cent of the water needs of a population of 11 million people. By way of comparison, the Amazon River, which begins in the mountainous region of southern Peru and makes its way down to the Atlantic basin, has an average annual discharge of 215,000 m^3/s. The Rimac's average discharge is 25.8 m^3/s (Surco-Huatica Comisión 2016). Archaeological evidence shows that early indigenous cultures began an extensive system of irrigation canals in what is now the Peruvian capital some 2000 years ago. Their main purpose was to irrigate the desert and use the land for agriculture. These waterways were originally built by redirecting sections of the Rimac River and they traditionally provided water for irrigation by flooding, taking advantage of the city's natural slope. Metropolitan Lima reaches an altitude of 850 m, and the two canals under consideration here begin to descend to the ocean at an altitude of 174 m, which roughly corresponds to where the historic center of the city is today (IRA 2015) (fig. 1).

Originally, there were four "mother" or main canals from which multiple other waterways branched off, in varying degrees of importance and size, crisscrossing the territory. The present article focuses on the two main ones: Surco and Huatica, whose area of influence extends over central areas of the capital, home to about one-third of the city's population. All green areas in the city depend on the canals for their survival, and the canals depend on the flow of the river for their existence. The Peruvian coast is a desert 2.250 km long and Lima, located roughly in the middle, receives an average annual rainfall of 7 mm, which places it in the category of hyper-arid territory. However, a combination of other factors, such as temperate climate, high humidity, an abundant phreatic layer and seasonal green belts contribute to a unique landscape. Two elements that enabled the efficiency and survival of the system over millennia are the progressive slope towards the sea – the route has a descent that varies by one grade per 100 m – and the force of gravity. Today, the Surco and the Huatica canals are managed by an official Water Board and are largely used to irrigate parks and green areas in Lima. The Surco runs for 29.5 km from its source in the Rimac River to the ocean; the Huatica, 15 km. When their main function was agricultural, these mother canals were on average six metres wide and 1.5 m deep, having an additional margin of another six meters on each side (Comisión 2007). Over time, the various indigenous cultures that inhabited Lima continued to expand the system by making new canal branches into existing ones. At the time of their greatest expansion (sixteenth century), they came to cover some 30,000 hectares, which largely corresponds to the total area of present-day metropolitan Lima.

According to Peruvian experts, a distinction must be made between excavating the first canals, which had a limited territorial reach and were not connected to each other (archaeologists have determined that they became connected in Lima around 4000 years ago), and the creation of a hydraulic system or irrigation system, which is the hierarchical organization of these waterways over a large territory (Chacaltana 2016). Available information points to the fact that this system began in Lima around



^ Fig. 3 Current route map of the two canals (Source: Surco-Huatica Water Board, 2003).

2000 years ago. For his part, architect Juan Günther (2012, 50), elaborated on the type of canals that were created, explaining that:

> Building them parallel to the contours of the water level risked causing the water to flow too slowly and silt up the soil it carries on the bottom, forcing the level of the canal to rise gradually until it becomes inoperable (...) On the other hand, building it perpendicular to the contours would have forced the torrent to increase its speed, with the consequence of eroding the bottom of the canal and thus increasing its depth to the point of ruining it as an irrigation feature.

That is a reason why, in Günther's view, the canals were built in a meandering shape and not in straight lines (fig. 2). Arguably one of the greatest achievements of the indigenous cultures here was the transformation of the desert into agricultural land over millennia, a feature that later sustained the local colonial economy. Lima's agricultural landscape remained virtually untouched until the first half of the twentieth century. From the 1950s onwards, the rapid and disorderly growth of the city on former agricultural land led to the destruction of part of the system. As a consequence, the available land watered by the canals was reduced to about 3,000 hectares (Observatorio del Agua 2017). The two canals referred to in this article irrigate 85 per cent of all green areas in central Lima or 1.150 hectares. This is the equivalent of 711 parks in 17 (out of 43) districts where more than three million people live (Comisión 2016) (fig. 3).

History and Evolution

Metropolitan Lima covers an area of about 3,000 km^2 and is home to 11 million people. Throughout pre-Hispanic or precolonial times, and for some 4,000 years, the territory was home to five cultural groups – the Incas were the last of these. Spanish Lima was founded in 1535 on an already existing indigenous system that included valleys with high agricultural production, roads and canals. Due to the very nature of these waterways, which are still in constant use, precise dating is impossible. In archaeology, therefore, inference is used. A key factor is that most of the abundant adobe architecture that has survived would not have been possible without access to abundant water sources – brought by the canals.

A study by the National Water Authority (ANA) found that the first canal in Lima could date back to 2000 BC, being associated with the ancient temple of "Las Salinas," in the district of El Agustino, next to the Rimac River (Casareto and Perez 2016). But this would have been only a canal and not part of any system of canals. It is only around 200 BC that the civilizations in this part of Peru embarked on a pattern of urban development different from that of earlier times, free from rivers (Canziani 2009). Santiago Agurto, another Peruvian architect, believed that the construction of the early canal system allowed the people of Lima to become independent from the riverbank and to be able to build ceremonial and administrative settlements in the heart of the valley, in wide and flat areas suitable for large urban development (Agurto 1984).

In the absence of written records from precolonial times, little is known in detail about how canals were managed. What is better known is that ancient cultures developed and there is knowledge of the relationships between the communities and their canals. There was a very close relationship between the population dedicated to their crops and the water system. This relationship was expressed in the form of

^ Fig. 4 Ancestral ceremony of the blessing of the canal, carried out by an Andean priestess (Source: Joaquin Narvaez).

dances, songs, rituals and cleansing festivals (fig. 4), some of which have survived in the rural areas outside Lima. In precolonial times, the most common crops were cotton, potatoes, avocados, chilli peppers, beans, sweet potatoes, guavas, pineapples and plums. With the arrival of the Europeans, new crops were introduced, like olives, apples, oranges and sugarcane.

Very early on, the Spanish realized the importance of the canals for their subsistence and one of the first pieces of legislation they passed was aimed at protecting them. During the colonial period, the institution of the Water Judge was introduced to deal with the many legal disputes that would arise (Cerdán y Pontero 1793). Many of the cases had to do with complaints from lowland users who had less access to water because their neighbors, in higher areas, were using more than they had been allocated.

Despite the constant legal conflicts, agriculture remained the primary activity in Lima until the mid-twentieth century. By then, there were some 800 estates and farms (Orrego 2008), all of which continued to benefit from the existing pre-Hispanic irrigation system.

After the 1950s, as the city grew through successive waves of informal settlements – the result of migration from poorer parts of the country – the irrigation system was severely affected. As agriculture gradually disappeared, many of the primary, secondary and tertiary canals were destroyed or incorporated into the sanitation system. As a result, there are only a few green areas in these new urban sectors. With fewer fields to irrigate, the Water Board reduced the width of the canals from six meters to one and a half. This process of unregulated urban growth revealed a system that was naturally fragile and became a scenario that represents a pattern of inequality in the city. Today, the greener parts of Lima, where the Surco and the Huatica canals survived, correspond to the richer areas. Here, they irrigate most parks, avenues, universities, golf courses and cemeteries (Comisión 2016).

Water Management

The early inhabitants of the territory managed to use this natural resource efficiently and in a sustainable manner. A few reasons help to explain this. One of them is that before the arrival of the Spaniards, the territory of Lima was politically divided into different groups and archaeological work so far has not found evidence of any continuous warfare (Eeckhout 2019; Gaither et al. 2012), a fact that would have affected the distribution of water. Another reason has been revealed by scientific studies that analyzed bones and stable isotopes of people who died in the area before the sixteenth century: they found consistency in the consumption of healthy diets (Marsteller et al. 2017; Williams and Murphy 2013; Béarez et al. 2003). This suggests a period of peaceful coexistence (albeit of indeterminate duration), possibly in the knowledge that their survival depended on the good use of the canals. It is possible there were rules that had to be respected. That is, each group of people knew who received how much water, where, at what time, and for how long. The same principles still apply today. In other words, this situation reflects the political balance of complex societies, whose planning is the result of a process of continual negotiation (Gavazzi 2014).

At the beginning of the twentieth century, the water boards were reorganized and incorporated into the role of the state. Irrigation Commissions and Water Boards were set up under the Local Water Authority (ALA), the Water Administration Authority (AAA), and the National Water Authority (ANA). The local water board is responsible for the main or mother canal. The Surco-Huatica Water Board is one of 17 such organizations in metropolitan Lima and is the only one serving millions of people. It is made up of 69 users who each pay a rate of 0.10 Peruvian cents per cubic meter of water (US$ 0.028 approx.). Among its members are local authorities (17 municipal districts for both canals), 10 public institutions (including the city's two main cemeteries), 7 private institutions (including 3 universities and 4 private clubs), as well as a small number of urban farmers.

The most common risk factors for the proper function of the canals along the main Surco canal (the Huatica now runs under the city streets) include those stemming from urban sprawl, encroachment on private and/or public land, waste dumping, illegal use of the waterway and unauthorized diversion of the route (Lizarzaburu 2018) (fig. 5).

The irrigation board organizes an annual cleaning operation twice a year, in February and August, excluding emergencies (overflows, floods, accidents), to allow for the correct flow of water (fig. 6). Although traditionally irrigation was accomplished by flooding, in recent years, more technical irrigation systems are being installed. In other cases, irrigation is carried out with water carts, in which trucks draw water from the canals. When the research on the canals I did for the campaign was initiated, in addition to the risk factors affecting them, some striking data related to the availability and consumption of water in Lima soon came to light:

- Peru ranks number 8 in potential water availability in the world, with 1.89 per cent of the to-

^ Fig. 5 Illegal dumping of waste is one of the major problems in functioning of the canals (Source: Javier Lizarzaburu).

^ Fig. 6 Cleaning of the canal (Source: Surco-Huatica Water Board).

tal (FAO 2013). However, 98 per cent of those resources go directly into the Atlantic basin.

- Most of the population, 66 per cent, lives close to the Pacific basin, where water availability is calculated at 2.2 per cent (ANA).
- The WHO recommends an average water usage of 100 liters per person per day. The average in Lima is 250 lt pp pd (Ministry of Housing 2018).
- The richest districts consume the most in Lima: San Isidro, 477 lt pp pd, and Miraflores, 436 lt pp pd.
- In comparison, in the city of Amsterdam, the average is 133 lt pp pd (Waternet), Paris 143 lt pp pd, down from 151 in 2008 (Statista).

If people were using so much water in a place where there is so little, it seems clear that there was a lack of awareness. Even though the use and distribution of water is not the responsibility of the water boards, this data together with other developments happening at that time prompted the Surco-Huatica Water Board to rethink their way of working (Lizarzaburu 2021). Additionally, the process of global warming has had its greatest impact here, causing the loss of more than 50 per cent of tropical glaciers, the source of water for the capital, in the last 50 years. And the process continues. In this context, Lima's environmental sustainability depends to a large extent on the proper management of this water infrastructure. Without the canals, green areas are impossible and Lima, with an average of 3 m^2 pp, already has a serious deficit of those.

In 2015, the Sustainable Development Goals and the New Urban Agenda were launched, and the Surco-Huatica Water Board understood that this new vision for city, landscape and natural resource management offered new opportunities. Consequently, they decided to incorporate some of the elements suggested by the international agreements. Thus, together with the campaign a vision of a sustainable city was developed, defined by:

- Sustainable management of water resources;
- Protection and enhancement of biodiversity;
- Creation of new, safe, accessible public spaces;
- Promotion of sustainable mobility;
- Recuperation of cultural heritage;
- Support for urban resilience through green areas (Comisión 2017).

Campaign/Decolonizing Heritage

While canals in a country like the Netherlands are part of the national identity, this is not the case in Lima. Here, the dominant narrative had historically obscured their existence as an indigenous creation, popularizing the myth that they were natural rivers. In this way, that narrative became a symbol of an erased memory that began during the colonial period and continued until recently. Originally the canals were a visible part of the urban landscape (fig. 7).

However, in recent decades, and in order to protect them, they were covered (fig. 8). This is the case for the entire length of the Huatica canal and for 21 km of the 29.5 km of the Surco canal. Thus, both continued to disappear from the urban fabric, losing their potential as generators of identity and as a structuring element of an urban space that fosters encounters and the shaping of citizenship.

In 2014, I started researching and writing about the Lima canals. My proposal for a full-fledged campaign to raise awareness about them was officially approved during an Extraordinary General Assembly of the Irrigation Commission on 29 February 2016. The main and most immediate objective was to secure recognition of the Surco Canal as Peru's Cultural Heritage, to be granted by the Ministry of Culture. Additional objectives included raising awareness about the canals' environmental importance and vulnerability, fostering links between citizens and their canals and green areas, and rehabilitating their indigenous, precolonial origin.

In the eight months that the campaign officially lasted, over 100 stories were published in the press, TV and radio, both in the national and international media. The social media campaign reached over two million people and 25 public meetings were held in citizens' associations, municipal auditoriums and cultural centers. As the campaign expanded, artists, urban and heritage activists and citizens came together in different ways to offer their support, all of which gave further momentum to the petition to have one of the canals declared national heritage.

Process for the Declaration of National Heritage and UNESCO Historic Urban Landscape Approach (HUL)

As part of the process, the Ministry of Culture required a document produced by the petitioners justifying the reasons for requesting such a declaration, which was produced. An advisory board was appointed to ensure academic and professional support, and the members provided advice along the way. Equally, some concepts had to be clarified, one of them the reasons why the canals should be considered heritage. The answer to this was based on the fact that there existed precolonial and colonial evidence, material and written, showing that it was a pre-Hispanic creation, that over time the system of canals had transformed the desert into valleys, and that despite having survived in

^ Fig. 7 Huatica canal in the 1940s as it went through the city of Lima (Source: Colección Juan Mulder).

^ Fig. 8 Covered canal: the curved paving follows the route of the canal, underneath (Source: Javier Lizarzaburu).

a very complex urban environment, they had a definite impact on the environmental sustainability of the city. Along with this, the document incorporated a section on the values that, in the opinion of the petitioning group, were associated with the canals. They included cultural, historical, environmental and territorial values.

In October 2016, the final report was submitted to the ministry. What made the experience unique was the willingness of the authorities to engage in regular contact with the petitioning group in order to advance the request. Despite that initial openness, during the first meetings some officials expressed their reluctance to grant national heritage recognition to the canal. The ministry contended that they only considered the “monumental and extraordinary” to be National Heritage – a view that eventually changed but made the process longer. The first legal argument supporting the request did not manage to convince the authorities.

It was later that the group learned of UNESCO’s 2011 Recommendation on Historic Urban Landscapes (HUL), and how heritage considerations had been adapted precisely in the light of changing urban environments. The group then decided that this approach fitted the case well. Together with the HUL argument, a UNESCO report on Heritage Canals, from 1994,[1] was included in the new document to the ministry. Two and a half years later, in March 2019, Vice-Ministerial Resolution N° 041-2019-VMPCIC-MC was officially published in which (one of the four segments suggested by the group) was declared to be part of Peru’s National Cultural Heritage (El Peruano 2019).[2]

Conclusions and Challenges

Although the main objectives of achieving heritage status and raising awareness about the canals were attained, the final result shows progress and setbacks. One of the shortcomings of the campaign is that it did not reach the most problematic areas. This was partly due to the fact the activities that were organized and the information that were produced were mainly disseminated through the media and social media, to which many of the people living in these areas do not have access. Organizing public presentations there to explain the process, as happened in other parts of the city, proved to be a difficult task. Consequently, many of the original problems there continue to exist. At the water management level, some fundamental changes are underway. The main one has to do with Lima’s vulnerability to climate change and its increasing levels of water stress. In the last five decades, over 50 per cent of the glaciers that feed the city have melted, and the process is now unstoppable. At the same time, every year Lima produces 500 million m^3 of wastewater. Of this total, 80 million m^3 are treated and discharged into the sea (OEFA 2014). On the other hand, the water provided to the city by the Surco and Huatica canals is on average less than 20 million m^3 per year (Inventario 2007). So, the organization is now working to achieve a far-reaching transformation. That is, the plan in the medium-to-long term is to stop using water from the river and start using treated wastewater instead, which would be exclusively for parks and green areas. It is an ambitious plan, but it seems there is a new understanding of the future threats and the focus is changing.

At the level of narratives, it was important to make the effort in reclaiming the indigenous memory and identity of the canals, especially in a city where this contribution historically tended to be minimized or erased. Beyond academia, this narrative of continuity did not exist, so this was the first time an integrated vision was put into the public domain. As part of the production of the book that was later published, more than 120 places watered by the canals, or which were irrigated by them at some point in the past, including parks, archaeological sites and public spaces, were visited. This made it possible to immerse oneself in the different layers created by this system. It's not just the green spaces. It is the variety of species of trees, birds and flowers that have made their habitat in a city where it never rains. They are the places that citizens use for sports, walks, games or wheelchairs. They are the spaces for community, commercial and artistic activities. Without these spaces that exist thanks to the canals, Lima would be less Lima. There are important challenges ahead, but there are also important lessons from the past, which have not lost their relevance.

Acknowledgment

This text is the result of work carried out by the author between 2014 and 2019 on the canals of Lima and the city-wide campaign he led to obtaining official recognition of them as part of Peru's cultural heritage, achieved in 2019. The two pillars of this work were memory and sustainability, and the underlying aim was to restore the canals' indigenous identity. The campaign and the publication of the book were funded by the Surco-Huatica Water Board. 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.

1. https://whc.unesco.org/archive/canals94.html
2. https://busquedas.elperuano.pe/normaslegales/declaran-patrimonio-cultural-de-la-nacion-al-paisaje-arqueol-resolucion-vice-ministerial-no-041-2019-vmpcic-mc-1752226-1/

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Collaboration Between Nature and Humans in the Desert: The *Qanat* System in Iran

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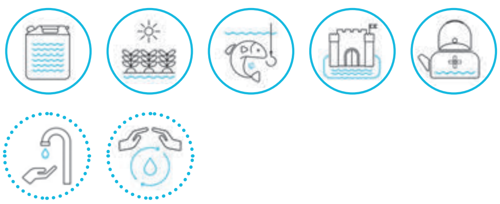
The qanat system exploits groundwater aquifers in arid and semi-arid regions with the help of local water facilities and infrastructure. The system originated in Iran's central plateau and then spread widely around the world, from the Middle East and Eastern Asia to Europe, North Africa and even South America. This historic water system, which reduces costs and energy consumption, offers a model of how humans can connect to their environment in a completely sustainable way. This system not only satisfies human water needs but does so without depleting natural resources. The relationship between humans and nature is very fragile in desert regions and the qanat system is capable of sustaining settlements even in Iran's hot and dry climate. This historic system enables settlements and agriculture to survive while inspiring a unique desert-specific approach in line with the UNESCO Historic Urban Landscape (HUL) approach. This ecosystem-like approach involves not only the qanat's canals but also associated natural structures and historical components like water reservoirs (Ab-Anbar), water mills (Asiab), water coolers (Yakhchāl), gardens (Bagh) and farms (Mazrae) and floodways (Masil).

KEY THEMES



CLIMATE

A B C D E

Bwh : Hot desert climate

< Fig.1 Qanat in Iran (Source: Payam Azadi, 2021. Wikimedia Commons, CC BY 4.0).

Introduction

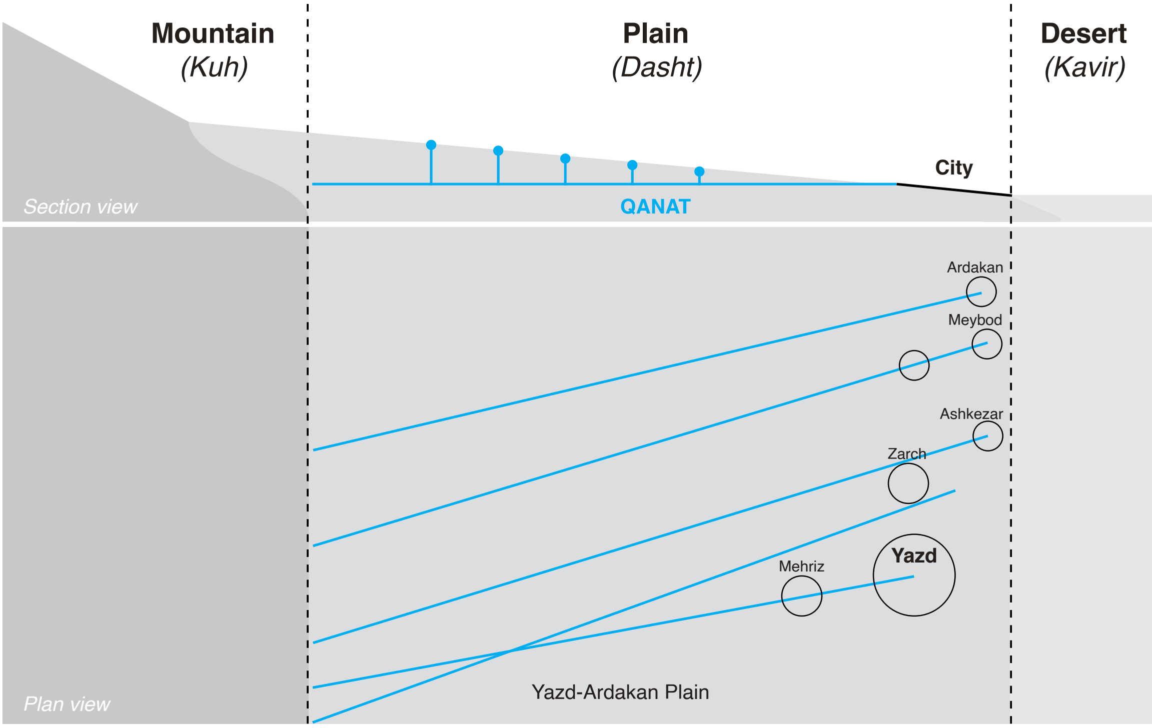
A significant part of central Iran is covered by dry deserts; obtaining adequate water has always been a challenge. Throughout the arid regions located in the margins of the central desert, the agricultural and permanent settlements are supported by the qanat ancient irrigation system (*kariz* in Persian). This system conducts water through underground tunnels to the earth's surface with the aid of gravity from the main well. It allows water to be transported over long distances without losing water to evaporation, and it provides water for drinking, agriculture and other uses at considerable distance from the main well (about two to eighty kilometers; Semsar Yazdi 2019).

The qanat system consists of a series of vertical shafts in sloping ground that are interconnected at the bottom by a tunnel with a flatter gradient than the ground level. The first shaft (mother well) usually sinks into an alluvial fan, to a level below the groundwater table. The shafts are sunk at intervals of 20 to 200 meters in a line between the groundwater recharge zone and the irrigated land. From a bird's eye view, a qanat system looks like a line of anthills leading from the foothills across the desert to the greenery of an irrigated settlement. Qanats are generally used on the edge of the central desert of Iran. The most important qanats in Iran are located in arid regions in the provinces of Yazd, Khorasan, Kerman, Markazi and Fars. Specific characteristics of qanats vary depending on the region, the type of urban and public space and building scale (Semsar Yazdi and Khaneiki 2016).

From an ecological point of view, qanat structures are part of integrated natural and human networks. With the aid of nature, the nearest snow-capped mountains provide permanent water reserves, flood paths move seasonal rainfall and serve as a temporary source of water, and water streams under the shade of trees, helping to prevent evaporation. The water reaches its final destination in urban areas, where it is used for agricultural and horticultural irrigation. Along with human intelligence and technology for water transportation, distribution, storage and management, qanats are linked to tributaries, channels, water outlets, gates and temporary ponds. This interlocking water system is an outstanding example of sustainable collaboration between humans and natural ecology.

The social and cultural significance of qanats cannot be underemphasized. The qanat is considered a communal technology for water extraction in arid and semi-arid parts of Iran. It requires collaboration and sharing, and it is impossible to build a qanat individually: an or-

^ *Fig. 2 Qanat system in Iran (Source: International Center of UNESCO on Qanat and Historic Hydraulic Structures).*



^ *Fig. 3 Ideogram of qanat system in Yazd-Ardakan plain (Source: Massoud Ghaderian).*

ganized group must gather its forces for construction. After construction, regulations are necessary to clarify the manner of using and sharing. All the techniques related to the qanats, from transfer to operation and maintenance, have become social and cultural traditions over time. Also due to the high value of water for desert dwellers, the qanat as a water supply has a high cultural and social position. Rituals and religious meetings are carried out next to the qanat demonstrating the socio-cultural importance of this water infrastructure. One of the best examples of the social and cultural dimensions of this water system is the marriage with the qanat. During the drought, when the qanat's water decreased, the Iranian villagers believed that if a woman (as a symbol of fertility) was married to the qanat, its water discharge would increase. Marriage with the qanat was performed in a special ceremony next to the mother of the well with joy and the giving of food.

As the vital water infrastructure of arid and semi-arid regions, qanats have played an important role in these regions' economies: water is an essential prerequisite for development. The qanat brings groundwater to the surface by gravity, which is economical and does not require the use of energy. Qanats have not only supplied water at minimal cost, but their components have also provided various water services such as transferring, storing, and cooling water in a sustainable manner. For example, an *ab-anbar* is the type of reservoir that has been the most common way to keep water cool in arid regions. A *yakchal* has been used as a refrigerator to store frozen water in winter to consume in summer. In addition to water-related services, the qanat's water has been the driving force for many daily supplementary services, such as applying the waterpower from water mills to grind wheat. The qanat system has not only been effective in reducing costs, but has also played an effective role in creating direct or indirect added value.

Current Approaches to Preserving and Managing Water Heritage

In the list of national heritage in Iran, initially, the qanats and their associated structures were registered separately. With the recognition of the qanat as a historical water supply system and traditional technology, in 2016, eleven Iranian qanats were listed as World Heritage sites. Those qanats are still active water carriers and have retained not only their architectural and technological structures but also their function. They continue to provide the essential resource of water, sustaining Iranian settlements and gardens, and they continue to be maintained and managed through traditional communal management systems. These management systems have remained intact and have been transferred from the distant past thanks to the collaboration of many, including users of the qanats. The government of the Islamic Republic of Iran established the International Center on Qanats and Historic Hydraulic Structures in Yazd, Iran, under the auspices of UNESCO. Since the world's recognition of the qanat, UNESCO has developed rules and regulations to ensure the continued functionality of the qanats and the water catchment areas included in the buffer zone, and they have been committed to protecting their essential function in the provision of water resources. Likewise, the agricultural areas affected by the distribution and use of qanat water resources have been protected through buffer zones to allow the full long-term protection of the qanat system.
In the past, committees consisting of local people were responsible for managing the water obtained by the qanats. This management included the construction and maintenance of the qanat and the distribution of water. The traditional communal management system, which is still in place, allows equitable and sustainable water sharing and distribution. Nowadays, urbanization, government agencies, including the Water Management Organization, are responsible for maintaining the qanats. In recent years, with the introduction of the qanats as cultural heritage, the National Cultural Heritage Organization has carried out activities in matters of protection and tourism related to the qanat. Some qanat researchers have suggested that highlighting qanats as tourist attractions could help justify the conservation of qanats. They believe that tourism and its revenues could help protect the qanat as well as stimulate regional development.

The approaches to preserving qanats vary depending on the organizations associated with their management. Three categories of institutions in Iran are in charge of qanats: water management organizations, cultural heritage organizations, and groups of public and communal owners of qanats. The Water Management Organization of Iran and its provincial branches generally ignore the role of the qanats as a water resource due to the low volume of water discharged by qanats. The Cultural Heritage Organization of Iran pays more attention to the qanat as a tourist attraction. Groups of co-owners focus on the amount of water produced and on managing property related to the qanats. Unfortunately, qanats have no particular role in spatial development planning and little research has been carried out related to Historic Urban Landscape (HUL) approaches.

^ *Fig. 4 Activities of daily living in the desert in tandem with the qanat system. Due to its activities and applications, the qanat system has played a significant role in the social, economic and cultural life of desert city residents. (Source: ICQHS, International Center of UNESCO on Qanat and Historic Hydraulic Structures).*

^ *Fig. 5 Water pumping by digging water wells, Yazd, Iran,1959. In the 1950s, the digging of wells to extract water directly from underground sources by pumps accelerated. At that time, people and officials were pleasure to gain direct access to water, while less than 50 years later, the water levels underground were greatly reduced, which resulted in the lack of water again, the destruction of the qanat system and its components (Source: Vaziri).*

Current and Future Challenges to this Water System

The historical and sustainable water system of qanat has been gradually replaced by the digging deep wells and expanding water pipes over the last fifty years in Iran. The construction of deep wells for pumping groundwater has caused most of the qanats to dry up. Furthermore, it is very difficult to rehabilitate them because the new deep wells have already lowered the natural water level significantly. In addition, with the expansion of the modern water distribution network along with urbanization, qanats have not been considered due to high maintenance costs and low levels of irrigation. A few qanats are being used only for agricultural purposes, while other abandoned qanats are often blocked or drained.

Along with the destruction of the qanat as an ecosystem, the natural and man-made components are also being destroyed. Gardens, agricultural lands and farms are examples of these natural components that had been used to protect against desert and seasonal floods as a green belt. The destruction of the city against recent floods and droughts is an example of the result of the destruction of the qanat and its green components. In the past, seasonal floods have been part of the water system in historical cities for watering gardens and farms which were green belts of cities. Nowadays, with the drying out of historical gardens and farms, seasonal floods are damaging the historic core of cities.

Conclusion and Future Approaches

Qanats are an environmentally friendly method of using groundwater aquifers. They can aid sustainable development in arid and semi-arid areas by utilizing local facilities and infrastructure, lowering costs and reducing energy consumption. They offer a way forward for a country facing environmental and economic crises. If economic, social, cultural and environmental values are aligned, the government, and society in general, will conclude that instead of focusing entirely on transferring water from the seas to cities, qanats can contribute to the water supply and also provide benefits as an ecosystem. The HUL approach will be extremely beneficial to integrating qanats in existing opportunities and future challenges. The UNESCO Recommendation on the HUL proposes a six-step action plan. In line with that plan we can think of the qanat in terms of:

1) Mapping cultural and natural resources

According to the Ministry of Energy and Water of Iran, there are more than 36,000 qanats in Iran. Only in fewer than 20 qanats has their main route has been accurately identified. Although it is difficult to map qanats due to their numbers, depth and complexity, it is impossible to protect them without knowing their location. New technologies can help to map qanats.

2) Consulting stakeholders, including communities, about which values and attributes to protect

All stakeholders, including local people and officials in the sectors related to water management and cultural heritage, should be familiar with the value of qanats and the historical water infrastructure as an ecosystem.

3) Assessing vulnerability

Due to the sensitivity of historical water infrastructures and qanats, annual monitoring is necessary to identify damage. It is also necessary to document maintenance operations along with protective action.

^ *Fig. 6 Destruction of historical fabric due to flooding, Yazd, Iran, 2022 (Source: Majid Jahrahi).*

4) Integrating heritage elements in spatial planning

After identifying the historical water infrastructure and qanats, an active role in urban development plans should be considered for them. This goal requires spatial analysis and spatial statistics at the urban network level.

5) Prioritizing policies and actions for preservation

Although protection policies for qanats have been on the rise in recent years, coordination between them at the national to local levels is still weak. A hierarchy of policies based on regional characteristics of qanats and stakeholders can help prioritize protection policies.

6) Developing partnerships to implement projects

Improving the performance of historic infrastructure and qanats is possible with knowledgeable intervention. Planning and design interventions are possible in the form of projects. To implement projects, it is necessary to develop a network of participants.

With the HUL approach, we could focus on the preservation of historical water infrastructure as water heritage by integrating development with environmental and socio-economic changes. This approach aims to provide sustainable planning and design interventions of water infrastructure within historical environments. In this way, qanats can become an inseparable part of the current urban infrastructure networks.

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"Catch the Flood Before it Catches You": Spate Irrigation in Arid Regions of Pakistan

Karim Nawaz
MetaMeta

Floods wreak chaos and destruction in many places, but for people in arid regions using spate irrigation, the floods that emerge from ephemeral rivers symbolize life, livelihood and prosperity. Communities pray for floods as they are the only source of water. Pakistan has the largest amount of land under spate irrigation in the world. Spate irrigation is a unique 1000-year-old system. Yet despite its many environmental, social, cultural, managerial and economic benefits, it is not widely known among academics, researchers or practitioners. The practice is based on indigenous knowledge learned from elders and passed down from one generation to the next, with enthusiasm and interest, as part of culture and heritage. This article explores the innovative aspects of this system, which is crucial as a sustainable means of livelihood. It explains how the system lets people effectively manage the spate flows, protecting them against the havoc caused by floods, and allowing land to be developed to meet the needs of future populations.

KEY THEMES

CLIMATE

A **B** C D E

Bwh : Hot desert climate*

** climate not specified in the original version*

< Fig. 1 Field-to-field irrigation in Pakistan (Source: Karim Nawaz).

Introduction

Spate irrigation is a unique system of water management used in arid regions. Its historical traces are found some 4000 years ago in the Arab Peninsula, where Queen Shiba's spate irrigation structure, known as Marib Dam, still exists in present-day Yemen (Frank et al. 2010). This system prevails in all four provinces of Pakistan. Although there are many different languages in Pakistan, spate irrigation is referred to as "naeen" everywhere. The famous spate streams and ephemeral rivers are Naeen Gaajin in the province of Sindh, Sanghar Naeen in the province of Punjab, Loni Naeen in the province or Khyber Pakhtunkhwa and Narri Naeen in the province of Balochistan. Pakistan has about 8.9 per cent of its total irrigated area (1.4 million ha) under spate irrigation system, the largest amount in the world (fig. 2).

Historic Water Management

Each ephemeral river or stream, despite its size, has its own unique water rights and management practices, which are well documented in the governmental land record of 1872. Floodwater (spate) is used for agriculture, rangelands, forestry, livestock, drinking, and recharging groundwater, making its economic importance vital in harsh climate conditions, thus in accord with SDG 13. Spate agriculture is purely organic in nature and meets local needs; its products are also used in commercial sectors.

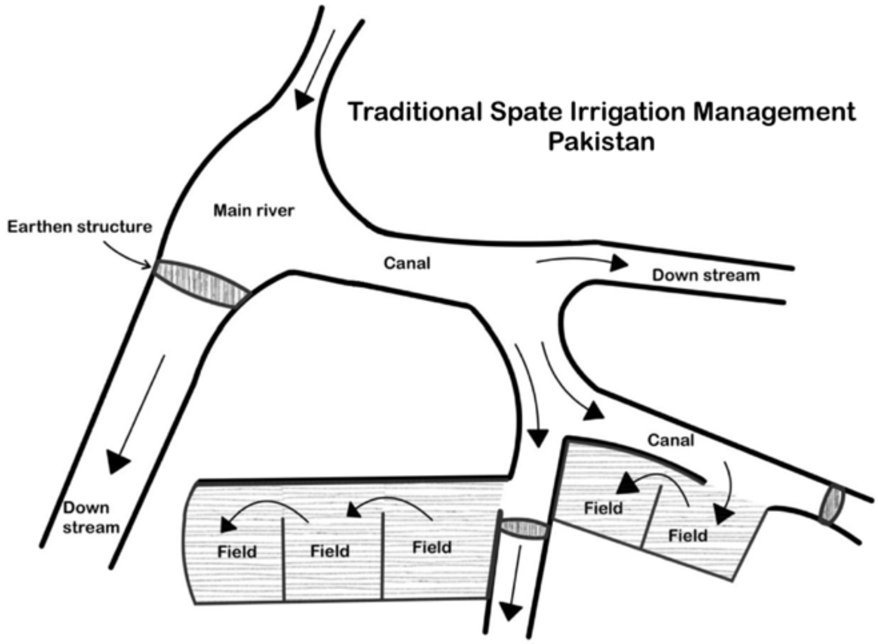
The spate irrigation system provides a unique case of social and cultural dynamics in dealing with climate change and variation. Two extreme ends of the spectrum are drought and extraordinary floods. With spate irrigation, the shocks of both extremes, drought and flood, are absorbed using socio-cultural strategies. Flash floods are used to produce specific crops and surplus floodwater is spread over wasteland used as common pasture equally by local people and nomads. Fields are farmed jointly by owners and others whose land did not receive floods, and nomads also work as field laborers. These socio-economic and cultural arrangements help to keep the population residing in the area, with emigration as the last resort.

Spate Irrigation - globally

Country	*Year of Irrigation*	*Total Irrigated Area (ha)*	*Spate Irrigated Area (ha)*	*Spate Irrigated as % of Total Irrigation*
Algeria	1992	555,500	110,00	19.8
Eritrea	1993	28,124	15,630	55.6
Libya	1987/1997	470,000	53,000	11.3
Morocco	1989	1,258,200	165,000	13.1
Pakistan	1990	15,729,448	1,402,448	8.9
Solamia	1984	200,000	150,000	75.0
Sudan	1997/1987	1,946,00	280,000	14.4
Tunisia	1991	385,000	30,000	7.8
Yemen	1987/1997	485,000	193,000	39.8

^ Fig. 2 Table showing spate irrigation in global perspective (Source: FAO Aquastat; Hadera 2001; Kohler 1999).

^ Fig. 3 Earthen diversion structure at Bhaati Spate River, DG Khan, Pakistan. The site is more than 250 years old (Source: Karim Nawaz, 2006).



^ Fig. 4 Traditional spate irrigation management, Pakistan (Source: Karim Nawaz, 2022).

Current Approaches

In Pakistan, some of the ephemeral rivers discharge 100,000 cusecs of water and can irrigate more than 200,000 acres; such robust targets can only be achieved through effective social organization and partnerships, as in SDG 17. Floods of ephemeral rivers are diverted by constructing a temporary structure across the river and flow is conveyed to fields by a network of canals (fig. 4). A flash flood lasts a few hours to a few days only and users manage the water within this extremely short duration. Financial contributions from shareholders of the water for the construction of new diversion structures is determined according to their respective allocated shares in the water and the size of a landholding. During spate flow diversion and application, a community guard (Raakha) continuously patrols and monitors sensitive sites, so that floodwater is distributed properly. These local water user associations of spate irrigation are cost-effective, easily approached by members of the community, and socially accountable as there is neither governmental involvement nor remuneration involved. Older generation farmers encourage the youth saying, “Don’t be afraid of flood, catch it before it catches you.”

Spate irrigation works with gravity so no energy is required, making it an affordable clean energy technique (SDG 7). The water distribution system has evolved over centuries to cope with local conditions such as culture, communal relationship with heritage, and environment. Deeply rooted socio-cultural values contribute to ensuring the equity and efficiency of this system in an “unkind” environment. The unique system of water rights and associated socio-cultural background are points of pride narrated to young children in village assemblies and storytelling events. Over time, farmers have learned to adjust their growing seasons by applying different types of seeds according to the time of year that floods occur and their relative size. Spate irrigation is an excellent version of climate change adaptation and farmers elsewhere need to learn from this local model.

For centuries, local populations in Pakistan had certain rituals and customs pertaining to this system. Rituals related to rain take place in many cultures but here the rituals are intended to make floods (spate) occur. When floods are late, a donkey is kept under the sun for a longer time during the day than usual; people believe that the animal's prayers will bring rain and floods. In another ritual, a person of religious background is brought to a dry riverbed and bathed in order to receive floods (Personal communication, 2006). Children color their faces black and go around the village, singing for rain and floods to come and collecting grains and chickpeas to prepare a dish which is fed to both villagers and birds. It is believed that the birds' prayers and requests will cause the rain and floods to come. People say special prayers for rain called "Salat e Estisqa."

Challenges

Unfortunately, floods retain connotations of negativity in many circles. There is also a lack of human resources, expertise and experience in dealing with floods as an opportunity. Heavy earth-moving machinery may not be available in time to exploit floods effectively. Currently, the response from the government of Pakistan to floods is to focus on rehabilitation rather than prevention. Yet, these floods are "life" for millions of inhabitants living in these harsh climatic conditions. Spate irrigation systems lack institutional support from the government, donors and international agencies. Local communities see floods as an opportunity while the government sees them as a disaster. Consequently, both respond differently. The government's strategy is to save the infrastructure by allowing floods to flow downstream and join major water bodies, while local communities want to mine the floods for numerous benefits. Recently, the government has started to store spate flows through the construction of dams. This has resulted in violating the rights of downstream users and, moreover, the heavy loads of sediment coming through the spate flow are filling the storage reservoir quickly and most of the modern designs have failed to work adequately.

The spate irrigation system is increasingly affected by climate change. Record-breaking rains and floods are beyond the capacity of the local population to cope. In addition to climate change, additional factors affecting the survival of this traditional irrigation system include population pressure and a lack of support from the government and international agencies. Also, traditional irrigation systems are not part of educational curricula so relevant professionals have not learned about this environmentally friendly and low cost system.

Way Forward

In the devastating floods in Pakistan in the year 2022 half the affected areas were dealing with water from spate rivers and the other half from the inundation of perennial rivers. Perennial rivers in Pakistan are mostly fed by melting glaciers, and their discharge is steadily declining. In such situations, spate irrigation systems can play an important role in food security and climate change adaptation. Spate irrigation has inbuilt disaster risk reduction and resilient approaches to disasters (floods) in ways that

^ Fig. 5 Field-to-field irrigation in Pakistan (Source: Karim Nawaz, 2006).

encourage sustainable human settlements (SDG 11). Spate flows need not be blocked in reservoirs: instead, they should be allowed to flow downstream to allow downstream users to benefit and to avoid the problem of siltation in reservoirs. Rather than storing flood water in reservoirs, we should make use of flood diversion strategies that have been practiced for centuries and that are based on the experience of farmers, in line with SDG 17.

After the floods of 2022, when one-third of the country was badly affected, an innovative strategy was recommended by Flood-Based Livelihoods Network (FBLN, based in the Netherlands) to capture the moisture created by floods before it is too late. Government and donor agencies welcome this approach and as a result, an immediate response was proposed to supply seed and sowing machinery to farmers. This resulted in one of the best examples in contemporary history of a considerable area used for crop cultivation in the wake of a flood.

It is important to involve local people and water user associations in further developing the system. Also helpful will be researching and developing drought resistant varieties of crops and finding ways of avoiding and minimizing the shock of dry years through off-farm activities.

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Sustainable Water Management and Indigenous Socio-Technical Heritage in Marrakech, Morocco

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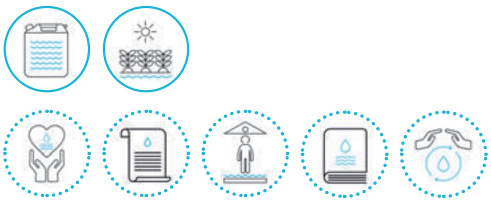
Morocco is considered a water-independent country by the World Bank, yet due to its topographical diversity, considerable land surface and challenges posed by climate change, it ranks among the most water-stressed countries on the globe. Marrakech, an oasis city in Morocco, thrived for centuries through the ingenious use of khettarat, a traditional system of underground wells and channels that tapped into local aquifers and made use of topography and gravity to sustainably deliver water to the city. Until the early 1990s, Marrakech could still meet all its drinking water demand with the use of khettarat. Owing to a combination of institutional, political and economic factors, the khettarat system went into sharp decline starting in the 1980s and was at risk of disappearing both as a form of heritage and as an Indigenous technology. Recent efforts by multiple stakeholders aim to safeguard and re-introduce khetterat. They demonstrate the importance of local socio-technical systems in ensuring equitable and sustainable development in Morocco and similar arid regions around the world.

Keywords: *water heritage, indigenous technology, Morocco, socio-technical, underground water system*

KEY THEMES



CLIMATE

A B C D E

Bsh : Hot semi-arid climate

< Fig. 1 A seasonal riverbed lies dry except for a small pool of standing water, on the outskirts of the Tata oasis, in southeastern Morocco (Source: Cristiana Strava, 2018).

Introduction

As a water-independent country[1] that does not share ownership or usage rights over its surface water or groundwater with any neighboring state, Morocco enjoys an unusual degree of freedom to determine its domestic water policies (World Bank 2020). However, the country faces challenges due to uneven distribution and uneven access to sustainable water sources across its territory. The situation has been exacerbated by accelerating climate change, as well as by political decisions to pursue water-intensive economic activities like mass tourism and export-oriented agriculture (Davis 2006). These factors have made this structural water deficit a defining feature and pressing challenge for economic and governmental actors. In 2022 Morocco experienced the worst drought in 40 years, with ordinary inhabitants feeling the impact throughout the country (Manfron et al. 2023), particularly in the Marrakech region (Elshamy 2022).

The conditions for this deficit were compounded by historical precedents, most of which were set in place during the twentieth century. France's Protectorate in Morocco (1912–1956) was characterized by a settler-colonial form of occupation. Land expropriated from the Indigenous population and export-oriented agriculture became key pillars of the colonial economy (Guerin 2016). The introduction of intensive, irrigated, industrial agriculture during the colonial period overdetermined the direction of water use and water-use policy for decades to come. Historians and political scientists have documented some of the economic and political outcomes of these transformations (Bouderbala 1984; Davis 2007). However, their ecological and social impacts have not been studied as extensively. In the following sections, I present several forms of historical water management, before describing the significance of a new water heritage museum. I then set these historical approaches against the backdrop of challenges posed by accelerating climate change and the return of mass tourism to the Marrakech area, before concluding with a set of recommendations.

Historical Attempts at Local Water Management: From the French Protectorate to Post-independence Morocco

Morocco is 80 per cent arid or semi-arid (fig. 1), and water availability has dropped from 3,500 m^3 per person per year in 1960 to 730 m^3 per person in 2005 and 645 m^3 per person in 2015 – well below the "water poverty level" of 1,000 m^3 per person per year as defined by the World Bank. According to the same data from the World Bank and the Moroccan Ministry of Equipment and Water, this ratio is expected to decline to the absolute threshold of 500 m^3 per capita per year by 2030 (Taheripour et al. 2020).

To address these conditions, in the post-independence era (1956–2000s), Morocco's monarchy embarked on several large-scale modernization projects, which led to changes in institutional and practical arrangements for the management of local water systems. This entailed, for example, the building of large hydro-power dams and reforms to ownership regimes that focused on providing incentives to move from communal to private ownership (Simonk 2021). Driven by a commitment to the

1. Water-independence is a measure of how much of the overall volume of a given country's renewable water resources come from sources that are designated as internal or external to that country's sovereign space. For Morocco this measure is 0 for external sources, hence it is a water-independent country. See World Bank (2020).

^ Fig. 2 A diorama inside the Aman Museum showcasing and labeling in three languages the underground components of a *khetarra*: a long gallery that taps into the water table and angles down toward an irrigation field or oasis community, and several maintenance wells that can be accessed from above ground. (Source: Cristiana Strava, 2023).

economic orthodoxies of the 1970s and 1980s, this ultimately prioritized economic growth through free-market logic over communally managed public goods. This in turn contributed, among other things, to the decline of agricultural commons such as the *agdal* and collectively managed water systems such as the *khettarat* (Strava and Amarouche 2022). Marrakech, an oasis city in Morocco, thrived for centuries through the ingenious use of these *khettarat* (fig. 2), a traditional system of underground wells and channels that tapped into local aquifers and made use of topography and gravity to sustainably deliver water to the city (Faiz 2002). Until the early 1990s, Marrakech could still meet all its drinking water demand with the use of *khettarat* (Faiz and Ruf 2010).

Institutional and Indigenous Approaches: Aman Museum for Water Heritage

On January 5, 2017, on the outskirts of the oasis city of Marrakech, Crown Prince Moulay Hassan inaugurated the Mohammad VI Museum of Water Heritage and Civilization - Aman, Morocco's first water heritage museum, built on land donated by the Ministry of Charitable Endowments and Religious Affairs (Ministère des Habous et des Affaires Religieuses, hereafter Habous). Nicknamed the Aman Museum after the local Indigenous Amazigh word for "water," and managed by the Habous, the museum and surrounding site, together with the local institutions involved in its planning, constitute a unique example of not only recuperating socio-technical water knowledge but also ensuring its preservation through education.

The choice of planning, building and managing the museum under the tutelage of the Habous is not as arbitrary or strange as it might first appear. Drinking water fountains and wells, as well as washing fountains needed for the performance of religious rituals and everyday cleaning, have been and continue to be a key infrastructure of Moroccan cities and small towns. Historically, establishing and maintain-

^ Fig. 3 The main atrium of the Aman Museum contains a 3D model of the region's hydrological system and is designed to visually connect all three floors, seeming to reference a deep and wide well (Source: Cristiana Strava, 2023).

ing this infrastructure has been the responsibility of religious institutions like the Habous, whose knowledge and custodianship of these socio-technical systems extend back many centuries (Ftaita 2010).

However, by bringing together previously disparate actors from the Moroccan community, policy and technical sectors, the museum provides an unprecedented example of mixed institutional stewardship. The work of setting up the museum was anchored in an inclusive approach that combines public outreach with public-private partnerships in the work of heritage preservation and knowledge ownership. This approach is further illustrated by the consortium of actors who participated in the planning, financing and scientific coordination of the museum: from the German Technical Cooperation Agency (GIZ; Deutsche Gesellschaft für Internationale Zusammenarbeit), to the local University Cady Ayyad in Marrakech, Moroccan engineers and historians of the environment and international museum consultancies (K Nour). The Aman Museum demonstrates that the preservation, valorization and management of unique water systems and associated forms of heritage can greatly benefit from cross-sectoral and international collaboration. Beyond extending this knowledge and custodianship into the future, the creation of Morocco's first water heritage museum and its location in one of the most water-stressed regions of the country might also be interpreted as a statement of commitment by local and international actors to safeguard and valorize Indigenous knowledge systems.

Across 10 permanent exhibits, through varied mediums and techniques, the museum traces the historical, bio-chemical, legal, spiritual, polit-

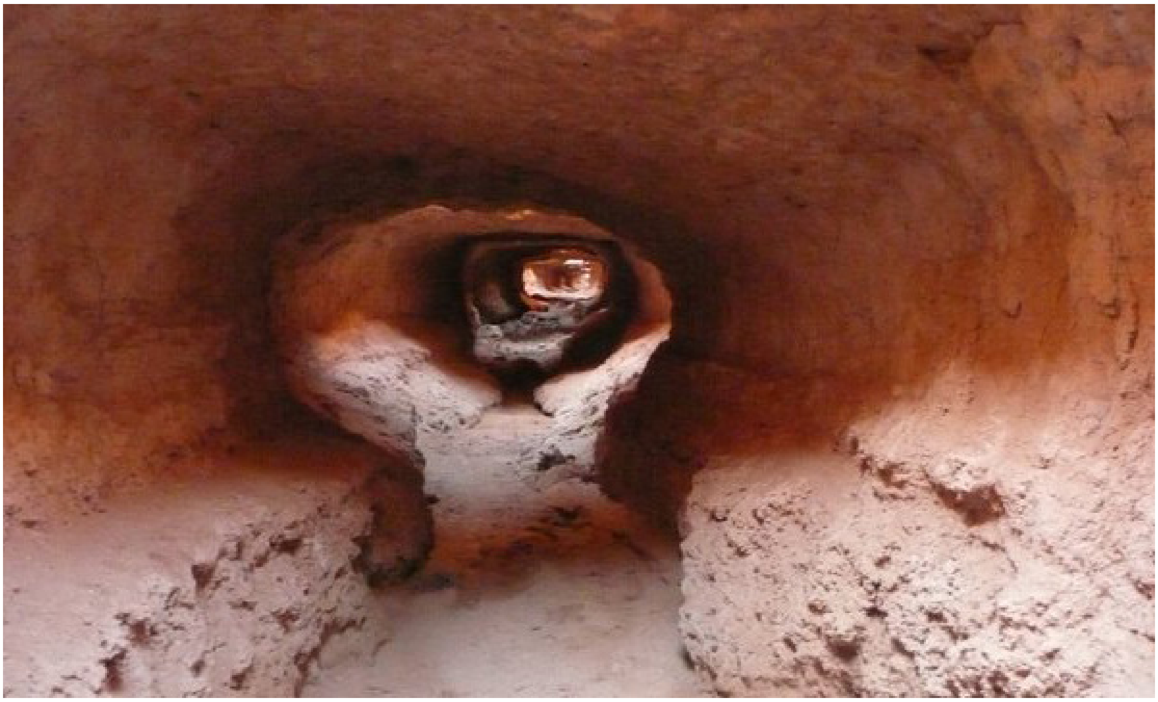
^ Fig. 4 The tops of *khettara* maintenance shafts with signs of dereliction and overgrown vegetation, threatening their collapse, Guelmim region, Morocco (Source: Cristiana Strava, 2010).

ical, socio-economic and geographical aspects of hydrological systems in the country (fig. 3). By placing a particular emphasis on the Indigenous knowledge and practice associated with *khettarat* and the skillful management of water in Morocco's arid regions, the exhibits offer more than educational information. They also remind local and international visitors of the immense knowledge that Indigenous communities already possess – and that this knowledge can be lost unless efforts are made to preserve it and bring it back to life (fig. 4–5).

Climate Impacts and Sustainable Tourism

The Aman Museum's proximity to Marrakech is not arbitrary and acts as a stark reminder of the human and climatic challenges faced by already stressed water systems. Until the early 1990s, Marrakech could still meet all its drinking water demand with the use of khettarat. However, at present, the oasis city consumes 66 million m^3 of fresh water per year which can lead to severe aquifer depletion. One significant factor is the over-pumping of groundwater from wells for intensive agricultural uses and leisure activities (thirteen golf courses, five waterparks and many private lawns and pools) that give the city its reputation as the "Las Vegas of Morocco."

As the city's tourism industry has returned to activity levels matching the years before the COVID-19 pandemic, pressure on the local aquifer is set to increase. Recent studies also highlight the impending threat posed by the rapid depletion of underground aquifers resulting from a decrease in rainfall and from their being heavily tapped for agricultural expansion (CESE 2014). For three consecutive years (2020, 2021, 2022),



^ Fig. 5 Inside an underground desiccated gallery of a *khettara* light shines from above through the maintenance shafts. The gallery is tall enough for an average-sized person to stand up straight and wide enough to comfortably walk through. (Source: Cristiana Strava, 2010).

the region recorded a steady drop in precipitation, with 2020 being one of the driest years on record since 1981. Aquifer water has also been degraded by seawater intrusion, nitrate pollution (from fertilizers or untreated sewage) and natural increases in salinity (Hssaisoune et al. 2020). Given the slow recharge rate of these aquifers, their depletion and degradation will have severe effects on Morocco's water systems.

However, like many other middle-income countries in the Global South, Morocco's national strategy for economic development continues to rely heavily on both a strong tourism sector as well as export-oriented agriculture. Taking into account the urbanization and population growth required to keep these sectors profitable, current predictions warn that unless urgent measures are enacted, Morocco expects to reach "absolute water scarcity" (less than 500 m^2 per person per year) by 2030 (Taheripour et al. 2020).

Conclusion

Recent efforts at recuperating, revitalizing and celebrating Morocco's rich Indigenous water heritage have been instrumental in mitigating, and in some cases even reversing, some of the most detrimental effects of previous water-management policies and practices in the country's arid regions (Dahan 2017).

Public-private partnerships and the phased but sustained introduction of renewable sources of energy can help alleviate water stress in Morocco's arid regions, while also helping to mitigate risks in other regions where flooding and coastal erosion pose a threat to local communities and their livelihoods. Artificial recharge of existing aquifers, seawater desalination and wastewater reuse are some of the promising approaches currently being tested across the country. Alongside efforts to revitalize local socio-technical water heritage, these approaches stand to offer viable solutions that have the potential to ensure equitable sustainable water futures for all (Hssaisoune et al. 2020).

However, it is also clear that current models of development that remain wedded to capitalist, market-driven and financial incentives cannot, in the long run, safeguard water resources and will ensure neither the survival of heritage practices nor that of communities who have developed and preserved these practices for centuries. Instead, the recuperation of Indigenous water-management knowledge in Morocco demonstrates that to build and maintain resilient and locally adapted solutions, decentralized, collective and communal forms of resource use and stewardship like the *khettarat* merit broader support and a more central role in water-management plans.

Policy Recommendations

- Establish new or reinforce existing partnerships between governmental agencies and local communities in charge of safeguarding water resources.
- Allocate structural funding to local efforts that integrate Indigenous knowledge in national water-management strategies.
- Concerted efforts can together ensure sustainable, participatory and locally appropriate approaches to water conservation, in Morocco as well as in similar semi-arid countries.

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A Hidden Water-Harvesting System: The Sassi di Matera

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The water-harvesting system of the ancient Sassi di Matera, in the Basilicata region of southern Italy, represents a clever way of living with water in an arid climate. The terrain, with its soft rocks (Calcarenite di Gravina), provided the foundation for the water-harvesting system that shaped the cave dwellings of Sassi physically, socially and culturally. People caught, guided and stored water in private and public spaces, mostly underground, ensuring its availability for all. In 1993 UNESCO declared the cave village a World Heritage Site. Unfortunately, the water-harvesting system of Sassi di Matera is no longer functioning. Its historic ingenuity is not as visible as the system deserves and its cultural and social values are almost forgotten. Using layered visual analysis – the illustrative method – knowledge can be collected and communicated in drawings to get insight regarding more resilient, circular, and people-related approaches (Bobbink, Chourairi and Di Nicola 2022). This article and the included drawings focus on the water system's value, from which we can learn today.

KEY THEMES

CLIMATE

A B C D E

Csa : Hot-summer Mediterranean climate

< Fig. 1 View of the Sassi di Matera from Belvedere Murgia Timone; in the foreground is the canyon of the stream Torrente Gravina (Source: Isabella Banfi, 2022).

A Smart Urban Water System

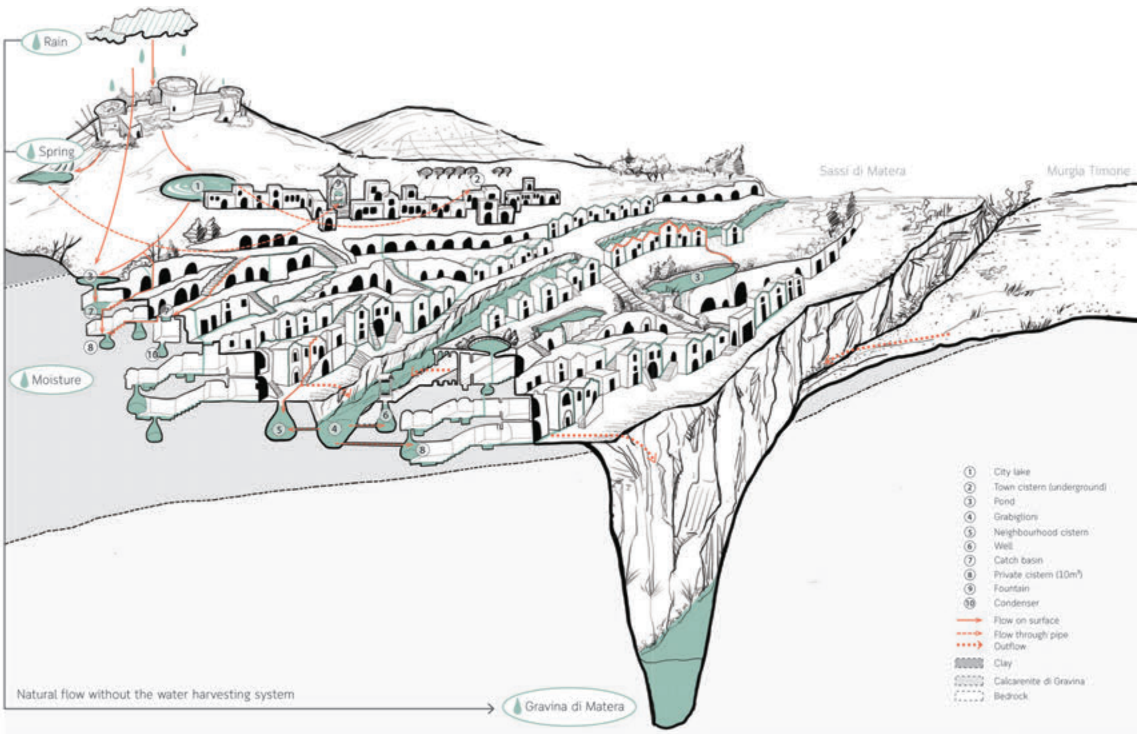
Due to low precipitation throughout the year, water is scarce in the Basilicata region, once known as Lucania. Since the Bronze Age, people have used soft rocks (*Calcarenite di Gravina*) to create cave dwellings and cisterns to store rainwater for domestic use and irrigation. The water-harvesting system includes wells, catchment basins, ponds, cisterns, condensers, fountains and *neviere* – large spaces carved in the rocks where snow is stored to cool food in summer – all horizontally and vertically connected by channels. About 2,210 cisterns were identified using a statistical approach, including 2,039 small bell-shaped cisterns, 170 neighborhood cisterns and two large cisterns of 1,300 and 5,000 m³ each (Manfreda 2016). The water harvesting in the Sassi demarcated private and public spaces. Private cisterns could store 10 m³ and consisted of basins and water channels on different levels, helping water to flow smoothly and become progressively cleaner. The *vicinato* – a shared courtyard where children played, and people met – was always accompanied by a cistern serving four – six families. Over the centuries, water shaped the town's physical state and influenced how people lived and worked. The system provided water for the development of an agropastoral society in which most people were engaged in agriculture and animal husbandry.

In 1920 the Sele Aqueduct began to deliver water through pipes to the houses, which resulted in neglect of the historic water-harvesting system. The *grabiglioni* (drainage canals) were covered in 1936 and turned into streets. In 1952 52 per cent of the inhabitants were still peasants (Pontrandolfi 2018). At that time, due to the increasing population, cisterns were transformed into living spaces. In 1952 when the town was labeled a "national shame" because of its poor living conditions, which included sanitation problems, crowding and a lack of electricity, the government evicted people from their homes. Between then and 1960, about 15,000 inhabitants left the ancient center of the community and moved to newly built houses uphill. As a result, the cave city became a ghost town.

In 1993 Matera became a UNESCO World Heritage Site because of its unique combination of site-contextual living and water-harvesting system. Funds were then raised to bring people back to the city. Today, the city's recovery is a success, with more than 700,000 visitors annually. The caves have been transformed into hotels, restaurants, lovely courtyards and alleys. Yet, reactivating the water system for use was deemed unfeasible due to modern demands regarding water quality, hygiene and quantity. Luckily, even though the water-harvesting system is no longer used, most of its elements are still in place.

Current Challenges to Preserving and Managing Matera's Water Heritage

Locals who own hotels and restaurants and those who have taken on other commercial initiatives are pursuing possibilities of preserving elements of the traditional water system so that, even without the water, the importance of the system is recognized as a part of the town's story. Antonella Passione, a member of La Scaletta – a cultural association committed since 1959 to the conservation and enhancement of the historical, artistic and environmental heritage of Matera and the Lucanian territory – renovated a series of *hypogea* spaces, a subterranean part of an ancient building, with three levels and seven cisterns. She converted the space into a restaurant, La Lopa, while maintaining its original shape, materials and appearance and

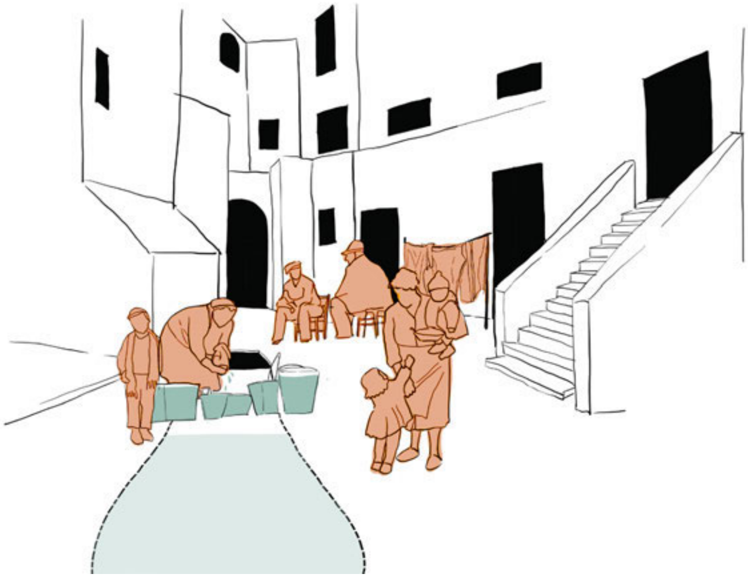


^ Fig. 2 Sectional perspective of the water-harvesting system of the Sassi di Matera depicting the circularity of the system and its sustainability (Source: Wenting Gao, 2022, based on literature review).

without altering the original waterproof layer. La Lopa is an example of preservation through transformation by focusing on the cultural and social values of heritage. Its name originates from the tool, a type of bucket, used to retrieve water from a well. Passione shows her guests the prints of these buckets, which are still visible on the wall. At the lowest level in the cellar, at a depth of 18 meters, she hosts cultural activities, displays films of the old Matera and explains to visitors the traditional water system. For Passione, retelling the stories is a way to remember the times in which, in Matera, resources like water were shared and re-used.

Art also offers ways of restoring appreciation for the traditional water system. Fernando Ponte, the director of Hotel Corte San Pietro, included eight cisterns in his hotel. When Matera was abandoned, the cisterns became garbage containers. When Ponte arrived, he cleaned them and tried to restore their original function to catch rainwater. However, less frequent and abundant rains made this idea unrealistic. Instead, he participates in the Matera Alberga, Arte Accogliente, a public art project integrating site-specific installations in six Sassi hotels. The art on display makes the visitors more aware of the water system and aims to demonstrate a new reality – a Matera that is welcoming, convivial and participatory. Inside one of the tanks, the artist Alfredo Pirri developed IDRA, an art piece that links the external open space with the interior of the restored cisterns in the courtyard of the hotel. In this way, visitors can still see the underground structures and the water-harvesting system, which was made of tuff, water and tradition.

Another attempt to display the water system is the recovery of *cisterna del comune in trasa-*



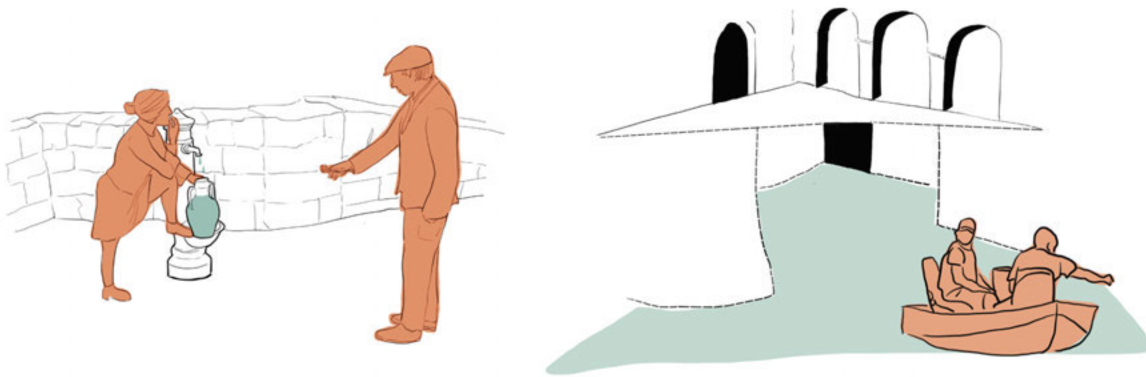
^ Fig. 3 Sassi di Matera: water-centered public life (Source: Wenting Gao, 2022, based on a literature review).

no-conca d'aglio. This project, initiated by Murgia Materana Park Authority and designed by the architect Vincenzo Stella, has revived an old state-owned cistern built at the end of 1700, when people drew water from it for their herds and flocks. Today, the water reserve is used for firefighting to protect the peculiar wood formations in the park (SassiLive 2021).

With the success of Matera, more and more investors are buying properties in Sassi for commercial activities. There are examples of cisterns that have been completely transformed, converted into "fancy" places with concrete floors and stone walls. Residents have been pushed out of the old town. If private stakeholders alter the spaces inside the caves, soon the underground system, and with it, the elements of the water system, will disappear. In this way, tourism contributes to the loss of heritage. Therefore, the value and development of Sassi di Matera as world heritage will largely depend on including the fascinating story of its water-harvesting system. That story is not only about a practical system, but about cultural and social values.

Lessons Learned

Due to Sassi's unique location and scale, tourism has generated new income for the region. This has not brought back the original function of the site. Instead, when night falls, the town lights up like a giant Nativity scene – an exhibition during the Christmas season of objects representing the birth of Jesus, who lived at a time when people lived in cave houses – a tourist-like image. But from the point of view of a landscape architect, there is so much more to discover and value in the Sassi. The town is an excellent example of how humans could live in harmony with nature by living in caves with fresh water running through them, using the local stone to live in and build with, and producing food by irrigation. Traditionally, people interacted with water daily, understanding its value because of the effort they made to harvest it.



^ Fig. 4 Left: Sassi di Matera: public fountain and local rocks (Calcarenite di Gravina). Right: Illustration of the largest town cistern, Palombaro lungo, showing the size of the cistern and the plaza above. (Source: Wenting Gao, 2022, based on a literature review).

Moreover, the water in public spaces encouraged people to gather. This way of living had a low environmental footprint due to its circular water system.

Today, environmental change makes rainfall unpredictable in Matera. There are periods of severe drought. Floods are also a problem, like in 2019, when rainfall flowing down from the hilltop brought mud and debris, posing a new risk to the cultural heritage. By opening the *Grabiglioni*, the drainage canals that channeled both rainwater and wastewater, this disaster might have been prevented. Using the illustrative method, several values can be defined related to the Sustainable Development Goals (SDGs) defined by the UN.

SDG 6

> *Ensure availability and sustainable management of water and sanitation for all."*

The close relationship between the settlement and its water harvesting is almost invisible. The water was hidden and treasured in the stone city as a resource accessible to all. The complex system not only ensured the sustainable management of water, but also helped to achieve equality in water usage. The spaces once used for water are today transformed into fancy rooms for tourism. Therefore, the outer form and internal mechanics of the Sassi di Matera should be valued equally.

SDG 8

> *Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all.*

Rainwater, spring water, moisture and ice were used sustainably for production, domestic use and drinking purposes. There was also a sustainable use of the building materials (local rocks) because houses built into the caves, and cisterns were made from the same rocks.

SDG 12

> *Ensure sustainable consumption and production patterns.*

The water-harvesting system in the caves depends on the local material, Calcarenite di

Gravina. Although most are no longer used, the cisterns are part of the tangible cultural heritage. Restoring the public features of the system by opening the streets, like the *Grabiglioni*, to prevent floods and installing more public fountains using local materials could enhance a sustainable future bound to water, local rocks and people.

SDG 15

> *Protect, restore and promote sustainable use of terrestrial ecosystems.*

The Sassi di Matera demonstrates how a human-made water system can be fully integrated into the living (building) and agricultural landscape. A water design on a regional scale could make not only the old town but the whole city and the region more connected and resilient.

What's missing in the Sassi di Matera is a broader strategy to make the water-harvesting system part of what is valued as heritage. With today's climate crises and the increasing regional droughts, the system can be an inspiration for addressing today's challenges. The recovery of the Cisterna del Comune is a good start. Moreover, water is part of a system that needs to be addressed through scales, from the source until it flows back into the river. The Sassi di Matera and its surrounding area have lost their sustainable knowledge of water harvesting and depend on water supply from afar. With water supplies under such pressure today, we need to learn from the past, especially since harvesting water also contributes to social interaction and helps raise awareness about the value of water.

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Revitalizing Istanbul's Water Heritage: The Valens Aqueduct

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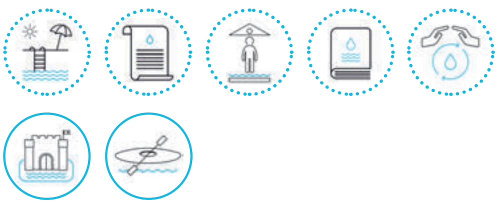
The ancient Valens Aqueduct in the metropolis of Istanbul, Türkiye, has the potential to raise public awareness of historical water management as well as of current and future water supply challenges. This monument stands as a highly visible remnant of what was once the longest water supply line of the Roman world. Although recognized and preserved as a heritage object testifying to its multi-layered history, it has lost its original function and its relationship to water management. We present a program that aims to develop solutions for revitalizing its tangible and intangible values as a prime example of water supply, management and culture through the ages. In this way, this heritage object can regain a connection with water, and water can become an engine for sustainable development.

KEY THEMES



CLIMATE

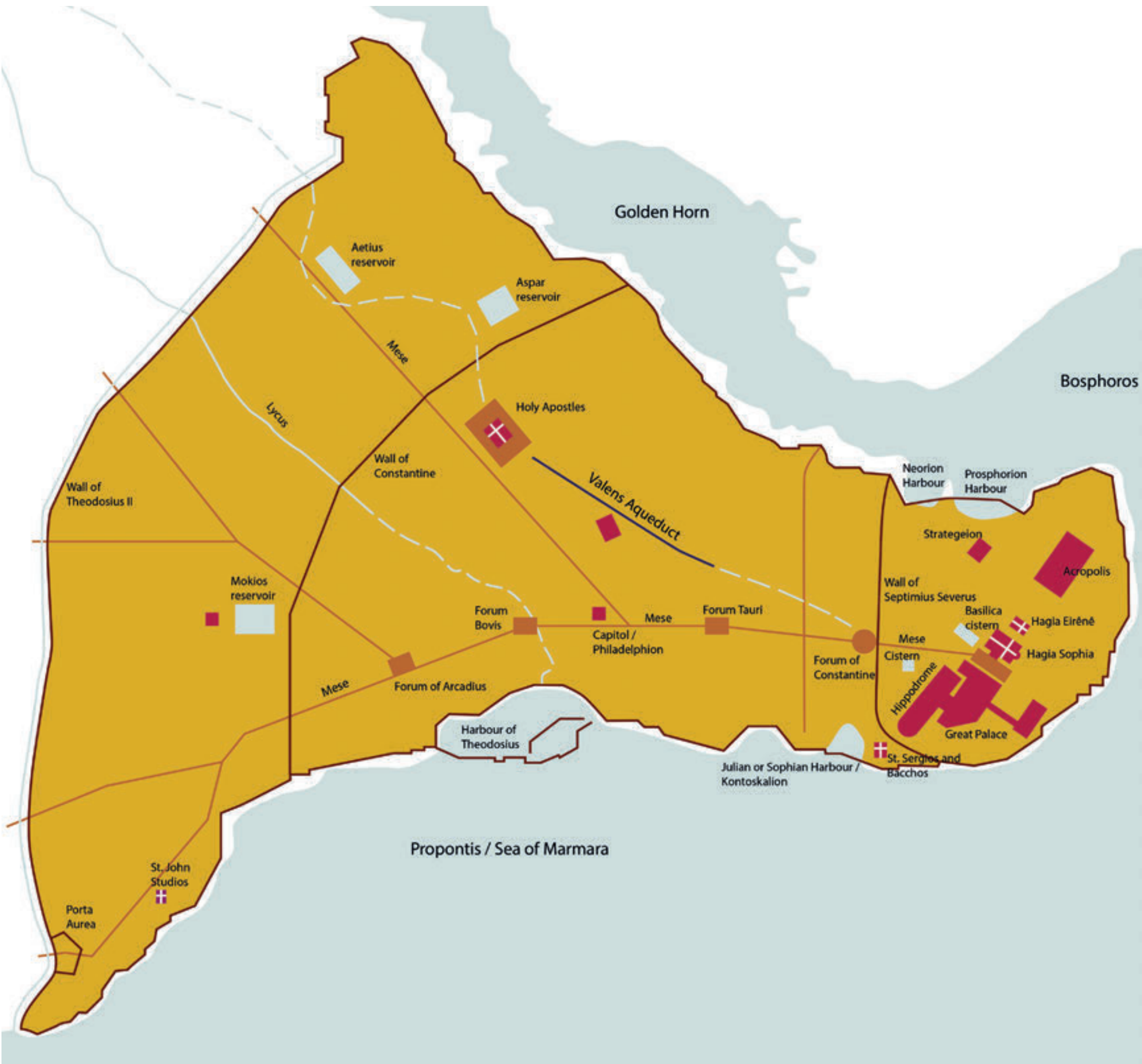
A B **C** D E

Csa : Hot-summer Mediterranean climate

< Fig.1 The Valens Aqueduct (Bozdoğan Kemeri) in Istanbul (Source: Mariëtte Verhoeven, 2022, CC BY-NC-ND 4.0).

Introduction

The presence and accessibility of freshwater was the most critical condition for settlement in the peninsula that Roman Emperor Constantine chose as the site for his new capital, Constantinople, in 324 (fig. 2). Although politically and commercially strategic, the location was a poor choice from the point of view of water supply since it lacked freshwater. In 373, the city was provided with a long-distance water supply line (Crow et al. 2008), named after the emperor to whom the construction is attributed: Valens. The Valens line consisted of a system of channels, bridges and tunnels that carried water through the landscape from Thrace, 185 km away. The line was extended in the fifth century to 250 km in a straight line, but the complete



^ Fig. 2 Plan of Constantinople in Late Antiquity (Source: Studio Hartebeest, 2021, adapted).

system was calculated to be at least 426 km in total (Ward et al. 2017).

Throughout its history, management of the Valens line had to be adapted to changing conditions, including droughts, hostile attacks and fluctuating population numbers. In the year 626, a large Avar army besieged Constantinople and the Valens line was cut, not to be restored until the year 766. From the twelfth century onwards, the long-distance water supply line largely fell out of use. However, the section now known as the Valens Aqueduct (Bozdoğan Kemeri), the 971-meter-long arched aqueduct bridge between the third and fourth hills of the historical city, was in use (primarily for urban gardening) until the fall of Byzantine Constantinople in 1453. After 1453, part of the old Byzantine system, including the Valens Aqueduct, was revitalized and restored by the Ottoman Sultan Mehmet II (Çeçen 1996, 33–4). An inscription on the monument mentions a further restoration around 1700. The aqueduct was depicted numerous times on Ottoman period city panoramas and was the subject of early photographers. Since the 1940s, the long-defunct aqueduct has had traffic speeding under its arches along the Atatürk Boulevard. Restoration work on the Valens Aqueduct started in 2018 on behalf of the Istanbul Water and Sewerage Administration (ISKI).

Current Situation

The Valens Aqueduct stretches over an area with a dense and varied urban fabric consisting of historical monuments, workplaces, restaurants, residences, parks, parking areas and one of the main thoroughfares of the historic peninsula (fig. 1). The aqueduct is listed as a national monument, and its surrounding area is registered as an "Urban Conservation Site." In addition to its national significance, the Valens Aqueduct is within the boundaries of the "Historic Areas of Istanbul" UNESCO World Heritage Site.

The Valens Aqueduct is under a complex heritage management and governance scheme. Due to the area's national and international protection status, there are conservation master plans regulating the monument's preservation under the responsibility of the Ministry of Culture and Tourism. As a historic water structure, the Valens Aqueduct is legally owned by ISKI.

Despite its universal significance, the aqueduct is facing several threats, including air pollution, ongoing urbanization and uncontrolled use of the aqueduct by citizens. Houses, cafes and shops have been built partly in and against the monument, putting the integrity of the monument at risk (fig. 3).

Since 2018, ISKI has been carrying out restoration work, focusing primarily on structural and material problems. The masonry is being thoroughly cleaned and the joints are being renewed and strengthened (fig. 4). The restoration plan also proposes installing a platform to allow walking over or alongside the aqueduct at different heights. It is not clear to what extent this plan articulates the original function of the aqueduct and its connection to water management.

Challenges and Initiatives

Every day in Istanbul, an estimated 16 million people need to be supplied with freshwater. The metropolis brings 50 percent of its water from other provinces because its own reservoirs are drying up (İlhan 2021). Consumers are hardly aware of the efforts made in water manage-

^ Fig. 3 Interior of the Valens Café (Source: Mariëtte Verhoeven, 2022, CC BY-NC-ND 4.0).

ment because the modern water supply system is largely invisible while the visible remains of the historical system are no longer in use for hydrological purposes.

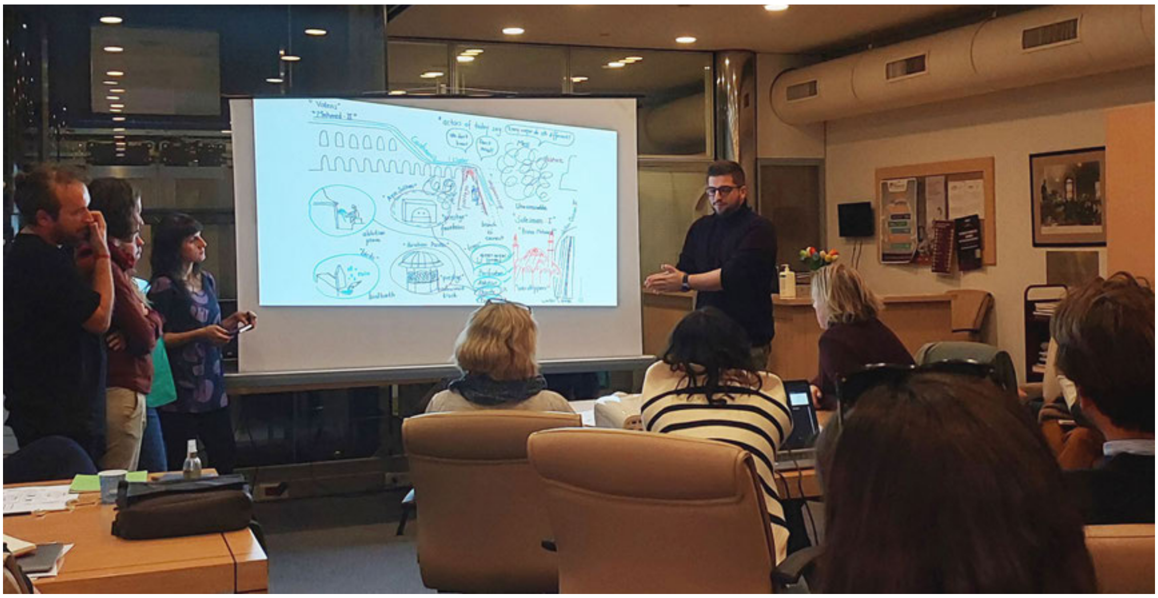
The Valens Aqueduct, an imposing structure in the heart of Istanbul, representing centuries of multi-layered history of urban water supply, is seen as an ideal showcase to tackle the challenges of developing a greater awareness of the precious value of water, and to restore the relationship between water and heritage. In 2021, under the umbrella of the Urban Heritage Lab of the Netherlands Institute in Turkey (NIT), where we collaborate with academic, public and private partners from Türkiye and the Netherlands, we started seeking public opinion by conducting an online public survey about the Valens Aqueduct. Although limited in scope and reach, it clearly indicated that many residents of Istanbul know the Valens Aqueduct and are aware of its original function. They see the monument as part of their history and strongly feel that it should be preserved, even though it no longer serves a hydrological function. Yet actual public engagement – notions of ownership by the community and a more in-depth or personal understanding of the heritage values of the aqueduct and of the historical water system that it was part of – is limited.

We decided to focus on actions and initiatives connected especially with SDG 4 (Quality Education) in order to: (1) increase knowledge and public awareness of the tangible and intangible values of Istanbul's water heritage, and (2) educate (future) heritage experts, planners and designers on how to integrate heritage in contemporary urban design.

To explore sustainable solutions for increasing knowledge and public engagement, representatives of Dutch and Turkish heritage organizations, NGOs and the creative industry met in September 2022 in Istanbul for a workshop. Two approaches emerged from the brainstorming session: a technological one and a more physical one. With the use of digital technologies, we want to develop a walking route app, which uses texts, images and videos to guide the user along the Valens Aqueduct and related heritage, providing not only insight into its multi-layered history but also contemporary testimonies. A more physical engagement could be established by using the Valens Aqueduct as a stage and backdrop for a Water Festival on World Water Day, with culture and art activities around the theme of water in past, present and future. These activities should be developed in collaboration with the local community so that they can come up with their own solutions for sustainable urban water supply and consumption issues, thereby connecting SDG 17 (Partnership for the Goals) with SDG 11 (Sustainable Cities and Communities).

An interdisciplinary academic course for graduate students and junior professionals from the Netherlands and Turkey ran from September to December 2022. This course, Water Heritage for Sustainable Cities, familiarized participants from a range of disciplinary backgrounds – architecture, urban planning, heritage studies, history, arts – with perspectives on water and heritage, especially those related to contemporary water challenges in a context of climate change and urban development. In a research-by-design exercise, participants learned to work in an interdisciplinary team to design proposals for the revitalization of the Valens Aqueduct (fig. 5). These proposals included reversible interventions in the urban fabric, art installations, educational programs, heritage walks, water harvesting systems and local community activities. The results will be published in 2023 and shared with stakeholders and the public.

^ Fig. 4 Restoration work on the Valens Aqueduct (Source: Mariëtte Verhoeven, 2022, CC BY-NC-ND 4.0).



^ Fig. 5 Adiscussion in the Water Heritage for Sustainable Cities course, October 2022 (Source: Netherlands Institute in Turkey, 2022, CC BY-NC-ND 4.0).

Conclusion

The biggest challenge for any plan to revitalize the Valens Aqueduct is to convince the relevant stakeholders in heritage and water management to preserve and protect the aqueduct not only as a historic relic but to employ it to restore the relationship between heritage and water. ISKI could, for example, through one of the proposed initiatives for the Valens Aqueduct, educate the public about its current efforts devoted to water management and supply in a sustainable future.

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Climate Change and Fish Farming: Venetian "Fish Valleys" as a Design Device for Coastal Adaptation and Mitigation

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Beginning in the fourteenth century, along the northeastern Italian coastline, Venetians began to create a series of hydraulic structures called "fishing valleys," which combined aquaculture production with lagoon and seawater management. According to the current scenarios provided by the Intergovernmental Panel on Climate Change, the coastal areas, where many historic fish farms still stand, will inevitably be affected by the rise in sea level. To be preserved, coastlines will require some sort of water defense or possibly a managed retreat. Can we redesign traditional fish-farm systems as climate, economic and environmental adaptation devices? Through a series of design scenarios, this contribution explores how traditional fish farming can help redefine the territorial scale by addressing climate change and reviving existing production systems.

KEY THEMES

CLIMATE

A B C D E

Csa : Hot-summer Mediterranean climate

< Fig. 1 A fish valley in the northern Venetian Lagoon (Source: Alessandro Destro, 2017).

Introduction: Fish "Changes" Landscape Design

The northeastern Italian coast, which extends from the Po Delta toward the Venice Lagoon and finally the Grado Lagoon, features many historical landscape elements, including traditional aquaculture systems (fig. 2). From the Latin *vallum*, literally "wall," fish farms were created during the Venetian Republic, between the fourteenth and fifteenth centuries, as productive landscapes (Rallo 1997; Benà and Rallo 2011). Initially, the *valli da pesca* were developed for fishing with nets: in spring, the most fished species – sea bream, sea bass, goldfish, mullet and eel – need to leave the sea and look for brackish water to reproduce (Vatova 1962). The fish would then approach the mainland moving toward the large rivers that flow into the lagoon, and there, these species were captured with a system of reed trellises placed in the middle of the waters (D'Alpaos 2010). However, when the technique was refined and the Venetian Republic acquired greater institutional power, this fishing system was gradually replaced with one that involved earth embankments (D'Alpaos 2010). The valleys were transformed into stable dammed and semi-dammed structures (fig. 3), and the aquaculture practice transformed the hydraulic system into an industry that became an emblem of skillful interaction between humans and nature (fig. 4).

In spring, the fry are sown. The gates overlooking the lagoon or the sea are opened in autumn and winter. The fish pass through a channel called a *colauro*. Fishermen then close the grids (fig. 1) and harvest the fish. The mature ones are destined for sale, and the ones still too young to harvest are placed in fishponds to grow until the following spring (Vatova 1962; Fabris 1993).

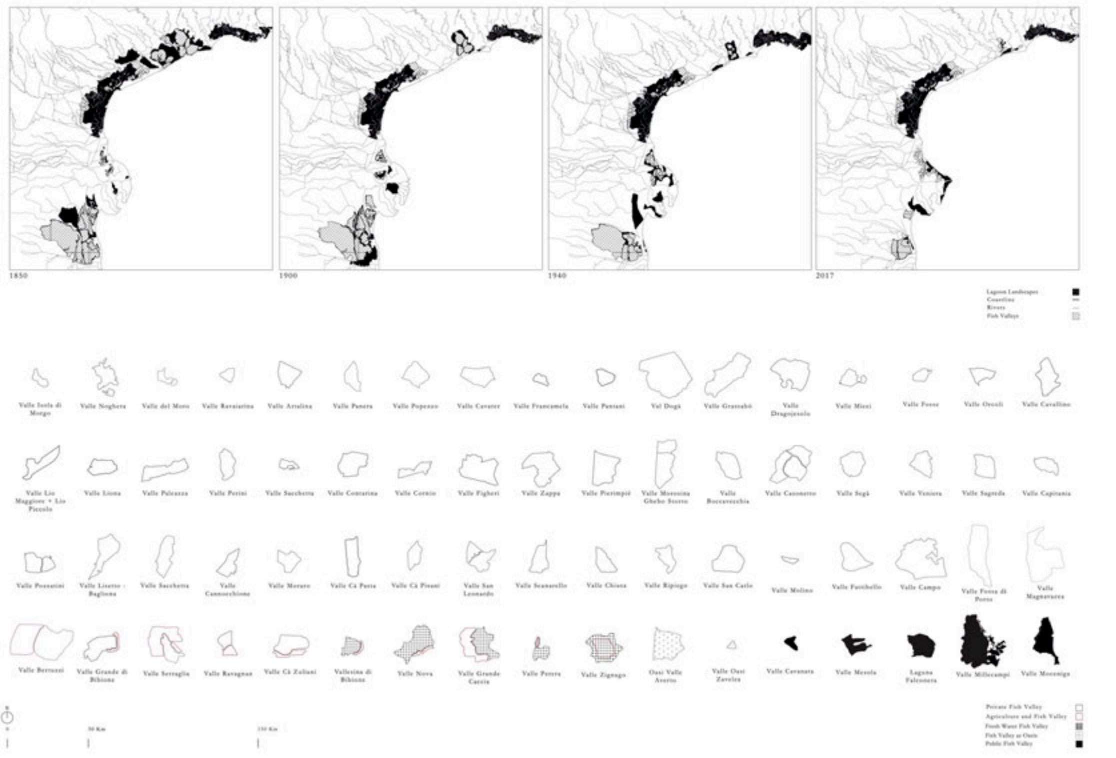
In addition to fishing, many other landscape practices have been taking place within these transitional areas between land and sea: breeding farm animals, cultivating cereals and producing rice fields and salt marshes (Provincia di Venezia 2009).

This historic aquaculture system has remained unchanged up to the present day. However, the economic crisis of fish farming at the end of the 1980s, the development of the global fish market and the growth of intensive farming have severely affected the economy of this traditional form of intensive fish farming (Cosolo et al. 2015; ICRAM 2007).

Methods

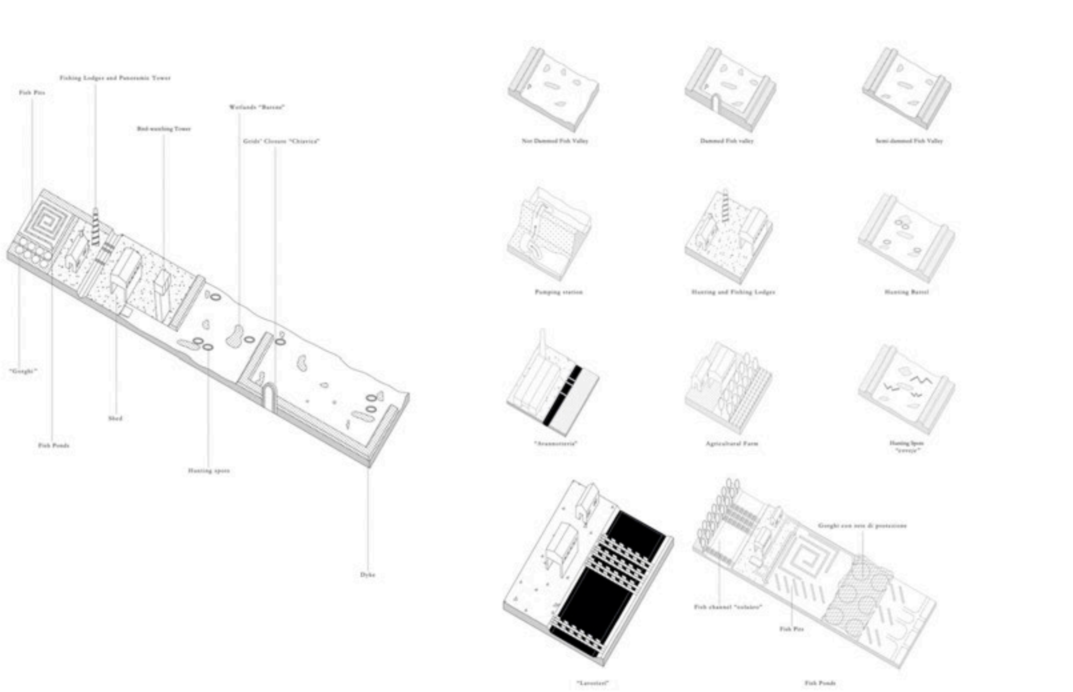
We have conducted research using multiple sources of information and methods. The "research through design" methodology involved mapping the landscape and urban systems. Ancient cartographies of northeast Italy and iconographic materials of former fish-farming systems were collected and carefully compared with the current systems. Geographic data collection and geographic information system analysis helped us investigate the landscape systems at multiple scales.

On-site investigations and fieldwork constituted the cornerstone of our knowledge acquisition and helped us adopt a "place-based approach" to the design process. An in-depth survey was conducted in the 2017–2018 academic year and partly originated from a year-long design process in northeast Italy. We traveled along the coast, observing the places of probable future climate transformation and getting to know the local people and cultures related to aquaculture systems. Our methodology included observing and studying from different scales as starting points for understanding. The survey included photographic investigations and sampling, and



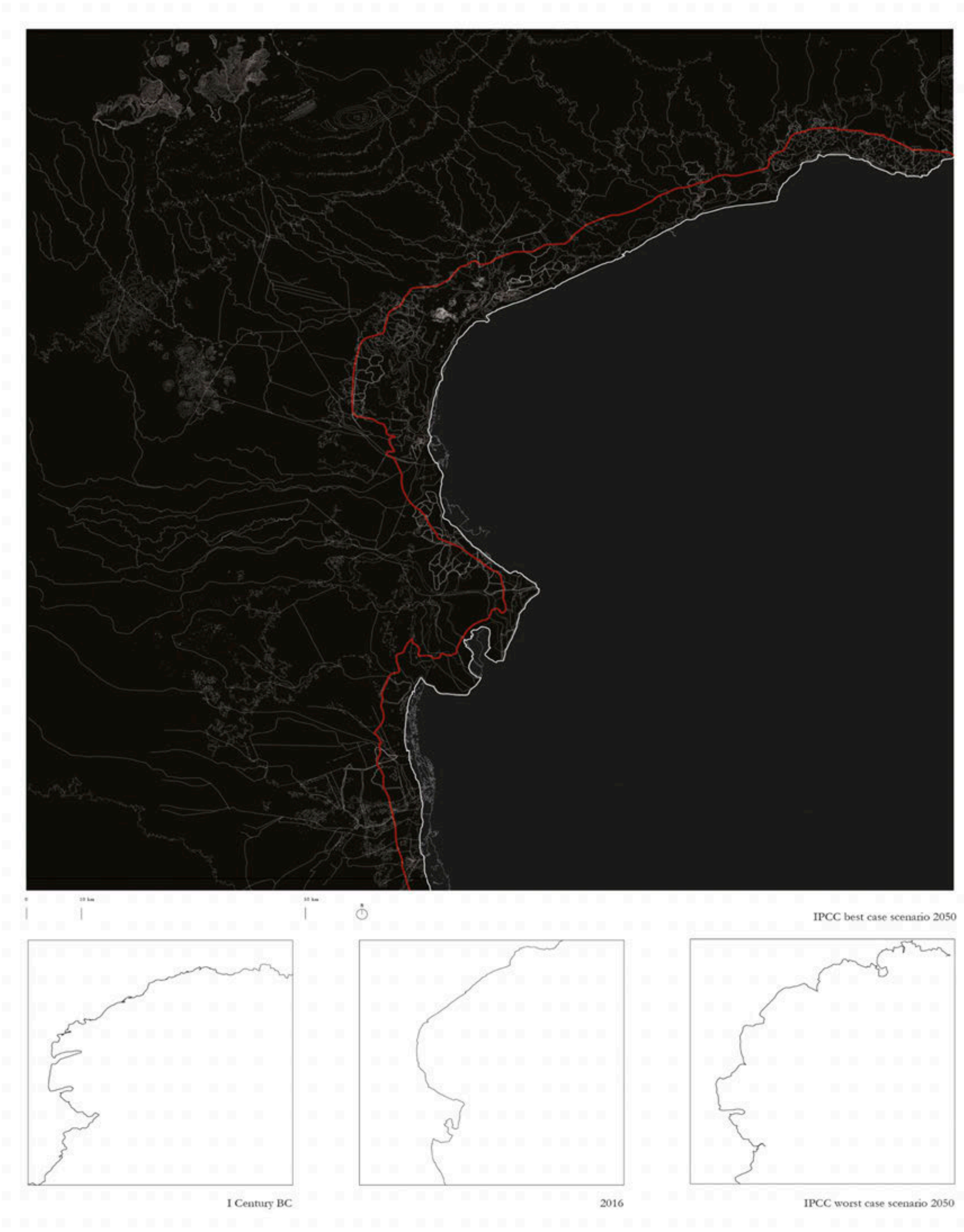
^ Fig. 2 On top, fish valleys' geographical distribution and evolution in the last 150 years (1850-1900-1940-2017) on the northeastern Italian coast. Below is the taxonomy of *valli da pesca* fish farms: today's existing fish valleys according to their different types and peculiarities (private and public fish valleys, fish valleys with agriculture, freshwater fish valleys, and fish valley oasis). (Source: Alessandro Destro, 2018. Supervised by Laura Cipriani, 2018. Edited by Laura Cipriani, 2023).

^ Fig. 3 A fish valley in the northern Venetian Lagoon (Source: Alessandro Destro, 2017).



^ Fig. 4 *Valli da pesca* typologies and elements (Source: Alessandro Destro, 2018. Supervised by Laura Cipriani, 2018. Edited by Laura Cipriani, 2023).

^ Fig. 5 Fishermen at work in a canal of the fish valley (Source: Alessandro Destro, 2017).



^ Fig. 6 On top, in red, is the 2050 coastline assuming a one-meter sea-level rise. Below are the palimpsests of the past and future (Sources: Laura Cipriani, 2018 and Alessandro Destro, 2017).

a study of water quality and plant species to comprehend the phenomena associated with the *vallicoltura* systems – this peculiar type of extensive fish farming practiced in the upper Adriatic Sea in brackish water basins and enclosed by embankments.

Another source of knowledge was interviews with local people involved in the fish farm industry: fishermen (fig. 5), workers, owners, concessionaires, public authorities and local economic players such as restaurateurs and historians of the "Museo del Territorio delle Valli e della Laguna di Venezia" fish farms museum.

Our literature review considered multiple sources of information, including non-academic sources, such as newspapers and documents, which helped us understand the mechanisms underlying the current crisis facing the aquaculture system and the opportunities that may exist for it.

Who Owns the Landscape between Water and Land?

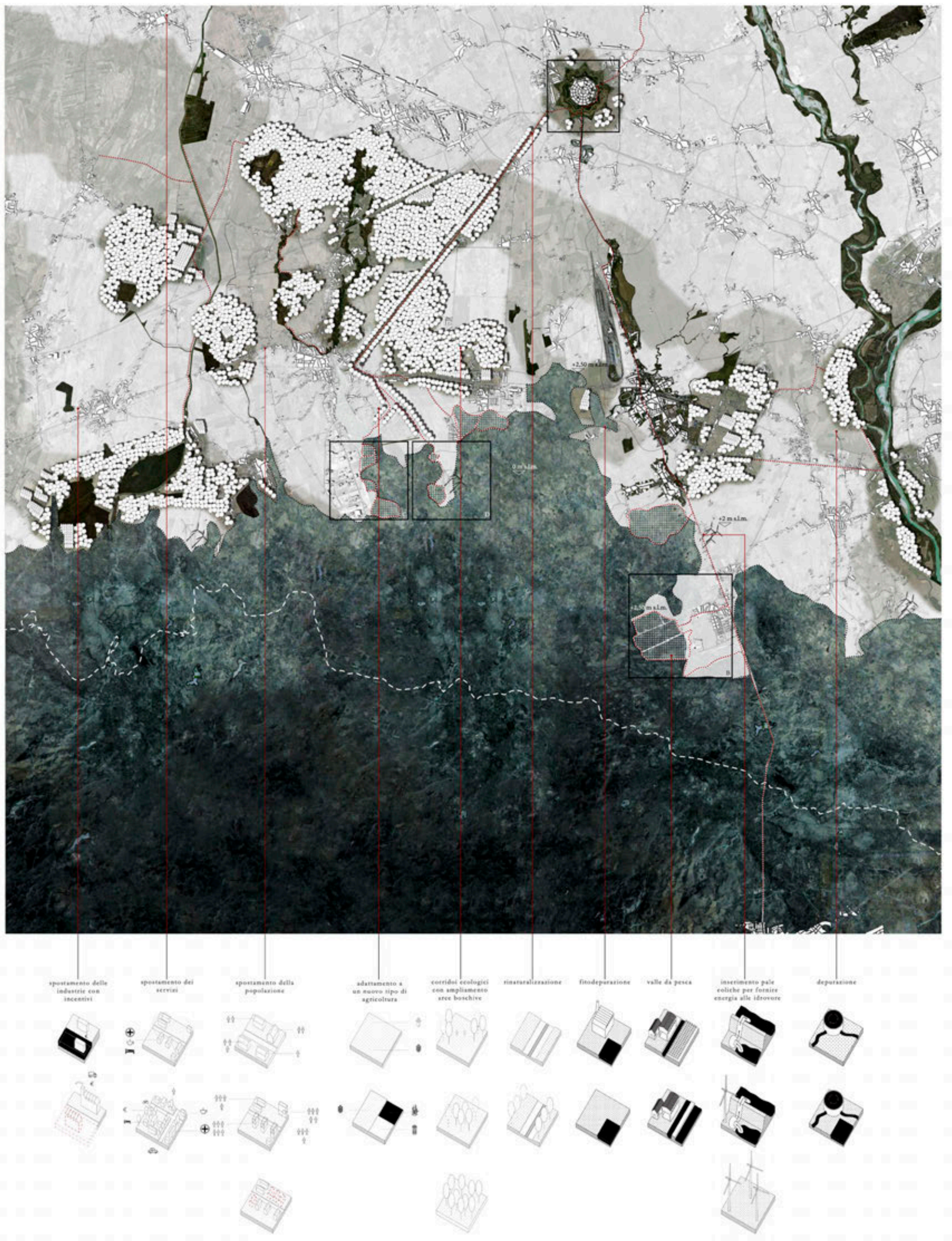
The ownership, hydrology, ecology, conservation and management of fish farms are highly debated. Who owns the landscape between water and land?

Initially, fish farms were lagoon parcels temporarily delimited by reed fences that prevented the expansion of the tide. The hydraulic resistance of the structures reduced sea-lagoon exchanges (D'Alpaos 2010). The Serenissima Republic soon regimented the valley areas, partly as state property and only to a small extent as private property (Rallo 1994, Fortibuoni et al. 2014, Rivoal 2021). Most structures are today private (Alpa et al. 2010), creating conflicts between the public and private sectors that also underlie significant hydraulic problems. The progressive embankment of the fish farms has effectively privatized and modified the hydraulic regimes of the lagoons and transition zones subjected to the action of the tides. The stable embankments of the fish farms limit the expansion of the waters coming from the hinterland upstream as well as of the brackish tidal waters coming from the sea. In addition, ongoing climatic changes necessarily require giving progressively more room to upstream and downstream waters (D'Alpaos 2010).

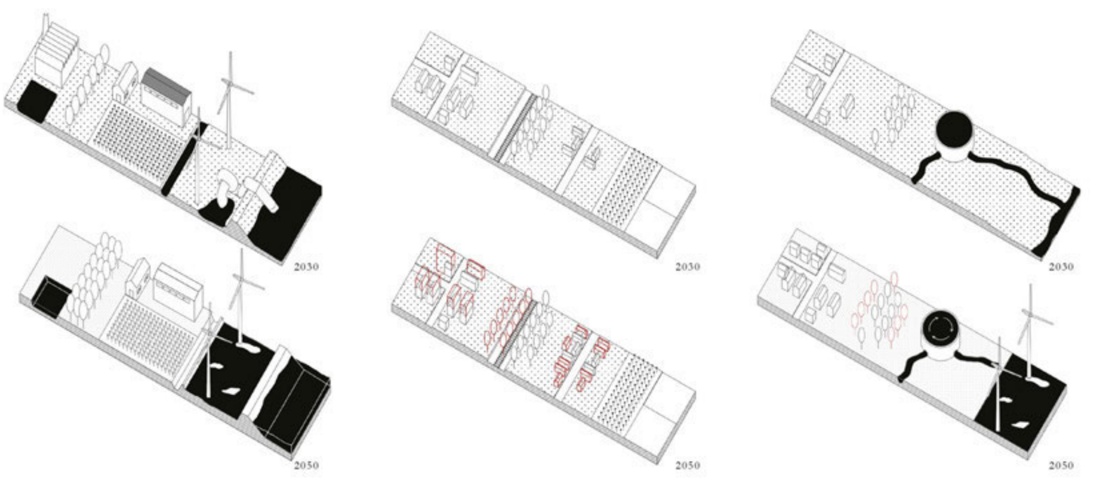
A further conflict is ecological. Today, the economy of the fishing valleys is mainly based on the income deriving from the rental of the valleys for hunting, which because of its frequency and intensity causes many ecological and environmental problems for birds and causes excessive lead pollution of the waters (Arpa 2023). This activity runs counter to European biodiversity conservation regulations since the fish farms in northeast Italy are in Sites of Community Importance and Special Areas of Conservation as part of the Habitat Directive, forming a network of protected sites called Natura 2000 (Regione Veneto 2020; Regione Friuli Venezia Giulia 2018; Regione Emilia-Romagna 1993). Furthermore, some of the fish farms are located near industrial or otherwise polluting areas. The farms near the Porto Marghera industrial area in the Venice Lagoon are examples. Finally, there is a regulatory conflict since the regional and local urban and landscape plans often overlap and differ in their protections for fish farms and their systems.

Fish Farming in Future Scenarios

What other management approach can be considered for the future? Should fishfarms be preserved or transformed? Can we redesign traditional fish-farming systems to make them ways of adapting to changes in climate, economy and



^ Fig. 7 Retreat scenario in the Marano Lagoon and the fish farms' transformation (Source: Benedetta Bertellini, Roberta Bertoglio, Alessandro Destro, Francesco Fagotto, Francesco Moretton and Matteo Tosoni, 2017. Supervised by Laura Cipriani, 2017).

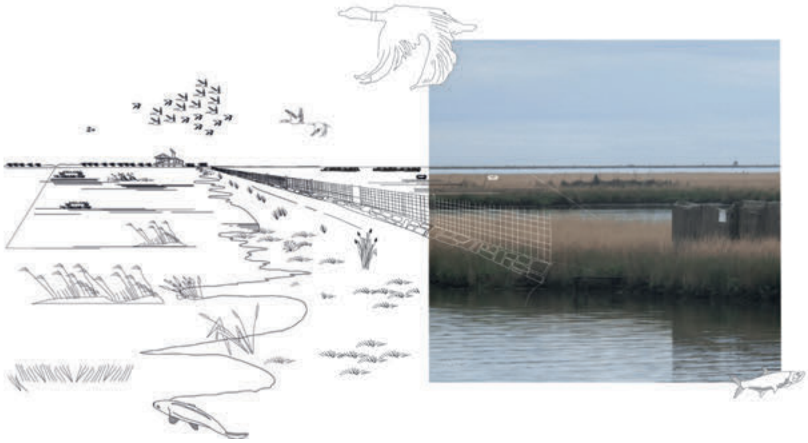


^ Fig. 8 Transformation of a fish valley in the Venetian lagoon (Source: Alessandro Destro, 2018. Supervised by Laura Cipriani, 2018).

environment? All cultural landscapes are products of progressive adaptation. Looking at the past teaches us that the Venetian fish farms have never been static systems but rather have evolved to meet the needs and technical-technological refinements that have taken place over time.

Sea-level rise will change the coastline and transform the territories and legislative and administrative systems of the areas concerned. According to the Intergovernmental Panel on Climate Change (IPCC 2014, IPCC 2022), northeast Italy will be one of the places most affected by climate change and sea-level rise. Assuming an increase in temperature of 1.5 °C, the coastline of 2050 will move to a position corresponding to the geo-morphological palimpsest of the first century BC, when the marine waters of the Upper Adriatic were at a much higher altitude than the current mean sea level (fig. 6). Just as in the past the great hydraulic engineers of the Venetian Republic diverted the main rivers that carried sediments into the lagoon to preserve Venice from silting up, so today, some areas of the coast of northeast Italy might reinterpret and adapt the historical tradition.

The project we have presented (Destro 2018; Cipriani 2019) proposes a series of scenarios for the medium to long term for the Venice Lagoon, the Marano Lagoon and the Po Delta to try to take advantage of the new environmental conditions by welcoming or rejecting the water that will come. Many agricultural lands in the water–land transitional areas can be made into fish farms because of the dikes present and the water adaptability and productivity of the area (fig. 7). Farms could be transformed into fishing valleys; this would involve raising their embankments, allowing coastal protection (fig. 8), and activating economies already present in the area (fig. 9). Extending the fish valleys into a territorial system can be a valid climate adaptation tool for coastal protection and a crucial climate mitigation tool for carbon sequestration and storage. Finally, aquaculture's traditional hydraulic, agro-pastoral and economic functions are expected to be transformed with new technological processes such as integrated multi-trophic aquaculture systems (Neori et al. 2004; Nesar and Marion 2016) for water purification, biomass (algae) growth and energy



^ Fig. 9 Fish Valley and its adaptation (Source: Alessandro Destro, 2018. Supervised by Laura Cipriani, 2018. Edited by Laura Cipriani, 2023).

production. From their humble origins as small landscape devices, fish farms could ultimately help redraw the coastline on a territorial scale.

Conclusion: Select the "Active Part" of the Past

The projects presented concerning the fishing valleys of northeast Italy induce a series of reflections that transcend the single case study with regard to the themes of water and heritage.

First, all cultural landscapes are the product of progressive adaptation led by social, economic, and technical-technological needs. Preserving does not mean leaving the past unchanged, but rather innovating tradition with an eye to the future. The designer's task is to know how to *select the "active part" of the past*. That means understanding and deciding what are the dynamic parts of the landscape's past and how and if they can be preserved while embracing the transformation according to new uses, forms, and scales of the present. Heritage also extends to all of a landscape's living and non-living systems: plants and fishes can be considered the heritage of an ever-evolving cyclical process. The cultural value lies in adapting site-based landscape devices to meet future challenges in the short, medium and long term.

Second, a close-scale landscape micro-device can change the territorial scale and, in this case, suggest a possible climatic adaptation.

Third, the economic sustainability of a landscape device is an essential element of adapting the past for the future. In plans aimed at mitigating and adapting to the climate crisis, protection from damage must be combined with the production of economic value. Only a plan to generate new economies and innovations can ultimately be effective.

Finally, to respond effectively to climate urgencies, administrators, institutions, planners, associations, communities, individuals and living entities must design and collaborate with the landscape. This implies the need for new governmental and legislative tools for the future.

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Settling-on-the-Move: Birsing Char-scapes in the Brahmaputra Valley

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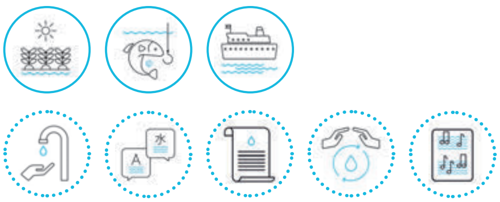
Chars are shifting riverine islands. This article focuses on Birsing Char, part of Birsing Jarua Village Panchayat, in the Brahmaputra River near the Indo-Bangladesh border. Generations of families have migrated across this porous border, settling in the Lower Brahmaputra Valley. This migration has intensified the sociocultural othering of Bengali Muslims amid Assam's identity politics and India's rising authoritarianism. Through fieldwork and interpretative mapping, the article uncovers forms of alternative knowledge, including local spatial practices and intangible heritage like songs and poetry, threatened by infrastructural development, policies of the Indian government and climate change. It explores how such knowledge can be harnessed and inspire alternative development policy and design in the context of global warming in the Brahmaputra Valley and in Assam's sociopolitical climate. The case underscores the urgency of recognizing marginalized chars as vital to the region's water legacy, as they contribute both to local livelihoods and broader ecological systems.

Keywords: *fluid landscapes, porous borders, cultural resilience, worldviews, climate change*

KEY THEMES



CLIMATE

A B **C** D E

Cwa : Humid subtropical climate

< Fig. 1 The cropping system is naturally adapted to water levels in the monsoon season (Source: Swagata Das, 2021).

Braided Brahmaputra, Shifting *Chars* and Porous Borders

As the Brahmaputra River enters Assam State in India, the sudden flattening of slope and confluence of tributaries give rise to an oscillating braided pattern, creating alluvium deposits in the form of river islands, locally known as *chars*. They are extremely transient, a "uniquely fluid environment where the demarcation between land and water cannot be well defined or made permanent" (Lahiri-Dutt and Samanta 2013, 1). While *chars* can appear legally ambiguous, they are crucial for many people: the last state survey conducted in 2002–2003 estimated 2,490,097 inhabitants in 2251 *char* villages of Assam (Directorate of Char Areas Development 2004). The actual number could be much higher as *charuas* (*char* dwellers) move in and out of *chars* before and after the survey is conducted, leading many to be excluded from official records.

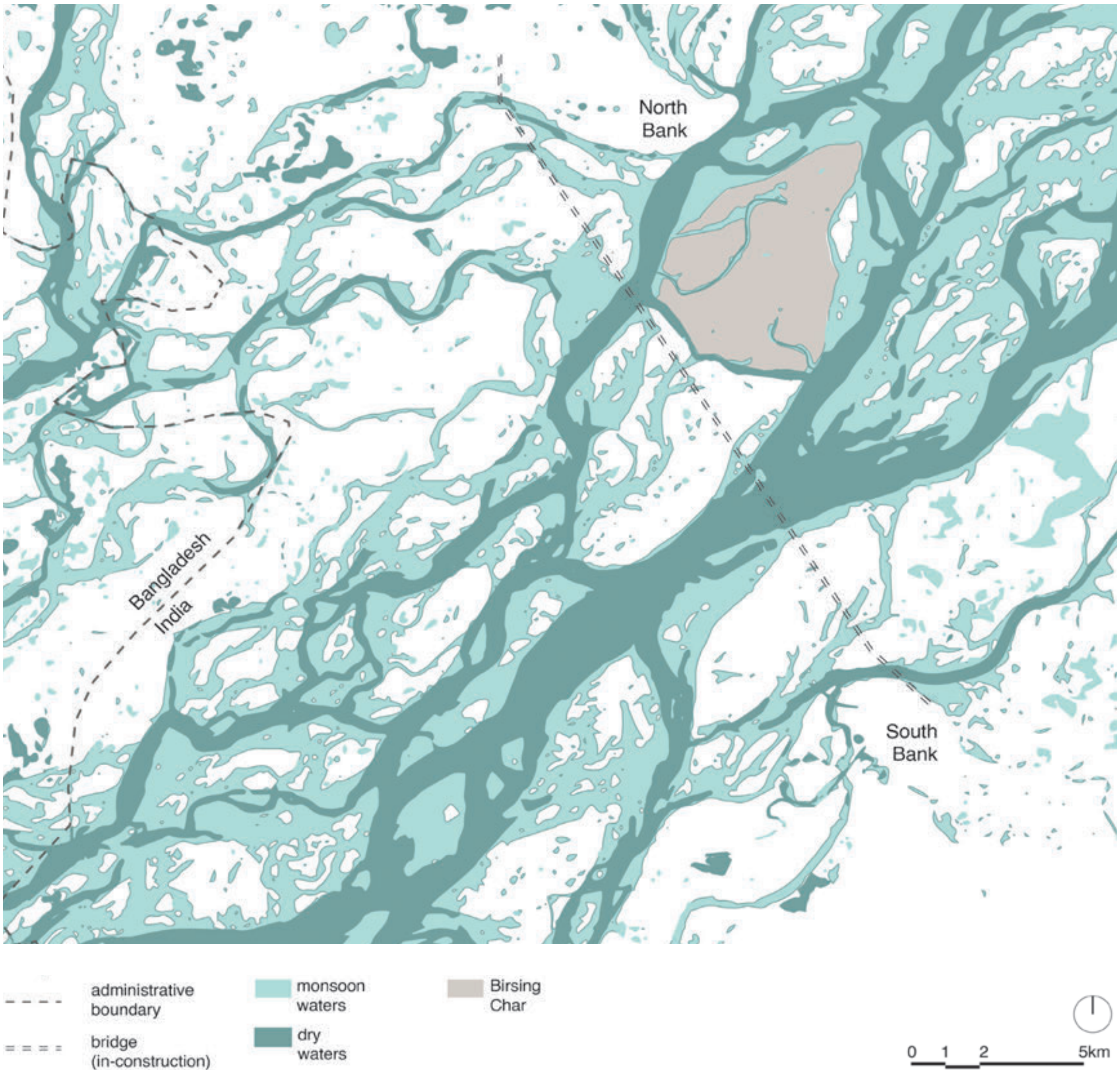
Many people's everyday lives do not adhere to categories of land and water, as they choose to "inhabit an undivided wetness" (Cunha 2018, 292). In the downstream area of Assam, generations of migrants navigate the fluid Indo-Bangladesh border (fig. 2). The shifting nature of these fluid territories renders administrative borders obsolete, creating a gray zone of statehood and non-statehood, along with a corresponding array of freedoms, restrictions and constraints.

Between Seen and Unseen: Sociocultural Othering of Bengali Muslims in Assam

In Assam, the interplay of rivers and land has always been closely linked to citizenship and immigration. In the nineteenth century, the British colonial state encouraged land workers from East Bengal (now Bangladesh) to migrate to Assam, transforming the Brahmaputra's floodplains into the "British empire's eastern-most jute frontier" (Saikia 2019, 1405). The colonial "Line System" not only restricted settlement areas and limited immigrants' economic activities (Chakraborty 2009), but it also created terminologies such as "immigrants" and "native" (Das 2023, 18) to categorize the population in Assam. These categorizations persisted through India's 1947 Partition and Bangladesh's 1971 Independence, fueling social tensions and contributing to endemic violence (Iqbal 2010), including the 1983 Nellie Massacre.[1]

Since 2016, with the rise of a right-wing Hindu government throughout India, including in Assam, Bengali residents have faced significant discrimination due to their religion. Bengali Muslims have experienced systemic violence, being perceived as "illegal immigrants," while Bengali Hindu migrants have been viewed as "refugees" (Das 2023, 27). This differential treatment has intensified the scrutiny and political marginalization of Bengali Muslims, particularly in *chars* near the Bangladesh border. Most *chars* in the Lower Brahmaputra are inhabited by descendants of Bengali Muslim migrants, popularly and derogatorily called "Miyah." In Assam, the recent implementation of the Citizenship Amendment Act (CAA), along with the National Registry of Citizens (NRC), exacerbates the stigmatization of cross-border migration from Bangladesh and promotes further ethnic and religious intolerance (Menon 2023). The CAA, passed by the Indian government, controversially grants fast-track citizenship to six religious minorities

1. During the anti-foreigner Assam movement (1979–1985), a mob comprising Tiwa, Koch, Hindu Assamese and other local ethnic groups killed over 2,000 Bengal-origin Muslims in Nellie, Central Assam. Rumors of imminent Muslim attacks on Tiwa villages incited the violence, prompting activists and local villagers to launch a preemptive assault on unsuspecting Muslims.

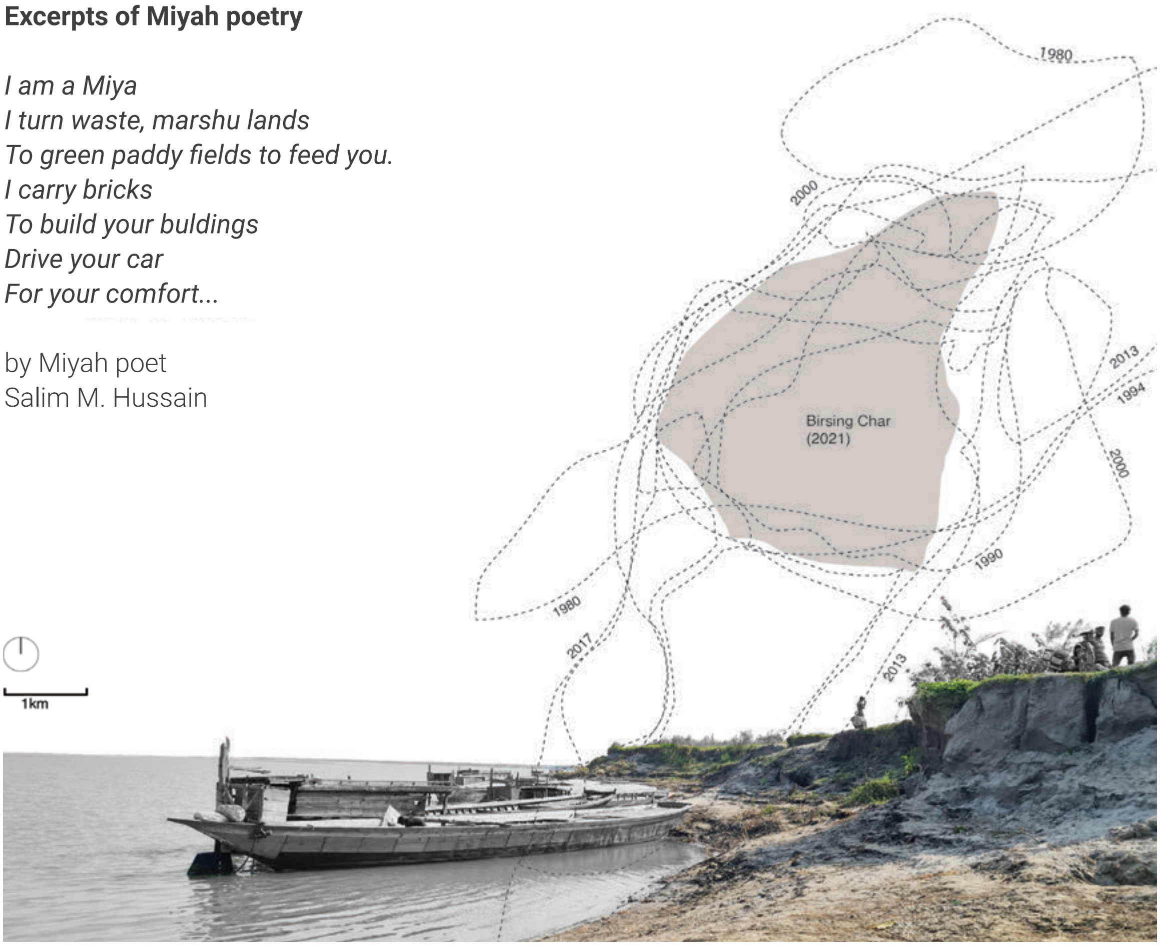


^ Fig. 2 The braided Brahmaputra River forms an ever-changing mosaic of environments shaped by nutrient-rich silt, sandy sediments and water channels. (Source: Swagata Das, 2024. Based on global-surface-water.appspot.com, Google Earth imagery accessed onJanuary, 6 2022 with excerpts of a Bhatiali song from Rahman, 2021).

Bhaitali song (Bangladeshi folksong)

O ki ore,
pagla re nodi
eiglai ki tor riti re bidhi
Boshotbhangiya korlu
re chharachhari...

(Oh mad river
is this your true nature
You have destroyed our homes
and forced us to live apart...)
Source: Rahman 2021



^ Fig. 3 Inhabitants adapt to the ever-shifting dry-land *chars* by moving, a way of settling that navigates danger and exploits local assets. It strongly contrasts with conventional notions of landownership and revenue mechanisms introduced during British rule. (Source: Swagata Das, 2024. Based on Google Earth imagery, sunflowercollective.blogspot.com and fieldwork carried out in December 2021).

while explicitly excluding Muslims, India's second-largest religious group.

Meanwhile, in 2019, Assam released its updated NRC list, which excluded a sizable portion of the Bengali-Muslim population. Although terms like Miyah are avoided in the wording of policies and the state refutes that the CAA and NRC are linked, their combination in the border territory of Assam threatens to render many stateless (Menon 2023) by introducing new political and economic uncertainties for the already marginalized *charuas*. In response, resistance movements, like the Miyah poetry movement, attempt to reclaim power and local identity. Figure 3 includes an excerpt from a poem that occasioned a police report being filed for "communal disturbance" (Bahn 2019).

Just as the state seeks to define who is Indian and who is not, it is equally obsessed with creating and enforcing more strict land-water separations, which undermine the fluid landscapes of *chars*. Monofunctional land use planning, a colonial legacy, does not correspond to the fluid *char*-scapes. The distortion caused by sociocultural othering (Lahiri-Dutt and Samanta 2013), also deeply rooted in colonial-era policies and exacerbated by contemporary legal measures, has further marginalized movement patterns of the *charuas*. The pejorative discourse has crafted a narrative that views *chars* primarily as territories to be saved against such othering, thereby obstructing a nuanced understanding of the intertwining of water, culture and the heritage of Assam's *char*-scapes, which now face additional challenges from climate change.

Chars as Places of Transition, Exchange and Seasonal Occupation

Chars are sites of rich water heritage with site-specific and dynamic relationships between fluid landscapes, human migration and cultural resilience. Along the Indo-Bangladesh border, *chars* serve as grazing lands and formal and informal cattle markets. The presence of the Indian Border Security Forces complicates the informal cattle trade, but subversive strategies, including bribery, sustain the lucrative business (Sur 2020). The continuously shifting river channels hinder efficient state control, while Bengali-Assamese inhabitants have acquired an intimate knowledge of how to move and reside (bypass and hide) within the idiosyncratic landscape. Such complexities frame an understanding of administrative borders as temporary (and permeable) barriers to exchange. *Chars* are also considered "granaries of the (Indian) state" (Chakraborty 2009, 3), producing significant amounts of paddy, jute and seasonal vegetables.

During the dry season (2021) and the monsoon season (2023), Das conducted fieldwork in a relatively stable *char*, locally known as Birsing Char,[2] revealing the fluid lives of Bengali-Assamese *charuas*, who must navigate an administrative gray zone due to religious discrimination and shifting waterscapes. Das traced the everyday life of a landless migrant family comprising a husband, wife and child who had settled in the relatively unstable part of Birsing Char, which gets seasonally flooded. They occupy a sole dwelling constructed on a mound with a mud plinth, thatched walls and tin sheet roofing (fig. 4). Their migration from various *chars* to relatively stable ecologies reflects generational patterns of relocation and highlights the appeal of Birsing Char for migrants with precarious citizenship status. First, certain villages on the *char* have been included as revenue villages (administrative units with land surveyed and entered into official records), granting them some form of state legitimacy. Second, the *char* population is comprisesd entirely of Bengali Muslims, offering a sense of communal refuge. Nevertheless, uncertainty looms since the land is prone to extensive erosion. People have developed various ways to simultaneously occupy nearby territories for complementary yet diverse livelihoods. The settlement culture developed over generations flexibly exploits a variety of continuously changing locational assets while navigating restrictions and avoiding state control.

Fieldwork revealed three distinct movement patterns of household members. Major floods

2. *Chars* do not have official names. Over the years, members of villages who have been displaced by flooding and erosion settle on *chars*, which then take the names of the original villages. In this case, the former village of Birsing split into three parts (Birsing Pt. I, Pt. II, and Pt. III) and occupies most of the higher stable ground of the *char*.

prompt long boat journeys by the entire family. The male member's seasonal migration with a neighbor occurs during the monsoon (June–September). They live on boats and engage in fishing during the lean agricultural period, while the woman and child sustain the family by cultivating kitchen gardens and bartering. Finally, daily movements between the Birsing Char and Dhubri towns are prompted by seasonal changes in *ghats* (passages leading to a river), as their livelihood includes farming, fishing, trading and livestock rearing. The settlement culture weaves together a multitude of localities, activities and agencies (of different family members and, by extension, the wider networks). Beyond serving as landing places for boats, *ghats* also function as public spaces with marketplaces and bays for loading and unloading. Dhubri town, once a bustling river port during British rule, now has four *ghats* used by local vessels to transport people and goods to and from neighboring *chars*. *Ghat bazaars* (fig. 5) on the north bank operate every Monday and Thursday, transforming the riverbank into a marketplace where *char* inhabitants trade essential commodities and products for survival.

The construction of the Dhubri-Phulbari Bridge (Choubey 2024), part of a spree of state-driven infrastructure development on the Brahmaputra, will soon restrict these movements. The bridge will cross the Birsing and other *chars*, threatening to erase (or severely limit) the local way of life by extending state control over the hinterlands. Official trade routes will replace traditional water heritage elements and practices in *ghat* bazaars. Traditional water routes will disappear, and charua-operated boats will be without freight.

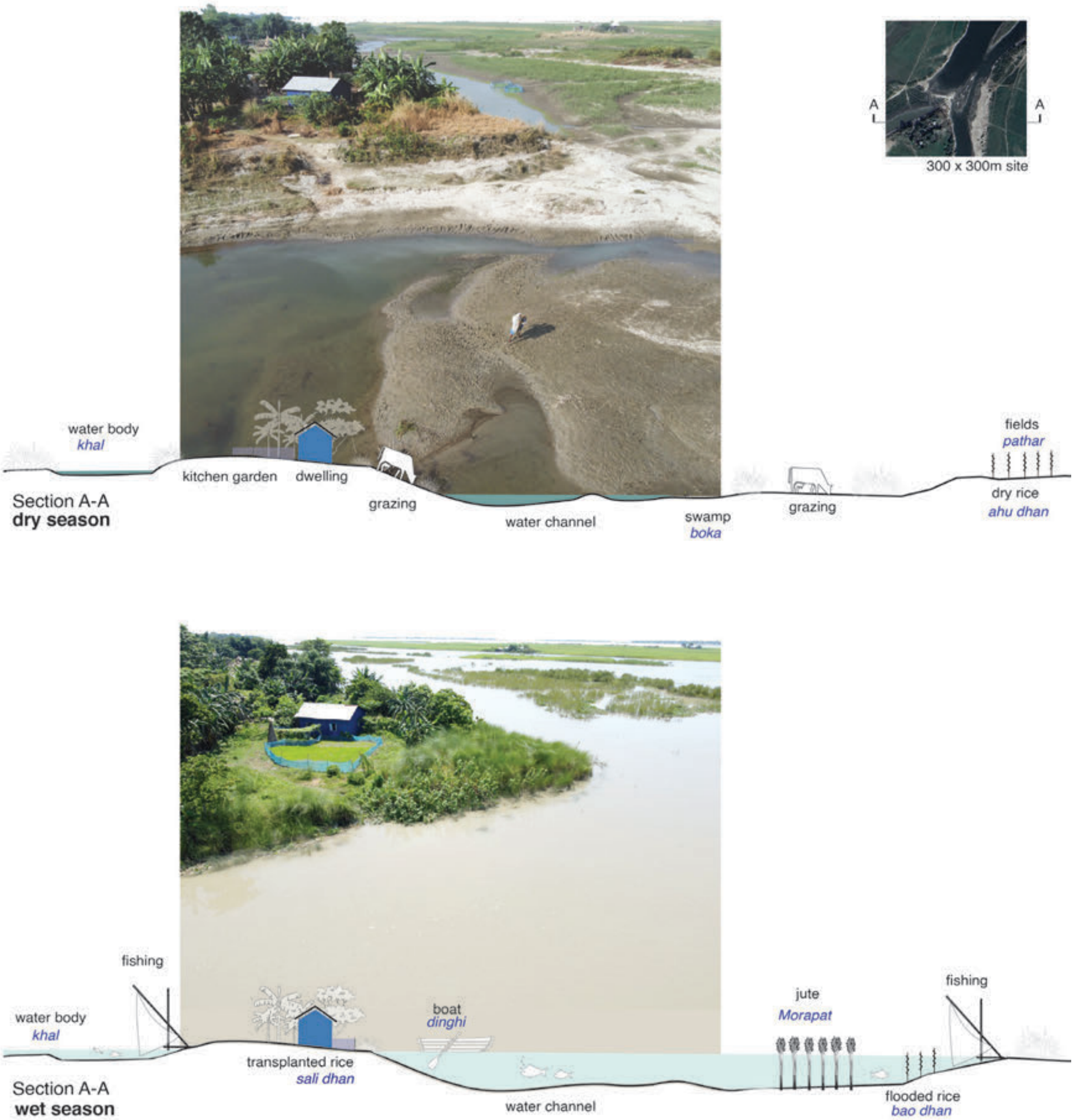
Fieldwork revealed that cultivation, attuned to seasonal cycles and water levels, remained the primary livelihood for the studied *char* family in 2021 and 2023. Drawing on his agricultural expertise, the male member plowed the sandy terrain and fertilized it with cow dung, poultry waste, ash and paddy husk before the arrival of monsoon. These organic fertilizers decompose in the rainy season to form fertile topsoil. The *chars* are typically covered in tall grasses and reeds set ablaze before sowing *ahu* (dry rice) in March/April. Harvest precedes the high water in July, with cultivation resuming after the floods recede. Leveraging the soil's moisture, winter crops like rapeseed, mustard and various pulses are sown post-monsoon to ensure sustenance during lean, dry months. Sali rice saplings thrive in manicured fields adjacent to homes, nurtured by rainwater and flood-borne silt before transplantation to fields. Low-lying areas, submerged during monsoons, are utilized for cultivating *boro* rice along with jute with longer stems (fig. 1). The knowledge of the *char*-scapes and sustenance practices stand as a testament to the resilience of *charuas*, which can support their livelihoods across seasonal transformations and the ever-changing environment.

***Char*-scapes as Water Heritage Rooted in Culture and Nature**

Char-scapes exemplify a multifaceted water-related heritage. *Charuas* have developed an adaptive crop calendar that mixes crops for risk distribution and the efficient use of water levels. Beyond farming, communities harness water-adapted livelihoods, engaging in fishing, boat-making and using boats to transport passengers. In times of need, they shift to non-farming livelihoods like carpentry, daily wage labor and small businesses, often coupled with seasonal out-migration. Religious and spiritual beliefs fortify their sociocultural resilience, while traditional ecological knowledge

^ Fig. 4 One family's inhabitation of a *char* reveals the territorial scale of occupation, different types of dwelling and movement within the landscape (Source: Swagata Das, 2024. Based on fieldwork in December 2021 and July 2023).

anticipates flooding and erosion. In essence, the *chars*' water-related heritage is a dynamic living legacy. It includes the practical knowledge (Scott 1999) that the *charuas* acquired over generations. The settling-on-the-move culture of the *charuas* contains a set of relations



^ Fig. 5 Seasonal waters and shifting geographies prompt inhabitants to adopt their livelihoods and cropping systems (Source: Swagata Das, 2024. Based on fieldwork).

between a multitude of locations (all with continuously evolving locational assets), activities that exploit these assets, and actors (ranging from different extended family members to the networks that link them with the wider world). These sets of relations dance with the natural rhythms of the river as well as with the whims of state politics while regularly being disrupted by catastrophic floods, large-scale infrastructural interventions and eruptions of violence between communities in this sensitive border area. Clearly, this settling-on-the-move culture embraces as much the opportunities offered by their refuge space, the *chars*, as by avoiding dangers and subverting state politics. The settling-on-the-move culture, until now, has proven sustainable.

Recently, climate change has impacted *chars* with erratic rains, higher temperatures, extended monsoons and an increasing number of extreme weather events (Das and Khanduri 2021). Flawed disaster management and eco-hydrologically insensitive development in Assam increase exposure to "natural" hazards, prompting communities to seek external state support and migrate away from the *chars*. One can wonder, however, whether, rather than relocation and subordination to the state, a new iteration of the settling-on-the-move culture of the *charuas* would be more advantageous. The practical knowledge acquired by the *charuas* has continuously and opportunistically been adapting to changing conditions. Rather than losing such living practical knowledge and shifting to supposedly more rational practices, it might be worthwhile to imagine how to maintain and adapt the practices of the *charuas* to the new conditions generated by global warming. For the *charuas*, their daily lifestyle is integral to such a living heritage (as embodied practical knowledge). It should be leveraged to achieve inclusive, sustainable development, social cohesion, equity and community well-being.

Conclusion

Charuas acknowledge the river's fluctuations, including flooding, which is not considered a risk but simply part of the natural cycle. In a culture of risk assessment, fervor for technological advancement and its attendant "fixes," awareness of flooding, erosion and sedimentation as intrinsic natural processes has been fading. However, in recent years, global warming has brought these processes back into focus. Additionally, the number of climate refugees migrating to India is expected to rise as the climate crisis intensifies (Asian Development Bank 2012). Migration driven by ecological factors is part of state-making processes in Assam.

Throughout history, *chars* have contributed to Assam's agricultural production and economy, and chars have been important places of refuge for Bengali Muslims. Their defiance of categorization, where water and land naturally recede and flow, have hosted undermined communities threatened by the CAA and NRC. Today, they invite contemplation of alternative realities and narratives that envision *char*-scapes as uncharted territories, retaining the freedom that their inherent illegibility offers. Simultaneously, they could function as productive landscapes to generate new economies, combined with specific densities to support them.

Policy Recommendations

- Planning policies need to acknowledge the fluid landscape of *chars* beyond conventional land-use categories and treat them as a distinctive case. The State Action Plan of Climate Change for Assam should include a dedicated chapter addressing the potential and vulnerability of *chars* and outlining new visions of the char environment and economy to build resilience in Assam's floodplains.

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Chinampas Agriculture and Settlement Patterns: The Contemporary Relevance of Aztec Floating Gardens

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The Chinampas are a system of floating gardens in the Valley of Mexico, including Mexico City, allowing for effective agriculture and sustainable water management since approximately 200 BC (Rojas-Rabiela 1993). Vernacular water systems like the Chinampas create opportunities for landscape architects to learn from historical approaches to water management to solve today's challenges (Bobbink and Ryu 2017; Bobbink 2019). Through a layered visual analysis – the illustrative method – vernacular knowledge about the Chinampas was collected and communicated by drawings to gather (new) visions toward more resilient, circular and interdisciplinary approaches (Surajaras and Rey 2021). The research is part of the "Circular Water Stories LAB," TU Delft, the Netherlands (https://circularwaterstories.org). Once the case study has been systematically documented, its circular character provides insights into landscape-based approaches to water-related cultivation. From there, it is possible to discuss the value of the traditional water system in addressing today's challenges.

KEY THEMES

CLIMATE

A B C D E

Cwb : Subtropical highland climate

< Fig. 1 "Chinampa," September 2015 (Source: Sari Dennise, CC BY-NC-SA 2.0, color modified from original).

Origins and Development of Chinampas as a Land and Water Management System

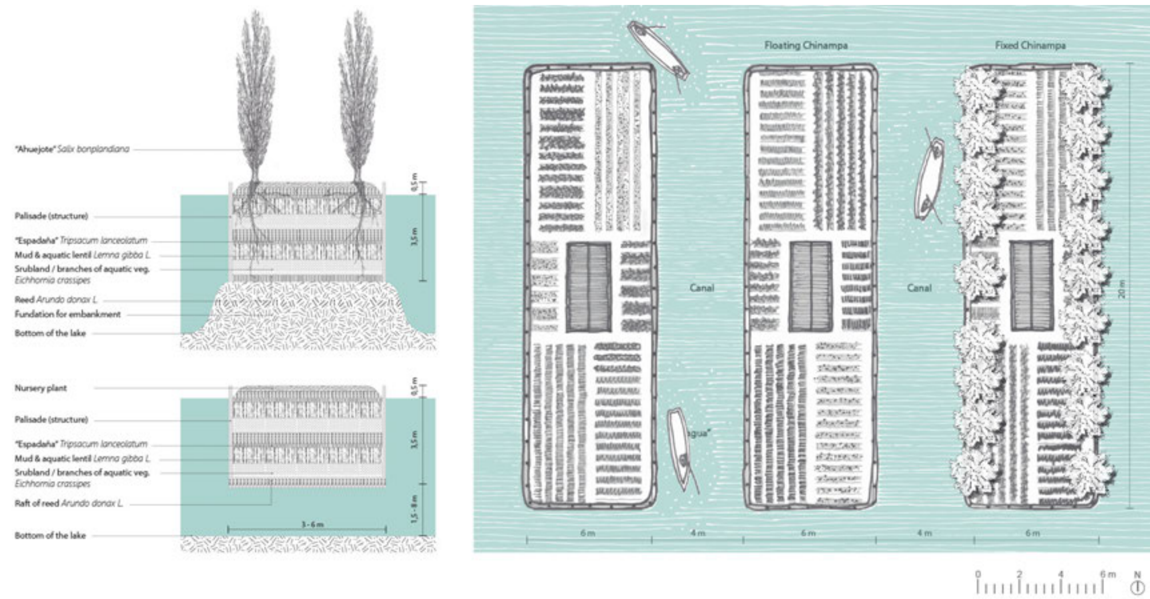
The Chinampas represent an ancient Mesoamerican land and water management system developed by the Aztec civilization to aid agricultural and territorial expansion in the enclosed basin of the Valley of Mexico, which once contained a wetland ecosystem of now-extinct interconnected lakes (Scarborough 2003). The Aztecs built the capital of their empire – Tenochtitlán – in the middle of the shallow waters of the now-extinct Texcoco lake, strategically protecting their city from external threats (Alcántara 2007). However, with the rapid growth of Tenochtitlán and its population, they soon faced a lack of land. Therefore, they started developing the Chinampas land-water management system to enlarge parts of the island where the water was shallow enough to reclaim land for settlement and agriculture (Gibson and Campos 1978). To do so, they developed a technical knowledge and practice of land reclamation that gradually expanded their territory into the surface water, transforming Tenochtitlán into a “floating city” (Surajaras and Rey 2021).

The Chinampas were developed through rafts made of reeds and fenced in a rectangle shape with a wattle (Alcántara 2007). The raft was then layered with mud, lake sediments and selected biodegradable and fertile topsoil constituted by grass, leaves, and husks. After being layered over and over, several artificial islands would eventually create a new landscape pattern (Surajaras and Rey 2021). Each of these islands formed a “Chinampa”: a movable land area that Aztecs tied with ropes to their canoes to take them from one place to another in the lagoon, according to the territorial needs of Tenochtitlán (Gibson and Campos 1978). When necessary, they fixed some of the Chinampas by planting trees such as *Salix bonplandiana* and *Taxodium mucronatum* in the corner of the raft to secure it to the bottom of the lake. The mobile islands were mainly used as nurseries for vegetables that would later be transplanted to the fixed Chinampas.

With the arrival of Spanish conquistadors and subsequent colonization, the Chinampas system was transformed from movable land patches to static ones due to the newly introduced tax system, which did not consider the moving islands “taxable land.” Therefore, the Spaniards ordered fixing all the floating gardens to the bottom of the lagoon with Ahuejotes trees *(Salix bonplandiana*) (Alcántara 2007). Furthermore, the lakes were drained to avoid flooding and to expand the city, transforming the lacustrine landscape into a dry valley, which led to the disappearance of large areas of Chinampas (Surajaras and Rey 2021).

Present and Future of Chinampas

The lake’s draining process continues to the present day with the illegal extraction of water through clandestine wells (Alcántara 2007). This systematic drainage, combined with the ever-growing urban pressure in Mexico City (former Tenochtitlán), has modified traditional Chinampa techniques and the cultural landscape. However, despite these past and current challenges, Chinampas use and management have partly survived in the southern part of the Valley of Mexico, in the lacustrine zone of Xochimilco and Tlahuac (Government of Mexico City 2017). These zones form an extensive island of traditional urban agriculture in the middle of a densely populated Mexico City. In these areas, a variety of vegetables and ornamental plants continue to be cultivated. Productive activities have diversified, creating conditions for devel-



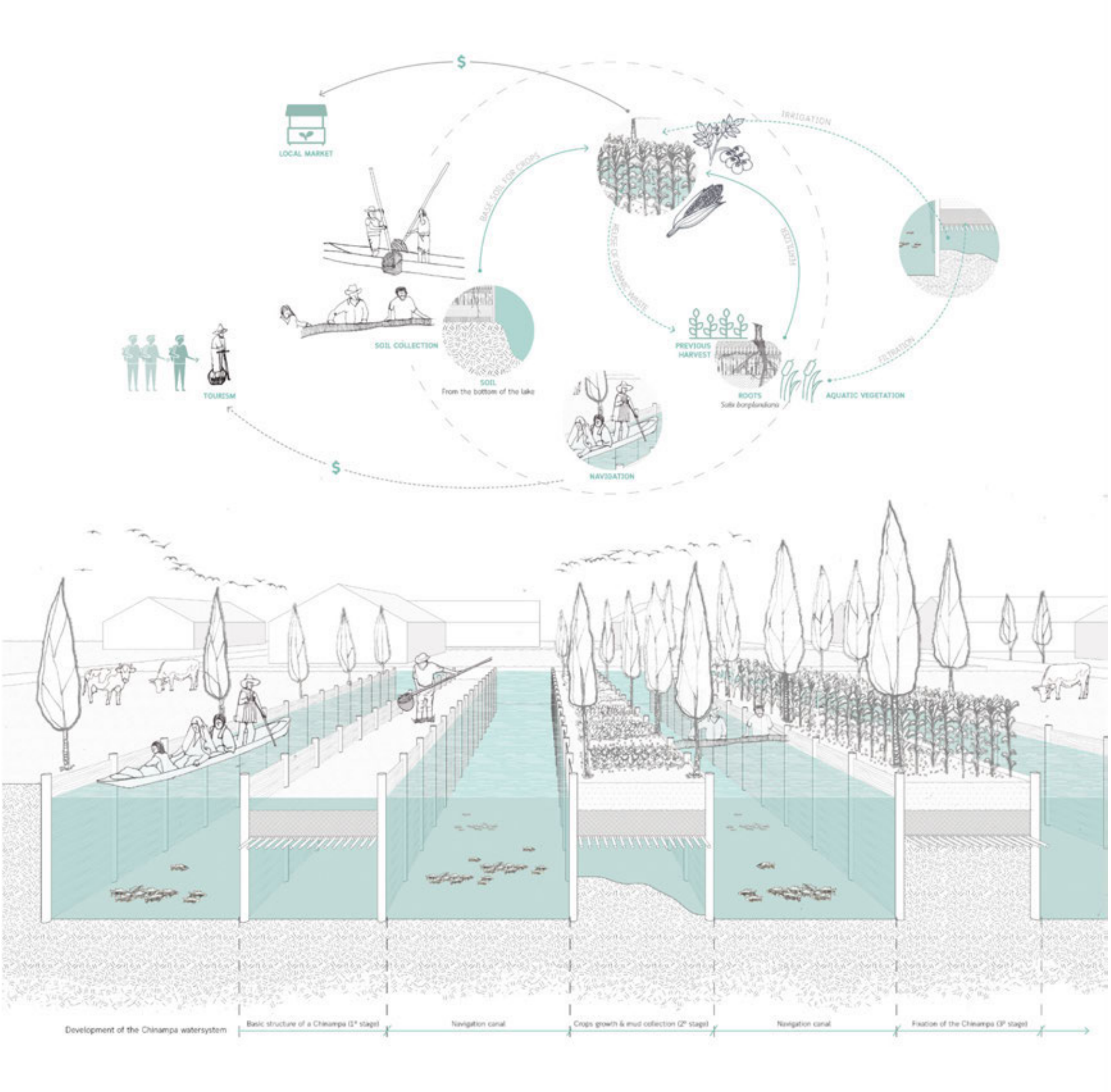
^ Fig. 2 Detail plan and section of Chinampas water system, 2019 (Source: Catalina Rey-Hernández, based on literature review).

oping the local economy and providing goods and services for the city. Tourism, stabled livestock, backyard crops, greenhouse floriculture and Chinampas horticulture are the main activities associated with the conservation of fertile soil fields (Echeverría 2009). Specifically, Xochimilco stands out for two kinds of cultivation: nursery production of horticultural plants to be later transplanted in the mainland, fulfilling a significant economic role. The second is the cultivation of ornamental flowers which are displayed in the Chinampas year round as an important tourist attraction as well as for symbolic reasons related to Mexican commemorations and local festivities (Government of Mexico City 2017). Many tourists are attracted by the traditional cultivation and the flower nurseries, which can be experienced by taking *piragüas* (traditional canoes) (Echeverría 2009).

One of the main changes in terms of the spatial development of the system has been in the Chinampas pattern and size: the pre-colonization Chinampas plots have been merged due to land reclamation and drainage processes, in which many areas are becoming bigger land plots to host new zones for urbanization. However, some of the Chinampas are still sustainably used for agriculture. Farmers use roots, lake bottom mud and organic waste from the previous harvest to maintain and build the Chinampas. They use and reuse 100 per cent of the resources from the fields, as their ancestors did. The use of organic matter in the construction of the land layers allows water to filter and soak the upper soil layers, generating natural irrigation. At the same time, the system helps water retention through its filtration of the subsoil, avoiding erosion and subsidence (Alcántara 2007; Echeverría 2009).

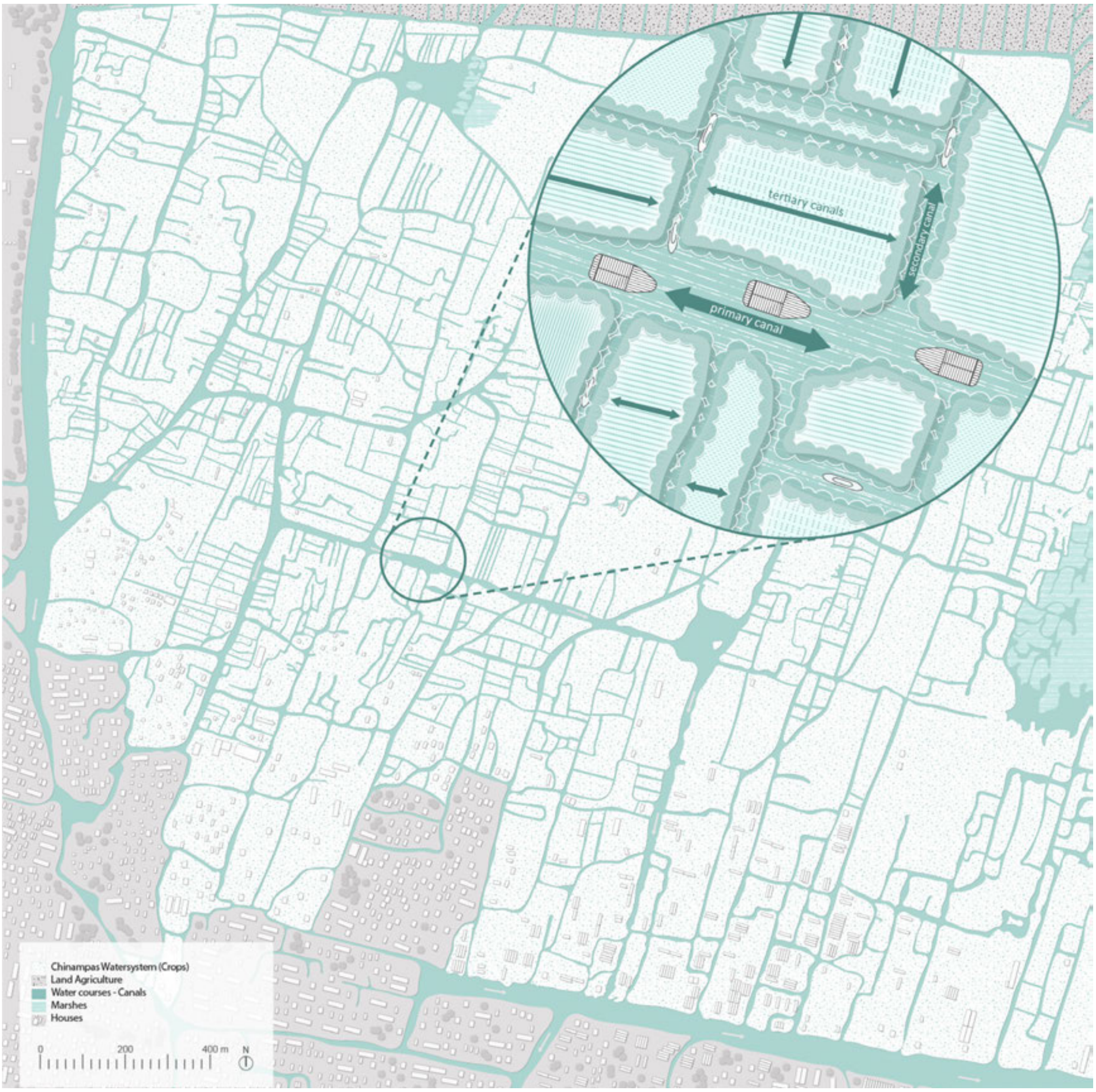
Lessons Learned

The Chinampas water system has been traditionally used for agriculture. Still, due to the



^ Fig. 3 Chinampas: Circularity of the system / Representation of sustainability (Top); Section perspective of the Chinampas water system (bottom), 2019 (Source: Catalina Rey-Hernández, based on literature review).

landscape and cultural transformations in the territory, the system has evolved to provide the possibility of new land uses such as cattle grasslands and horticulture combined with new economic activities like tourism. There is a new awareness of this system's landscape and economic value, encouraging farmers to continue using these sustainable traditional agricultural methods. Using the illustrative method, several values can be defined in relation to the Sustainable Development Goals (SDGs) defined by the UN.



^ Fig. 4 Overall (current) plan of Chinampas water system in Xochimilco (Source: Catalina Rey-Hernández, 2022, based on satellite image from Google Earth).

SDG 6

"Ensure availability and sustainable management of water and sanitation for all."

Ethnographic and identity values: Because the Aztecs created the system, it is one of the most tangible legacies still in use by farmers who continue to identify themselves as inhabitants of the Valley of Mexico. Vital to the construction of their identity is the water-related community they have been able to build around the construction and maintenance of Chinampas, creating sustainable and circular water system management as part of their daily lives.

SDG 8

"Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all."

Strategic values: Building Chinampas is an ingenious way to use the site conditions to achieve maximum profitability with minimum resources and infrastructure by taking advantage of natural wetlands that help generate efficient crops without using external energy sources.

SDG 11

"Make cities and human settlements inclusive, safe, resilient, and sustainable."

Values of sustainability and circularity: The materials from the surrounding area provide a sustainable way to use resources, creating cyclical crop harvests using natural irrigation and filtration of the water. The system uses the water existing in the site for natural irrigation, bringing it back into the biological circuit.

SDG 12

"Ensure sustainable consumption and production patterns."

Material and tangible values: The structural elements of the system derive from the knowledge of traditional construction techniques of the Aztec culture and are vernacular and situated. Due to its composition and materiality, the Chinampa water system allows constant humidity throughout its structure, which is helpful for growing a variety of crops.

SDG 15

"Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

Landscape values: The lacustrine landscape of the Valley of Mexico has dramatically changed due to the drainage used to build a city and avoid flooding events. Most of the territory has been transformed, from a lacustrine to a mountain valley landscape. However, approximately 16 per cent of the original Chinampa's extension remains (Armillas in Rojas-Rabiela 1993; DW 2020), along with its traditional and ancient understanding, generating a cultural landscape that rescues the water qualities of the former lakes with resilience and an adaptive version of land cultivation.

The analysis of Chinampas, especially its circular character, is instructive regarding landscape-based methods of water-related cultivation. Understanding water and land management systems based on the circularity of resources makes it possible to extrapolate specific design strategies that can be used to tackle current urban-rural issues related to sustainability and resource consumption patterns. By learning from these landscape-based approaches, we can (re)formulate the role of landscape as a multifunctional provider, where natural entities such as wetlands and lakes can be seen and understood as potential areas for multifunctional development by embracing cultural (heritage), as well as social, economic and ecological values.

Acknowledgment

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The Longue Durée of *Weitian* Landscapes in the Yangtze River Delta

Wei Lei, Kelly Shannon and Bruno De Meulder
KU Leuven

The ancient weitian (polder) system in the Yangtze River Delta represents a particular form of water urbanism, integrating productive polders, villages and prosperous water towns (shui-xiang). Over millennia, the hudang-weitian (shallow lake polders) transformed the muddy plains around Taihu Lake into a highly productive area. Zhenze, founded in the twelfth century, is an important water town that initially operated within a network of garrisons and trading ports. This case study illustrates the resilience of weitian landscapes and how twentieth-century water management reshaped the small polders into larger wei-qu (polder zones) through a process of lian-wei-bing-wei (joined and merged polders). While urbanization and industrialization continue to erase many historic polders, the region's water towns are being preserved and developed, largely for tourism. The case highlights both the benefits and shortcomings of the weitian transformations, emphasizing the need for a balanced approach that both facilitates development and preserves the region's unique deltaic conditions.

Keywords: *polders, canals, deltaic landscape, water urbanism, mapping*

KEY THEMES

CLIMATE

A B C D E

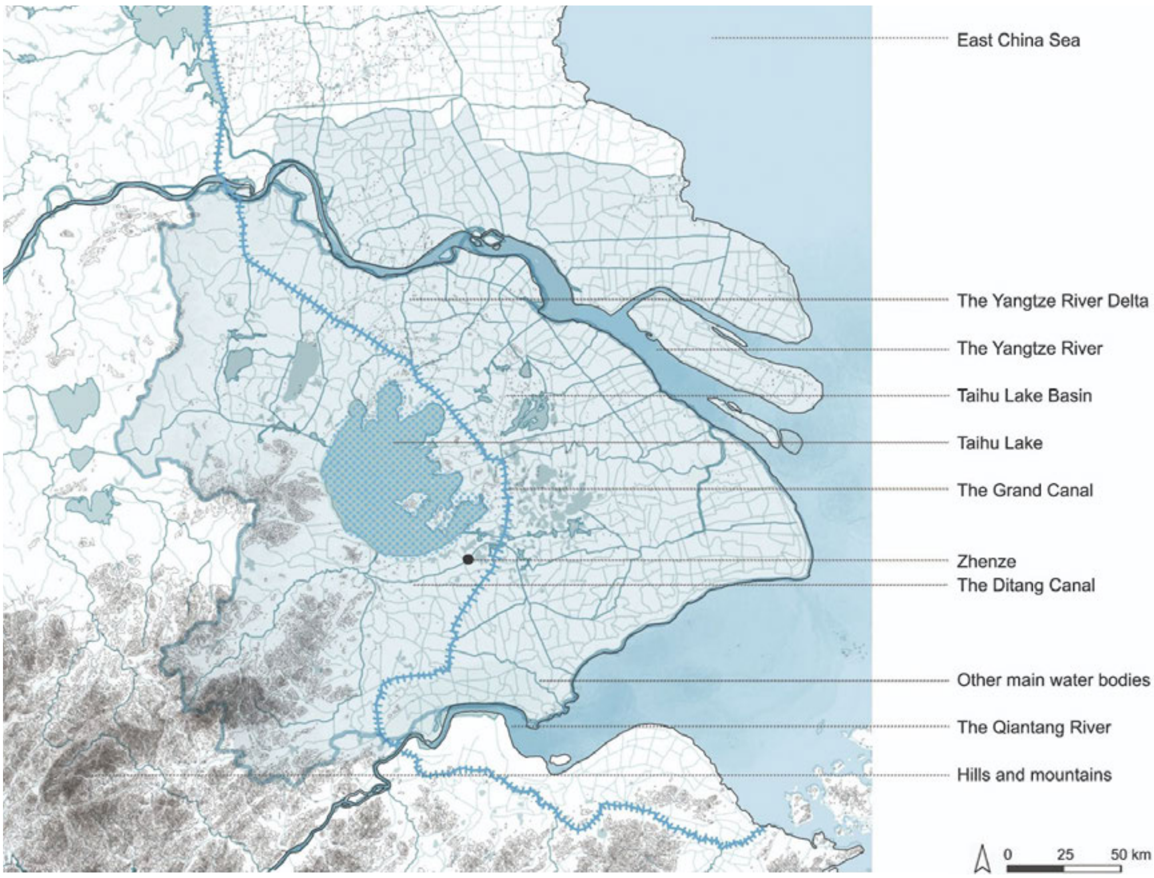
Cfa : Humid subtropical climate

< Fig. 1 Zhenze and its waters – river, canals and irrigation channels – interwoven with clusters of various types of settlements (Source: Wei Lei, 2023).

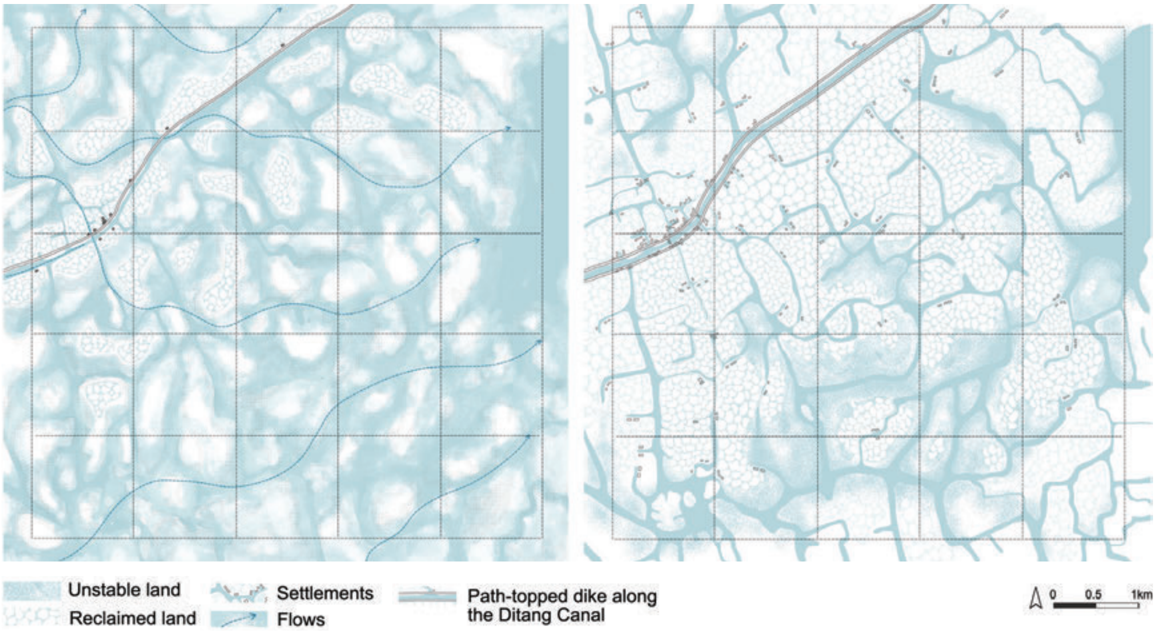
The Ancient *Weitian* of the Yangtze River Delta

The ancient system of *weitian* emerged in the Yangtze River Delta in 400 BCE. Taihu Lake (fig. 2), the region's largest natural lake, was the first area of the delta to be reclaimed. The topography of the Taihu Lake Basin tilts from northeast to southwest. Reclamation began with the relatively higher area of soil accumulation immediately alongside the lake and then expanded to areas where the lower topographies were formerly underwater (Miu 1985; Zheng 1987). During China's early dynasties (before the tenth century), kingdoms and vassal governments co-occupied the territory and developed top-down *tuntian* (garrison reclaimed fields) to facilitate agricultural activities and settlements. An extensive polder network was developed by troops when warring states sought to control grain production, ensure military supply and feed migrants fleeing rebellions in the north. *Tangpu-weitian* (channels parallel and perpendicular to the lakeshore), also known as *da-wei* (big polders), formed a hierarchical water management system with main waterways, gridded dikes and dammed channels. The unit of grid-shaped *da-wei* was comparable in size and shape to those of circumvallated cities of the same period, such as Suzhou (Miu 1985).

With China's dynastic government waning beginning in the tenth century, extensive garrison reclamation was no longer a priority. The centralized development and management of



^ Fig. 2 Taihu Lake and its spatial relationship with the Grand Canal, the larger delta, the sea and the case study town of Zhenze (Source: Wei Lei, 2023).



^ Fig. 3 Zhenze's poldering process circa 1000 CE (left) and circa 1600 CE (right) (Source: Wei Lei, 2023. Based on maps in Chronicle of Wujiang [1488] and Chronicle of Zhenze [1746]).

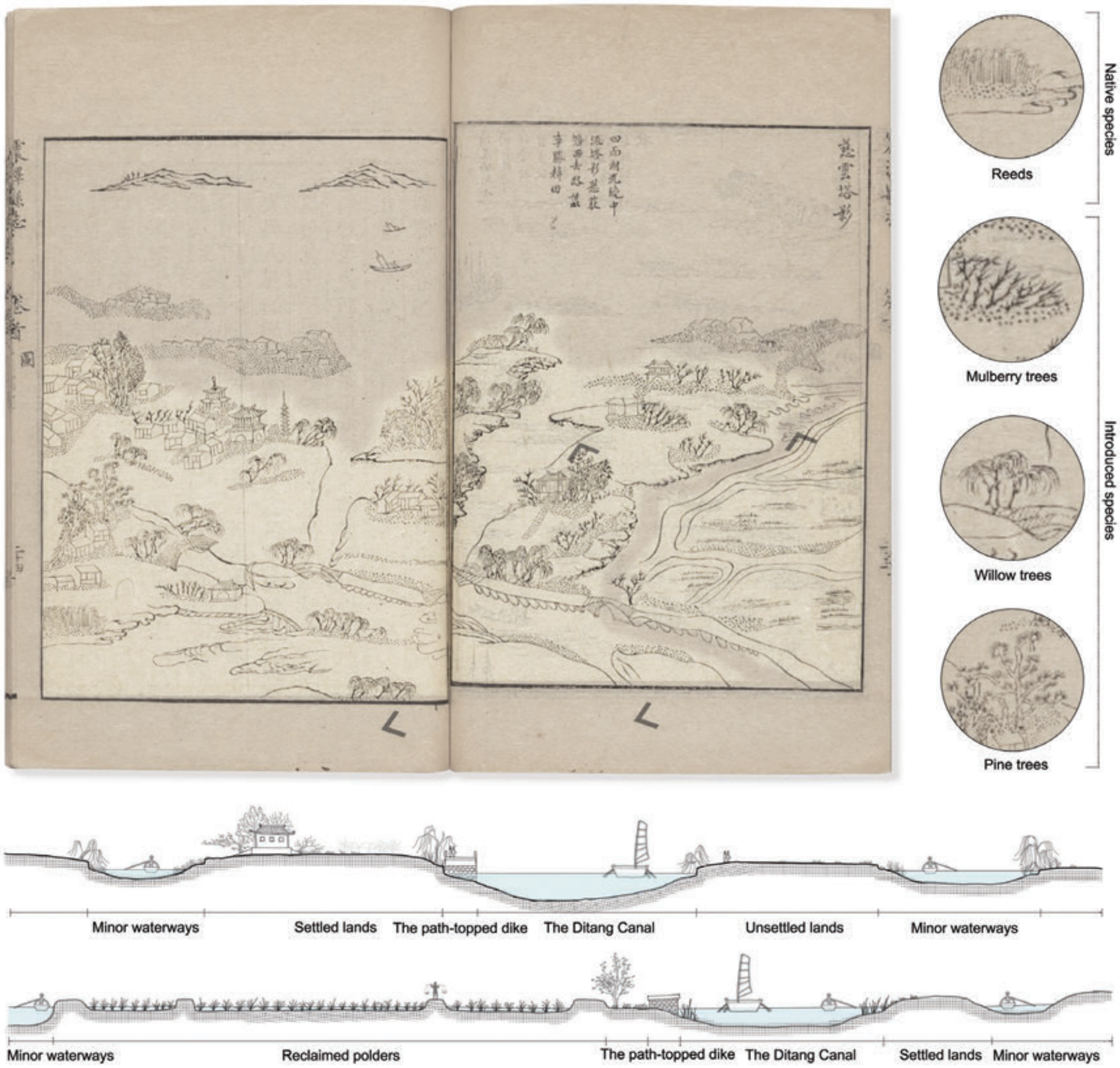
reclaimed lands was replaced by a land leasehold system that included tenant farmers. During this time, the Taihu Lake Basin remained a major rice-producing region, with the government claiming a significant share of production through taxation. The large-scale *tangpu-weitian* that was formerly reclaimed by garrisons was not well-maintained by the tenant farmers and gradually disintegrated. During the same period, path-topped dikes functioning as long bridges along the north-south canals were constructed, significantly interfering with the east-west flow of water from the lake to the sea. The bridge-shaped dikes slowed the flow, increasing sedimentation in the lower eastern lakeside areas. Taking advantage of the sedimentated lakeside, families engaged in reclamation leading to the development of *hudang-weitian* (shallow lakes polders), which families also maintained. These shallow lake polders were generally small and they were not dispersed in a systematic way. Their forms led to their being called *yulin-wei* (fish scale-patterned polders).

Zhenze Water Town

As the agricultural reclaimed lands continued growing in low-lying areas, water towns emerged along major canals in such areas (Wang 2016). Zhenze, once a trading port and typical twelfth-century garrison settlement, is located on the southeastern bank of Taihu Lake and along the Ditang Canal — a dredged northeast--southwest waterway. In the eighth century, the canal had been strengthened with path-topped dikes to facilitate land transportation and protect the town from waves coming from the lake.

Complemented by accelerated sedimentation (caused by seasonally lower water flows combined with high sediment load), newly reclaimed lands and large-scale settlements were developed (fig. 3). From the eighth century onwards, many new buildings were constructed along the canal's dikes, taking advantage of the elevated typology and proximity to transportation. Typically, building fronts were aligned with the streets and backsides were adjacent to the canal and accessed via staircases. Bridges connected streets separated by water. Movable barriers were installed under bridges in key locations for defense purposes, creating densely settled areas surrounded by water gates, resembling fortified, gated cities.

By the sixteenth century, Zhenze was a substantial town recorded to have around 1000 families and thriving commerce (Fan 1990). From that point on, like many water towns in the vicinity of the lake, Zhenze's polder-based rice yields



^ Fig. 4 Polders for production and canal banks for settlement, as seen in Zhenze, along the Ditang Canal, as depicted in the eighteenth century (Source: Chronicle of Zhenze, 1746]; Wei Lei, 2023).

could no longer feed the growing local population after taxes were paid in rice (Fan 1990). As a solution, multi-cropping and new forms of cultivation emerged (Huang 2000; Xie 2015). Plant species were introduced that aided water management and new types of production. Willow trees were planted along dikes to make them stronger. Mulberry trees, for breeding silkworms used to make silk, were planted on higher ground, close to the settlements, and in smaller elevated areas within the paddy fields. Ornamental plants (e.g., pine trees) also appeared and indicated a growing class of affluent local families (fig. 4). The higher profits of the silk industry shifted Zhenze's reliance on polder-based agriculture to mulberry cultivation (Wang 2013; Fan 1990). The new types of cultivation and industries meant that Zhenze and other water towns had to rely on imported grains, mainly from upstream regions along the Yangtze River (Fan 1990). Zhenze remains one of China's major silk-producing towns.

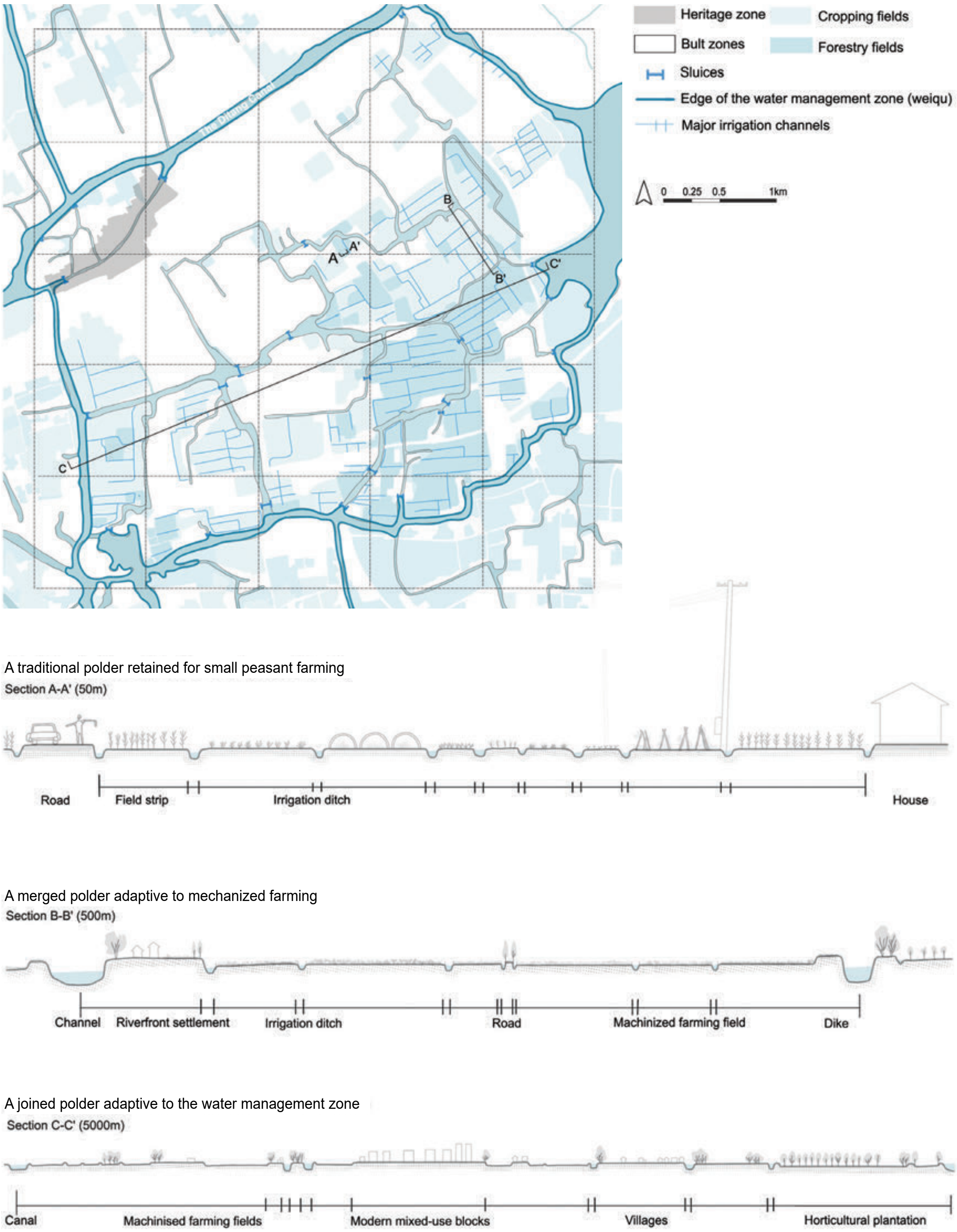
Contemporary Water Management

After the founding of the People's Republic of China in 1949, the long-standing water management system based on small polders underwent significant transformation. Because of several wars in the nineteenth and twentieth centuries and the declining silk profits, Zhenze's mulberry plantations were drastically diminished (Fan 1990). As part of the Great Leap Forward (1958–1962) and the People's Commune (1958–1984), a communist social movement introduced *weiqu* (water management zones) (Zhenze Chronicle Compilation Committee 1999). The primary goal of constructing water management zones through the *lian-wei* (joined polders) and *bing-wei* (merged polders) initiatives was to increase crop yields. Channels between the fish scale-patterned polders with *bing-wei* were filled to create greater expanses of fertile land. New gridded irrigation channels were dug, and the larger, continuous fields were adapted to mechanized cultivation. At the same time, clusters of merged polders were serviced by electric pumps and regulated by sluices. The sluices formed larger water management zones and created *lian-wei*. These water management zones, redefined by the outer dikes, resulted in a much-reduced dike length compared to the previous cumulative length of all the polders. The reduced length of dikes made them easier to improve and maintain. The new polder-based water management system was thus believed to be more flood-resistant and necessary to reach higher yields. (Jiangsu Provincial Revolutionary Committee Water Conservancy Bureau 1978).

Today, there are three types of polders that operate on radically different scales:

1. *Yulin-wei* are used for traditional farming. The few that remain are typically located near farmers' houses, where they are well-maintained and primarily used by retirees as both a local food source and for socializing.
2. *Bing-wei* are grids of irrigated fields surrounded by water and are visible on aerial photographs.
3. *Lian-wei* are often separated by major canals and lakes, dammed by channels and lakes and regulated through sluices; like *bing-wei,* they are visible from above (fig. 5).

Despite the increased size and mechanization, the fundamental idea of a polder-based water management system has not changed. Nevertheless, the water management systems of the latter two types are often difficult to perceive due to their large scale. In terms of cultural identity, the *yulin-wei* remain an important feature of the Taihu Lake environment.



^ Fig. 5 Zhenze's three co-existing hierarchical polder-based water management systems within the *weiqu* (Source: Wei Lei, 2023).

Division of the Productive, Protective and Consumptive Landscape

Before modernization, the yield production per *weitian* remained relatively low, even though fields were cultivated to their near-full capacity (Huang 2000). This was primarily because accurate water levels, necessary for various phases of crop growth, were difficult to control. The *yulin-wei* were usually only protected by a thin dike, which could withstand flooding but were very sensitive to water fluctuations and unable to maintain ideal water levels. Beginning in the eleventh century, hydrologists periodically proposed reinstalling the historic water management system based on *da-wei* (Sun and Geng 1980; Zheng 1987). Near Zhenze, a new and significantly wider Ditang Canal for contemporary water transportation was excavated in 1935 on the canal's northwestern side rather than widening the old canal. In the 1990s, the old Ditang Canal became completely redundant when the polder located in the urban core was merged with the neighboring water management zone. In 1997, the often-closed sluices were added to the entrance and exit of the town (fig. 6), rendering water transportation nearly impossible. Nonetheless, the water town has been aggressively marketed as a tourist destination, along with productive *weitian* in nearby water villages. *Yulin-wei* are showcased in agritourism operations. The once thriving legacy of the productive landscape system has effectively been rendered mute. Its protective capacity remains vital and the impeding increased consequences of global warming will prove its effectiveness,

^ Fig. 6 The addition of modern sluices between the polders forms *weiqu*. The entrance of Zhenze is now demarcated by a sluice (added in 1997) near the ancient Yuji Bridge (Source: Wei Lei, 2023).

although the entire system has been compromised through massive urbanization and the accompanying loss of permeable surfaces.

Overall, the once intricate relationship between aspects of the landscape devoted to production, protection and consumption has been severely altered. Nevertheless, the ancient water town of Zhenze itself remains largely intact thanks to its enduring silk industry, contemporary tourism and heritage conservation policies. In the 1990s, a joint application for 14 Yangtze Delta water towns was made to UNESCO World Heritage. The application included Zhenze and was considered an opportunity to boost a cross-regional cultural landscape renaissance (Kong and Jiang 2022). In 1995, the first batch of water towns was listed for national protection as Jiangsu Provincial Historical and Cultural Towns. Zhenze was included in the second batch in 2001, and in 2002, its first conservation plan was established. Nonetheless, the town's official heritage zone has a noticeable spatial boundary defined by a few historic blocks, and this remains the case following its rating as a National 4A-level Scenic Spot in 2014. Unfortunately, its water management system is not included in the conservation policy and continues to transform dramatically. The region's polder landscapes, as both cultural heritage and water management systems, still await integration into the relatively new Chinese territorial planning system that took effect in 2018 (Xie et al. 2022). Clearly, from multiple perspectives, more attention is paid to the cliched built architectural form of the water towns. Appreciation of the continually transformed polders has significantly suffered due to a shift in values and the predominance of more mechanization of water management and a focus on large-scale road-based infrastructure.

Conclusion

The millennia-old *weitian* of the Taihu Lake area of the Yangtze River Delta region is a form of water heritage that is highly sensitive to continued hydrologic engineering, reclamation, modernization, industrial transformation and shifting socio-political environments. The town of Zhenze illustrates the shifting relations of water management and polder-based practices in the Taihu Lake area. Socio-political changes in the region have led to radically different spatial configurations, in terms of both sizes and forms, of the poldered landscape. The interrelation of civil engineering (water management system), agriculture and settlements can be considered an early form of landscape urbanism, long before the "ism" was popularized in the 1990s. At the same time, their very existence as a polytechnic system is threatened by the region's excessive urbanization and the fact that they have not yet been defined as heritage (Wang et al. 2023). Instead, water towns' revenue-generating tourism-driven conservation approach largely neglects the history of their having emerged in concert with the poldered regional-scale landscape. At the same time, the small and relatively inefficient fish scale-patterned polder is favored for heritage protection more because of its striking appearance than for its role in water management and production.

Policy Recommendations

- Polder conservation is important not only in relation to heritage but also for polders' value in water management. The modernization and urbanization of the Yangtze River Delta region make it difficult to balance exploitation and natural rhythms. The contemporary deltaic hydrology and topography are witnessing more engineering intervention than at any time in history and in ways that pose significant challenges to the landscape traditions of water towns. The territory's water management could learn valuable lessons from the longue durée of the *weitian* landscapes.

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CAUTION

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Fairmount Water Works and its Water Stories

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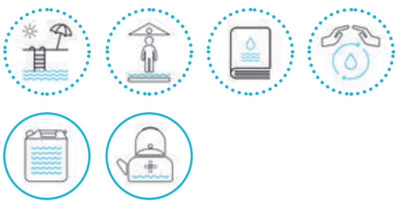
Karen Young
Executive Director, Fairmount Water Works

The Fairmount Water Works of Philadelphia has many stories to tell that span its rich 200-year history. It speaks to the history of technology in America, urban water systems, public health and civic architecture. Although struggling with the increasing impact of climate change, it still has a significant role to play today as a heritage site and as an iconic expression of architectural beauty, civic pride, environmental education and protection and the stewardship of water for all.

KEY THEMES



CLIMATE

A B **C** D E

Cfa : Humid subtropical climate

< Fig. 1 Contemporary view of the Fairmount Water Works looking southeast with the Philadelphia Museum of Art and Philadelphia skyline as backdrop (Source: Fairmount Water Works Interpretive Center photographer).

History of Fairmount Water Works: Philadelphia's Public Water Supply System

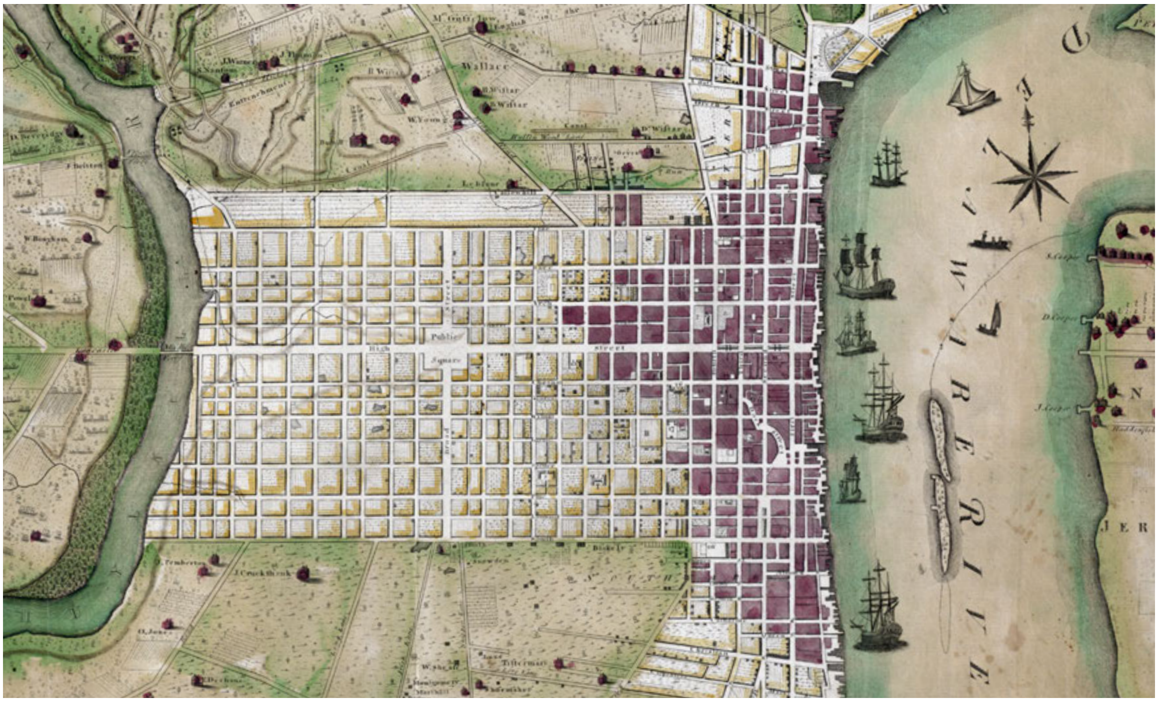
The Fairmount Water Works is a "landmark" in many ways (fig. 1). It was named a National Historic Civil Engineering Landmark in 1975, a National Historic Landmark in 1976, and a National Historic Mechanical Engineering Landmark in 1977. It also serves as a significant landmark for a kind of environmental education that connects the natural world with the built environment. As a cultural landscape, it asserts the principle that access to clean, safe water is a human right and therefore, a civic responsibility.

Water Works: The Arc of History

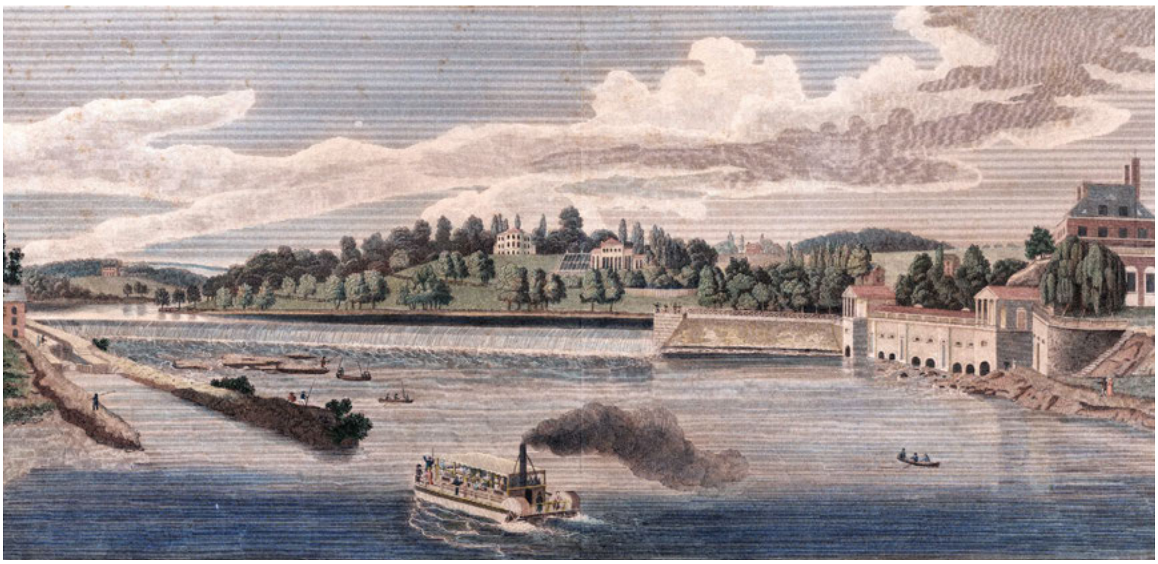
In 1683, William Penn's vision for Philadelphia was to create a grid pattern of streets laid out from river to river - a city of 2 square miles between the Delaware and the Schuylkill (fig. 2). The Delaware River, wider and navigable, became home to the city's active port, and development emanated from its docks and piers. The Schuylkill River was a pristine, more sublime waterway with rapids and elevation changes and it was late to develop along its shores. With the growing plague of yellow fever epidemics of the late 18th century (blamed erroneously on fouled water), increasing waste in the streets and contamination of groundwater, the city became desperate for a clean, reliable source of water. The relatively undeveloped and bucolic Schuylkill River, far away from the active port, appeared the best option (Smith 2013). As early as 1801, with its first pump house at Centre Square, Philadelphia made a commitment to engineering a water system that would be public, reliable and healthy. Soon the larger and more reliable Fairmount Water Works (1815–1909) was designed (fig. 3). It came to be admired as a successful experiment for the city and the nation, creating a public water distribution system renowned for what was called its water of uncommon purity (Smith 2013).

The Fairmount Water Works stands as a remarkable collection of white temple-like structures that rise from the eastern embankment of the Schuylkill River and yet it functioned as a public utility. These iconic buildings are now part of Philadelphia's public park system and once housed pioneering technology that supplied drinking water to Philadelphia. Pumped from the Schuylkill River to a high spot, water was then conveyed by gravity through an underground infrastructure system. This engineered system of engines, water wheels, pumps and pipes was originally steam powered (1815) , but the steam system was quickly replaced with water power created by a spillway just upstream that raised the level of the river and redirected the flow behind and through the buildings to drive water wheels inside. Pumps forced the water nearly 90 feet above to fill reservoirs on the adjacent hill called the Faire Mount. Gravity conveyed the water downhill in an underground system of hollowed out logs, which were soon replaced by cast iron pipes, to reach homes, businesses, public pumps and fountains (Gibson 1998).

In its heyday (1820–1840s), the Water Works was one of the most visited sites in the United States, second only to Niagara Falls. People came from around the world to witness its unrivaled scene of artistic expression for the public good, with its open-air pathways and gardens, and evidence of technological innovation (Gibson 1998). Prominent figures such as Mark Twain, Charles Dickens and Frances Trollope were among the numerous tourists. It was the prototype for water-supply systems around the globe (Gibson 1998).



^ Fig. 2 The 1683 plan for Philadelphia was designed in a grid pattern from river to river. This c. 1796 map shows that the city grew instead from east to west along the Delaware River and expanded north to south along the riverfront. The large brown-ringed, rounded rectangle in the upper left corner is a high flat landform called the Faire Mount, the future sight of the reservoir and Water Works. Natural streams are delineated by winding black lines; many streams were eventually covered over and used as sewers and the infilled land became the foundation for building development, particularly of row home (Source: P. C. Varle, artist, and Scott, engraver).



^ Fig. 3 View of the dam and waterworks at Fairmount, Philadelphia, with pleasure boats in foreground (Source: Published by Edward Parker, 1824. Thomas Birch, artist, and R. Campbell, engraver [after painting by Birch]).

In the early years of the republic, Philadelphia was at the center of design for high style civic institutions related to health, education, commerce and even prison reform as seen in other landmark buildings such as Pennsylvania Hospital, Girard College, the Second Bank of Pennsylvania and Eastern State Penitentiary (Bass Warner 1987).

Above all, it could be argued that a reliable, safe and accessible water system was at the very heart of the thriving city and what enabled Philadelphia to become a manufacturing powerhouse during the industrial age of the nineteenth century. The city was seen as such a forerunner in health, economy and commerce that it earned the name "Workshop of the World". (Bass Warner 1987)

Starting in the early nineteenth century, in an effort to protect the quality of the city's water, the city purchased large tracts of land bordering the Schuylkill River upstream of the Water Works to prevent unwanted development. As more and more land was purchased, the Fairmount Park Commission was created to oversee the property. Today Fairmount Park is 8,700 acres and one of the largest city parks in the world – and it all started in an attempt to protect the city's drinking water. However, despite these efforts, pollution from industry and coal mining upstream as well as outside the city began tainting the water supply. Growing industrial cities upstream, such as Norristown, Pottstown and Manayunk, used the river as a convenient sewer in an era when the economic benefits of industry outweighed any environmental concerns.

During this time, the growing drinking water system, with additional reservoirs to meet the exponential increase in population, did not supply filtered water, but rather relied on impurities settling out in large reservoirs. As the population grew and water pollution from both human and industrial unsanitary waste increased, thousands of people died from diseases such as typhoid and cholera, which were caused by contaminated drinking water. In 1890, Philadelphia suffered one of the worst typhoid epidemics in the nation. By 1909, the Water Works was decommissioned, replaced by several slow-sand-filtration plants constructed upstream on the Schuylkill as well as on the Delaware River. Filtration, along with the introduction of chlorine treatment in 1913, all but eradicated typhoid cases (Gibson 1998).

Saving the Fairmount Water Works: Adapt or Collapse

Between 1911 and 1972, no longer a functioning part of the drinking water system, the structures were transformed for new uses, first as a public aquarium (1911–1962) and then as a recreational pool facility, the Kelly Natatorium, (from 1962–1972). In 1972, flood damage from Hurricane Agnes caused the facility to shut down for good and the site was all but abandoned (fig. 4). After 180 years of constant use, and now threatened with complete deterioration, saving the Water Works buildings became imperative.
As Philadelphia prepared to celebrate the Bicentennial of the Declaration of Independence in 1976, the movement to showcase the "founding" city's significant landmarks and institutions gained interest. This included an effort to save the deteriorating Water Works. Recording and acknowledging the site's history was the first step. Around the time of the Bicentennial, research and a full set of drawings were recorded in the Historic American Engineering Record and the site was successfully nominated as a National Historic Engineering Landmark (Gibson 1998).

^ Fig. 4 Interior view of aquarium looking south, showing display tanks aquarium located below north and south wings and pavilion, Fairmount Waterworks, east bank of Schuylkill river, Aquarium drive, Philadelphia, Philadelphia county, Pennsylvania, US (Source: HAER PA,51-PHILA,328--64).

Documenting and designating the site was just a starting point to making it once again a vital part of the city's life. Without a plan for the buildings, the site languished and by 1984 it was listed as endangered by the National Parks Service and had become a vacant eyesore. Fortunately beginning in the 1980s, public/private partnerships between the park, the Junior League and other civic partners began the 40 years of strategic planning, adaptive reuse plans, and preservation fundraising that would save the Fairmount Water Works. The effort became a model for public-private partnership with its engagement of park leadership, through the Fairmount Park Commission (now called Philadelphia Parks and Recreation), public institutions as the Philadelphia Water Department, and numerous nonprofit partners including the Fairmount Park Conservancy, Women for the Water Works, and the Fund for the Water Works. These partnerships helped fundraise to match park capital dollars and promote long-term stewardship and use of the buildings. Moreover, committed leadership was key. A renowned philanthropist and park commissioner Ernesta Ballard, took on the project leadership in the late 1990s, and the entire site was transformed and over $30 million was invested. The buildings and terraces, historically significant sculptures, the Cliff Path Trail, South Garden and gazebos were restored in phases, followed by the 1926 Italian Fountain and subsequently the Boardwalk Trail and pedestrian bridge which led to improved wetlands along the bank of the river. Together these places formed an integrated environmental, recreational and historic landmark site, forming a kind of grand "gateway" of sorts.

The Fairmount Park Commission (now called Philadelphia Parks and Recreation) and the Philadelphia Water Department with the Fund for the Water Works, a nonprofit entity, worked to advance the long-term stewardship and use of the buildings.

Water Management: Commitment to Public Education

Civic commitment to public health beginning in 1801 and continuing to this day is both a legacy and constant pledge of the Philadelphia Water Department (PWD). In the early nineteenth century, the focus was on the provision of safe drinking water to its citizens and a reliable supply of water to the mills and factories that contributed to the prosperity of Philadelphia. Over the last 200 years, PWD has evolved from a single, iconic pumping station to a utility that protects Philadelphia's rivers, which are its drinking water sources, ensuring that stewardship activities are watershed wide. This legacy has evolved into a 3,000-mile system of pipes, pumping stations and treatment plants.

Today, the portfolio of water resource services that PWD provides, along with the regulatory requirements and aspired best practices for all facets of water resource management, is staggering. It provides safe and reliable drinking water, cleans wastewater and manages stormwater using a model program called Green City, Clean Waters, celebrated by the nation, which blends traditional infrastructure with nature inspired green stormwater infrastructure that seeks to engineer nature-inspired systems that better balance our natural ecological systems while collecting ever more challenging stormwater flows.

PWD recognizes that customers and residents need to be informed about and engaged in the stewardship of water resources to have confidence in the quality of services it receives and to affirm the value of their investment in their public utility. For PWD, education and engagement are an essential ethic. This is the reason PWD in the early 1980s, under the leadership of Ed Grusheski, made the commitment to transform the Fairmount Water Works into an Interpretive Center as part of the department. After two decades of effort, the Fairmount Water Works Interpretive Center (FWWIC) opened in fall 2003. Since then, passionate educators, interpretive exhibits, and a groundbreaking school curriculum use the power of place to increase understanding and transform visitors of all ages into ambassadors for our water environment.

Achievements and Challenges

Since its opening in 2003, the FWWIC has been operating as the educational center of the PWD. It has also become a regional and national destination for innovative water and watershed education programming, such as integrated STEAM (Science, Technology, Engineering, Arts and Math) education that fuses environmental education, scientific research and community engagement (fig. 5). People of all ages and backgrounds learn about the region's urban watershed ecosystem and sustainable technologies that improve water quality. Visitors are urged to take action to protect land and water resources. FWWIC is uniquely positioned to serve teachers and schools equitably throughout Philadelphia's urban watershed, connecting each school with locally relevant watershed projects in and around their neighborhoods.
More than 25,000 adults, 20,000 families and more than 7,000 school-aged children are served by the FWWIC's programs and exhibits each year. There is no admission fee and the site is partially

^ Fig. 5 Adaptively reusing the landmark site for groundbreaking freshwater mussel research and public education (Source: GreenTreks, Courtesy of Habithèque Inc.).

^ Fig. 6 Aquatic scientist in the lab (Source: Fairmount Water Works Interpretive Center).

^ Fig. 7 Performance in the Kelly Pool space of Tributaries, a choral piece commissioned for the Fairmount Water Works Interpretive Center (Source: Kate Devlin; Courtesy of Habithèque Inc.).

compliant with the American Disabilities Act.

The FWWIC 's commitment to place-based education has grown and flourished. As a field trip experience, education programming has been innovative and creative from the start. This National Engineering Landmark site has offered a unique and powerful setting for students to experience first-hand the dynamic ecosystem of the river, the evidence-based exploration of the technological innovations responsible for creating a successful drinking water system and discovery of cutting-edge architectural design in the context of the early republic (fig. 6). The FWWIC has received several awards for its innovative education accomplishments such as the Dr. Ruth Patrick Excellence in Education Award (2015), the Meaningful Watershed Education Experience Partner of Excellence Award (2020) and the Pennsylvania Environmental Council Special Places Award (2021). In 2021, Hurricane Ida brought record-breaking flooding to Philadelphia, and near catastrophic damage to the FWWIC. But the persistent challenge following severe storms is the repeated expense and burden associated with removing river debris and industrial cleaning. Despite this, FWWIC remains committed to cleaning, redesigning, restoring, and replacing needed elements – with a focus on making operations more flood resistant. The next major campaign is focusing on adapting to the increasing demands of climate change while continuing to interpret water history.

Innovative Exhibitions at the Fairmount Water Works Interpretive Center

In 2016, with a combination of private funding from the Pew Center for Arts and Heritage and the Mclean Contributionship and operational support from the PWD, the FWWIC installed a demonstration Freshwater Mussel Hatchery (Prizzia 2016). The working research laboratory and interpretive exhibits like this one offer education about the ecological benefits of freshwater mussel restoration within the Delaware River watershed. This site-specific living enclave was the first of its kind in the region, in addition to breaking new ground within the field of interpretation for its genuinely interdisciplinary approach to environmental education – integrating history, science and the arts (Prizzia 2016).

In 2019, the exhibition POOL: A Social History of Segregation was awarded an exhibition grant from The Pew Center for Arts and Heritage matched by on-going support from the PWD. A 4,700 square-foot, multidisciplinary seasonal exhibition, set in the Fairmount Water Works' former Kelly Pool (known as the "Aquarium Pool" by those who swam there), the exhibition explores the role of public pools in our communities, with the goal of deepening understanding of the connection between water, social justice and public health (Dawson 2018).

Through an inspiring collective of artists, swimming champions, aquatic activists, researchers and scholars, POOL weaves together history, site-specific artwork, storytelling, scholarship, and place-based learning (fig. 7) (Dawson 2018). The exhibit installations throughout the historic structure build on one another to illuminate a history of segregated swimming in the US and its connection to present-day drowning risks affecting Black communities. At this moment in time, the persistence of institutional racism has fueled a movement that has touched every major city and small town in the US. POOL's messages and experiential goals connect the Fairmount Water Works to this landmark time in American history and validate how important shared social and public spaces are to fostering social change.

The multidisciplinary stories told in the Mussel Hatchery and within POOL are framed by the site's unparalleled power of place – a thread that links the future with the past and connects visitors to the urban landscape and watershed of today. The FWWIC traces connections between individuals and our water sources, linking global water issues of the present to one of Philadelphia's greatest civic contributions: the engineering innovations of the historic Water Works site. Both projects advance the commitment to water for all – whether for drinking, swimming or agriculture.

What is the Future?

Today the parks department tries to make the site more resilient at a time of increasing natural disasters, while providing a welcoming environment for all Philadelphians. The Fairmount Water Works stands as an example of a civic commitment to safe, clean and reliable water access; it embodies engineering innovation and an aesthetic expression of the public good and the persistence and perseverance of water suppliers, public park managers and the people of Philadelphia who celebrate its legacy and power of place by not allowing it to deteriorate beyond repair. Will it survive the new threats brought on by climate change? The answer lies within the civic commitment to do what needs to be done to ensure the preservation of this legacy for generations to come.

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Karen Young has more than 20 years of experience developing and implementing urban environmental programs with an emphasis on informal/experiential learning. She has worked with city agencies, non-profits and museums to develop programs, lessons and materials focused on urban water supply systems and resource management for students in grades 4–12 that engage both teachers and students in interactive, engaging experiences and take participants outside to explore the natural environment. She has been the executive director of the Fairmount Water Works since 2007.

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On the Frontline of Climate Change: The Underwater Cultural Heritage of Stone Tidal Weirs

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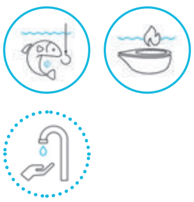
Tokyo University of Marine Science and Technology

Stone tidal weirs are not just relics of the past; they also serve as a guide to future sustainable marine ecological conservation. They symbolize the ability of humans to adapt, use, and live in balance and harmony with the ocean environment. Situated along intertidal or coastal zones, these stone tidal weirs are on the frontline of climate impact and are often abandoned as the local community cannot afford the costs of repair. This has led to loss of this valuable traditional resource management system that contributes to tangible and intangible heritage of coastal communities, as well as to culture and biodiversity.

KEY THEMES



CLIMATE

A B C D E

Cfa : Humid subtropical climate

** climate not specified in the original version*

< Fig.1 Stone tidal weirs in Japan (Source: Akifumi Iwabuchi).

^ Fig. 2 Stone tidal weirs in Timor-Leste (Source: Akifumi Iwabuchi).

Introduction

Stone tidal weirs, a form of underwater cultural heritage, are a type of fish trap or barrier, operated only by tidal amplitude. These structures are made of large rocks or coral limestone, extending along the shoreline on a colossal scale in a semicircular, circular, arrow-like, or almost linear shape (fig.1). Stone tidal weirs are completely submerged during high tide, but emerge into full view at low tide, allowing people to collect fish, which cannot escape their stone walls (Iwabuchi 2014). Many examples still exist and provide a tangible link to a sustainable or eco-friendly fishing practice that has incorporated traditional ecological knowledge and is connected to the spirit world, providing balance and harmony for indigenous people for thousands of years. In other words, this tangible heritage also has intangible or living heritage features, and combining the two it forms a local traditional resource management system. In many local coastal communities, almost all the weirs are still used for fishing. They are located within seascapes created and maintained by harmonious interactions between humans and marine ecosystems (Montgomery et al. 2015). For instance, the indigenous ecological knowledge tells local people that the quantity and quality of fish has been improved after they build stone tidal weirs along the coastal zones. However, this traditional knowledge is usually shared only among local networks and not at the national level.

Current Approaches to Preserving and Managing Water Heritage

Today these weirs are not just relics of the past, but they also serve as a guide to future sustainable marine ecological conservation. Stone tidal weirs symbolize the ability of humans to adapt, use and live in balance and harmony with the ocean environment. Stone tidal weirs contribute to marine biodiversity. Compared to intertidal zones without stone tidal weirs, those with stone tidal weirs host a greater diversity of marine species (Pattrick et al. 2022; Zayas 2019).

The stone tidal weirs also contribute to rich intangible heritage values that often inspire creativity and continuity of traditional knowledge for local communities (Jeffrey 2013). For example, in Hainan Island, China, the traditional ecological knowledge of local songs and other oral traditions, which mention the lunar calendar and days and times of the flood and neap tides. Local fishermen have passed down songs from generation to generation as a reminder of the fishing season at stone tidal weirs. In commemoration of a good haul at a stone tidal weir, the Mullet Memorial Service Pagoda was built in western Japan by its owner. Mullet, and fish in general, are anthropomorphic beings with spirits, which are respected profoundly by local people in Japan. In celebration of large catches with stone tidal weirs, therefore, the local community conducts ceremonial rituals and erects religious memorial service pagodas, which are actuated by the community spirit of local coastal communities. The rich local traditional ecological knowledge around stone tidal weirs is maintained by members of local coastal communities, which perform fishery-related ritual activities such as beach-opening ceremonies and frequent community-led repair work. On the island of Hawai'i, some stone tidal weirs have been diverted into fishponds to be used by locals to produce fry (young fish). Traditionally, local communities use stone tidal weirs twice a month during the spring tide; a custom that has been preventing overfishing. In Timor-Leste, only fish spears are allowed to be used inside stone tidal weirs, because the stone tidal weirs

^ Fig. 3 Stone tidal weirs in the People's Republic of China (Source: Akifumi Iwabuchi).

function not only as fishing gears but also as fish spawning grounds. Local fishermen only manage to catch large fish with the spears, while small fish continue to grow (fig. 2). As a communal activity, Timorese throw raw chicken meat into stone tidal weirs at the beginning of the fishing season, praying for good fishing, and then they all undress together to repair stone tidal weirs.

Current and Future Challenges to this System

The stone tidal weirs are extremely vulnerable to global climate change, specifically to the ocean climate crisis. Recent field surveys and participant observation reveals that many stone tidal weirs have been abandoned or simply not repaired, largely because of ocean environmental change. If sea levels rise more than a meter, stone tidal weirs no longer function as fishing gear. These days, many fishermen in coastal communities agree that the tide is not ebbing as much as previously. Climate change is fueling destructive storms and high waves, and then subsequently, coastal erosion; after stone tidal weirs have been destroyed, many coastal communities cannot afford to repair them and leave them abandoned. Once stone tidal weirs are abandoned, fewer fish are caught. As the attention of local people shifts to destructive modern fishery, all aspects connected to cultural diversity have also disappeared. In order to maintain sustainable coastal communities, biocultural diversity must be retained; stone tidal weirs can serve as a symbol of such diversity.

All over the world, indeed, the underwater cultural heritage of stone tidal weirs is in danger of being lost, as cultural heritage and as traditional fishing gear. Especially in East Asia, typhoons are the greatest threat to stone tidal weirs. As a result, it is now difficult to carry out community activities and take care of spirits properly. In Southeast Asia, stone tidal weirs near larger towns have been catching not fish, but only ocean plastic debris. Just outside them, modern fishery fleets and fishing nets are catching almost all the available young fish, which could manage to escape the stone walls of stone tidal weirs as well as from fishermen's spears. In addition, ocean acidification is depriving stone tidal weirs of their important function as an artificial womb for marine species.

Conclusion and Future Approaches

Stone tidal weirs have improved community health, since higher-nutrient fish contributes to people's well-being, and is associated with lower child mortality, improved cognitive performance, and strengthened immune function. Heritage items situated along the intertidal or coastal zones, including the underwater cultural heritage of stone tidal weirs, would be the first cultural property to disappear as a result of climate change. On the other hand, some coastal communities have started to use the stone tidal weirs as a tourist attraction and the site of environmental education for younger generations (Zayas 2019). According to the UNESCO 2001 Convention on the Protection of the Underwater Cultural Heritage, the stone tidal weir is one of the most typical underwater cultural heritage items to be safeguarded, but its future is uncertain. A few countries, such as the Federated States of Micronesia or Taiwan, have already started to safeguard the underwater cultural heritage of stone tidal weirs, within the framework of national governmental cultural policy. However, many countries, such as China (fig. 3), Japan, or Timor-Leste, do almost nothing to safeguard them, mainly because stone tidal weirs are not the underwater cultural heritage of shipwrecks.

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Indigenous Water Engineering and Aquaculture Systems in Australia: The Budj Bim Cultural Landscape and Baiame's Ngunnhu (the Brewarrina Aboriginal Fish Traps)

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Australian National University
Bradley Moggridge
University of Canberra

In Australia, First Peoples have practiced sustainable forms of water management for millennia. They have done so by respectfully caring for Country through their use of engineering and maintenance processes, including sophisticated fish and eel trapping structures and weir systems. Some of the largest continuing sites of water engineering and aquaculture in the world are still visible and used by local Aboriginal groups – the Budj Bim in Victoria and Baiame's Ngunnhu (Brewarrina Aboriginal fish traps) in New South Wales (NSW). Recent scholarship and successful heritage listings, including the World Heritage listing of the Budj Bim Cultural Landscape and work by and with traditional custodians in these river systems, are starting to bring into public discourse and knowledge these sophisticated and important places of global cultural significance. The principles used in the design of these systems, and the social and environmental contexts of their maintenance and convening power over millennia, are particularly important as we navigate new technologically mediated forms of water management today and into the future. These management challenges include communities in Australia and globally working on the importance of significant places, values, rights, justice and voice for Indigenous peoples in building sustainable futures, including through innovation and safe, sustainable and responsible cybernetic approaches to water governance and the SDGs.

Keywords: *First People, aquaculture, eel traps, fish traps, Free, Prior, and Informed Consent (FPIC)*

KEY THEMES

CLIMATE

A B C D E **Cfb** : Oceanic climate*

** climate not specified in the original version*

< Fig.1 Brewarrina Aboriginal fish traps – Baiame's Ngunnhu – 10 April 2024, view from outside the Brewarrina Aboriginal Cultural Centre on tour with Bradley Hardy (Source: Bradley Hardy, 2024).

Introduction

Fish-trapping systems are found all over Australia in both coastal and inland water systems (Martin et al. 2023). Traditional custodians of Country, whether of land, water, sea or sky have continuously kept knowledges and forms of governance of these structures alive through cultural practices, including the maintenance of songlines, ceremonies, oral histories and art (Neale and Kelly 2020). The ingenuity and sophistication of the fish-trapping and aquaculture practices of Aboriginal and Torres Strait Islander peoples have always been known by the communities managing and maintaining them; they have also been acknowledged by settler colonists in Australia (see examples in Pascoe 2014; Dargin 1976; Coutts et al. 1978). More recently, specific instances of these systems have been acknowledged as heritage places at the state, federal and international levels. In particular, the Budj Bim Cultural Landscape in South-Eastern Victoria is considered one of the oldest examples of an aquaculture complex in the world. It has been carbon dated to at least 6,600 years, constructed from basalt rocks from a volcanic lava flow, and managed by the Gunditjmara using a variety of practices and technologies, including adding woven traps to the rock structures (UNESCO 2019; Gunditjmara and Wettenhall 2022; Rose et al. 2016). The cultural landscape and effective management of water for the community, including food production, also includes clear evidence of rock-built living structures, supporting the relatively sedentary lifestyles of Aboriginal peoples in the area (Pascoe 2014; ADEE 2017). Another prominent example, Baiame's Ngunnhu at Brewarrina on the Barwon River in the Barka-Darling River basin system and on the edge of the Great Artesian Basin groundwater system in Northern NSW, is also millennia old. Baiame's Ngunnhu is central in the creation stories of Country and cultural practices and ceremonies of the many Aboriginal groups who have built, maintained and used the large system of rock weirs and fish traps, shaped itself like a large fishing net (DAWE 2005). The Ngunnhu is the "largest system of traditional fish traps recorded in Australia" (NSW Government 2022) and is believed to be over 40,000 years old which would make it one of the oldest surviving human-made structures in the world (Ngemba CWP 2019). It is known as one of the most important meeting places for Aboriginal people in South-East Australia. The Ngunnhu is particularly used during medium and low-flow periods in the river but has been engineered to withstand high flows. Repair and maintenance is possible in low-flow periods (Dargin 1978). Both examples of Indigenous engineering, culture and shaping Country for community are important in dispelling the myths of *terra nullius* and *aqua nullius* (Marshall 2017) perpetuated through the colonization of the Australian continent, particularly because they are both sites of important Indigenous resistance, knowledge, values and strength of community (Bell and Johnston 2008; Gunditjmara and Wettenhall 2022; Maclean et al. 2012).

Current Approaches to Preserving and Managing Water Heritage

Heritage preservation and management of fish and eel-trapping sites across Australia varies, with traditional custodians and land management corporations working with governments

1. As explained by AIATSIS (2022), "Country is the term often used by Aboriginal peoples to describe the lands, waterways and seas to which they are connected. The term contains complex ideas about law, place, custom, language, spiritual belief, cultural practice, material sustenance, family and identity."

^ Fig. 2 Water flows through the Brewarrina Aboriginal fish traps – Baiame's Ngunnhu – 10 April 2024, view from outside the Brewarrina Aboriginal Cultural Centre on tour with Bradley Hardy (Source: Bradley Hardy, 2024).

and other bodies to develop recognition and support of these sites. Each system and community's journey is different, with much work still ongoing.

Baiame's Ngunnhu was inscribed on the NSW State Heritage Register on 11 August 2000 (NSW Government 2022) and on the National Heritage List on 3 June 2005 (DCCEEW 2021a), with the Ngemba people as traditional custodians, and recognition of the shared importance, maintenance and cultural significance with many neighboring First Peoples. The importance of the site is highlighted in the Brewarrina Aboriginal Cultural Museum constructed in 1988, which now stands in the listed area following an extension in 2015. Significant efforts have been undertaken in engagement and truth-telling to the community through in-person tours and social media, including an active Facebook page, and the system is now highlighted in many education programs, including in cultural, engineering and cybernetics education, at all levels in Australia (e.g., Ruddell and Randell-Moon 2022; Butta 2021; Pascoe 2019). The Ngunnhu has been significantly impacted by colonization. For example, changes have been made to the system to allow paddle steamers to navigate, and weirs have been constructed for irrigation, which has changed water regimes and blocked the passage of fish. Listings and management plans suggest that both the preservation of values and additional restoration are possible and a number of activities have been undertaken to support this, including some trap wall reconstruction and an engineered fish ladder (MacClean 2012; NSW Government 2022). The ability to restore water in the area (Jackson 2022) and to support traditional custodians in leading restoration efforts and governance will be key to success. Discussions are ongoing regarding the potential for World Heritage listing and an application is in development (Ngemba CWP 2019).

The Budj Bim Cultural Landscape is managed by traditional custodians through the Gunditj Mirring Traditional Owners Aboriginal Corporation and a range of other governance mechanisms (ADEE 2017). Budj Bim was inscribed on the National Heritage List on 20 July 2004, recognized as an Engineering Heritage National Landmark on 20 October 2011 (Peake 2011; Jordan 2011), and inscribed on the UNESCO World Heritage List on 6 July 2019 (DCCEEW 2021b). The Traditional Owners work under a participatory and collaborative framework with the Victorian Government and others, as outlined on the Budj Bim Cultural Landscape website, and have aligned their efforts with future management objectives as outlined in their Masterplan 2022–2030 (Arup 2022); these include the pursuit of economic opportunities through low impact tourism, site development, cultural preservation and ensuring community access. Budj Bim is regularly used in education in a range of domains, including as an applied case study in the University of Melbourne's Indigenous Engineering and Design course, where students learn and work with Traditional Owners on Country (Bowra 2020; Prpic and Bell 2022).

The significance of fish-trapping structures and technologies across Australia is also given a prominent place in the First Australians gallery in the National Museum of Australia in Canberra.

Current and Future Challenges to these Water Systems

As a Federal nation, throughout the continent there are jurisdictional differences and historical legacies of colonization that impact approaches to the custodianship of fish-trapping sites that are significant to Indigenous people. At both national and state levels, reforms related to water policy are underway to improve the management of land, water and extreme events. Increasing variability and shifts in climate due to global warming, along with high water demand and extractions throughout the river basin, are impacting flow regimes, ecological health and fish availability, and hence the ability of traditional custodians to care for the Country and these sacred sites. This is particularly the case in the Barwon and Barka-Darling Rivers, part of Australia's famous and over-allocated Murray-Darling River Basin, where Indigenous water injustice through a lack of allocations is particularly acute in relation to colonial-settler allocations (Hartwig et al. 2021). Reforms to support justice for Aboriginal and Torres Strait Islanders across Australia are also gaining significant attention following the Statement from the Heart signed in Uluru (PCoA 2018) and the 2023 Constitutional Referendum (not passed) on an Indigenous Voice to Parliament, although this is only one part of the proposed changes required for justice for First People, which include the need for Treaty, Truth and *Makaratta* (reparations and "walking with a limp") (Loughrey 2022; PCoA 2018; Linder and Hobbs 2023). In Victoria, state-level Aboriginal Water Initiatives and processes that recognize and pro-

^ Fig. 3 The Brewarrina Aboriginal Cultural Museum – 10 April 2024, on tour with Bradley Hardy (Source: Bradley Hardy, 2024).

mote Aboriginal-led management of water as part of Country have gained support through government action, collaborative partnerships, and efforts to raise public awareness. These initiatives are increasingly seen as a source of pride at both the state and national levels, providing momentum for further action following initial steps toward rectifying injustices. These include the foregrounding of Aboriginal engineering ingenuity through the Budj Bim Cultural Landscape with its World Heritage listing and strategic management plan, and the recognition of the Yarra River in Melbourne as a living entity with legal protections through the Yarra River Protection (Wilip-gin Birrarung murron) Act 2017 (Wardle 2021). Despite some small federal reforms to include greater provisions for Indigenous values and more Indigenous engagement in formal structures in the Murray-Darling River Basin and current discussions on reforms to enhance this component of the National Water Initiative, at the NSW state level, work toward Indigenous recognition, water rights and Aboriginal-led water governance initiatives have had a rockier history. Progress was made during the time of the NSW Government Aboriginal Water Initiative (Taylor et al. 2016), but since the initiative's discontinuation and due to larger political conflicts and media attention on issues such as massive fish kills and alleged water theft (Jackson 2021), progress has been slower. Potential directions for future water reforms are in dispute; these include increasing investments in water infrastructure, including by installing new dams, higher weirs and irrigation technology upgrades, which local Barka-Darling Indigenous communities say will further impact their ability to care for Country, including the fish traps. Moving forward on core issues of Indigenous justice in NSW will likely provide traditional custodians of Country – including the Ngemba custodians of Baiame's Ngunnhu and neighboring First Peoples groups who share it as a significant cultural place – with a greater platform for gaining broad support for Ngunnhu futures in an uncertain and changing world. These futures will include whether greater legislative protections and/or international-level recognition is sought and how these might uphold Indigenous values and rights (Moggridge 2021; Moggridge and Thompson 2021; Hartwig et al. 2021, 2022; SoE 2021), offering cultural, economic, social and environmental benefits to Indigenous and other communities with whom the fish traps are shared.

Conclusion and Future Approaches

The millennia-old Indigenous aquaculture complexes around Australia, of which Budj Bim and Baiame's Ngunnhu are prominent examples, present a range of principles that can support more sensitive and sustainable ways of caring for Country, kinship networks and community globally. These are engineered systems that work carefully with flow, ecology, climate changes and culture to sustain communities and help them thrive. These examples of water engineering, aquaculture and cultural heritage also extend global knowledge about continuing cultural practices, heritage preservation and evolution into deep time in a way that is not so commonly recognized outside of Australia but is gaining traction (e.g., Iwabuchi 2022). More importantly, these systems are not just part of cultural heritage and the past but are intimately involved in current discussions and practices about building the future (Bell 2021a, b): they are enmeshed in the "everywhen," an Indigenous perspective on circular time (McGrath et al. 2023). These are sophisticated technological systems that show environmental and social sensitivity through their careful design and engineering. Continuous maintenance and renewal rely on complex governance processes focused on respect, meeting, sharing and ceremony. Working with Country – connecting to it, shaping practices and adapting with it rather than working against it to control "resources" that are seen as separate from place and community can be an inspiration when addressing many of today's challenges with technology, environment and society (Butta 2022). Indeed, Country-centered design is supporting the development of culturally appropriate technologies needed to underpin sustainability, including artificial intelligence (Abdilla et al. 2021). Such design is being included in education at all levels. The principles and inspiration from these examples and others across ancient living water systems can facilitate means of creating more effective Country-centered and "two-ways" governance systems, help to bridge knowledges in today's world and offer open space for listening to Indigenous leaders (Bawaka et al. 2015; Daniell and Daniell 2019; RiverOfLife et al. 2021). This is a holistic and cybernetic approach that has more universal application when linked to the implementation of the UN Declaration on the Rights of Indigenous Peoples (UN 2018) and the pursuit of the achievement of the SDGs in safe, responsible and sustainable ways (Daniell et al. 2022).

Policy Recommendations

- Any proposed international, national or local actions related to Baiame's Ngunnhu, Budj Bim and other Indigenous places of value should be led by traditional custodians and/or through free, prior and informed consent (FPIC) to develop proposals (UN General Assembly 2018). Appropriate processes for FPIC should benefit and not burden traditional custodians and be carried out in alignment with the UN Declaration on the Rights of Indigenous Peoples (UNDRIP).
- Translation of FPIC and UNDRIP principles to specific proposals may require significant professional and cultural support to ensure recognition and practice in accordance with the relevant First Peoples' cultural protocols, depending on who seeks to engage in the process.
- Investing in Indigenous leadership and high-quality FPIC processes can build sustainable support and justice for Indigenous peoples.

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The Erie Canalway: Stewardship and Multivalent Significance of Historic Waterways

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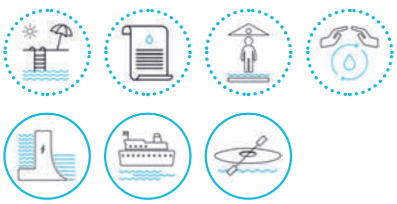
United States National Committee of the International Council on Monuments and Sites (World Heritage USA) Water and Heritage

Once North America's longest constructed transportation system, the Erie Canalway has been in continuous operation for nearly 200 years (ASCE 2022; Goodstadt et al. 2020). The Canalway transformed New York City into the nation's chief port and helped New York State (NYS) become a commercial, industrial and financial center (Library of Congress, n.d.; Hay 2014). Beyond moving people and goods, the Canalway carried ideas, innovations and social movements; it connected Europe, the US Eastern seaboard and the US interior; it has been credited with facilitating settlement efforts, advancing democracy and strengthening national identity (Goodstadt et al. 2020; Hay 2014). The system of the Erie Canalway is a National Historic Landmark and is listed on the NY State and National Registers of Historic Places; it is a National Historic Civil Engineering Landmark and is part of the Erie Canalway National Heritage Corridor. The Canalway contributes to SDG 9 (Industry, Innovation, Infrastructure) through its resilience over two centuries and its repurposing from transportation infrastructure to a historic, cultural and recreational corridor. Its innovation captures the paradigm shift of water engineering for transport to water management in terms of ecology and culture. The Canalway also illustrates some of the challenges associated with SDG 6 (Water and Sanitation), especially in regard to water-related ecosystems.

KEY THEMES



CLIMATE

A B C D E **Dfb** : Humid continental climate

< Fig.1 Active recreation trails along the Erie Canal are a destination for cyclists (Source: Courtesy of Robert Tilley, 2022).

Introduction

The Erie Canalway was once a model for future canals in the US. When it opened in 1825, the Canalway was 363 miles long and was subsequently modified and incorporated into New York State's 450-mile canal system, which included navigational channels, locks, lift bridges, dams, powerhouses and maintenance structures, as illustrated by fig.2.

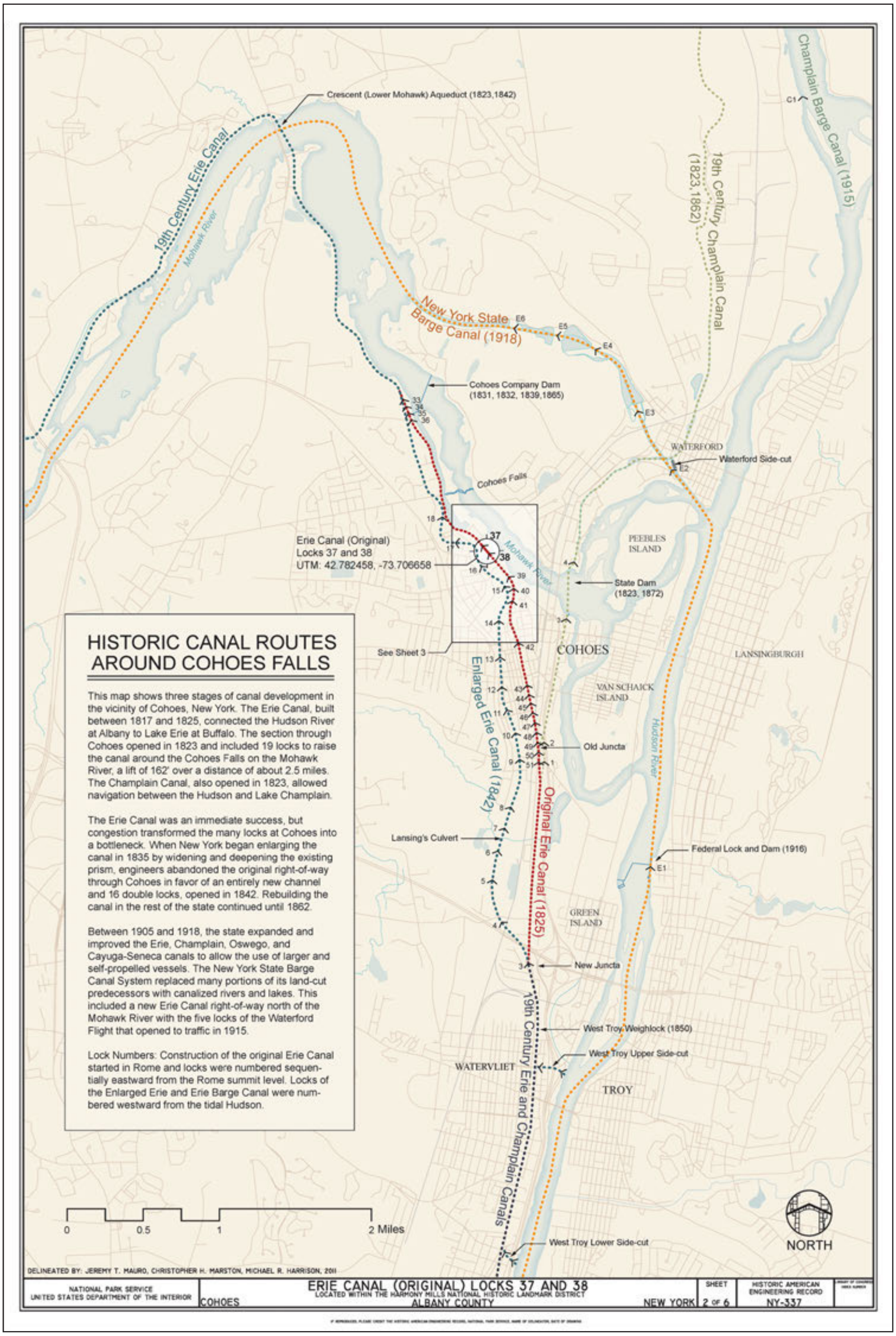
The Canalway facilitated transport of grains, European manufactured goods from the ports and lumber between the big lakes and the East Coast. Major New York State cities – from the Great Lakes to the Hudson River – are located along the trade route established by the Erie Canalway (e.g., Buffalo; Rochester; Syracuse; Utica; Albany; New York City). Builders oriented canal towns toward the Canalway; architecture including school buildings, churches, opera houses, main street and industrial buildings reflected prosperity from 1825 until the end of the nineteenth century, as seen in fig. 3 (Hay 2014; Tobin 2017).

A route for westbound and predominantly European immigrants and cargo, the Canalway opened the country west of the Appalachian Mountains and offered a cheap and safe way to carry produce to market. During the Civil War, the Canalway transported food, supplies and social ideas between the Northeast and the Midwest, facilitating the Federal war effort. Pivotal social movements such as abolition, women's rights and religious revivalism took place along the Canalway. Historic published travel accounts bear witness to how the Canalway captured the public imagination and inspired popular music, prints, children's books and postcards (Hay 2014).

As railroads became the dominant mode of transport and shipping, the Canalway traffic declined (Library of Congress, n.d.). The system deteriorated when the New York State Thruway bypassed canal communities, diminishing its commercial influence (Preservation League of NYS 2022). Contemporary challenges include enhancing regional economic development and preserving cultural value regionally, nationally and globally. Repurposing the historic corridor to meet contemporary transportation, recreational and cultural heritage needs is a premier example of combining historic water management with contemporary ecological and cultural water practices, sustainable development and public education.

Current Approaches to Preserving and Managing Water Heritage

In December 2000, the US Congress passed the Erie Canalway National Heritage Corridor (ECNHC) Act. The Act designated the Canalway's natural resources, the New York State Canal System and the communities along the Canalway a National Heritage Area. The legislation acknowledges the value the Canalway played in local, regional and national growth and its value as a historic, cultural, recreational, educational and natural resource. The Act designated the ECNHC Commission as the primary management entity for the implementation of the Erie Canalway Preservation and Management Plan (ECPMP), which included stakeholder inputs, key strategies and guidance for implementation (New York State 2010; Erie Canalway National Heritage Corridor 2006). Water managers continue their involvement through active maintenance to provide consistent draft for water transportation vessels (New York State Canal Corporation, n.d.). Water management has further expanded to include environmental stewardship with regard to stormwater pollution and



^ Fig. 2 Erie Canal (Original), Locks 37 and 38, 84 North Mohawk Street, Cohoes, Albany County, NY, Historic American Engineering Record (Source: Courtesy Library of Congress, no known restrictions on publication, documentation compiled after 1968).

^ Fig. 3 Erie Canal at Salina Street, Syracuse, Detroit Publishing Company, c. 1900 (Source: Courtesy of the Library of Congress, no known restrictions on publication)

invasive species (New York State Canal Corporation, n.d.). The Plan's key goals include:

- expressing and consistently protecting the Corridor's historic and distinctive sense of place; applying the highest standards of environmental quality to the Corridor's natural resources;
- achieving maximum scope and diversity for the Corridor's recreation opportunities, in harmony with the protection of heritage resources;
- encouraging current and future generations to value and support preservation of the Corridor's heritage;
- advancing balanced and self-sustaining economic growth and heritage development along the Corridor and;
- promoting the Corridor as a "must do" travel experience for regional, national and international visitors.

Formerly linking markets, the Canalway now connects natural, cultural, recreational and historic resources. Heritage and recreational tourism have flourished, attracting enthusiasts of history, culture, fishing, swimming, boating, bicycling and hiking (fig.1).

The Erie Canal Museum, National Heritage Corridor and Canal Corporation educate the public about the Canalway's history and significance. The Erie Canal Museum features permanent exhibits, temporary themed exhibits, educational programs, and virtual and in-person field trips (Erie Canal Museum 2023).

The ECPMP emphasizes the natural, historic, cultural and recreational resources of the canal system and its impact on the economy and quality of life because of public and private investments. Direct investments in the ECNHC include funds from the National Park

Service (NPS), NPS Heritage Partnership Program (HPP) and other non-NPS federal agencies (e.g., Department of Transportation; Department of Housing and Urban Development). Funding during 2002–2017 included non-federal Match Funds (61 per cent), NPS/HPP (25 per cent), other NPS funds (12 per cent) and Non-NPS federal funds (1.5 per cent) (Erie Canalway National Heritage Corridor 2023).

Current and Future Challenges to this Water System

The stewardship of a canalway requires collaboration between elected officials and government agencies, private enterprise and nonprofit entities. The Canalway's existence is a testament to the success of its management; however, with rapidly changing climate patterns, globalization and development pressures, the Canalway faces unprecedented challenges. Beyond politics and funding, significant challenges to sustainable stewardship include invasive species (vegetative and aquatic), water pollution, environmental degradation of adjacent lands and supporting regional economies.

Environmental and ecological impacts from the physical (hard-edge) barrier the Canalway creates are becoming apparent. From its inception, the Canalway's construction divided three critical wetland ecosystems, separated them from their native water sources, disrupted natural hydrology and reduced essential nutrients, thereby reducing their effectiveness within the framework of resilient storm water management (Navarro 2020). These ecological challenges and the Canalway's linear nature have facilitated the migration of invasive species (e.g., Round Goby fish; Water Chestnut plant) economically impacting the area with expensive prevention, treatment and removal requirements and decreasing property values (Navarro 2020).

The Canalway threads through large cities and small villages where nonpoint source stormwater pollution accumulates and transports to sensitive areas, the result of the expansion of impervious surfaces draining to the Canalway through connected waterways. While the need to reconnect specific waterbodies exists, others require isolation to minimize pollution.

Growing demand for improved access and increased outdoor recreation for kayakers, boaters and cyclists utilizing the Canalway as a "regional linear park" requires attention. The challenge is to re-integrate the Canalway into towns after its separation from construction of busy roadways. Improving access can help foster a growing economy centered around recreational tourism along the Canalway.

The greatest obstacles to addressing these challenges are effective stakeholder management and cooperation. Most of the solutions require periodically restricting access to (or through) parts of the Canalway. Adjacent landowners, the recreation sector and other canal-dependent economies may experience direct, negative impacts (Preservation League of New York State 2022).

Conclusion and Future Approaches

For nearly two centuries, the Canalway has faced and adapted to substantial challenges: transformations in cargo shipping and travel, governmental policy shifts, hydrology-related engineering problems, extreme weather events and changing societal attitudes toward the natural world, many of which continue to shape the present management of the Canalway and affect local and regional interpretations of previous uses. Challenges offer opportunities for embracing tensions embedded in supporting active uses of historic waterways to meet contemporary demands while acknowledging and engaging with multiple cultural narratives around water and heritage corridors.

Lessons from interpretative and adaptive use of historic canalways can be applied to other waterways, including aqueducts and river reaches. They may also be applied to other heritage corridors inscribed on the landscape, including historic roads, railways and international borders.

Unique qualities of historic waterways, with their complex intertwined values regarding nature and culture, provide a shared creative space to encourage collaboration across academic disciplines, stakeholder groups and political affiliations. This approach will prove critically important in the future. The evolution of uses across generations combined with public involvement will be instructive in addressing new challenges for the Erie Canalway to maintain the functionality and ongoing contemporary relevance of this heritage corridor. With globalization, swings in international transportation, increasing redevelopment pressures, ecological effects from aggressive nonnative species, regional environmental stresses and climate change, the collective "lived experiences" embodied by the Canalway represent a legacy of resilience to guide adaptive management of the Canalway and serve as insightful models for historically informed stakeholder engagement for other heritage transects.

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